Promotor: Prof. Dr. ir. Patrick Van Damme
Faculty of Bioscience Engineering
Department of Plant Production
Laboratory of Tropical and Sub-Tropical Agriculture and Ethnobotany
Coupure links 653
B-9000 Gent, Belgium
(Patrick.VanDamme@UGent.be)

Co-Promotor: Dr. Ina Vandebroek
Institute of Economic Botany
The New York Botanical Garden
Bronx River Parkway at Fordham Road
Bronx, New York 10458, USA
(ivandebroek@nybg.org)

Chairman of the Jury:

Prof. Dr. ir. Norbert De Kimpe
Faculty of Bioscience Engineering
Department of Organic Chemistry
Coupure links 653
B-9000 Gent, Belgium
(Norbert.DeKimpe@UGent.be)

Members of the Jury:

Prof. Dr. ir. Christian Vogl
University of Natural Resources and Applied Life Sciences
Institut für Ökologischen Landbau
Gregor Mendelstrasse 33
A-1180, Vienna, Austria
(christian.vogl@boku.ac.at)

Prof. Dr. ir. François Malaisse
Faculté Universitaire des Sciences Agronomiques
Laboratoire d'Ecologie
Passage des Déportés, 2
B-5030 Gembloux, Belgium
(malaisse.f@fsagx.ac.be)

Prof. Dr. Paul Goetghebeur
Faculty of Science
Department of Biology
K.L. Ledeganckstraat 35
B-9000 Gent, Belgium
(Paul.Goetghebeur@UGent.be)

Prof. Dr. Mieke Verbeken
Faculty of Science
Department of Biology
K.L. Ledeganckstraat 35
B-9000 Gent, Belgium
(Mieke.Verbeken@UGent.be)

Prof. Dr. ir. Dirk Reheul
Faculty of Bioscience Engineering
Department of Plant Production
Coupure links 653
B-9000 Gent, Belgium
(Dirk.Reheul@UGent.be)

Dean: Prof. Dr. ir. Herman Van Langenhove

Rector: Prof. Dr. Paul Van Cauwenberge

THOMAS EVERT

QUANTITATIVE ETHNOBOTANICAL RESEARCH ON KNOWLEDGE AND USE OF PLANTS FOR LIVELIHOOD AMONG QUECHUA, YURACARÉ AND TRINITARIO COMMUNITIES IN THE ANDES AND AMAZON REGIONS OF BOLIVIA

Thesis submitted in fulfillment of the requirements
For the degree of Doctor (PhD) in Applied Biological Sciences

Dutch translation of the title:

KWANTITATIEF-ETNOBOTANISCHE STUDIE OVER DE KENNIS EN
HET GEBRUIK VAN PLANTEN VOOR LEVENSONDERHOUD
BIJ QUECHUA-, YURACARÉ- EN TRINITARIOGEMEENSCHAPPEN
IN DE ANDES- EN AMAZONEGEBIEDEN VAN BOLIVIË

Photograph front cover: aerial roots of a hemi-epiphytic species in the tropical forest environment of TIPNIS

Photographs back cover: Trinitario man performing the traditional dance of the *macheteros*; Yuracaré boy eating *Iriartea deltoidea* fruits under a *Geonoma deversa* roof; Quechua women from Apillapampa peeling potatoes

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Acronyms and Abbreviations

ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
BOF	Bijzonder Onderzoeksfonds (Special Research Fund, Belgium)
CA	Correspondence Analysis
CCA	Canonical Correspondence Analysis
CETEFOR	Centro Técnico Forestal (Technical Forestry Centre, Bolivia)
CINEP	Centro de Investigación y Educación Popular (Centre of Popular Investigation and Education, Bolivia)
CITES	Convention on International Trade in Endangered Species
CONISUR	Consejo Indígena del Sur del TIPNIS (Indigenous Council of the south of TIPNIS, Bolivia)
dbh	diameter at breast height
DCA	Detrended Correspondence Analysis
FAO	Food and Agriculture Organisation
FEPADE	Fundación Ecuménica Para el Desarrollo (Ecumenical Foundation for Development, Bolivia)
Fic	Factor of Informant Consensus
FIV	Family Importance Value
FUV	Family Use Value
HIV	Harvest Impact Value
IAR	Informant Agreement Ratio
IARs	Informant Agreement Ratio for species
INE	Instituto Nacional de Estadística (National Institute of Statistics, Bolivia)
IUCN	The World Conservation Unit
IV	Importance Value
m.a.s.l.	meters above sea level
MCAD	Multiple Causal Agent Disorders
MD	Medical Doctor
MDSMA	Ministerio de Desarrollo Sostenible y Medio Ambiente
MNeS	Number of Species with Negative properties

NCS	Number of Construction Species
NFS	Number of Food Species
NGO	Non-Governmental Organization
NMaS	Number of Material Species
NMS	Number of Medicinal Species
NSF	Number of Species in a Family
NSGF	Number of Species per Growth Form
NSoS	Number of Species with Social Uses
NTFP	Non-Timber Forest Product
PHC	Primary Healthcare Centre
PCA	Principal Components Analysis
OFT	Optimal Foraging Theory
QUAV	Quality Use Agreement Value
QUV	Quality Use Value
RDA	Redundancy Analysis
RUV	Relative Use Value
SCAD	Single Causal Agent Disorders
s.d.	Standard deviation
SERNAP	Servicio Nacional de Áreas Protegidas (National Service of Protected Areas, Bolivia)
TIPNIS	Territorio Indígena Parque Nacional Isiboro-Sécure (Indigenous Territory and National Park Isiboro-Sécure, Bolivia)
TM	Traditional Medicine
UD	Use Diversity
UE	Use Equitability
UV	Use Value
VLIR	Vlaamse Interuniversitaire Raad (Flemish Inter-University Council, Belgium)

Glossary

aetiology	term used to refer to the study of causality, i.e. why and how things occur, or even the reasons behind the way that things act
allopatric speciation	speciation as a consequence of geographical separation of a population
alma	soul
animo	spirit, ‘that what animates people’
awayu	characteristic cloth of the Andean culture, based on wool obtained from sheep or lama; used to carry almost anything on one’s back, including babies
ayni	traditional practice from Andean Bolivia based on reciprocity (e.g. exchange of labour)
ayllu	traditional collective social system from Andean Bolivia consisting of producer groups which own and work the land together
Chagas' disease	blood-borne parasitic diseases caused by *Trypanosoma cruzi*; therefore also called American trypanosomiasis
charango	small 10-stringed instrument that is characteristic of the Andean culture
chicha	home-made beer; in the Andes mostly prepared from maize, wheat and/or barley and in the Amazon from cassava, rice or maize
curandero/a	Spanish term to address traditional healer both in the Andes and Amazon
desombro	Trinitarios term to address the culture-bound syndrome of *susto*, fright disease
emic	taken from the perspective of a particular culture; opposed to etic which refers to the researchers’ point of views
espundia	term used to refer to cutaneous leishmaniasis, a skin infection caused by *Leishmania* parasites that are transmitted by sand-fly bites
glacis	erosional or depositional pediment, with little slope
hacienda	colonial period Andean estate, used to produce consumption products such as wheat, wine and beef to mining centres and the

	local Hispanic population
hechizo del agua	water curse
hestera	large (floor) mats people use to sleep or sit on, typically manufactured from the leaves of the giant reed *Gynerium sagittatum* var. *glabrum*
huesero/a	traditional bonesetter
idiosyncratic	'at the level of the individual'; derived from idiosyncrasy which is defined as a structural or behavioural characteristic peculiar to an individual or group
japa	Apillapampa term for a health condition in animals that is evidenced by bloodshot, swollen, bluish eyes; also refers to the name of a plant that causes it
jatiri	Apillapampa term to address traditional healer
jochi	term which refers to large rodents from the Amazon region (*Cuniculus paca* and *Dasyprocta agouti* among others)
lejía	cake of alkaline-rich plant ash that is chewed together with coca leaves to promote physiological effects
llajwa	hot sauce from *Capsicum* spp.
madre	culture-bound syndrome associated in Apillapampa with heavy labour on agricultural fields; several of its symptoms correspond with the biomedical definition of a hernia, but according to Vandebroek *et al*. (2008) it could be related to Chagas' disease
maldición	curse
Massenerhebung effect	the effect whereby mountains surrounded by large ranges will tend to have higher tree lines than more isolated mountains
mnemonic	a mnemonic device is a memory aid
Mojeños	Bolivian ethnic group of which Trinitarios are a subgroup
mutualism	a biological interaction between individuals of different species, where all individuals derive a fitness benefit
NatureServe	non-profit environmental conservation organisation
non-timber forest products	defined as all plant and animal products that are derived from forest landscapes, including human-modified ones

ontology	term used to refer to the study of being or existence
Pachamama	Quechua term for addressing Mother Earth
partera	midwife
phusqa	handicraft for spinning wool, consisting of a wooden stick of about 30-40 cm long with a transversally located disk at about one fourth of its length
pirua	cylindrical container manufactured from tree bark that is open at both ends and used for storing rice
pito	edible flour that is generally eaten uncooked
puchichi	term which refers to abscesses or furuncles
quesillo	fresh cheese, typically manufactured in Andean Bolivia
rosquete	a biscuit made of flour, eggs, fat and sugar
singa	long stick used for steering a canoe
site score	point that represents a site in an ordination diagram
sobandero	Spanish term used by Trinitarios to address Trinitario shaman
sombra	shadow
speciation	the evolutionary process by which new species arise
species score	point that represents a species in an ordination diagram
swidden	slash and burn cultivation field
sympatric speciation	the genetic divergence of various populations inhabiting the same geographic region, such that those populations become different species
tiharauqui	the historical equivalent of the present-day Trinitario shaman
tkonñahi	Trinitario term to address shaman
trapiche	sugar cane press
vinchuca	bloodsucking bug (probably *Triatoma infestans*), one of the vectors of the Chagas' parasite (*Trypanosoma cruzi*).
wayra	wind- or airborne diseases that can cause symptoms varying from stiff muscles to (facial) paralysis

yuca	cassava (*Manihot esculenta*)
yulula	traditional way of cooking whereby meat, fish or vegetables are wrapped in large plant leaves on top of a grill
Yungas	humid forests along the slopes of the Eastern (Bolivian) Andes between 500-3500 m.a.s.l.

1.

Introduction

1.1. Traditional Ethnobotany: a "Science in Struggle with Time"

Dedicated to studying all aspects of reciprocal relationships between plants and local peoples, traditional ethnobotany is more and more becoming a 'science in struggle with time'. Precisely the cornerstones of ethnobotany, i.e. traditional knowledge and plant diversity, are currently being lost at an accelerated speed (Cox, 2000) by seemingly unstoppable forces such as globalization, climate change, habitat destruction and "human progress".

The 2007 IUCN Red List of Threatened Species contains 14,043 endangered plant species (www.iucn.org). Paradoxically, up to present the exact total number of angiosperms that inhabit planet earth is still unknown (Prance *et al.*, 2000; Wilson, 2003). According to Wilson (2003), an average of about 2,000 new flowering plant species is annually described, and instead of the presently accepted 272,000 higher plant species on earth there might probably be well over 300,000 (Prance *et al.*, 2000; Bramwell, 2002; Wilson, 2003; Scotland and Wortley, 2003). Given the continuous destruction of biodiverse habitats worldwide, it is far from surrealistic to assume that numerous undiscovered species pass away from the world unrecorded and unmourned (Cox, 2000). Also traditional knowledge systems are rapidly fading away. Half of the approximately 6,000 languages spoken at the beginning of the 20th century have now vanished, along with the cultures they once kept alive. Eighty percent is spoken only by small groups of elders (Kraus, 1992).

Largely similar processes are occurring in Bolivia. As one of the least studied countries worldwide, Bolivia's biodiversity has long been underestimated. Scientists are just beginning to understand the biological wealth of the country (Ibisch and Beck, 2003). Recently, it has been suggested that Bolivia should be situated among the 10 to 15 countries with the highest biodiversity worldwide (Ibisch, 2003c). With an estimated number of 20,000 it would rank tenth or eleventh in terms of absolute numbers of higher plant species (preceded by Brazil, Colombia, China, Mexico, Venezuela, United States, Indonesia, India, Ecuador and Peru) (Ibisch and Beck, 2003). Yet, also in Bolivia, many species are threatened with extinction. Meneses and Beck (2005) assembled a preliminary red list of threatened plant species for Bolivia according to criteria applied by IUCN. They found that between 1998 and 2005, the number of species on this list has increased from 254 to 897. This corresponds with a factor 3.5 in only seven years of time.

Bolivia's biological diversity parallels a multiplicity in ethnic groups who developed survival strategies throughout history for coping with the extremely variable ecological living conditions that occur in the country. Total cultural diversity of Bolivia consists of 37 ethnic groups (Plaza and Carvajal, 1985; Gimenez Turba, 1996), and accounts for more than eighty different languages and dialects (Ibarra Grasso, 1996). Ethnic groups represent more than 60% of the Bolivian population of approximately 8.3 million in 2001 (Calvo, 2003c; www.ine.gov.bo). Ethnic diversity is highest in the lowlands, comprising around 30 indigenous groups, which only account for 5% of the Bolivian population. Most indigenous people reside in the Andean area, the traditional homeland of Quechuas and Aymaras. With 55% of the country's total population, the latter outnumber by far the indigenous lowland population (Calvo, 2003a).

Ethnic diversity in Bolivia is as fragile and prone to permanent loss as biological diversity. According to Raymond (2005), 11 languages known to Bolivia are spoken by less than 500 individuals, 6 of which are nearly extinct. Seven Bolivian languages are already extinct. The main reasons for extinction of ethnic groups in Bolivia relate to the effects of epidemics (Evans 1903) and (historical) impacts of the rubber industry (Pacheco, 2003). The reduction in number of several ethnic groups of hundreds to thousands of people to small tribes of merely a dozen individuals had already taken place by the beginning of the past century (Fawcett 1915). In addition, various ethnic groups that still survive today have lost their own language under pressure of other dominant neighbouring groups. For example, the Chane have been 'Guaranised'; the Kallawayas have been 'Quechuased' and the Urus have been 'Aymarised' (Plaza and Carvajal, 1985; Bastien, 1987a). In spite of the increasing loss of traditional knowledge and lifestyles in Bolivia (Denevan, 1980; Plaza and Carvajal, 1985; Ibarra Grasso, 1996; Bourdy *et al.*, 2000; Pacheco, 2003), ironically several uncontacted groups still roam the lowland forests. After Brazil and Peru, Bolivia is the third country in the world with the highest number of uncontacted groups (Brackelaire, 2006).

It is clear that Bolivia is a priority setting for ethnobotanical research for several reasons: its biocultural diversity is (1) among the highest of South America; (2) severely understudied;

and (3) threatened to disappear at an unprecedented speed. The present study is a direct response to these issues. It aims to enhance Bolivia's biocultural knowledge through an ethnobotanical focus on three ethnic groups residing in the two main phytogeographic and cultural areas of Bolivia, i.e. the Andes and Amazon.

1.2. Research Areas

Bolivia is blessed with a rich endowment of natural resources. Three major regions, harbouring a total of 12 different ecoregions (figure 1.1), are distinguished: (1) the high mountain chains of the Andes and the *Altiplano*; (2) the eastern Andean slopes and the Interandean valleys; and (3) the lowlands that occupy approximately 65% of the Bolivian territory (Ibisch et al., 2003). The present study was conducted in the latter two regions. Both research areas are characterised by extremely different ecological conditions.

The first part of this study was conducted among the Quechua people from Apillapampa, an Andean community situated in the Interandean valleys with a marked seasonal semi-arid climate and xeric vegetation (Navarro, 2002; figure 1.2). The second part of this study was conducted in five Yuracaré and Trinitario communities from the southern part of *Territorio Indígena Parque Nacional Isiboro-Securé* (National Park and Indigenous Territory Isiboro-Securé; TIPNIS), one of Bolivia's 21 protected areas (Ribera, 2003; see figure 1.1). The southern part of TIPNIS is characterised by a humid pluvial climate and a rainforest cover (Navarro, 2002).

Apillapampa is situated in the Capinota province and can be reached by bus and truck services operating between the city of Cochabamba and the towns of Capinota and Apillapampa, respectively (figure 1.2). The southern part of TIPNIS is located in the Chapare province and is accessed by a bus service between Cochabamba and Isinuta, via the transit city of Villa Tunari (figure 1.2). From Isinuta and nearby San Gabriel, small vans or shared taxis depart for Ismael Montes, situated at the southeastern margin of the park, from where the Yuracaré community of Sanandita (figure 1.2) can be reached after a 2-3 hour travel on foot or in canoe, depending on the season. On the other hand, a quasi-daily truck service connects Isinuta with (mainly Andean settler) communities located deep into the park. The main access road, still in use today, was inaugurated in 1970 and coincided with a major immigration wave of Andean settlers into the park (Paz, 1991; Lilienfeld and Pauquet, 2005). Although trucks seldom go that far, the settler community of Ichoa forms the endpoint of this road. From thereon, the Yuracaré and Trinitario communities San Jose de la Angosta, San Antonio de Moleto, El Carmen de la Nueva Esperanza and Tres de Mayo (figure 1.2) can be reached on foot after walks of 0.5-4 hours.

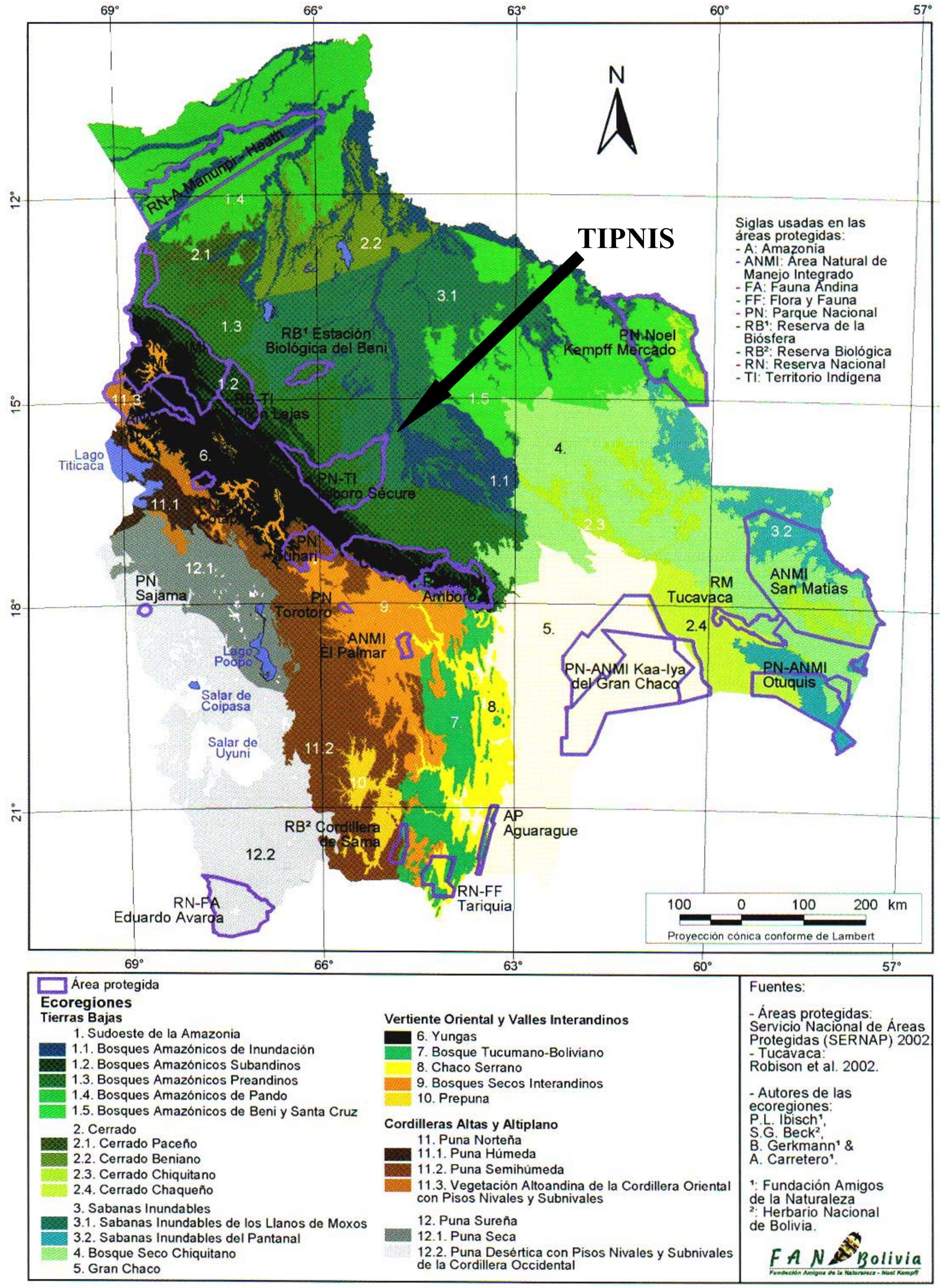

Figure 1.1: Map of the twelve ecoregions of Bolivia. Notice how five ecoregions are subdivided, yielding a total of 23 ecological regions. Bolivia's 21 protected areas are indicated by purple polygons. TIPNIS is situated near to the geographical centre of Bolivia (Ibisch and Mérida, 2003).

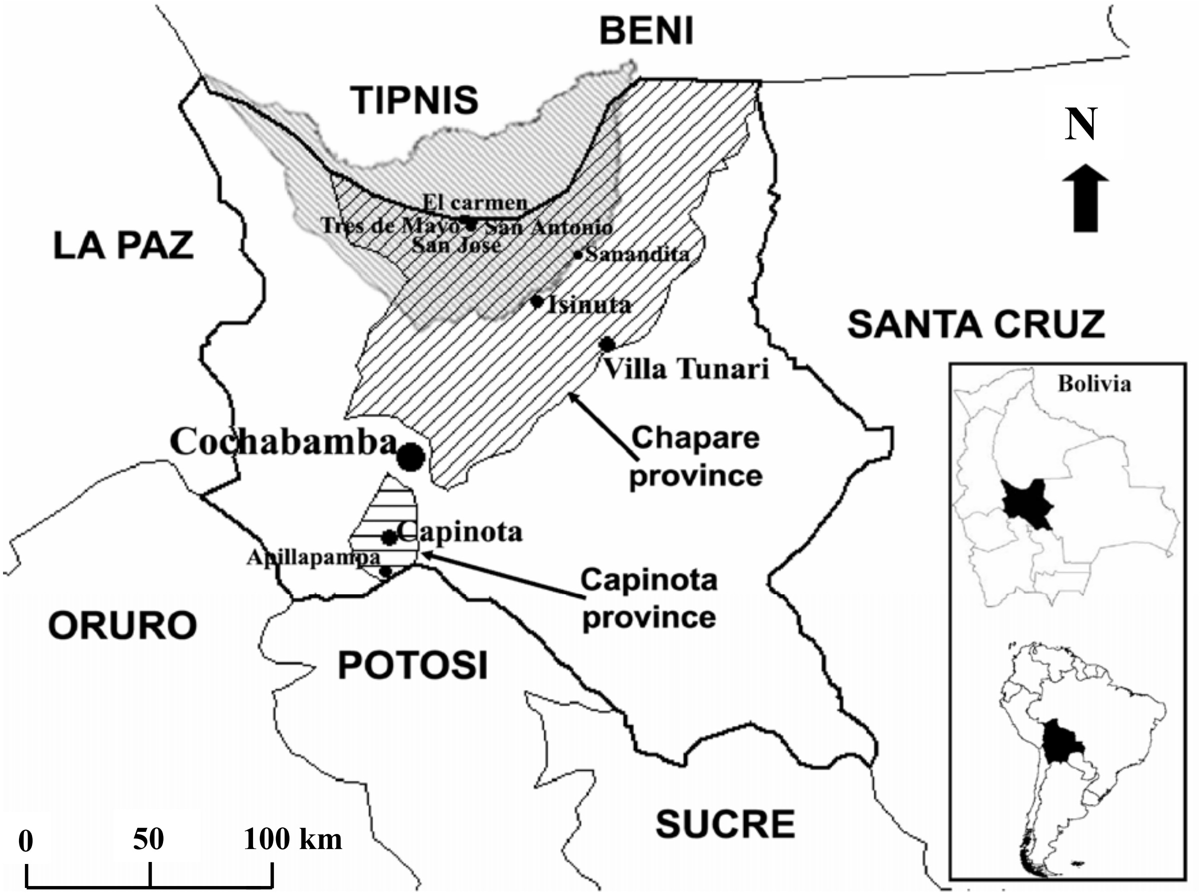

Figure 1.2: Location of the study areas in the Cochabamba department. The grey area represents TIPNIS (map elaborated by the author by means of DIVA-GIS (www.diva-gis.org))

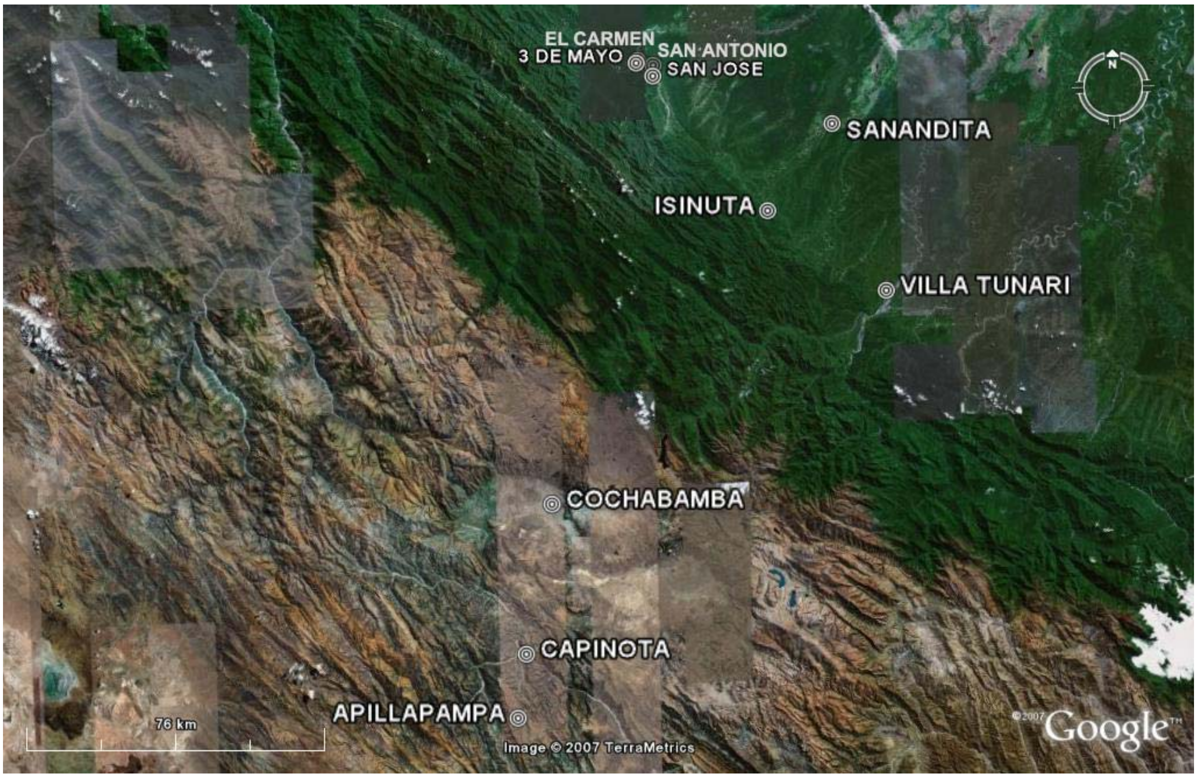

Figure 1.3: Location of the communities that participated in the present study (GoogleEarth, 26/11/2007)

1.2.1. The Quechua Farmers from Apillapampa

Apillapampa is an Andean community of around 2,500 Quechua-speaking farmers (430 families) (FEPADE, 1998). It is situated at approximately 3,250 m above sea level (figure 1.4A). From all indigenous groups in Bolivia, Quechuas account for 31% of the national population, or more than two and a half million people (Calvo, 2003a). The Quechua language was introduced to Bolivia by the Incas. The prehispanic period of the Bolivian Andes consists of a pre- and a post-Inca period. The greatest of the pre-Inca civilizations was Tiahuanacu, a culture that developed south of the Titicaca Lake in the Bolivian highlands (Calvo, 2003b). One of its important accomplishments was the development of an agricultural system with raised fields. After the fall of Tihuanacu around the twelfth century, independent *Aymara* kingdoms emerged in the *Altiplano* and Andean valleys, characterised by a common language. They practised a vertical control of a maximum of ecological units along an altitudinal gradient. This enabled them to access natural resources from different altitudes. In the *Altiplano*, the *Aymara* kingdoms established their political units where they raised camelids, cultivated tubers and high altitude cereals like quinoa (*Chenopodium quinoa*). In the lower valleys and *Yungas* (humid forests along the slopes of the Andes between 500-3500m) they established ‘colonies’. In the Interandean valleys, maize was cultivated while hot peppers, wood, and honey were collected (Calvo, 2003b). The *Yungas* were (and still are) a source of coca (*Erythroxylum coca* Lam.), a very important cultural plant species of which the leaves were chewed to alleviate hunger, thirst, and fatigue. This system of vertical control allowed people to take optimal advantage of the biodiversity that exists at different altitudes.

The Quechua-speaking Incas first arrived to Andean Bolivia from the region now known as Peru in the second half of the 15th century. They modified the existing social, political and economic structures, and introduced or amplified technologies for the intensification of agriculture, such as crop terraces along mountain slopes and irrigation canals (Calvo, 2003b). Traditionally, Quechuas were organised in *ayllus*, i.e. a collective social system consisting of producer groups that owned and worked the land together (Torrico Prado, 1971; INDICEP, 1977; Cereceda, 1978). In the Interandean valleys whereto Apillapampa belongs, the Incas founded military garrisons in defence against lowland indigenous warriors. The Incas also practised a vertical control of ecological units, but at a much larger scale than the Aymaras. The distance between colonies and the political nucleus (present in Cuzco, Peru), as well as the number of colonies, increased as compared to the colonies of the Aymara kingdoms (Calvo, 2003b).

The Spanish invasion of the Inca empire, initiated in 1532 (Torrico Prado, 1971; Bastien, 1987a), led to a partial destruction of the pattern of vertical control of different ecological units and induced the establishment of *haciendas* in the Interandean valleys. *Haciendas* were estates charged with the provision of consumption products such as wheat, wine and beef to mining centres and the local Hispanic population. The first important reform of the 20th century was the Agrarian Reform of 1952 that converted Andean people of the Interandean valleys and *altiplano* to communities of ex-haciendas with land rights. From that moment on, the Andean people were no longer called *indígenas* (indigenous peoples), but *campesinos* (farmers) (Calvo, 2003b). Apillapampa is an example of such an ex-hacienda whose present production model is based on the pre-Hispanic exploitation of multiple ecological zones along steep mountainsides (FEPADE, 1998).

Figure 1.4 A: Panoramic view of Apillapampa; B: Agricultural fields are ploughed with a pair of oxen and locally manufactured wooden ploughs; C: Applying a herbal smoke bath to chapped feet. D: Traditional costume from Apillapampa; E: Weaving textile from locally produced and processed wool; F: Typical pottery from Apillapampa

One of the most important cultural inheritances of Quechua people consists of the worshipping of *Pachamama* (Mother Earth) by means of complex rituals. Another important traditional practice that is still in use in Apillapampa is the concept of *ayni*, which is basically based on reciprocity (e.g. the exchange of labour) (Torrico Prado, 1971; Alberti and Mayer, 1974; Cereceda, 1978; Marzal, 1992). Andeans excel in traditional medicine (figure 1.4C), basically as an adaptation to a hostile and unpredictable environment (Bastien, 1982; Larme, 1998; Vandebroek *et al.*, 2004b). Essential parts of the material culture of Quechuas are indigenous textile based on wool obtained from sheep or lamas and pottery (INDICEP, 1977) (figure 1.4D-F).

Nowadays, main economic activities of people in Apillapampa are agriculture and animal husbandry (figure 1.4B). Only one third of the land is arable. The majority of people practices agriculture with a vertical management of ecological units according to altitudinal zoning (FEPADE, 1998). Main crops are potato, wheat and maize. Only 25% of the total crop production is commercialised. Cattle (sheep, goats, cows, horses and donkeys) are considered a source of savings. Meat is generally consumed only during festivities or in case of low crop yield. Because of the weak economic situation, villagers engage in temporary or permanent migration (FEPADE, 1998; Vandebroek *et al.*, 2004a and b). As such, various families also own lands in the tropical forests of Chapare province (figure 1.1) where they grow coca as a source of income. Quechua is the native language in Apillapampa (74% of the adult population is monolingual (INE, 2001) but many male adults and particularly children speak Spanish relatively well.

1.2.2. The Yuracarés and Trinitarios from TIPNIS

TIPNIS was created and officially declared a national park in 1965. As the result of a social mobilization of local indigenous groups (Yuracarés, Mojeños and Tsimane') that led to a series of protests and marches directed at the acquisition of collective private property rights, the national park was also declared indigenous territory in 1990 (Lilienfeld and Pauquet, 2005). TIPNIS is inhabited by Yuracaré, Trinitario and Tsimane' ethnic groups and also by colonizing Andean Quechua (and to a minor extent Aymara) settlers (Beetstra, 2005a). The Andean settler populations counts about 13,000 individuals with a proportional ethnic representation of 14:1 Quechua:Aymara (Rico Pareja *et al.*, 2005; Beetstra, 2005a). These settlers continue to make their way inwards and are currently only stopped by the National Service of Protected Areas (SERNAP) in cooperation with Yuracaré and Trinitario communities. There exists some uncertainty regarding the actual number of Yuracaré and Trinitario people that reside in the Cochabamba part of TIPNIS. Different sources mention between 16 and 53 settlements, representing 387-909 families and 1,874-5,154 individuals (Beetstra, 2005a). The Tsimane' settlements are restricted to the northern side of the park. Colonist communities are principally concentrated along unpaved roads where vegetation is mainly secondary or relict, while Yuracaré and Trinitario people have their settlements set up in the direct vicinity of primary vegetation and on high river banks (figure 1.5E).

TIPNIS extends from 200 to 3,000 m.a.s.l. and covers an area of 12,000 km² at the border between Bolivia's departments of Beni and Cochabamba (between 16°23'-16°40'S and 65°41'-65°57'W) (Lilienfeld and Pauquet, 2005). The communities that participated in this study are all situated in the lower part of TIPNIS, below 300 m.a.s.l. Main economic activity of Trinitarios and Yuracarés is slash and burn subsistence cultivation in swiddens (figure 1.6A) of principally rice, banana and cassava (figure 1.5D), supplemented with fishing and to a lesser extent hunting of large rodents, wild swine, deer, birds, monkeys, etc. People breed domestic animals like dogs, pigs, chickens and ducks for local consumption. Recently also goats have been observed. Coca leaves are grown to a limited extent as cash crop. Yuracarés and Trinitarios from the participating communities are bilingual (in Spanish and their native language).

1.2.2.1. Yuracarés

The Yuracarés speak an unclassified language (Van Gijn 2006). Contemporary Yuracarés number up to approximately 2,280 individuals, representing 0.03% of the total Bolivian population (Calvo, 2003a). However, this estimate might underestimate real figures. During a census in 1994-1995, 3,339 Yuracarés were counted (INE, 1994-1995, cited by Gimenez Turba, 1996). Before they had contact with the western world, Yuracarés engaged in a semi-nomadic lifestyle and had only limited practice of agriculture (d'Orbigny, 1945; Nordenskiöld, 2003; Querejazu, 2005a). The *Bactris gasipaes* palm (*tembe*) played a particularly important role in the Yuracaré society who partially based its annual calendar on the phenological cycle of this palm species. In past days, the ripening of *tembe* fruits initiated a process of reallocations of settlements, as well as a period of festivities with ritual ceremonies (Richter, 1930a; Haenke, 1974; Paz, 1991; Querejazu, 2005a). Yuracarés never lived in large communities and their social organization was based on large families ("*familia grande*"), grouping up to ten independent nuclear families (Paz, 1991; Nordenskiöld, 2003; Querejazu, 2005a and 2005b). From a historical point of view, Yuracaré territory (including TIPNIS) was inhabited in a very scattered manner (Paz, 1991).

The Yuracarés were/are very skilled archers (figure 1.5B, C & F) and canoe builders (Von Holten, 1877; Miller, 1917; Richter, 1930d; Torrico Prado, 1971; Nordenskiöld, 2003). Their best-known cultural traits are probably the barkcloth garments on which they applied beautiful geometric patterns by means of wooden stamps (figure 1.5A&B) (Mather, 1922; Richter, 1930c; Nordenskiöld, 1924 and 2003). A social and cultural practice of the Yuracarés that intrigued many anthropologists throughout history was the arrow duel (figure 1.5A). During this ceremony, two male opponents alternatively shot arrows at one another with specially designed blunt arrowheads that caused superficial wounds only (d'Orbigny, 1945; Kelm, 1997; Nordenskiöld, 2003; Querejazu, 2005a). Another painful custom of Yuracarés was to pierce the skin of arms (in case of men) (figure 8.30F) and legs (in case of women) with sharp animal bones during festivals in honour of girls who were experiencing their first menstruation. In the case of men, this practice was believed to improve courage and effectiveness during hunting, whereas it would prevent laziness in women (d'Orbigny, 1945).

Although the first literature reference about Yuracarés dates back to 1584 (Kelm, 1966; Nordenskiöld, 1924), they remained uncontacted by Westerners until 1768 (Church, 1912; Miller, 1917; d'Orbigny, 1958)). Even then, contacts remained restricted to the margins of the Yuracaré living environment (Richter, 1930a). Franciscan missions were established but without the expected success. They never reached the heart of the region inhabited by Yuracarés, including the area enclosed by the rivers Isiboro and Securé (i.e. our study area).

Figure 1.5 A: The arrow duel of the Yuracarés (drawing by d'Orbigny; source: Nordenskiöld, 2003); B: Groups of Yuracarés with decorated barkcloth garments (photo taken in 1915; source: Querejazu, 2005a); C & F: Contemporary Yuracarés still manufacture arrows; D: Yuracaré woman preparing alcoholic beverage (*chicha*) from cassava (*Manihot esculenta*) E: Yuracaré house and homegarden

Therefore, this area never became affected by Franciscan missions (Richter, 1930a; Paz, 1991; Querejazu, 2005a). As a consequence, the Yuracarés who participated in this study conserved their independence and traditional lifestyle until a colonization wave by highland settlers in the 1970s forced them to become sedentary (Paz, 1991; Querejazu, 2005a).

1.2.2.2. Trinitarios

Present-day Trinitarios represent one of four subgroups of the Mojeños (who are also called Moxeños, Moxos, Mojos or Muso (Caballero, 1706; Ibarra Grasso, 1996)). Actually, like Yuracarés, the Mojeños represent a minority group in the Bolivian society with almost 5,000 individuals or 0.06% of the national population (Calvo, 2003a). As for Yuracarés, this number probably underestimates the real figure since almost 20,000 Mojeños were counted during the 1994-1995 national census, half of which were Trinitarios (INE, 1994-1995, cited by Gimenez Turba, 1996). The Trinitario language belongs to the Arawak language family, one of the most important of South America (Ibarra Grasso 1996; Querejazu 2005b). In pre-Columbian times, the Mojeños established a peculiar society in the periodically flooded plains of Moxos (Beni department). They lived in large villages on the borders of rivers, lakes and marshes, as well as in the forest (Church 1912) of which they originally believed to be the children (Parejas 1976). Forests, rivers and lakes were considered Holy, and relocations of villages always took place in the proximity of the place of origin.

Denevan (1980) identified the Moxos plains as one of the cradles of the most advanced pre-Colombian societies of the Amazon basin with population densities of up to 28 persons/km^2, the highest of lowland South America (Denevan, 1996). Villages were extraordinary large in comparison to those of other lowland ethnic groups and counted up to 2,000 people (Denevan, 1980; Block, 1997; Lehm, 1999; Bert *et al*., 2004). At the time of first contact with Western society, Mojeños had domesticated ducks and practiced a well-developed slash and burn agriculture using stone axes to clear forest vegetation (Erickson, 1980; Denevan, 1980). To mitigate the effect of seasonal flooding, they built large constructions and agricultural infrastructures that consisted of variously shaped artificially elevated plains for their villages and crop fields. These ‘earthworks’ are still present as archaeological evidence today (Denevan 1980). Just like the early Romans, Mojeños had built up a network of ten thousands of linear kilometres of embankments of causeways. These were used for travel on foot and during the wet season when the plains were flooded, in combination with travel by canoe. It is very probable that these “roads” were used to facilitate intra-ethnic communication and transport, as well as to maintain inter-ethnic contacts, alliances, etc. (Erickson, 2000a).

Mojeños were/are skilled oarsmen. The canoe was one of their cultural traits (Balzan, 1894; Denevan, 1980; Ribera, 1997). Also, the famous dance of the *macheteros*, during which dancers wear precious mounted feather crowns on their heads, is an essential part of their cultural patrimony and is actively practiced until today (figure 1.6 B-D) (Eder, 1772; Denevan, 1980; Nordenskiöld, 1924 and 2003). One of the principal aspects that distinguished the Mojeños culture from the majority of Amazonian societies was their social organisation and hierarchic priesthood (Denevan, 1980; Lehm, 1999).

Figure 1.6 A: satellite image of the communities of El Carmen de la Nueva Esperanza and Tres de Mayo with a mosaic of patios, swiddens, fallows and high forest (source: Google Earth 12/12/2007); B: Dancing Mojo in a church in Trinidad (drawing by Keller-Leuzinger, 1874; source: Nordenskiöld, 2003); C & D: Trinitarios performing the dance of the *macheteros* outside and inside the church of El Carmen

Mojeños have a long history of cultural influence (see Lehm 2002, Wegner 1931). The first contact with European culture took place long before catholic missions were established, as Mojeños had connections with Caucasians (mainly gold diggers) in Santa Cruz (Nordenskiöld 1924; Block, 1980). The earliest record from the Moxos provinces dates from 1562. The first Jesuit contact was established in 1595 and Moxos was a Jesuit province for 100 years (1667-1767), during which the Mojeños were concentrated in missions together with other ethnic groups who spoke different languages (d'Orbigny, 1845; Lehm, 1999).

From the nineteenth century (1887) onwards, the Trinitarios started to migrate away from Moxos in search for the "Holy Land" or *Loma Santa* as a response to land pressure problems in their original homeland area (Riester 1976; Lehm 1999). The Trinitario communities who participated in the present research (El Carmen de la Nueva Esperanza, San Jose de la Angosta and partly Tres de Mayo) were founded as a result of this migration from the late 1970s onwards (Vandebroek *et al.*, 2004b).

1.3. Objectives

Biological resources are of crucial importance to the economic development of poor tropical countries. The most serious constraints that keep on hampering the development of sustainable use and management of biological resources in Bolivia are deficient basic ethnobotanical knowledge, as well as the lack of access to this knowledge by the scientific and Bolivian community at large (Balslev, 2006). Ethnobotanical research is currently experiencing a revival in Bolivia, as evidenced by numerous recent publications (e.g. Patzi, 1984; Girault, 1984 and 1987; Bastien, 1987a; Boom, 1987 and 1989; Cardenas, 1989; Moretti *et al.*, 1990; Hensen, 1991; Hinojosa, 1991; De Lucca and Zalles, 1992; Oblitas Poblete, 1992; Alba and Tarifa, 1993; Zalles and De Lucca, 1993; Alba, 1994; Torrico *et al.*, 1994; Birk, 1995; Quintana and Vargas, 1995; Toledo, 1995; Abdel-Malek *et al.*, 1996; Sagaseta, 1996; Pestalozzi; 1998; Uberhuaga, 1998; Bourdy, 1998 and 1999; Alexiades, 1999; Arrazola, 1999; De Walt *et al.*, 1999; Baelmans *et al.*, 2000; Muñoz *et al.*, 2000a, b and c; Sikkink, 2000; Bourdy *et al.*, 2000, 2002 and 2004; Vidaurre, 2000 and 2006; Beck *et al.*, 2001; Hinojosa *et al.*, 2001; Nate *et al.*, 2001; Prado, 2001; Ureña, 2001; Paniagua, 2001 and 2005; Rios and Rocha, 2002b; Vandebroek *et al.*, 2003, 2004a and 2004b; Reyes-Garcia *et al.*, 2003a and b and 2006; Carretero, 2005; Macía *et al.*, 2005; Ponz *et al.*, 2005; Toledo and Salick, 2006).

The ethnobotany of large groups such as Quechuas and Aymaras is among the best investigated in Bolivia. Like the present investigation, most studies have been local-scale approaches (i.e. carried out in one or few local communities). In view of the large area and high number of ecological units occupied by these people, there exists a considerable variation in the knowledge from one community to another. Hence, in order to obtain an overall picture of their ethnobotanical knowledge, it is important to conduct multiple local-scale studies throughout the entire geographical area occupied by Quechua-speaking people. Most ethnic groups from the Bolivian lowland area have more restricted distributions, but the ethnobotany of many of these groups remains largely unstudied.

The present study responds to these issues for the particular cases of Quechuas, Yuracarés and Trinitarios. It is basically the continuation of a postdoctoral project titled 'Applied Ethnobotany for the Phytochemical-Pharmacological Evaluation of Bolivian Plants: a Multidisciplinary Approach' that was conducted by Dr. Ina Vandebroek from 1st of July 2000 until 30th of June 2002. Apart from the work by Vandebroek *et al.* (2003; 2004a; 2004b; 2008) and Vandebroek and Sanca (2006), no significant ethnobotanical investigations focusing on overall plant use have been carried out among the Yuracarés and Trinitarios living in TIPNIS, nor in any Quechua community from the Capinota province.

This study follows a quantitative approach because it (1) quantifies useful plant species in their natural growing habitats and (2) is based on participant consensus. Quantitative ethnobotany has been defined as 'the application of quantitative techniques to the direct analysis of plant use data' (Phillips and Gentry, 1993a). Over the past twenty years, research scholars have advocated the necessity to quantify ethnobotanical research (Prance *et al.* 1987; Prance 1991; Phillips and Gentry 1993a and b; Phillips *et al.* 1994; Phillips 1996; Höft *et al.*, 1999). This is important to guarantee confidence in (statistical) data analysis, hereby promoting ethnobotany as a rigorous science (Phillips and Gentry 1993a and b; Höft *et al.*, 1999). In Bolivia, quantitative ethnobotanical research is underrepresented in ethnobotanical publications (Vidaurre *et al.*, 2006). The present study builds upon the relatively young tradition in quantitative ethnobotany and intends to demonstrate the numerous opportunities it offers in hypothesis testing and interpreting human-plant relationships.

The **main objectives** of the present study are:

- to develop a complete inventory of *all* useful plant species and their uses known to Quechuas from Apillapampa, and Yuracarés and Trinitarios from TIPNIS;
- to assess the abundance and diversity of plant species in different vegetation types that prevail in the study areas;
- to compare the usefulness of different vegetation types to local people;
- to identify the principal factors that explain plant use knowledge in the studied communities; and
- to provide feedback of research results to the participating communities.

During the course of the present study, several additional research questions arose. In Apillapampa, we were intrigued by the fact that, although most families cultivate timber species, they still rely heavily on wild plant populations for fulfilling basic fuel needs. This observation resulted in a study of the impact of local firewood harvesting on populations of wild (sub-)woody plants. In TIPNIS, our attention was drawn to the high number of useful plant species that are managed by Yuracarés and Trinitarios. Therefore, managed species became a special focus of attention during the TIPNIS study. During ethnobotanical interviews with Trinitario participants, we also gradually came to understand the complex role of the Trinitario worldview in the aetiology of certain folk illnesses. This led us to investigate Trinitarios' interpretation and treatment of *susto* or fright disease, a folk syndrome that is well known from societies throughout Latin America.

1.4. Thesis Outline

This dissertation consists of two general parts. Part one, including chapters 2 to 5, is dedicated to our research in Apillapampa, whereas part two, including chapters 6 to 11, deals with the results obtained from our study in TIPNIS.

For the design of appropriate conservation and management plans, quantitative information is required on the diversity, population structure, and distribution patterns of useful (and non-useful) species (van Andel, 2000). Therefore, in **chapter 2** a description is made of the xeric vegetation in Apillapampa. The following research questions are addressed:

1. Which plant species occur in the living environment of people from Apillapampa?
2. Which vegetation types and ecological zones can be distinguished in Apillapampa and to what extent does the indigenous ecological classification system correspond with our research findings?
3. Do these ecological zones correspond with existing phytosociological classifications from the literature?
4. Which plant species are characteristic and/or abundant in these ecological zones in the landscape surrounding Apillapampa?
5. Which variables explain the variation in plant diversity of sites throughout the landscape and to what extent can these variables be used to predict plant diversity?
6. Do people have a notion of vegetation degradation and are they able to identify possible causes?

In order to proceed to an evaluation of the usefulness of different species and vegetation types to local people, a complete review of the usefulness of all collected plant species is given in **chapter 3**. Different plant species and their uses are discussed in terms of eight broad use categories (medicine, food, fuel, materials, social uses, environmental uses, animal food and poison). Particular interest is given to the extraordinarily high number of medicinal plants used in Apillapampa. The main research questions of this chapter are:

1. Which use categories are most important in Apillapampa?
2. What are the most useful species per use category in Apillapampa?
3. Which demographic characteristics of participants influence plant knowledge in Apillapampa?
4. Which plant families contain the highest number of useful species and are most useful in each use category?
5. Are currently available plant use indices sufficient to quantify the cultural importance of medicinal species?
6. Why do people in Apillapampa use so many different medicinal species for treating similar health conditions?

An evaluation of factors that influence the usefulness of plant species and vegetation units to people in Apillapampa may provide important information to develop conservation and management plans. In **chapter 4,** the following research questions are investigated:

1. What proportion of the total number of species available at different sites throughout the landscape is used by people in Apillapampa?

2. Which variables best explain the variation in usefulness of vegetation units occurring throughout the landscape, and to what extent can these variables be used to predict usefulness?
3. What is the nature of the relationship between the diversity of vegetation units and their usefulness?
4. Which plant characteristics guide usefulness as perceived by people in Apillapampa?

An important subsistence-related plant use in Apillapampa is fuel. From literature, it is known that firewood harvest from wild species can have detrimental effects on the environment. In **chapter 5**, the impact of firewood harvesting on local plant populations is therefore assessed for Apillapampa. This leads to the following questions:

1. Based on judgements of local participants, which firewood species might be negatively affected in Apillapampa by fuel harvesting?
2. Which environmental variables best explain variation in the height of (sub-)woody plant species occurring at sites throughout the landscape in Apillapampa? What is the role of anthropogenic disturbance variables?

Presentation of results for our study in TIPNIS follows a similar structure as the one for Apillapampa (i.e. for chapters 2, 3 and 4 versus chapters 6, 8 and 9, respectively). In **chapter 6**, a vegetation description is given of three forest types occurring in southern TIPNIS. This is particularly important in view of the absence of detailed ecological studies on the forest vegetation of TIPNIS. The questions addressed here are:

1. Which plant species occur in the living environment of Yuracarés and Trinitarios from the southern part of TIPNIS?
2. Which plant species are characteristic and/or abundant in the forest types sampled in TIPNIS?
3. Do these forest types correspond with existing phytosociological classifications from the literature?
4. What are the patterns of plant diversity in these forests?

During our work in TIPNIS, we were soon confronted with a dilemma about the choice of plant props during ethnobotanical interviews. We decided that for our field situation, a combination of different interview techniques would be the most practical solution. In **chapter 7**, we provide an overview of the advantages and disadvantages of different plant collection and interviewing methods. One of the methods we used most was interviews based on plant photographs. The fact that this technique is seriously underrepresented in ethnobotanical literature, led us to test the ability of Yuracaré and Trinitario participants to recognise plant species from photographs.

In **chapter 8**, an overview is provided of the usefulness of all collected plant species in TIPNIS. Similar to results from Apillapampa, different plant species and their uses are discussed in-depth in terms of eight broad use categories (medicine, food, fuel, construction, materials, social uses, environmental uses and poison). The most important plant uses are highlighted for Yuracarés and Trinitarios separately. This chapter attempts to provide an answer to the following research questions:

1. What are the most important plant use categories in TIPNIS?
2. What are the most useful plant species within each use category in TIPNIS?
3. Which demographic and ethnic characteristics of participants guide plant use knowledge in TIPNIS?
4. Which plant families contain the highest number of useful species and are most useful in each use category?
5. Are known plant use indices adequate to quantify the cultural importance of medicinal species and are indices proposed in chapter 3 also valid for interpretation of our TIPNIS data?
6. Why do people in TIPNIS use so many medicinal species for treating similar health conditions?
7. How is the ethnomedical system of Trinitario people organised?

The usefulness of forests for indigenous peoples is often cited as an important reason for rainforest conservation (Myers, 1982; Prance *et al.*, 1987; Phillips *et al.*, 1994; van Andel, 2000). It has been suggested that there exists a hidden potential to combine local forest people's needs with the conservation of forests (Phillips *et al.*, 1994). Therefore, in **chapter 9** we assess the usefulness of different forest types for Yuracarés and Trinitarios. Additionally, an evaluation is made of factors that influence the usefulness of plant species to people. This chapter addresses the following research questions:

1. What proportion of species in different forest types is used by Yuracarés and Trinitarios?
2. Do different forest types vary in usefulness?
3. Are there ethnic differences in usefulness of forest types between Yuracarés and Trinitarios?
4. Which plant characteristics contribute to plant usefulness as perceived by Yuracarés and Trinitarios?

An important sub-discipline of ethnobotany is directed at studying plant management techniques applied by local people. **Chapter 10** provides an overview of some management practices applied by Yuracarés and Trinitarios. Particular attention is paid to plant management in homegardens and swiddens (i.e. slash and burn cultivation fields). This chapter also provides a comparison of overall plant knowledge of Yuracarés and Trinitarios. The main questions addressed in **chapter 10** are:

1. What are the principal plant management techniques used by Trinitarios and Yuracarés?
2. Which particular plant species are managed by Yuracarés and Trinitarios and why?
3. Are plants from anthropogenic disturbance habitats more useful to Yuracarés and Trinitarios as compared to plants from natural habitats?
4. Are there differences in plant knowledge for different use categories between Yuracarés and Trinitarios and are these differences reflected in plant management practices?
5. What is the role of ethnic affiliation in plant use knowledge?

Numerous folk illnesses are characterised by their widespread distribution throughout Latin America. *Susto* or "fright disease" is one of these folk illnesses. In the Trinitario culture, *susto* represents a complex intertwining of different ontological and worldview-related concepts. This inspired us in **chapter 11** to investigate the following questions:

1. What are the principal symptoms of *susto* among Trinitarios and who are the victims?
2. How do Trinitario ontology and worldview relate to *susto* aetiology?
3. What are the main treatments of *susto* among Trinitarios?

Finally, in **chapter 12**, the results obtained for Apillapampa and TIPNIS are summarized and discussed jointly. The relevance of our research findings and their potential role in future conservation and management plans are presented and highlighted.

2.

Floristic composition and diversity of semi-arid vegetation in Apillapampa

2.1. Introduction

The first part of this PhD study was conducted in the direct surroundings of Apillapampa, an Andean community in Bolivia situated along the road connecting Capinota with Arampampa (figure 2.1). Apillapampa is situated at about 3,250 m.a.s.l. and 17° 51'S 66° 15' W. No on-site climate data are available, but the nearest village of Capinota (2,400 m.a.s.l.) is characterized by a semi-arid bioclimate with a mean annual temperature of 17.8°C and a mean annual precipitation of 447 mm (Navarro, 2002). Hence, a somewhat lower temperature and higher precipitation can be expected for Apillapampa. According to the local NGO FEPADE (1998) mean annual precipitation in Apillapampa is around 630 mm. There is a pronounced dry season with 6-8 arid months (Ibisch *et al.*, 2003).

Various ecological classification systems have been proposed in Bolivia (e.g. Navarro, 2002; Ibisch *et al.*, 2003), but up to date none of these has achieved a completely accurate delimitation of the actual diversity of Andean environments (García and Beck, 2006). According to the classification in ecoregions proposed by Ibisch *et al.* (2003), the study area is situated in the central Tropical Andes (figure 2.2) on the interface between the Bolivian dry inter-Andean valleys and the semi-humid *puna* ecoregion (figure 2.3). The Tropical Andes has been identified as the leading biodiversity hotspot worldwide with an estimated 20,000 endemic plant species (Myers *et al.*, 2000). Within the Tropical Andes (figure 2.2), the Bolivian inter-Andean valleys represent a regionally important centre of endemism (Antezana and Navarro, 2002; Ibisch *et al.*, 2003). Harbouring around 16-18% endemic plant species, the flora of this ecoregion is mainly composed of locally evolved species derived from a southern-central South American stock (López, 2003a and 2003b). Therefore, the plant species of the dry inter-Andean valley region between 1,300 and 3,200 m.a.s.l. are more related to those present in southern-central South America (figure 2.2) than to the flora of northern South America that ranges southwards to Peru (López, 2003b). In terms of species, arid and semi-arid Andean plant formations are predominated by Andean elements, whereas in terms of genera, a dominance of genera with widespread distribution occurs (cosmopolitan and subtropical genera). Probably more than 2,000 species of vascular plants occur in the Andean dry valleys of Bolivia (López, 2003b). Cacti and thorny, leguminous trees are a more or less conspicuous characteristic of the landscape, at least in secondary vegetation.

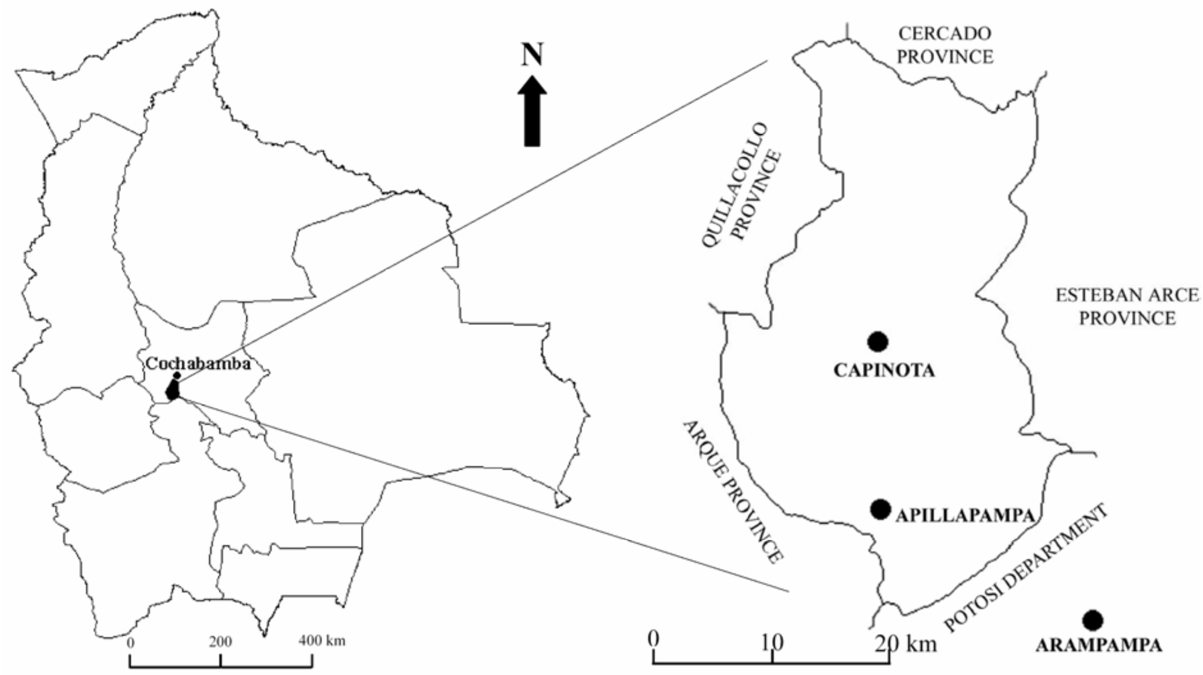

Figure 2.1: Location of the study area within Bolivia and Capinota province, respectively. Notice in the left side image how the city of Cochabamba is situated just north of Capinota province (map elaborated by the author by means of the programme DIVA-GIS (www.diva-gis.org)).

The part of the study area that is situated above the dry inter-Andean valleys belongs to the semi-humid *puna* bioregion (Ibisch *et al.*, 2003) (figure 2.3). In accordance with the trend that floristic diversity decreases with rising levels of aridity, diversity in the *puna* region is lower than in other major Bolivian vegetation formations. Nevertheless, the total species number remains high when considering the difficult habitat conditions for plant growth (García and Beck, 2006). Unfavourable factors include high radiation (particularly UV-B), low temperatures, and alkaline and saline soils. In spite of limitations imposed by altitude and these extreme climatic conditions, the *puna* harbours about 1,500 different plant species and about 40 endemic genera. Vegetation is characterized by: (1) open grasslands with *Festuca* *dolichophylla, F. orthopylla* and several species of *Stipa*; (2) *tholares* (evergreen resinous shrubs of *Baccharis*); and (3) *Polylepis* and *Buddleja* forests (Ibisch *et al*., 2003; García and Beck, 2006). Treeline in the tropical Andes generally occurs around 3,200-3,500 m (Rivas-Martínez and Tovar, 1982) but tends to be slightly higher in the more subtropical Bolivian Andes (Davis *et al*., 1997). For example, *Polylepis* trees are known to occur up to altitudes of 5,000 m (Kessler, 2006).

Figure 2.2: Location of Northern, Central and Southern Andes in South America. The figure in the lower right corner situates the Tropical Andes (sources: www.biodiversityhotspots.org and www.pilotfriend.com).

The more detailed phytosociological classification proposed by Navarro (2002), corresponds largely to the division in ecoregions by Ibisch *et al.* (2003). According to Navarro (2002) the vegetation of the study area belongs to both *prepuna* (2300-3200 m.a.s.l.) and *puna* (3,100-3,200 m.a.s.l. up to 3,900- 4,000 m.a.s.l.). The *prepuna* zone belongs to the inferior mesotropical bioclimatic level with soils of the calcaric cambisol and distric-umbric leptosol type (Navarro, 2002). The bioclimatic level of the *puna* zone is classified as supratropical. Soil data of this zone are not available in Navarro (2002).

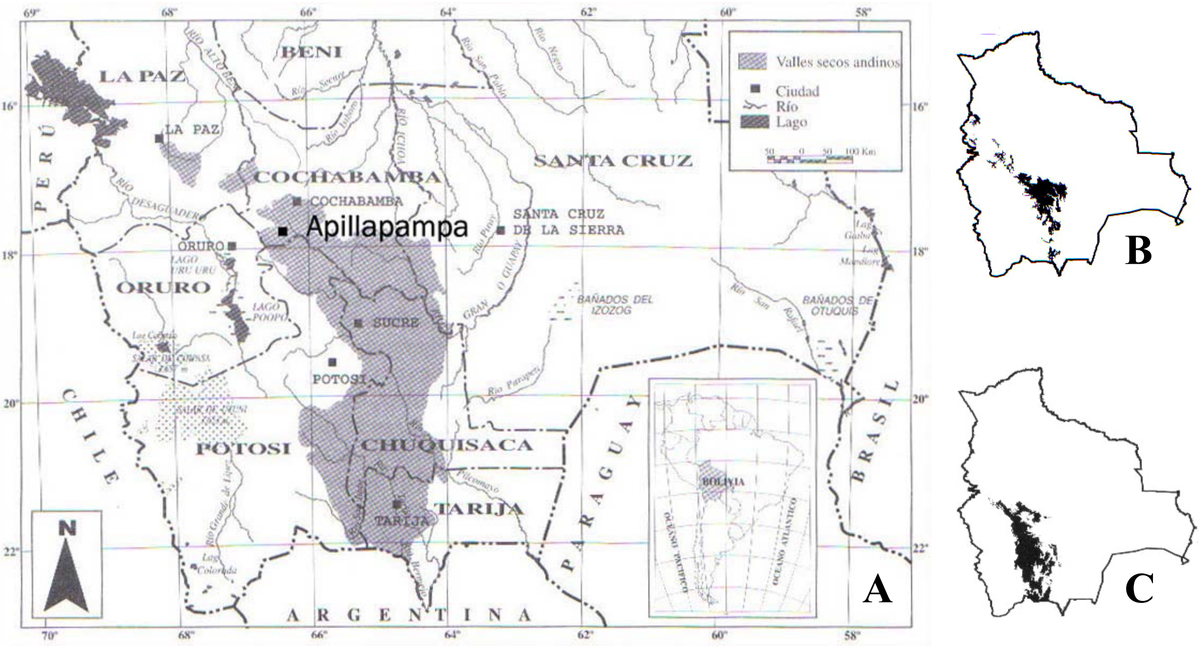

Figure 2.3A: Dry inter-Andean valleys according to Lopez (2003a&b); B. Dry inter-Andean valleys according to Ibisch *et al*. (2003); and C. Semi-humid *puna* according to Ibisch *et al*. (2003).

In the *prepuna* part, two main zones can be distinguished. The first ranges from 2,300-2,400 to 2,700-2,900 m.a.s.l. and is characterized by a combination of *Schinopsis haenkeana* and *Aspidosperma quebracho-blanco* (cf. Ibisch *et al*., 2003) often replenished with *Vasconcellea quercifolia*. The second zone ranges from 2,600–2,700 to 3,100–3,200 m.a.s.l. and has a potential climax vegetation dominated by *Kageneckia lanceolata, Prosopis laevigata* and *Schinus molle*. In eroded soils or intermittently burned zones, this vegetation is substituted by shrubs, including *Dodonaea viscosa* and *Baccharis dracunculifolia*. Between 3,100-3,200 and 3,900-4,000 m.a.s.l., i.e. the *puna* part of the study area, potential climax vegetation is formed by *Polylepis besseri* and *Berberis commutata*. *Berberis rariflora* and *Schinus microphyllus* are among the associated species. Further floristic data about associated, accompanying and substituting species are provided in Navarro (2002).

The study area is highly fragmented as a result of past and present human activity (Pendrotti *et al*., 1988; Navarro, 2002; Ibisch et al., 2003; García & Beck, 2006). The highlands of the central Andes have been inhabited for at least 15,000 years (Dollfus, 1984). At present, agriculture and animal husbandry are among the most important factors causing fragmentation, since most households own agricultural fields in each vertical vegetation zone. Relicts of climax vegetations are mainly situated on soils with limited agricultural potential and/or in areas that are more or less safeguarded from harvesting of firewood and intensive grazing by livestock (cf. Kessler, 2006).

In this chapter, we will describe the managed and wild flora in Apillapampa. Based on transect data it is verified whether the ecological zoning described by Navarro (2002) is also valid for our research area. The level of correspondence between floristically-defined ecological zones and local ethnoecological classification will be discussed in brief. Next, a more detailed description will be provided of the dominant species and families in each ecological zone. Finally, the impact of (natural and anthropogenic) environmental variables on the floristic composition in transects will be examined and potential threats to local plant diversity will be identified.

2.2. Methods

2.2.1. Ecological Sampling

Basically, two general methods have been applied for sampling the vegetation in the research area: fieldtrips and transects. Both methods are complementary to each other in the sense that the first ensures collection of plants in every local habitat such as in agroecosystems, ruderal places, cliffs, river banks, wells, crevices, etc., whereas the second technique allows to detect inconspicuous plants that would otherwise be missed (cf. van Andel, 2000).

2.2.1.1. Fieldtrips

During December 2002-November 2003, 31 fieldtrips were undertaken in the research area. During these fieldtrips, plants were gathered haphazardly as well as in an orderly manner (e.g. by focusing on medicinal plants only), and frequently (an) indigenous participant(s) accompanied the main researcher. All possible growth forms were sampled and specimens were collected and preserved according to international botanical standards.

2.2.1.2. Transects

Ecological and botanical data of the herbaceous and woody flora of the study area were collected between December 2002 and May 2003 (rainy season) by means of twenty-nine 0.01 ha transects of 50 x 2 m^2 (Figure 2.4; green trees). In the dry season, between August and October 2003, the (sub-)woody flora (including Cactaceae) was sampled in seven additional transects (figure 2.4; red trees). Sampling sites were situated between 2,730 and 3,750 m.a.s.l. and were selected after obtaining agreement with each landowner.

All sites were reached after walks in the presence of the landowner or one of his relatives. Walking time varied between twenty minutes and more than three hours. At each site, transects were constructed in areas that had not been visibly influenced by agricultural practices. However, due to severe landscape fragmentation, it was impossible to find sites with completely undisturbed vegetation. All sites had at least partly been subjected to harvesting of firewood or grazing by livestock. In some cases, there was evidence of (recent) burning. Following the advice of Bonham (1989), individual transects were separated by horizontal distances of minimum one hundred meters.

Uphill starting points of transects were chosen more or less arbitrarily by throwing a stone behind the back. A compass bearing was subsequently chosen, generally parallel to the dominant site slope. A transect line was then constructed by means of a 50 meter tape and according to the predetermined compass bearing (figure 2.5). To guarantee comparison between transects that are constructed on different slopes (Peters, 1996; Roberts-Pichette and Gillespie 1999), a horizontal transect surface of 100 m^2 was set standard. From the starting point onwards, an iron pole was located at each point of noticeable slope change along the transect line (poles A-C in figure 2.5), as well as at the provisional end point, i.e. at a distance of 50 m or more along the transect line (point X in figure 2.5).

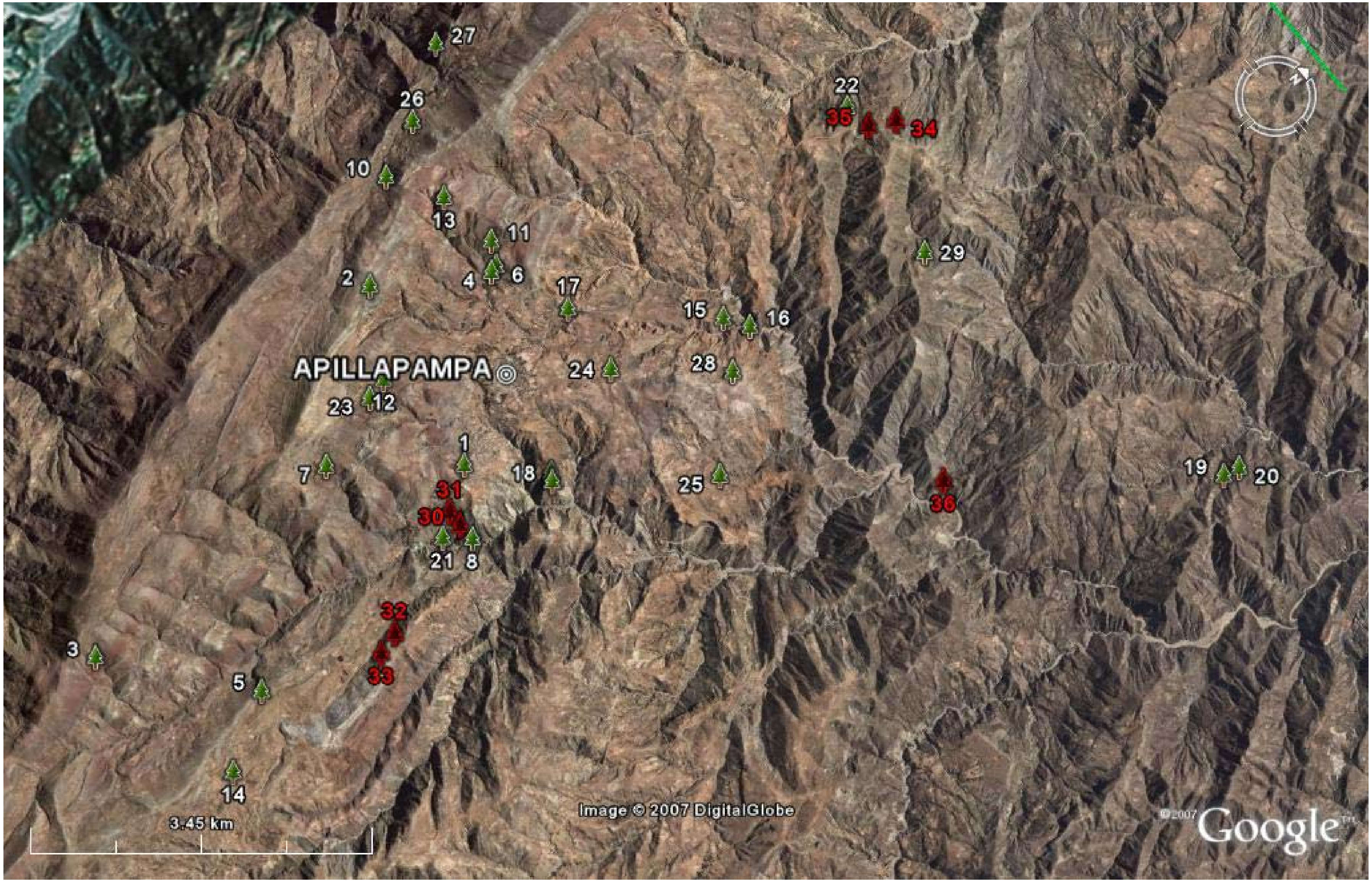

Figure 2.4. Distribution of sampled transects (in the green ones herbaceous plus (sub-)woody plants were sampled and in the red ones only (sub-)woody plants were collected) (source: Google Earth 26/11/2007)

Next, a nylon rope was attached to all planted poles, at a predetermined vertical distance above ground (usually 70 cm, as the poles used measured 100 cm). At this point, the compass bearing was double-checked and possible deviations adjusted. Slopes between all poles were determined by means of the slope-measuring facility of the *Suunto X6* altimeter. Distances between poles along the transect line were determined with a 50 meter tape (d_l and d_2 in figure 2.5). Using slope and distance data between two different poles, the corresponding horizontal distances were calculated using the formula Cos θ equals horizontal distance divided by distance along the slope (θ being the measured slope). The corresponding horizontal distances of all transect segments, except the last (i.e. l_l and l_2 in figure 2.5), were then summed. This sum was subtracted from 50 to obtain the horizontal distance of the last segment. The latter value was used, together with the measured slope of the (provisionally constructed) last segment, to calculate its corresponding distance along the slope. Subsequently, the lower pole's position was adjusted correspondingly, to obtain an exact horizontal transect distance of 50 meters.

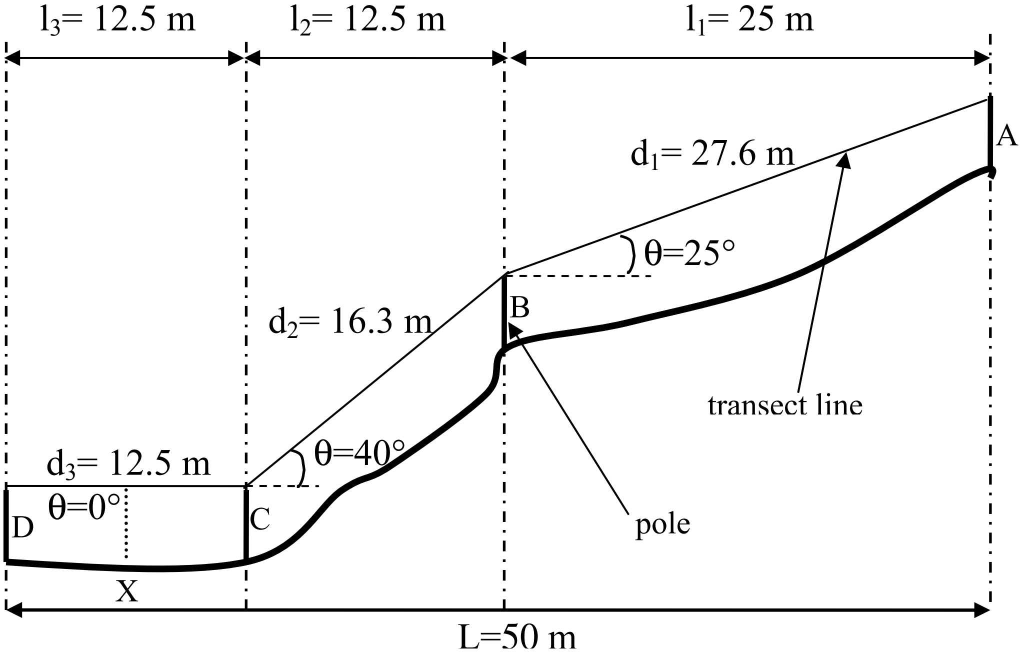

Figure 2.5: Example of the methodology applied for determining slope correction. Poles are located at points of noticeable slope change (A-C). A 50 meter tape is attached to the poles and after about 50 m or more along slope, a provisional pole is placed (location X). Next, slopes of all fixed segments are measured and corresponding horizontal distances are calculated and summed: $l_1 + l_2 = d_1 * \cos(25°) + d_2 * \cos(40°)$.= 37.5. This total is subtracted from 50: 50m-37.5m=12.5m to obtain the horizontal distance of the last segment. The slope of the last segment is measured by means of the provisional pole placed at X (in this case 0°). Based on these data the length along slope of the last segment is calculated: $d_3 = l_3/\cos 0°$ and the last pole is put in place (D). Hence, the length of the transect along the slope (i.e. 56.4 m) is considerably larger than 50 m.

As the slope distance is always higher than the horizontal distance on non-horizontal terrain, the original transect was always prolonged for transect lines laid out parallelly to the dominant site slope. Next, the head or coin method was used to decide upon which side of the transect line to sample. At the chosen side, and opposite to each pole, additional poles were located at a distance of exactly two meters. After that, the nylon rope was attached to the newly placed poles, thus demarking a horizontal surface of 100 m². For ease of working, the rope was lowered when appropriate.

All non-Poaceae individuals of plant species with a height or length of ≥0.1 m at maturity were counted systematically, including three sub-woody hemi-parasites. Small crawling herbs rooting at their nodes with internodes of less than 0.1 m were not included. When it was not possible to separate individual shrubs from one another, we treated each different clump as an individual, following the advice of Roberts-Pichette and Gillespie (1999). At the moment of sampling, many plant species were represented by juveniles smaller than 0.1 m. At that point we were not yet certain whether the corresponding adult plants would eventually grow taller than 0.1 m. Therefore, these specimens were all counted and collected. Sterile and juvenile collections were supplemented afterwards with fertile specimens of the same species at a later phenological stage to verify their respective botanical identities and height at maturity. Once all collections were identified to species level, only those species growing to a height or length of at least 0.1 m at maturity were included in the transect data sets. A similar method of excluding small plants based on plant height has been reported elsewhere (e.g. Bernstein *et al*., 1997). Only those plant individuals of which more than half of the basal surface or more than half of the number of ramets were on the inside of the transect-line were counted. To facilitate counting and to avoid making mistakes, a small portion of the belt transect was delineated using two movable cords, placed perpendicular to the original transect-line. Every individual was recorded as a unique 'morphospecies'. Subsequently, a voucher collection was made if the taxon was encountered for the first time or in case there was uncertainty about its botanical identification (cf. Phillips *et al.* 2003).

Each voucher was made according to botanical standards. Collected specimens were identified by the author in the Herbario Nacional Forestal "Martin Cardenas" of Cochabamba and by taxonomical specialists (see acknowledgements). Throughout this thesis, Cronquist's classification (1988) was followed, and Fabaceae-Caesalpinioideae, Fabaceae-Mimosoideae, and Fabaceae-Papilionoideae were pooled together into Fabaceae. Voucher specimens were deposited in the Bolivian herbaria of Cochabamba (BOLV) and La Paz (LPB).

2.2.1.3. Presentation of Results

During the rainy season, annual and perennial species flourish, but once the rain stops and soil dries nearly all annual plants completely disappear, with exception of plants growing in humid areas such as wells or stream banks. During the dry season only (sub-)woody plants, Cactaceae and some epiphytes remain visible. In view of this clearly marked seasonal variation in vegetation, results obtained from transect sampling are presented separately for the rainy and dry season. In chapter 4, this allows for a proper assessment of the perceived usefulness of the vegetation on a seasonal basis. The situation in the rainy season is represented by the first twenty-nine transects wherein all plant species of 0.1 m and larger (except Poaceae) were sampled. In the following we will refer to the situation in the rainy season as *plants >0.1 m*. The situation in the dry season is represented by the sub-sample of (sub-)woody plants (including Cactaceae) of the same twenty nine transects sampled in the rainy season plus seven additional transects that were sampled during the dry season. The dry season situation will be referred to as *(sub-)woody plants*.

2.2.2. Data Analysis

2.2.2.1. Diversity Indices

Diversity in transects is expressed as Alpha diversity (α, the species number or richness) and Shannon-Wiener diversity (H, hereafter called Shannon diversity). Shannon diversity is calculated as $H = -\sum p_i * \log(p_i)$, whereby p_i is the proportional abundance of species *i* on the total abundance of all species. Shannon diversity considers both species richness and evenness. Hereby, increases in species richness as well as a more even abundance of individual species both lead to a higher Shannon index. Therefore, two different sample sites with equal Shannon diversity can have a different richness and evenness.

2.2.2.2. Species-Area Curves

To determine whether the sampled transects are representative for the flora of Apillapampa, species-area curves were constructed by means of the BioDiversity-Pro program which is specially designed for analysing data in biodiversity research (McAleece, 1997).

2.2.2.3. Cluster Analysis

Cluster analysis is a statistical tool to identify groups with similar characteristics from raw data and helps to find structure in data. It attempts to subdivide or partition a set of heterogeneous elements into relatively homogenous groups (Höft *et al*., 1999). Many clustering methods exist and it is practically impossible to choose a 'best' method because of their heuristic nature. If there is a markedly discontinuous structure in data, it will be detected by almost any method, while a continuous structure will almost always be obscured by cluster analysis (Jongman *et al*., 1996).

For both *plants>0.1 m* and *(sub-)woody plants*, species abundance matrixes consisted of rows with transect data and columns with species data. Cells contained the number of individuals by which species were represented in transects. Similarity/dissimilarity matrixes of our quantitative data were calculated by means of the PC-ORD 4.0 statistical program (McCune & Mefford, 1999), using Bray-Curtis, Jaccard and Euclidian distances measures. Various agglomerative hierarchical clustering analyses were performed, including *nearest neighbour* (also called single linkage, whereby the merger of two subsets of objects is based on the minimum distance between objects), *farthest neighbour* (also called complete linkage, whereby the merger is based on the maximum distance between objects) and *unweighted pair-groups method analysis* (UPGMA, also called group average linkage; links a new item to the arithmetic average of an existing group).

No straightforward criteria exist to guide the decision making process on what clustering method to choose. There are almost as many methods to decide which cluster method is best as there are clustering methods. Some of these use statistical tests, or better pseudo-statistics since the rigorous conditions for application of the tests are never satisfied (see Jongman *et al*., 1996). In this respect, PC-ORD calculates the degree of chaining. Chaining is the sequential addition of small groups to one or a few large groups. Dendrograms that are highly chained are usually undesirable as they are generally not helpful in defining subgroups. The method for calculating the degree of chaining compares the average path length of the dendrogram with the minimum (no chaining) and maximum possible (complete chaining) average path length. The path length for any item in the dendrogram is the number of nodes that connect it to the highest level in the dendrogram. Complete chaining occurs when each new item is added to a single, increasingly large group (McCune and Mefford, 1999).

2.2.2.4. Ordination Analysis

The basic aim of ordination is to represent species and site data points in a two-dimensional space in such a way that points that are close together correspond to sampling sites that are similar in species composition whereas points that are far apart correspond to sites that are dissimilar in species composition. Two general approaches are used in ordination. In direct gradient analysis, one is interested from the beginning in the impact of particular environmental variables on the occurrence and abundance of species. Transects are arranged in a virtual ecological space along axes that are linear combinations of environmental variables (e.g. altitude, moisture, etc.), and the influence of the respective factors on vegetation is determined (Höft *et al*., 1999). By contrast, indirect gradient analysis focuses entirely on the floristic composition of transects for constructing ordination axes. The explanatory variables in indirect gradient analysis are therefore not known environmental variables, but “theoretical” or latent variables that are constructed in such a way that they best explain the variation in species data (Jongman *et al*., 1996).

For both direct and indirect gradient analysis there exist two types of ordination techniques: those that are related to (1) a linear (monotonic) response model in which the abundance of any species either increases or decreases with the value of each of the latent environmental variables (e.g. Principal components analysis (PCA) and Redundancy Analysis (RDA)); and (2) an unimodal response model, whereby any species occurs in a limited range of values of the latent variables (e.g. Correspondence Analysis (CA), Detrended Correspondence Analysis (DCA), Canonical Correspondence Analysis (CCA) and Detrended Canonical Correspondence Analysis (DCCA)) (Jongman *et al*., 1996). According to Jongman *et al.* (1996) it is advisable to start analyzing ecological data by using unimodal models (CA, DCA or CCA) and to decide afterwards whether one could simplify the model to a monotonic one. This initial analysis will provide a check on how unimodal the data are. If the lengths of the ordination axes are less than about two standard deviations (2 s.d.), most of the response curves will be monotonic, whereafter one should consider using PCA or RDA. Here we used DCA for determining lengths of ordination axes.

Environmental conditions are often difficult to characterize exhaustively. There are many environmental variables and even more ways of measuring them, and it is often difficult to know which variables the species react to. Species composition may therefore be a more informative indicator of the nature of an environment than any given set of measured environmental variables. Ordination can help to show whether important environmental variables have been overlooked. In the framework of this study, data were analyzed first by means of indirect gradient analysis as a “best fit” arrangement of species and transects in ordination diagrams that “unrestrictedly” maximizes the dispersion of species scores (i.e. CA). Species scores are the points that represent species in the ordination diagram. In a second step, direct gradient analysis was conducted to examine whether similar compositions are obtained when site scores are restricted to linear combinations of measured environmental variables (i.e. CCA). Site scores are the points that represent sites (i.e. transects in our study) in the ordination diagram. If plots show largely comparable trends or groupings in both CA and CCA diagrams, this would mean that the measured environmental variables explain the variation in data well. The inverse scenario would indicate that important environmental variables have been overlooked. When there is no relation between the mutual positions of the sites in the ordination diagram and the measured environmental variables, an important variable has definitely been missed (Jongman *et al.*, 1996). In the present investigation, the following environmental parameters were measured:

1. mean altitude of transect (quantitative variable);
2. travel time (on foot) from Apillapampa village centre to transect (quantitative variable);
3. transect slope (quantitative variable);
4. exposition (measured as compass bearing) (quantitative variable);
5. plantation of exotics (*Eucalyptus* spp., *Pinus radiata* or *Spartium junceum*) (binary variable);
6. river in direct vicinity (< 10 m away from transect) (binary variable);
7. evidence of firewood harvesting (binary variable);
8. evidence of grazing (binary variable);
9. path crossing transect (binary variable); and
10. evidence of fire (binary variable).

However, it is proper to point out some potential bias in these environmental data. Whereas mean altitude, transect slope and exposition have been sampled more or less evenly over the entire spectrum, repetitions of long travel times were fewer than for short travel times. The presence-absence variables *firewood*, *grazing* and *fire* may also be subjected to bias. They represent only a limited number of observations (taken at the time of sampling) whereas an absence status may have been assigned erroneously to transects when evidence had already vanished.

All ordination calculations were done by means of the PC-ORD 4.0 program (McCune and Mefford, 1999). For direct gradient analysis, this programme requires the input of two matrixes: a **main matrix** representing plot-species data and a **second matrix** representing plot-environmental variables data. Obviously, only the main matrix is needed for performing indirect gradient analysis. As for cluster analysis, in the present study the main matrix consisted of rows with transect data and columns with species data for both *plants>0.1 m* and *(sub-)woody plants*. Cells contained the number of individuals by which species were represented in transects. In the second matrix, rows also represent transect data while columns are environmental variables. Transect scores were centred and normalized such that the mean is zero and the variance one. Following the recommendation of Ter Braak (1994), scores for rows in the main matrix (i.e. transects) were calculated as linear combinations of the columns in the second matrix (i.e. environmental variables). The existence of a relationship between main and second matrix was tested by means of a Monte Carlo test, which investigates how the observed eigenvalues and species-environment correlations compare with those from randomized runs. For example, to evaluate the significance of the first CCA axis, a p-value is computed that is simply the proportion of randomized runs with an eigenvalue greater than or equal to the observed eigenvalue (McCune and Mefford, 1999). The significant contribution of environmental variables to the ordination axes can be examined by means of the inter- and intraset correlations. Inter- and intraset correlations indicate the relations between environmental variables and the ordination axes for the "original" (CA) and the fitted site scores (CCA), respectively. Intraset correlations are obtained by dividing interset correlations by species-environment correlations (cf. Ter Braak, 1986). Only values >│0.5│ contribute substantially to the axis.

2.3. Results and Discussion

2.3.1. Complete Inventory

During the present ethnobotanical study, 626 plant collections were made in Apillapampa. As such, a total of 441 species was inventoried, not taking into account agricultural crops (Appendix 1). These taxa are distributed over 91 botanical families and 269 genera. Four hundred and twenty three (423) species have been identified to species level, an additional 6 to genus level, whereas 12 (of which 9 Poaceae) have only be identified to family level. After consultation with taxonomical specialists (D. Goyder (Asclepiadaceae) and A. Krapovickas (Malvaceae)), two collected species appeared to be new to science. One of these (corresponding to collection numbers ET356 and ET459) has been described as *Philibertia globiflora* Goyder, whereas the absence of fruits hampers description of the collected Malvaceae specimen (ET487). In spite of the flowering state of the specimen, the specialist was unable to identify the species' genus.

Best-represented families are Asteraceae (23.8% of all recorded species), Fabaceae (8.4%), Poaceae (6.1%), Solanaceae (5.4%), Lamiaceae (3.2%), Scrophulariaceae (2.5%), Asclepiadaceae (2.3%) and Malvaceae (2.3%) (table 2.1). Most diverse sampled genera include *Baccharis* (15 species), *Solanum* (14), *Stevia* (8), *Salvia* (7), *Eupatorium* (6), *Plantago* (6) and *Tillandsia* (5).

The floristic composition of the plants sampled in the study area corresponds well with data from literature. According to Moraes and Beck (1992) the flora of the Interandean valleys ("*valles interandinos*") and the high Andes ("*altoandino*"), which includes our research area, is characterized by a more or less constant presence of 18-28% Asteraceae, 4-7% Fabaceae and ≤5% Pteridopyta. Based on all collections that are deposited in Bolivia's national herbarium (LPB), Lopez (2003a), calculated that the most species-rich botanical families for the Interandean dry valleys are Asteraceae (16%), Cactaceae (9%), Poaceae (9%), Fabaceae (8%), Solanaceae (5%), Bromeliaceae (4%), Pteridophyta (4%), Malvaceae (3%), Euphorbiaceae (3%), Verbenaceae (2%), Lamiaceae (2%), Asclepiadaceae (2%). Hence, it is clear that these families largely overlap with the families that are best represented in this study (table 2.1), although actual proportions may differ.

More than half of all plant species inventoried are herbs (54% or 236 species; for subdivisions see figure 2.6). Shrubs account for 22% or 94 species. There are 6% grasses (27 species), 6% trees (26 species), 5% lianas or vines (20 species), 3% ferns (11 species), 2% hemi-parasites or parasites (10 species), 2% cacti (7 species) and 1% epiphytes (5 species).

Apart from the typical food crops, at least 44 species are actually cultivated in Apillapampa (Table 2.2). The centres of origin of 25 of these cultivated species are outside South America.

Many of these species, such as *Eucalyptus* spp., *Cupressus* sp., *Pinus radiata*, *Spartium junceum, Prunus* spp. have been introduced to Apillapampa by the local NGO FEPADE. Other species are also cultivated in the study area, but to a very limited extent. For example*,* *Arundo donax*, a tall reed whose culms are used for roof thatching is largely restricted to lower altitudes and cultivation in the surroundings of Apillapampa is only successful on a few low altitude sites. The same accounts for *Schinopsis haenkeana, Inga* cf. *striata, Alnus acuminata, Acacia visco, Erythrina falcata* and *Jacaranda mimosifolia*. Although native to the Andean valleys of Bolivia, *E. falcata* does not seem to occur in the natural vegetation of Apillapampa. Therefore, the only observed cultivated mature tree represents an allochthonous species in Apillapampa. The same accounts for numerous other cultivated species such as *Alloysia triphylla, Alnus acuminata, Passiflora mollissima*, *P. umbilicata* and *Solanum betaceum*.

In addition to the 25 introduced cultivates, 29 ‘wild’ exotic species (table 2.3) occur in the area of Apillapampa. Hence, approximately 12% of the inventoried local flora is introduced. All but one (*Ranunculus repens* var. *flore-pleno*) of these wild exotics are agricultural weeds and/or ruderals.

Table 2.1: Family distribution in number of species and percentages

Family	Number of Species or Families	Percentage
Asteraceae	105	23.8
Fabaceae	37	8.4
Poaceae	27	6.1
Solanaceae	24	5.4
Lamiaceae	14	3.2
Scrophulariaceae	11	2.5
Asclepiadaceae	10	2.3
Malvaceae	10	2.3
Verbenaceae	9	2.0
Apiaceae	9	2.0
Convolvulaceae	8	1.8
Rosaceae	8	1.8
Amaranthaceae	7	1.6
Brassicaceae	7	1.6
Bromeliaceae	7	1.6
Cactaceae	7	1.6
Euphorbiaceae	7	1.6
Plantaginaceae	6	1.4
Amaryllidaceae	5	1.1
Cheilanthaceae	4	0.9
Polygalaceae	4	0.9
Polygonaceae	4	0.9
families with 3 spp.	17	11.6
families with 2 spp.	8	3.6
families with 1 spp.	44	10.0

2.3.2. Agricultural Crops

A large part of daily live in Apillapampa is dedicated to animal husbandry and crop production activities. Plant production is mostly focused on (1) Andean tuber crops (Cadima Fuentes, 2006) such as various species and varieties of potato (*Solanum* spp. and *S.*

tuberosum), *oca* (*Oxalis tuberosa*), *isaño* (*Tropaeolum tuberosum*) and *papa lisa* (*Ullucus tuberosus*); and (2) grain crops such as wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), maize (*Zea mays*), as well as the more traditional cultivates *amaranto* (*Amaranthus* spp.) and *quinoa* (*Chenopodium quinoa*). Beans such as *haba* (*Vicia faba*) and *tarwi* (*Lupinus mutabilis*) are cultivated to a more limited extent. Under custody of the local NGO FEPADE, many (introduced) vegetables such as carrot (*Daucus carota*), radish (*Raphanus sativus*), *acelga* (*Beta vulgaris* var. *cycla*), onion (*Allium cepa*), artichoke (*Cynara cardunculus* var. *scolymus*), tomato (*Lycopersicon lycopersicum*) and (native) cucurbitaceous species such as *Cucurbita maxima* and *C. pepo* are now cultivated. The main cultivated fodder crop is the introduced alfalfa (*Medicago sativa*).

Wild ancestors and relatives of most of the native agricultural crops grow in the research area, such as *Ullucus tuberosus* subsp. *aborigineus*, wild potato species (e.g. *Solanum acaule, Solanum megistacrolobum, Solanum* sect. *Petota* and *Solanum* sp. that produce small tubers), *Tropaeolum pentaphyllum* subsp. *megapetalum*, *Amaranthus hybridus*, *Lupinus* cf. *alaristatus*, *L. erectifolius*, *L. tatei*, *Oxalis calachaccensis* and *O. eriolepis*.

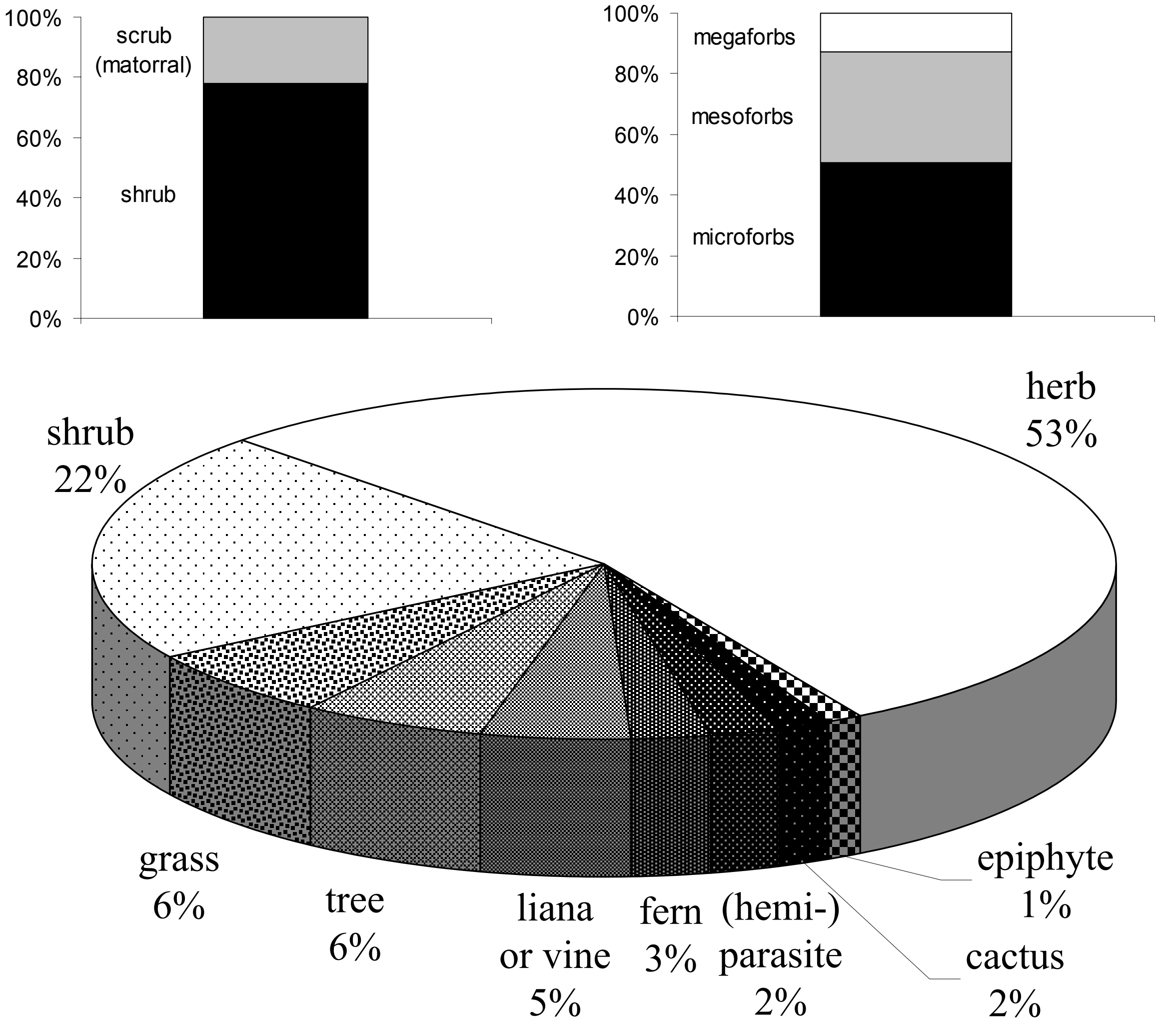

Figure 2.6: Distribution of all inventoried plant species in Apillapampa according to growth from. Following Rivas-Martínez (1997) and Navarro (2002), bushes are divided into scrubs (< 1m) and shrubs (1-4 m). Herbs are divided into microforbs (<0.3 m), mesoforbs (0.3-1m) and megaforbs (1-3m).

Table 2.2: Plant species that are reported and observed as being cultivated in Apillapampa. Twenty five of these species have been introduced from outside South America. Main uses in Apillapampa are given per species, whereby Fo=food; Fu=fuel; Ma=material; Me=medicine; An=animal food; Env=environmental uses; and Soc=social uses (data based on the inventory from the present investigation, as well as on Vandebroek *et al*., 2003).

Scientific Name	Main use	Origin	Sources
Agavaceae			
Agave americana	Ma, Fu, Env	introduced (Mexico)	Zeven & Zhukovsky, 1975
Anacardiaceae			
Schinopsis haenkeana	Ma, Fu, Me, Env	native	Mabberley, 1990
Schinus molle	Ma, Me, Fo, Env, Fu	native	Zeven & Zhukovsky, 1975
Apiaceae			
Petroselinum hortense	Fo	introduced	Bennett & Prance, 2000
Apium graveolens	Fo	introduced	Bennett & Prance, 2000
Apocynaceae			
Vinca major	Env, Me	introduced	Bennett & Prance, 2000
Asphodelaceae			
Aloe vera	Me	introduced	Bennett & Prance, 2000
Asteraceae			
Porophyllum ruderale	Fo, Me	native	Ulloa, 2006
Bignoniaceae			
Jacaranda mimosifolia	Ma, Fu, Env	native	Killeen *et al*., 1993
Betulaceae			
Alnus acuminata	Ma, Fu, Env	native	Killeen *et al*., 1993
Cactaceae			
Cleistocactus buchtienii	Env, Fo, Soc	native	Mabberley, 1990
Opuntia ficus-indica	Me, Fo, Env, An	introduced (Mexico)	Mabberley, 1990
Caryophyllaceae			
Dianthus caryophyllus	Me, Env	introduced	Bennett & Prance, 2000
Chenopodiaceae			
Chenopodium ambrosioides	Me, Soc	native	Mabberley, 1990
Cupressaceae			
Cupressus sp.	Env, Ma, Fu	introduced	Killeen *et al*., 1993
Euphorbiaceae			
Ricinus communis	Me	introduced	Bennett & Prance, 2000
Fabaceae			
Acacia visco	Me, Ma, Env, Fu	native	Killeen *et al*., 1993
Caesalpinia spinosa	Env, Fu	native	Mabberley, 1990
Erythrina falcata	Fo, Ma, Fu, Env, Me	native	Killeen *et al*., 1993
Inga cf. *striata*	Fo, Fu, Ma	native	Killeen *et al*., 1993
Medicago sativa	An, Me, Fo	introduced	Bennett & Prance, 2000
Prosopis laevigata	Fo, Me, Ma, Env, Soc, Fu	native	Killeen *et al*., 1993
Spartium junceum	Fo, Me, Ma	introduced	Killeen *et al*., 1993
Lamiaceae			
Mentha cf. *spicata*	Fo, Me	introduced	Bennett & Prance, 2000
Malvaceae			
Lavatera assurgentiflora	Env	introduced (N. America)	www.itis.gov Mabberley, 1990
Moraceae			
Ficus carica	Fo	introduced	Bennett & Prance, 2000
Myrtaceae			
Eucalyptus citriodora	Me, Ma, Fu	introduced	Bennett & Prance, 2000
Eucalyptus globulus	Me, Ma, Fu	introduced	Bennett & Prance, 2000

Table 2.2 continued

Scientific Name	Main use	Origin	Sources
Passifloraceae			
Passiflora mollissima	Fo, Me	native	Zeven & Zhukovsky, 1975
Passiflora umbilicata	Fo, Me	native	Wood, 2005
Poaceae			
Arundo donax	Ma	introduced	Bennett & Prance, 2000
Pinaceae			
Pinus radiata	Me, Ma, Fu	introduced (N. America)	Killeen *et al*., 1993
Rosaceae			
Rosa x *noisettiana* cf.	Me, Env, Fo, Ma, Fu	introduced	Mabberley, 1990
Rubus cf. *ulmifolius*	Me, Fo, Env, Fu	introduced	Hammer *et al.,* 2004
Prunus persica	Me, Fo, Fu	introduced	Bennett & Prance, 2000
Prunus domestica	Fo, Fu	introduced	Bennett & Prance, 2000
Rutaceae			
Ruta graveolens	Me	introduced	Bennett & Prance, 2000
Salicaceae			
Populus nigra	Me, Ma, Fo	introduced	www.itis.gov
Salix babylonica	Me, Ma, Env, Fu	introduced	Wood, 2005
Salix humboldtiana	Me, Ma, Env, Fu	native	Killeen *et al*., 1993
Solanaceae			
Capsicum pubescens	Fo	native	Ulloa, 2006
Solanum betaceum	Fo	native	Zeven & Zhukovsky, 1975
Nicotiana otophora	Me, Soc, Ma	native	Killeen *et al*., 1993
Verbenaceae			
Aloysa triphylla	Me, Fo, Fue	native	Killeen *et al*., 1993

Table 2.3: Uncultivated exotic species in Apillapampa (data based on the inventory from the present investigation, as well as on Vandebroek *et al*., 2003)

Scientific name	sources	Scientific name	sources
Apiaceae		**Geraniaceae**	
Apium leptophyllum	Mabberley, 1990	*Erodium cicutarium*	Zeven & Zhukovsky, 1975
Asteraceae		*Erodium moschatum*	Zeven & Zhukovsky, 1975
Sonchus asper	Bennett & Prance, 2000	**Lamiaceae**	
Sonchus oleraceus	Bennett & Prance, 2000	*Marrubium vulgare*	Bennett & Prance, 2000
Taraxacum officinale	Bennett & Prance, 2000	**Malvaceae**	
Chrysanthemum parthenium	Bennett & Prance, 2000	*Malva parviflora*	Bennett & Prance, 2000
Brassicaceae		**Plantaginaceae**	
Brassica rapa	Mabberley, 1990	*Plantago lanceolata*	Mabberley, 1990
Capsella bursa-pastoris	Bennett & Prance, 2000	**Polygonaceae**	
Sisymbrium irio	Mabberley, 1990	*Polygonum aviculare*	Mabberley, 1990
Sisymbrium officinale	Mabberley, 1990	*Rumex conglomeratus*	Bennett & Prance, 2000
Caryophyllaceae		*Rumex crispus*	Bennett & Prance, 2000
Stellaria media	Bennett & Prance, 2000	*Rumex cuneifolius*	Mabberley, 1990
Chenopodiaceae		**Primulaceae**	
Chenopodium cf. *murale*	www.sntc.org.sz	*Anagallis arvensis*	Mabberley, 1990
Chenopodium graveolens var. *bangii*	Simon, 1996	**Ranunculaceae**	
Fabaceae		*Ranunculus repens* var. *flore-pleno*	Mabberley, 1990
Medicago lupulina	Mabberley, 1990	**Scrophulariaceae**	
Medicago polymorpha	Mabberley, 1990	*Veronica persica*	Bennett & Prance, 2000
Melilotus albus	Mabberley, 1990	**Urticaceae**	
Melilotus indicus	Mabberley, 1990	*Urtica urens*	Bennett & Prance, 2000

2.3.3. Transects

2.3.3.1. Floristic Composition and Sampling Effort

The previous analysis dealt with all inventoried plant species, thus including plants sampled in transects, agricultural fields, the village environment, ruderal places, fallows, along rivers, cliffs, etc. Here we will consider only plants sampled in transects. The advantage of ecological sampling in transects is that it allows for estimating individual species densities (i.e. average number of individuals of a species on a unit area basis) and frequencies (i.e. distribution of a species through a stand, that is the percentage of transects in the sample in which a species occurs). In addition, indices can be calculated to estimate plant diversity as well as diversity of plant-use for the particular areas where transects are constructed. Through measurement of characteristic environmental parameters for each sample site, potential relations between plants and/or plant communities and environmental variables can be explored.

***Plants>0.1 m*: Situation in the Rainy Season**

In the 29 transects sampled, 280 species were collected in total, belonging to 68 families. The 10 plant families that are best represented are: Asteraceae (31%), Fabaceae (8.5%), Solanaceae (5.3%), Asclepiadaceae (3.6%), Lamiaceae (3.6%), Verbenaceae (2.9%), Cactaceae (2.5%), Apiaceae (2.1%), Convolvulaceae (2.1%) and Scrophulariaceae (2.1%). Pteridophyta are represented by 10 species (3.9 %) and five families. The vegetation is principally herbaceous (59.3% of all species), followed by shrubs (i.e. (sub)woody and ≤ 4 m high; 26.9% of all species). Trees represent only 3.3% of all collected plant species.

Alpha diversity in the sampled transects varied between 12 and 67 species (mean 41 ± 13 (s.d.)), whereas Shannon diversity between 1.64 and 3.61 (mean 2.54 ± 0.39 (s.d.)). The number of individual plants in transects ranged between 115 and 4,949 (mean 1,506 ± 950 (s.d.)). Thirty three percent of all sampled plant species occurred in only one transect. There exists a positive correlation between the diversity of a transect and the number of species that are found exclusively in that transect ($r=0.58$; $p=0.001$ for Alpha diversity and $r=0.63$; $p<0.001$ for Shannon diversity; Pearson correlation).

To determine whether the 29 sampled transects are representative for the flora of Apillapampa, a species-area curve was constructed. Figure 2.7 shows that the slope of the curve declines as the sample area increases. The curve clearly starts to level off and enlarging the sample area would probably have yielded only a few more species.

***(Sub-)woody Plants*: Situation in the Dry Season**

In the 36 transects sampled, 96 botanical species were collected, belonging to 26 families. The best-represented families in the (sub-)woody inventory are: Asteraceae (27.1%), Solanaceae (10.4%), Fabaceae (8.3%), Cactaceae (7.3%), Lamiaceae (6.3%), Verbenaceae (5.2%), Anacardiaceae (4.2%) and Rosaceae (4.2%). Diversity in the sampled transects varied between 4 and 28 species (mean 13 ± 5 (s.d.)) for Alpha diversity and between 0.21 and 2.72 (mean 1.76 ± 0.57 (s.d.)) for Shannon diversity. The number of individual plants sampled in transects varied between 69 and 607 (mean 261 ± 131 (s.d.)). Some 29% of all sampled *(sub-) woody plants* were encountered in only one transect. Again, there exists a positive correlation between the diversity of a transect and the number of species that were found exclusively in that transect (r=0.61; p<0.001 for Alpha diversity and r=0.38; p=0.02 for Shannon diversity).

Figure 2.7 shows that the species-area curve levels off. Therefore, the 36 sampled (sub-) woody transects represent the available (sub-)woody flora rather well, and expanding the sampling effort would probably have yielded not many more new species.

If the first 29 transects are being arranged according to increasing Alpha and Shannon diversity, similar rankings are being generated for *plants>0.1 m* and *(sub-)woody plants*. Hence, the diversity of transects is probably predominantly determined by the *(sub-)woody plants* they harbour.

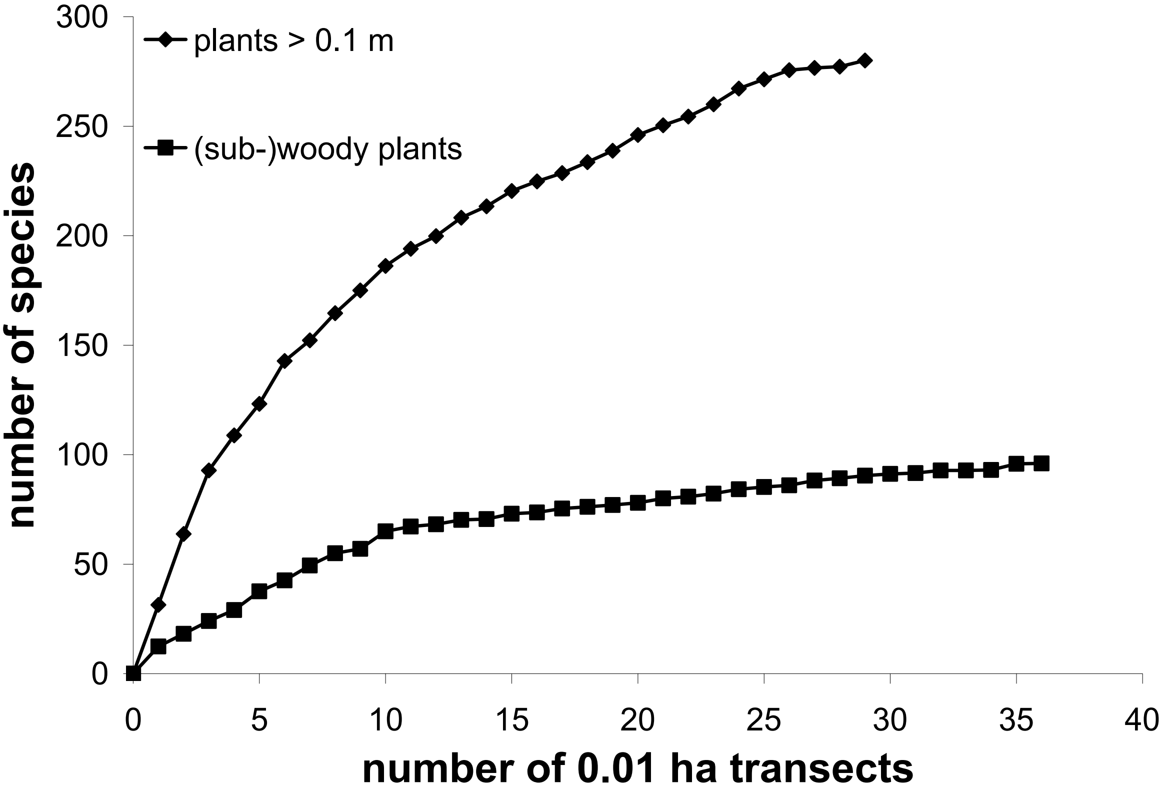

Figure 2.7: Species-area curves of twenty nine transects with *plants>0.1 m* and of thirty six transects with (sub-)woody plants

2.3.3.2. Determining the Border of *Prepuna* and *Puna* Ecological Zones

Cluster and ordination analyses were conducted to reveal possible groupings of our transects according to the ecological zones described by Navarro (2002).

<u>Clustering</u>

For *plants>0.1 m*, the best result was obtained with the UPGMA clustering method and the Bray-Curtis distance coefficient. The latter coefficient (also known as the Sørensen or Czekanowski coefficient) was originally applied to presence-absence data, but can also be applied to quantitative data. The coefficient is most useful for ecological community data. As compared to Euclidean distance, it retains sensitivity in more heterogeneous data sets and gives less weight to outliers (McCune & Mefford, 1999). UPGMA is also commonly used in ecology and systematics studies (Jongman *et al.*, 1996; Höft *et al.*, 1999).

The degree of chaining for our *plants>0.1* data is 18%, indicating that the used method clusters data well. The dendrogram depicted in figure 2.8 separates transects fairly well according to the altitudinal zoning described by Navarro (2002), with two broad groups representing the *prepuna* (roughly <3,200 m.a.s.l.) and *puna* (roughly >3,200 m.a.s.l.) ecological zones. Only transect 1 is excluded from both groups. Strangely, *prepuna* transect 21 which was sampled at about 3,100 m.a.s.l. shows in this scenario highest similarity with *puna* transects 7 (3,450 m.a.s.l.) and 27 (3,550 m.a.s.l.), possibly indicating a small-scale discrepancy in expected vegetation patterns on that location. According to García & Beck (2006), such "irregularities" are due to orographic and the Massenerhebung effects (see Grubb, 1971) that can engender different ecological conditions, and thus differences in vegetation structure and composition on identical altitudinal levels. Transects 9 and 18 have a rather distinct floristic composition as compared to other transects. Both were sampled on a site consisting of giant rocks, thus creating a peculiar sort of microclimate with apparently reduced evaporation throughout the dry season. In the dendrogram they are therefore placed in between the *prepuna* and *puna* group, showing slightly more affinity with the latter cluster.

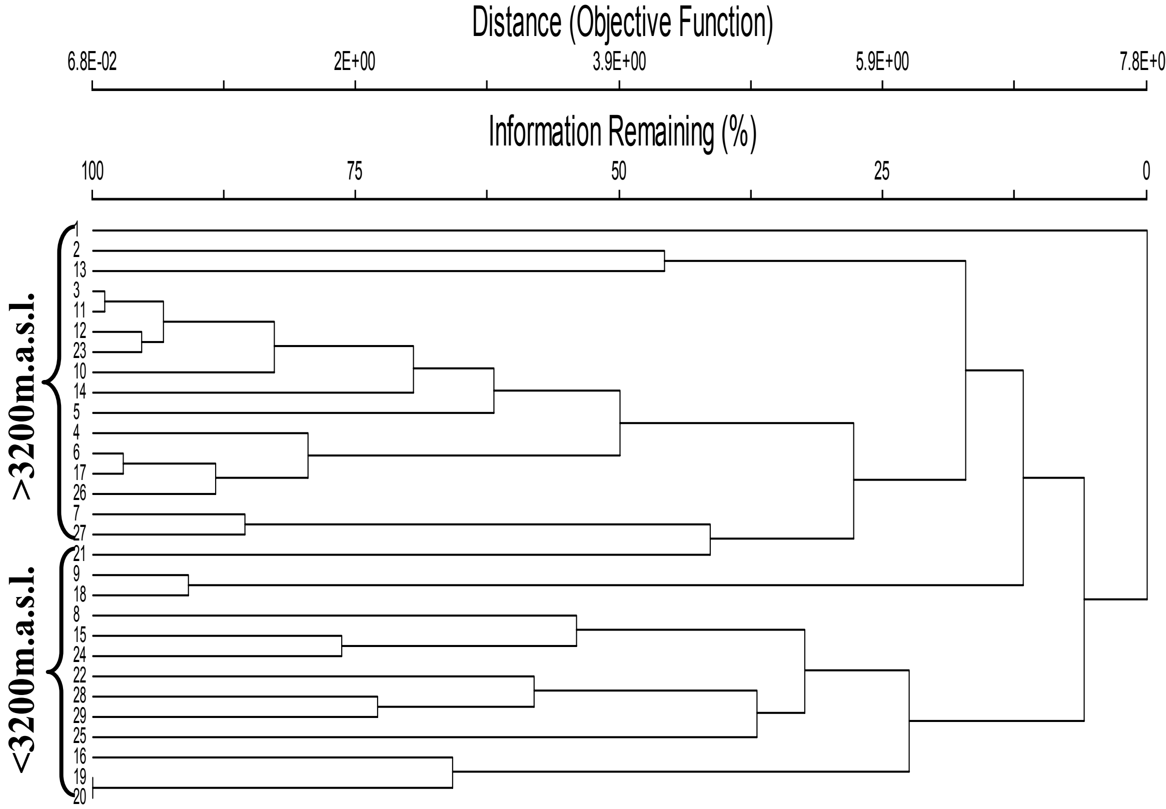

Figure 2.8: Tree plot indicating similarities between transects in terms of species densities, based on Bray-Curtis distance measure and UPGMA clustering method for *plants>0.1 m*

For *(sub-)woody plants*, no single combination of ecological distance and clustering methods was found that divides transects into groups that correspond relatively well to the ecological *prepuna* and *puna* zones. This is probably an indication of the fact that *(sub-)woody plants* show a much more continuous structure over the sampled transects as compared to *plants>0.1 m*, indicating that locally (sub-)woody plants have broader altitudinal ranges than herbaceous plants.

Ordination of Plant Species Sampled in Transects

Correspondence Analysis of Plants>0.1 m

Detrended correspondence analysis (DCA) showed that the lengths of the ordination axes are all above 2 s.d. Therefore, correspondence analysis was applied to detect whether groupings of transects can be distinguished on the basis of species composition and abundance. The eigenvalues of the first three ordination axes are higher than 0.5, indicating a good dispersion of species scores (Jongman *et al.*, 1996) (Table 2.4).

Table 2.4: Eigenvalues and cumulative percentage of variation (%) explained by the first three ordination axes for *plants >0.1 m*

Axis	eigenvalue	%
1	0.79	9.5
2	0.63	17.1
3	0.62	24.6

Figure 2.9 shows how transects cluster together more or less according to their ecological zoning, in correspondence with the results from clustering analysis (figure 2.8). Transects that were sampled in the *puna* zone (>3,200 m.a.s.l.) form a rather dense group whereas *prepuna* transects (<3,200 m.a.s.l.) occur much more disperse. Hence, transects in the *puna* zone seem to be much more alike floristically than transects from the *prepuna* area. Of course, the dividing line between both zones in figure 2.9 is hypothetical and solely based upon our data. The transition from one ecological zone to another will not occur abruptly but rather gradually extend over 100-200 altitudinal meters (cf. García & Beck, 2006). Transect scores that are situated near to the dividing line in figure 2.9 are located in this transition zone and contain elements that are characteristic for both ecological zones. As already anticipated by the cluster analysis (figure 2.8), assignment of transects 1 and 21 (based on altitude belonging to the *puna* and *prepuna* zone respectively) to either one of both groups is uncertain. Also transects 9 and 18 are somewhat isolated between the *prepuna* and *puna* area.

Altitude above sea level seems to be the environmental variable with the greatest influence on the species composition of a transect and is most probably significantly correlated with the first axis in figure 2.9. Altitude increases from left to right on axis 1. The lowest sampled transects are 19 and 20, situated at 2,850 m.a.s.l., followed by transects 16 (2,910 m.a.s.l.) and 25 (2,910 m.a.s.l.). Transects with highest locations are transects 2 (3,750 m.a.s.l.), followed by 13 (3,670 m.a.s.l.), 14 (3,630 m.a.s.l.) and 10 (3,610 m.a.s.l.). Species overlap between the highest and lowest transects is almost zero. Essentially the same grouping is obtained for detrended correspondence analysis (DCA), and therefore it is not depicted here.

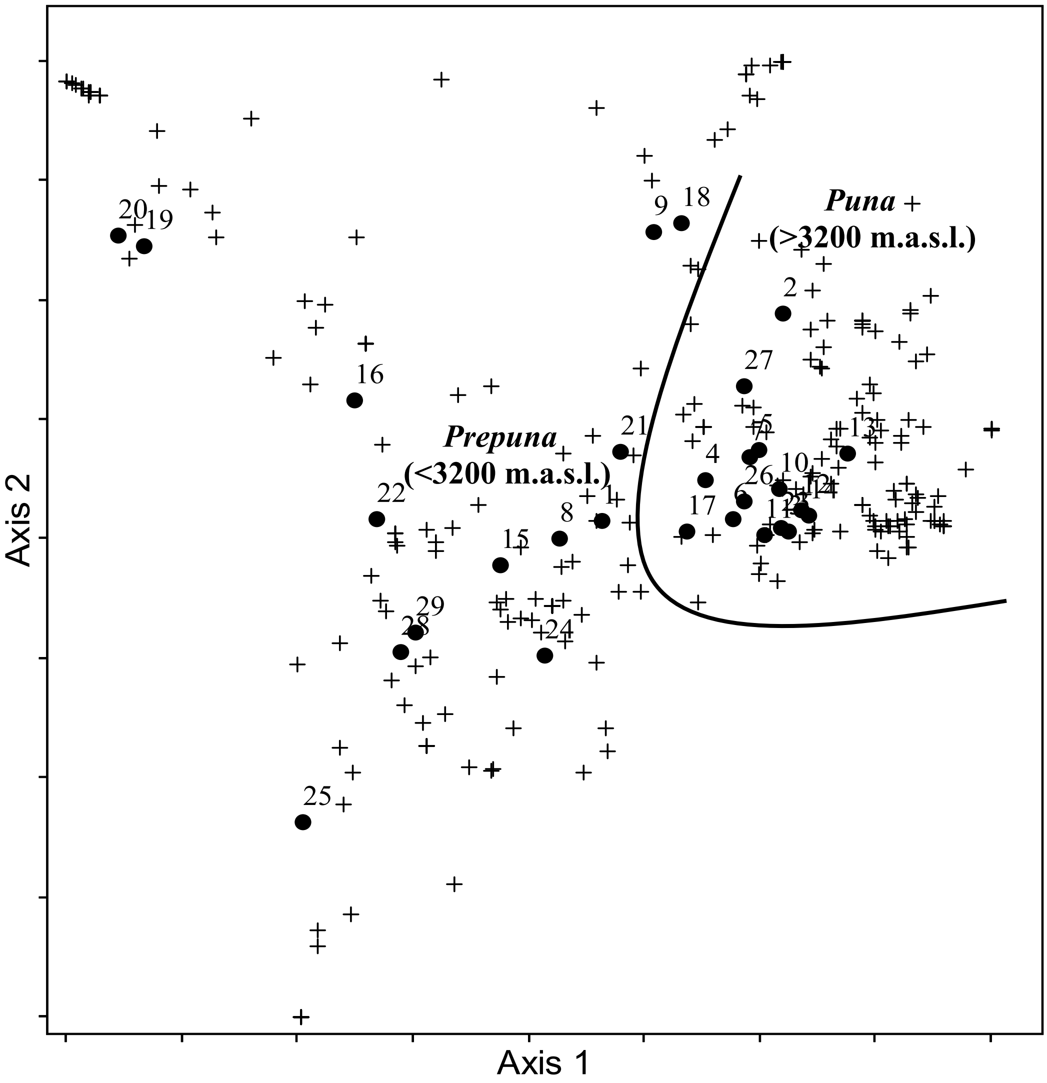

Figure 2.9: Ordination diagram of a Correspondence Analysis (CA) for *plants>0.1 m*. Dots (•) with numbers represent transects and crosses (+) mark the points where species abundance is highest, with (imaginary) concentric circles away from the species position indicating lower abundance of a species (Kindt & Burn, 2002). Scores of transects with high numbers of individuals for a given species tend to be close to the score of that species in the diagram. Hence, the closer together transects are represented, the more their species compositions will correspond. Species names are not given for clarity.

Correspondence Analysis of (Sub-)woody Plants

For *(sub-)woody plant* transects, lengths of the ordination axes are well above 2 s.d. (DCA), justifying correspondence analysis application. The eigenvalues of the first three ordination axes are higher than 0.5, indicating a good dispersion of species scores. Thus, 20.1% of the total variation in data is explained by the first two axes (Table 2.5).

Table 2.5: Eigenvalues and cumulative percentage of variation (%) explained by the first three ordination axes for *(sub-)woody plants*

Axis	eigenvalue	%
1	0.88	11.1
2	0.71	20.1
3	0.64	28.2

Similar to the situation for *plants>0.1 m* (figure 2.9) a grouping of *puna* transects on the right side of the ordination diagram (figure 2.10) is observed. Separation is less clear-cut for the (sub-)woody plants, since four transects 9, 18, 21, 30 (all situated below 3,200 m.a.s.l., theoretically belonging to the *prepuna* zone), are unmistakably grouped together with the *puna* transects. However, figure 2.10 clearly shows the occurrence of one of CA's major 'faults', called the arch effect. It is "a mathematical artefact, corresponding to no real structure in the data" (Hill & Gauch, 1980). After elimination of the arch effect by 'detrending' (DCA) a straight (hypothetical) line can be drawn between *puna* and *prepuna* transects (figure 2.11).

Transects 9, 18, 21 and 30 are positioned here along the (theoretic) borderline of *puna* and *prepuna*. Their (sub-)woody species composition contains elements from both *puna* and *prepuna* vegetation. Although separation of transects in *prepuna* and *puna* groups is more blurry than for *plants>0.1 m*, better results are obtained with ordination than with clustering analysis. However, in agreement with cluster analysis, the ordination diagrams confirm that there is a relatively more continuous structure in *(sub-)woody plants* over the sampled transects as compared to *plants >0.1 m*.

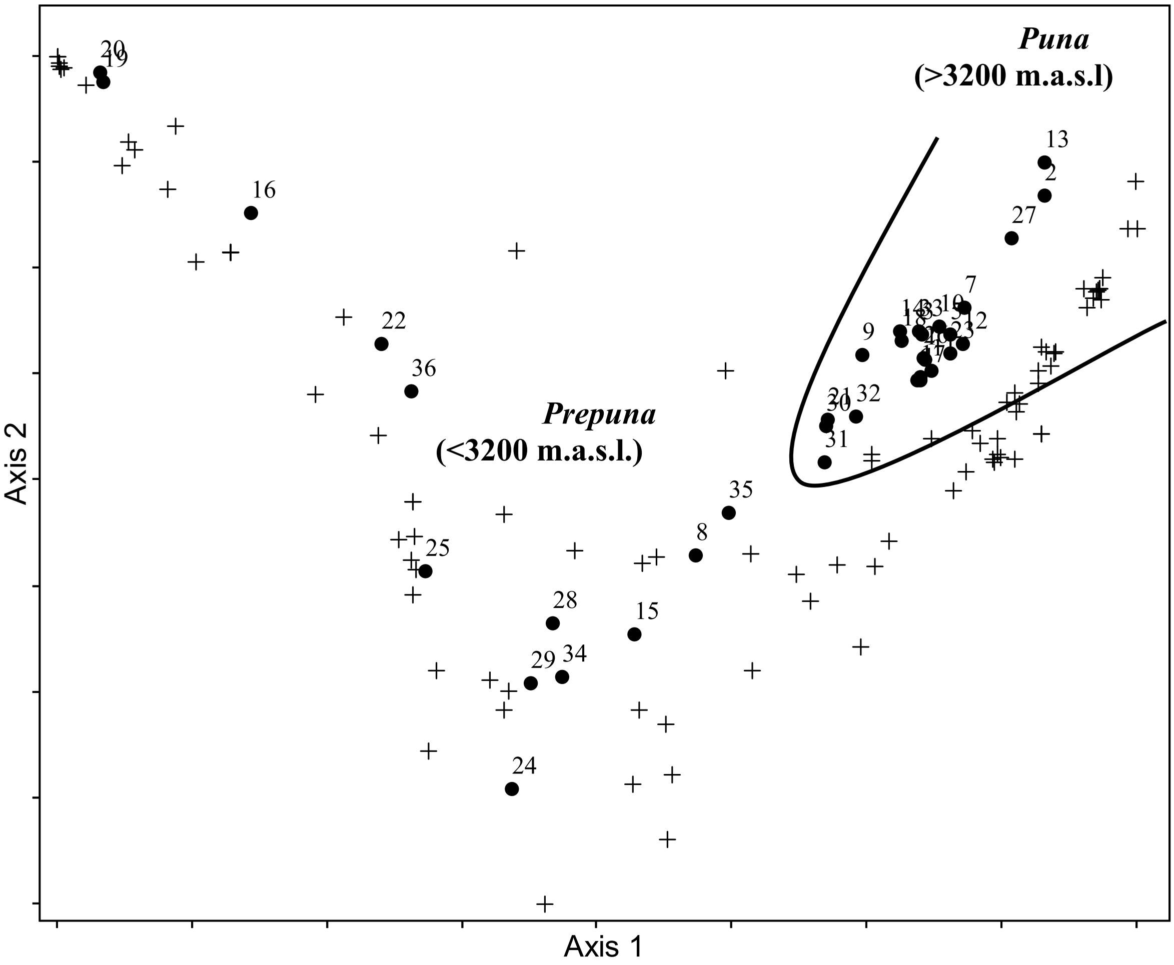

Figure 2.10 Ordination diagram of a Correspondence Analysis (CA) for (sub-)woody plants. Dots (•) with numbers represent transects whereas crosses (+) represent species. Species names are not given for clarity. In this plot, the arch effect is clearly visualized through the V-shaped composition in which transect and species scores are arranged.

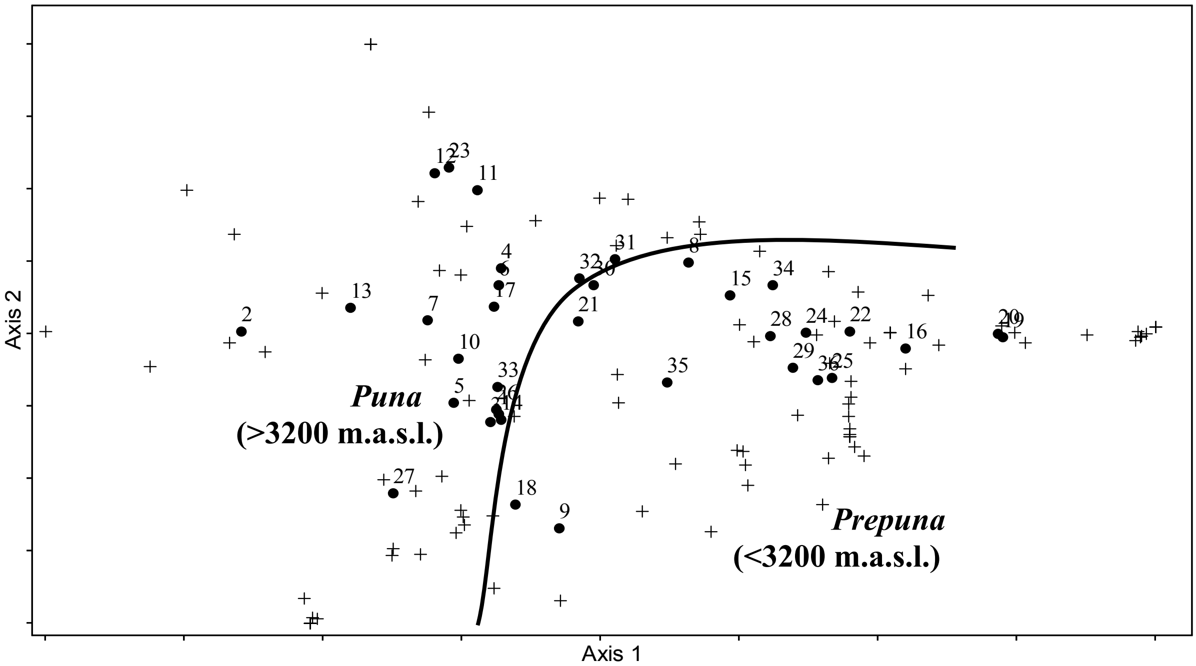

Figure 2.11: Ordination diagram of a detrended correspondence analysis (DCA) for (sub-)woody plants. Interpretation is analogous to figure 2.9. In this plot, the arch effect is removed through "detrending" leading to a more straightforward division between *puna* and *prepuna* ecological zones.

2.3.4. *Prepuna* and *Puna* Ecological Zones in Apillapampa

2.3.4.1. Ethnoecological zoning

Apillapampeños divide their living environment in three altitudinal zones using the village as a reference and central point. Lands that are situated higher (broadly >3,300 m.a.s.l.) belong to the *alturas* zone while the term *bajas* is used for terrains at lower altitudes (broadly <3,100 m.a.s.l.). The intermediate altitudinal belt comprising the village of Apillapampa is called *medias*. Intriguingly, the *medias* zone seems to correspond fairly well to the ecological transition zone between *prepuna* and *puna* vegetation as also demonstrated by the previous cluster and ordination analyses. According to Navarro (2002) the *prepuna* ecological zone stretches from 2,300 to 3,200 m.a.s.l., whereas the *puna* zone extends from 3,100-3,200 m.a.s.l. up to 3,900-4,000 m.a.s.l. High correspondence between indigenous vegetation classification systems and phytosociological categorisation, based on quantitative sampling and ordination techniques have been reported elsewhere as well (e.g. La Torre-Cuadros and Gerald, 2003).

During ethnobotanical interviews (see chapter 3, section 3.3.1. for methodology used) it was systematically asked in what zone each plant could be found, choosing between *alturas*, *medias* and *bajas*. Information was obtained for 368 species, excluding strictly cultivated plants. A large number of species (251) was claimed to have a broad altitudinal range, occurring in all three zones, whereas others were said to be restricted to the *bajas* (30 species) or to the *alturas* (11 species). As a transition zone, the *medias* contains typical species from both *bajas* (63 species) and *alturas* (13 species). No wild species were mentioned to exclusively grow in the *medias* (figure 2.12).

According to participants, a higher number of species can be found in the *bajas*, as compared to the *alturas* (figure 2.13). Logically, one would expect the number of species found in the *medias* to balance between both, but the latter number turns out to be lower. This might be related to the fact that the *medias* comprises the area where people actually live and spend most of their time and therefore probably have a more profound impact on vegetation, resulting in a lower species number.

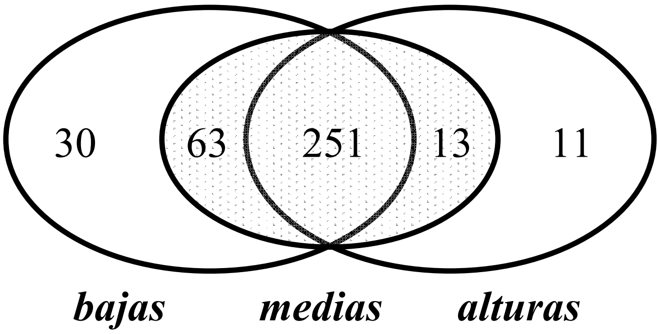

Figure 2.12: Distribution of plant species over altitudinal zones as confirmed by at least two respondents (the dotted area represents the *medias*)

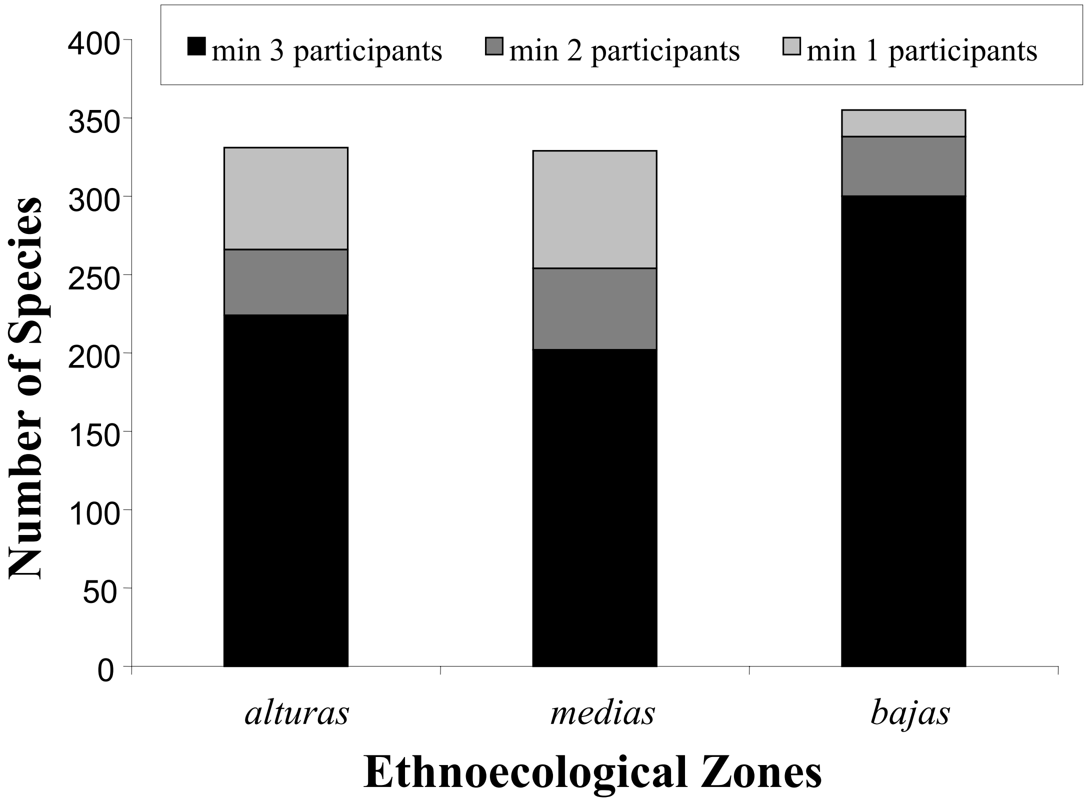

Figure 2.13: Numbers of species with ethnoecological zone where they are reported to grow. To show that the appearance per zone of a number of species is not confirmed by all participants, numbers of species that are confirmed by three participants are presented as subsets of those confirmed by two and one participant, respectively. Min 1 participant means at least one participant has indicated that the species grows in one of the ethnoecological zones.

Human communities living in dry environments have developed numerous strategies of natural resource use (Gragson, 1997; Ladio and Lozada, 2004). A frequently applied strategy is the utilization of different environments and ethnoecological units, which may be defined in accordance with altitudinal gradients (Ladio and Lozada, 2004). This seems to be the case for Apillapampa. Indeed, although other, more decisive factors may have dominated the choice to establish Apillapampa at its current location, it cannot be denied that it is a strategic place in terms of accessibility to a wide variety of landscapes. At the edge of two ecological zones, people maximize the number of faunal and floral elements upon which they can draw for their livelihoods (Berkes and Folke, 1994; Turner *et al*., 2003: Ladio and Lozada, 2004).

In ecological terms, edges are transition zones from one ecosystem to another. A well-known characteristic of these edges is that they often exhibit high levels of productivity (turnover in biomass), and species richness or biodiversity (Odum, 1971). The theme of ecological edges has been extensively discussed by Turner *et al*. (2003). The latter authors suggest that indigenous peoples are drawn towards ecological edges since "social groups living on ecological edges, […] are more likely to be flexible and resilient than those situated within more homogenous environments." Resilience is defined here as "the ability to absorb shocks and perturbations, the ability for self-organization and the ability to learn and adapt" (Tuner *et al*. 2003). According to the latter authors, ecological edges allow humans to respond to expected natural cycles and interrelationships, and provide the means for people to better adjust to periods of unanticipated and unpredicted change.

2.3.4.2. Dominant Species and Families in *Puna* and *Prepuna* Vegetation Recorded in Transects

As demonstrated by the outcomes of both cluster and ordination analyses, transects are separated in two main groups representing *prepuna* and *puna* ecological zones whereby 3,200 m.a.s.l. can be used as an approximate dividing limit. Although the transition between both ecological zones is known to occur over a wider altitudinal range, the latter limit will be used as a simplified interpretation of reality when discussing the dominant families and species of both zones. The number of sampled transects per ecological zone and sampling strategy are given in table 2.6.

Table 2.6: Number of sampled transects per ecological zone and sampling strategy

	Prepuna	*Puna*
Plants >0.1 m	13	16
(Sub-)woody Plants	17	19

Both the number of species and families encountered in the *puna* zone are considerably lower than in the *prepuna* zone. This finding supports the ethnoecological characterisation that more species occur in the *bajas* than in the *alturas* (figure 2.13). Two hundred and twelve (212) *plant species >0.1m* and 77 *(sub-)woody plant species* were encountered in *prepuna* transects as opposed to 153 and 51 for *puna*, respectively. Also, the number of families that is represented by at least one individual is higher for *prepuna* transects than for *puna* transects (59 and 23 versus 50 and 15 for *plants >0.1m* and *(sub-)woody plants*, respectively).

The best-represented families in terms of total number of individuals in *all* sampled transects are Asteraceae, Fabaceae, Oxalidaceae, Apiaceae, Lamiaceae and Verbenaceae for *plants >0.1 m* and Asteraceae, Lamiaceae, Fabaceae, Verbenaceae, Rhamnaceae and Solanaceae for *(sub-)woody plants* (table 2.7). All these families, except for Oxalidaceae and Rhamnaceae, also occupy the top ten of the most species-rich families in the entire inventory (table 2.1).

Asteraceae and Fabaceae dominate *prepuna* and *puna* floras for *plants>0.1 m*, representing 46.2% and 53.6% of the total number of individual plants, respectively. In the *prepuna* zone, *(sub-)woody plants* are dominated by Lamiaceae, Verbenaceae, Rhamnaceae and Asteraceae. These four families alone embody 70.8% of all sampled (sub-)woody *prepuna* plants (table 2.7). Rhamnaceae and Verbenaceae representatives largely disappear in the (sub-)woody *puna* flora which is dominated by Asteraceae and Lamiaceae (acccounting for 64.1% of all plants). Asteraceae grants its overall dominance in the research area to the high number of species by which it is represented (23.8% of all inventoried plant species), rather than to high abundances of a few species.

Table 2.7: Family dominance of *plants>0.1 m* for the twenty most common families in the sampling area; values represent percentages of individuals

Plants >0.1 m				***(Sub-)woody Plants***			
family	**entire area**	***prepuna***	***puna***	**family**	**entire area**	***prepuna***	***puna***
Asteraceae	34.4	29.8	36.2	Asteraceae	26.1	16.5	33.1
Fabaceae	17.0	16.4	17.4	Lamiaceae	24.9	19.6	31.0
Oxalidaceae	6.1	-	9.3	Fabaceae	8.5	2.4	12.6
Apiaceae	5.9	1.1	8.6	Verbenaceae	8.1	18.2	-
Lamiaceae	5.5	4.4	6.6	Rhamnaceae	7.3	16.5	-
Verbenaceae	4.2	6.4	3.0	Solanaceae	6.9	8.8	5.1
Convolvulaceae	3.9	7.0	2.3	Scrophulariaceae	5.1	4.0	5.7
Solanaceae	3.4	5.0	2.5	Berberidaceae	3.8	-	6.4
Plantaginaceae	3.1	3.4	2.9	Cactaceae	1.9	3.8	0.4
Rhamnaceae	1.5	4.1	-	Rosaceae	1.7	1.2	2.0
Amaranthaceae	1.2	2.8	-	Oleaceae	1.1	2.4	-
Araceae	1.2	3.2	-	Rubiaceae	0.8	0.7	0.8
Geraniaceae	1.1	-	1.8	Anacardiaceae	0.8	0.6	1.1
Scrophulariaceae	1.1	1.0	1.2	Euphorbiaceae	0.7	1.5	-
Ranunculaceae	1.0	0.9	1.1	Polygalaceae	0.6	-	1.0
Berberidaceae	0.9	-	1.4	Loranthaceae	0.5	1.7	0.1
Cheilanthaceae	0.7	0.9	0.6	Ephedraceae	0.4	0.4	0.3
Adiantaceae	0.5	-	0.5	Sapindaceae	0.3	0.7	-
Malvaceae	0.4	1.2	-	Grossulariaceae	0.3	-	0.4
Cactaceae	0.4	1.1	-	Boraginaceae	0.2	0.4	-
Total other families	5.9	10.6	4.3	Total other families	0.3	0.6	0.0
Total number of species	280	212	153	Total number of species	96	77	51
Total number of families	68	59	50	Total number of families	26	23	15

These results differ somewhat from the data provided by Ibisch *et al.* (2003). According to the latter authors, the (most?) important families of the inter-Andean valleys (comprising the *prepuna*) include Anacardiaceae, Asteraceae, Cactaceae, Fabaceae and Verbenaceae. For the semi-humid *puna* they list Asteraceae, Cactaceae, Fabaceae, Caryophyllaceae, Gentianaceae, Poaceae and Rosacaeae as important representatives. However, these authors do not provide details about the criteria on which their selection of "important botanical families" were based. Moreover, the ecoregions denoted as *inter-Andean valleys* and *semi-humid puna* cover much greater surface areas and ranges of altitudes than our own research area.

Plants>0.1 m

In table 2.8, plants are ranked according to decreasing abundances. Species with the highest abundances in the overall *plants>0.1 m* flora are small herbs, such as *Trifolium amabile*, *Eryngium nudicaule* and *Oxalis eriolepis* (represented by >2000 individuals each). Most frequently occurring species are *Viguiera tucumanensis* (in 83% of transects), *Baccharis dracunculifolia* (83%), *Ophryosporus heptanthus* (76%) and *Minthostachys andina* (66%). Even though (sub-)woody species might be more evenly distributed over the landscape, as evidenced by higher frequencies, these data suggest that in terms of abundance the vegetation in the wet season in Apillapampa is dominated by herbaceous plants.

Table 2.8: Most abundant species in all 29 transects sampled for *plants>0.1 m*. Absolute density represents the total number of individuals per plant species counted in all 29 transects. Relative density is the proportion of individuals of a species from the total number of individuals in all transects. Relative frequency is the proportion of the frequency of a species from the sum of frequencies of all species. Note that 15 of the 20 most abundant species have herbaceous growth forms.

	absolute density (#ind)	**relative density (%)**	**relative frequency (%)**
Trifolium amabile	2,659	5.6	1.2
Eryngium nudicaule	2,562	5.4	0.6
Oxalis eriolepis	2,192	4.6	1.2
Viguiera tucumanensis	1,790	3.7	1.9
Bidens andicola	1,741	3.6	1.2
Cologania broussonetii	1,292	2.7	0.9
Minthostachys andina	1,196	2.5	1.5
Glandularia aristigera	1,108	2.3	0.9
Plantago tomentosa	918	1.9	1.1
Stevia galeopsidifolia	880	1.8	0.8
Melilotus indicus	865	1.8	1.0
Solanum acaule	799	1.7	1.2
Salvia haenkei	769	1.6	1.2
Stevia aff. *bangii*	707	1.5	0.5
Kentrothamnus weddellianus	706	1.5	0.7
Cosmos peucedanifolius	702	1.5	0.7
Adesmia miraflorensis	670	1.4	0.8
Stevia boliviensis	663	1.4	0.8
Stevia tunariensis	629	1.3	0.5
Lantana balansae	555	1.2	0.4
Total of other species	24,206	50.6	80.9
Total	47,799	100	100

In table 2.9, the twenty most abundant species are listed for the *prepuna* and *puna* ecological zones, separately. An immediate eye-catcher is that absolute densities of these species in the *puna* zone are almost consistently 1.5-2 times higher than in the *prepuna* zone. This is in accordance with our finding from paragraph 2.3.6 that the number of individuals correlates positively with altitude for *plants>0.1 m*. As shown in table 2.9, the most abundant species in both zones are quite distinct and only five genera and three species overlap: *Cologania broussonetii*, *Viguiera tucumanensis* and *Plantago tomentosa*.

Cologania broussonetii, Kentrothamnus weddellianus and *Stevia* aff. *bangii* are the most abundant species in the *prepuna* transects, whereas *Viguiera tucumanensis* (in 85% of *prepuna* transects), *Baccharis dracunculifolia* (77%) and *Tagetes terniflora* (77%) are the most frequent ones. In the *puna* zone, the most abundant species are *Trifolium amabile*, *Eryngium nudicaule* and *Oxalis eriolepis*. *Ophryosporus heptanthus* (sampled in all (100%) *puna* transects), *Minthostachys andina* (88%) and *Baccharis dracunculifolia* (88%) are the most frequent species.

Table 2.9: Most abundant and most frequent species in *prepuna* and *puna* transects for *plants >0.1 m*. Species are ranked in order of decreasing density. Species density is expressed here as the mean number of individuals per transect (i.e. $100m^2$) as the number of transects sampled in *prepuna* (13) differed from *puna* (16).

Prepuna				***Puna***			
	dens (# ind/ $100m^2$)	**rel dens (%)**	**rel freq (%)**		**dens (# ind/ $100m^2$)**	**rel dens (%)**	**rel freq (%)**
Cologania broussonetii	69	5.2	1.2	*Trifolium amabile*	165	8.5	2.1
Kentrothamnus weddellianus	54	4.1	1.4	*Eryngium nudicaule*	159	8.2	1.1
Stevia aff. *bangii*	50	3.8	0.8	*Oxalis eriolepis*	132	6.8	1.4
Lantana balansae	43	3.2	0.8	*Bidens andicola*	104	5.4	1.8
Spathantheum orbignyanum	42	3.2	0.9	*Viguiera tucumanensis*	78	4.0	2.1
Viguiera tucumanensis	42	3.2	1.7	*Minthostachys andina*	66	3.4	2.2
Dalea boliviana	42	3.2	0.3	*Stevia galeopsidifolia*	55	2.8	1.6
Medicago lupulina	35	2.6	0.3	*Glandularia aristigera*	55	2.8	0.6
Zinnia peruviana	34	2.6	1.4	*Melilotus indicus*	50	2.6	1.4
Solanum acaule	32	2.4	1.2	*Cosmos peucedanifolius*	44	2.3	1.4
Onoseris alata	30	2.3	0.6	*Salvia haenkei*	42	2.2	1.6
Eupatorium clematideum	24	1.8	0.9	*Adesmia miraflorensis*	41	2.1	1.3
Conyza bonariensis	24	1.8	0.6	*Stevia boliviensis*	39	2.0	1.3
Gnaphalium gaudichaudianum	24	1.8	1.1	*Plantago tomentosa*	39	2.0	1.4
Plantago tomentosa	23	1.7	0.8	*Stevia tunariensis*	33	1.7	0.8
Crotalaria sagittalis	22	1.6	0.2	*Geranium soratae*	30	1.5	0.8
Hypochaeris chillensis	20	1.6	1.2	*Gnaphalium melanosphaeroides*	30	1.5	1.1
Glandularia aristigera	18	1.4	1.2	*Amicia* cf. *andicola*	26	1.4	0.3
Proustia cuneifolia	14	1.1	1.4	*Ophryosporus heptanthus*	25	1.3	2.5
Salpichroa tristis var. *tristis*	14	1.1	0.5	*Cologania broussonetii*	25	1.3	0.5
Total of other species (all transects)	8,604	50.2	81.8	**Total of other species (all transects)**	10,421	35.1	72.1
Total # of individuals	17,133	100	100	**Total # of individuals**	30,524	100	100

(Sub-)woody Plants

Species with the highest abundances in the overall (sub-)woody transect flora are the bushes *Minthostachys andina, Salvia haenkei* and *Kentrothamnus weddellianus* (table 2.10). As for *plants>0.1 m*, the most frequent species are *Baccharis dracunculifolia* (in 83% of transects), *Ophryosporus heptanthus* (78%) and *Minthostachys andina* (64%).

Table 2.10 Most abundant species in all 36 transects sampled for *(sub-)woody plants*. Absolute density represents total number of individuals per plant species counted in all 36 transects. Relative density is the proportion of individuals of a species from the total number of individuals in all transects. Relative frequency is the proportion of the frequency of a species from the sum of frequencies of all species.

	absolute density (#ind)	relative density (%)	relative frequency (%)
Minthostachys andina	1,229	11.0	4.3
Salvia haenkei	832	7.4	3.2
Kentrothamnus weddellianus	819	7.3	2.1
Baccharis dracunculifolia	727	6.5	5.6
Adesmia miraflorensis	671	6.0	2.1
Lantana balansae	565	5.0	1.1
Ophryosporus heptanthus	477	4.3	5.2
Salvia orbignaei	343	3.1	1.1
Plazia daphnoides	336	3.0	0.2
Berberis boliviana	294	2.6	2.2
Calceolaria parvifolia ssp. *parvifolia*	290	2.6	3.4
Cestrum parqui	285	2.5	3.4
Barnadesia macrocephala	271	2.4	2.2
Proustia cuneifolia	245	2.2	2.2
Satureja boliviana	218	1.9	1.9
Baccharis prostrata	218	1.9	2.6
Salpichroa tristis var. *tristis*	191	1.7	1.5
Agalinis lanceolata	160	1.4	3.2
Senna aymara	157	1.4	2.1
Lantana fiebrigii	141	1.3	1.5
Total of other species	2,745	24.5	49.1
Total	11,214	100	100

Table 2.11 lists the twenty most abundant (sub-)woody plant species growing in the *prepuna* and *puna* ecological zones, respectively. The most abundant *(sub-)woody plants* in both zones are more similar than *plants>0.1 m*, with six overlapping species and eight genera. This outcome further supports the notion of a more continuous distribution of *(sub-)woody plants* along the altitudinal gradient as compared to *plants>0.1 m* (cf. paragraph 2.3.3.2). The prevalence of genus *Baccharis* at higher altitudes in Andean Bolivia (Navarro, 2002; García and Beck, 2006) is reflected in five different species listed in the top twenty of most abundant *puna* species.

Kentrothamnus weddellianus, Lantana balansae and *Salvia orbignaei* are the most abundant species in the *prepuna* transects, while *Baccharis dracunculifolia* (in 82% of *prepuna* transects), *Proustia cuneifolia* (71%) and *Kentrothamnus weddellianus* (65%) are the most frequent ones. In the *puna* zone, the most abundant species are *Minthostachys andina*, *Salvia haenkei* and *Adesmia miraflorensis*. *Ophryosporus heptanthus* (sampled in all *puna* transects), *Minthostachys andina* (84%) and *Baccharis dracunculifolia* (84%) occur most frequently.

In terms of vegetation cover, other authors have likewise identified *Kentrothamnus weddellianus* as the most dominant species in comparable *prepuna* sites (see Navarro, 2002). Additionally, the latter author documents many other species that were also sampled in our *prepuna* (and *puna*) transects but are not necessarily among the 20 species with highest abundance. These include *Kageneckia lanceolata, Schinus molle, Vasconcellea quercifolia, Prosopis laevigata, Zanthoxylum coco, Lycianthes lycioides, Aloysia gratissima, Baccharis dracunculifolia, Dodonaea viscosa, Salvia haenkei, Echinopsis cochabambensis, Calceolaria parviflora, Opuntia sulphurea, Echinopsis obrepanda, Puya glabrescens, Minthostachys andina, Spatanthium orbignyanum* and *Ipomoea pubescens*.

Table 2.11: Most abundant and most frequent species in *prepuna* and *puna* transects for *(sub-) woody plants*. Species are ranked according to decreasing density. Species density is expressed here as the mean number of individuals per transect-surface (i.e. 100m^2) due to different numbers of sampled transects in the *prepuna* (13) and *puna* (16) zones, respectively.

prepuna				***puna***			
	dens (# ind/ 100m^2)	**rel dens (%)**	**rel freq (%)**		**dens (# ind/ 100m^2)**	**rel dens (%)**	**rel freq (%)**
Kentrothamnus weddellianus	48	16.4	3.8	*Minthostachys andina*	56	16.3	5.8
Lantana balansae	33	11.3	2.1	*Salvia haenkei*	39	11.2	4.0
Salvia orbignaei	20	6.9	2.1	*Adesmia miraflorensis*	35	10.0	2.9
Baccharis dracunculifolia	18	6.0	4.8	*Baccharis dracunculifolia*	22	6.5	5.8
Proustia cuneifolia	14	4.9	4.1	*Ophryosporus heptanthus*	22	6.5	6.9
Salpichroa tristis var. *tristis*	11	3.6	1.0	*Plazia daphnoides*	18	5.1	0.4
Minthostachys andina	9	3.2	2.4	*Berberis boliviana*	15	4.5	4.4
Calceolaria parvifolia ssp. *parvifolia*	9	3.2	2.1	*Barnadesia macrocephala*	14	4.1	4.4
Lantana fiebrigii	8	2.8	2.7	*Cestrum parqui*	10	2.9	4.0
Lippia boliviana	8	2.8	1.7	*Baccharis prostrata*	10	2.8	4.0
Menodora pulchella	7	2.4	1.4	*Senna aymara*	8	2.4	4.0
Salvia haenkei x orbignaei	7	2.3	1.0	*Calceolaria parvifolia* ssp. *parvifolia*	7	2.0	4.4
Trichocereus tunariensis	6	2.1	1.4	*Baccharis sagittalis*	7	1.9	0.4
Satureja boliviana	6	2.0	0.7	*Agalinis lanceolata*	6	1.9	4.7
Salvia haenkei	6	1.9	2.1	*Calceolaria engleriana*	6	1.8	2.9
Cestrum parqui	5	1.8	2.4	*Satureja boliviana*	6	1.8	2.9
Ophryosporus macrodon	4	1.3	2.4	*Baccharis papillosa*	5	1.5	2.2
Acacia aroma	4	1.2	1.7	*Solanum collectaneum*	5	1.4	1.1
Kageneckia lanceolata	3	1.2	1.4	*Berberis commutata*	4	1.2	4.0
Solanum pilcomayense	3	1.0	1.0	*Baccharis buxifolia*	4	1.1	1.8
Total of other species (all transects)	1074	21.5	57.7	**Total of other species (all transects)**	865	13.2	28.8
Total # of individuals	4995	100	100	**Total # of individuals**	6576	100	100

For the *puna* zone no representative inventories were found in literature, but most characteristic genera for this ecological zone mentioned by Navarro (2002) are also represented in our floristic data. These include: (1) the woody species *Berberis*, *Schinus*, *Dunalia*, *Barnadesia* and *Mutisia*; (2) the herbaceous species *Bowlesia*, *Bomarea*, *Thalictrum*, *Solanum* and *Bartsia*; and (3) the Pteridopyta *Adiantum* and *Asplenium*. Pestalozzi (1998) performed a study of the high Andean vegetation. Although his study area was situated at a higher altitudinal range (3,800-4,500 m.a.s.l.) as ours (2,700-3,800 m.a.s.l.), the author collected many species that are also represented in our inventory. Some of these characteristic species of Pestalozzi's (1998) study that were also abundant in the present investigation include: *Trifolium amabile*, *Conyza deserticola,* *Solanum acaule*, *Quinchamalium procumbens, Tarasa tenella, Valeriana decussata, Bidens andicola, Astragalus garbancillo, Vicia graminea*, *Gentiana sedifolia*, *Hypseocharis pimpinellifolius*, *Calceolaria parvifolia, C. engleriana, Tetraglochin cristatum, Senecio clivicola, Satureja boliviana, Adesmia miraflorensis, Stipa ichu* and *Polylepis besseri.*

Hence, in spite of some local differences, floristic inventories from other biographical *prepuna* and *puna* zones (Navarro, 2002) seem to correspond fairly well with our data. However, a number of species identified by Navarro (2002) as characteristic for the vegetation of our research area, such *Escallonia millegrana, Acacia visco, Buddleja tucumanensis* or *Jacaranda mimosifolia,* were only sampled during fieldtrips and not in transects. It is unclear whether the scarce abundance of these species is mainly determined by their natural distribution or by anthropogenic pressure that led to their depletion. In order to gain more insight in the factors that determine the distribution of species in the research area, in the following paragraphs (2.3.5 and 2.3.6) we will evaluate the impact of some environmental variables (anthropogenic and natural) on species composition in transects.

Recently, Navarro and Ferreira (2007b) published a detailed vegetation map of Bolivia at scale 1:250,000. Localizing the exact position of Apillapampa on this map, reveals that three major vegetation types would occur in the research area. The first (code 1 in figure 2.14) corresponds with the inferior *prepuna* zone between 2,200-2,900 m.a.s.l. we described in the introduction. It is characterised by the series of *Vasconcellea quercifolia* - *Schinopsis haenkeana* and is consistent with the observations of the present study. However, the other two vegetation types match our descriptions of the research area far less. The second vegetation type (code 2 in figure 2.14) occupies a similar altitudinal range as the previous (2,200-2,800 m.a.s.l.). According to Navarro and Ferreira (2007b) it represents dry mountainous *prepuna* forest which is characterised by the series of *Escallonia millegrana-Kageneckia lanceolata.* Although we collected both these species, the first is extremely rare in the research area (which could of course be due to past overexploitation) while the second species is still fairly abundant and has been seen growing up to at least 3,500 m.a.s.l.

Strangely, no transitional vegetation type is included in the map for the altitudinal interval from 2,900 to 3,300 m.a.s.l. between the former two types and the third vegetation type (code 3 in figure 2.14) which would occur at altitudes between 3,300-3,900 m.a.s.l. According to Navarro and Ferreira (2007b) this last vegetation type represents *puna* vegetation, characterised by the series of *Dasyphyllum hystrix-Polylepis tomentella.* However, these species do not grow in our research area and the only *Polylepis* species prevailing at high altitudes is *P. besseri*. Hence, it is clear that the map of Navarro and Ferreira (2007b) is still not accurate enough to significantly represent (climax) vegetation of our research area. This immediately demonstrates the value of the present study for future updates of this map. Our data have been passed on to the first author of the map (Gonzalo Navarro).

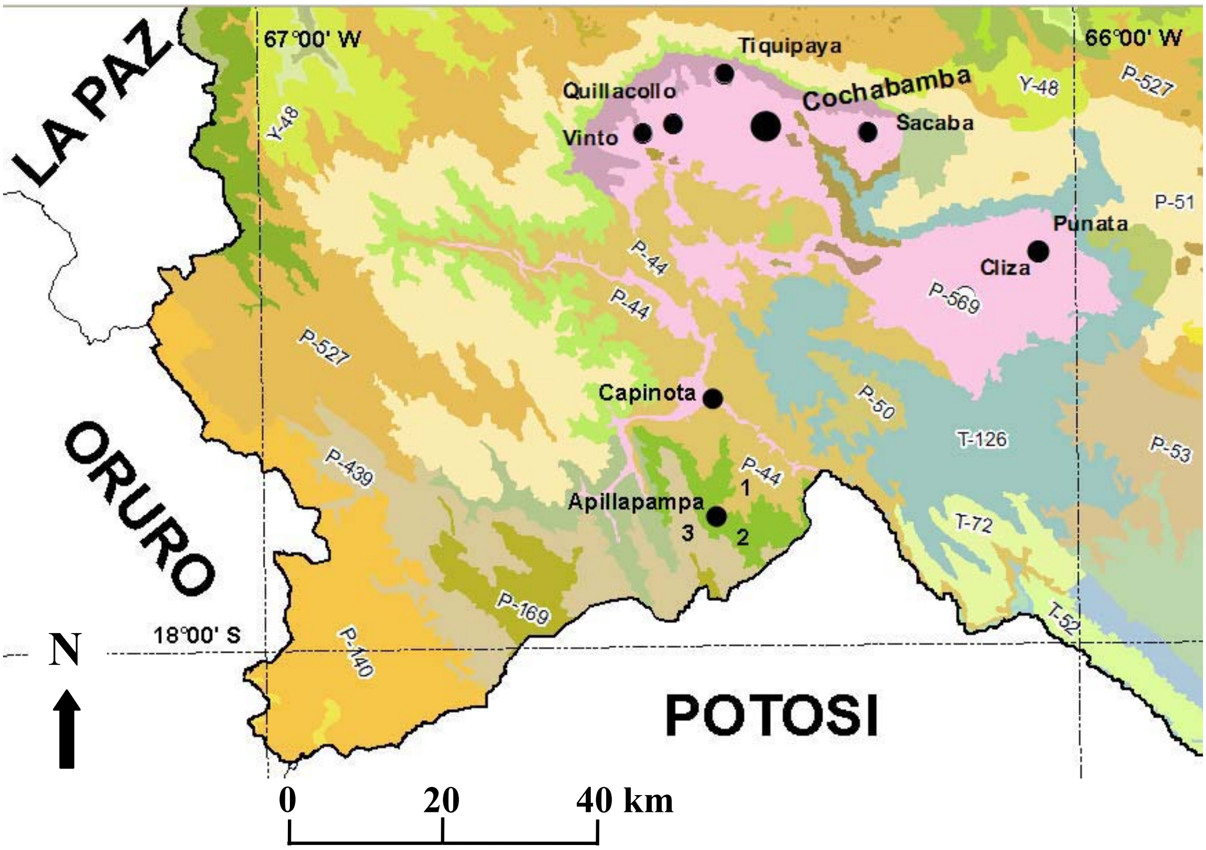

Figure 2.14: Vegetation map of the research area, based on Navarro and Ferreira (2007b). Codes correspond to vegetation types defined by Navarro and Ferreira (2007b): 1. Inferior semi-arid *prepuna* forest of the Rio Grande basis, characterized by the series of *Vasconcellea quercifolia-Schinopsis haenkeana*, at altitudes between 2,200–2,900 m.a.s.l.; 2 Dry mountainous boliviano-tucumano *prepuna* forest, and northern *prepuna,* characterized by the series of *Escallonia millegrana-Kageneckia lanceolata* at altitudes between 2,200–2,800 m.a.s.l.; 3 *Polylepis puna* forest of the oriental central mountain chain characterized by the series of *Dasyphyllum hystrix-Polylepis tomentella* at altitudes between 3,300–3,900 m.a.s.l.

2.3.5. Which Environmental Variables Explain the Variation in Species Abundance Data Best?

An appropriate technique to answer this question is Canonical Correspondence Analysis (Ter Braak, 1986). Since the "best fit" arrangements of species and transects (i.e. CA) have already been visualized (figures 2.9-2.11), here it is examined whether similar compositions are obtained when transect scores are restricted to linear combinations of the environmental variables that were measured (i.e. CCA).

Plants>0.1 m

Eigenvalues of the first two axes (explaining 15.5% of total variance in data) are higher than 0.5, which indicates a good dispersion of species scores over the ordination axes (table 2.12). Monte Carlo test results revealed that correlations between species and environmental parameters are only significant for the first two axes (table 2.13). Altitude is correlated best with the first axis, whereas travel time, firewood harvest and proximity to a river are correlated with the second axis (table 2.14). Figure 2.15 shows a picture that is largely similar to figure 2.9. Dispersion of transects over the first ordination axis is similar for both CA and

CCA (Kendall's τ_b= -0.95; $p<0.001$), since eigenvalues of the first two axes are only slightly lower for CCA (table 2.12) as compared to CA (table 2.4). These data confirm our initial impression that the first CA axis correlates with altitude. Division of transects based on altitude is even more apparent in the CCA diagram (figure 2.15) than for CA (figure 2.9). Transect scores of the *prepuna* zone are situated on the left side of the second axis (the only exception being transect 27). Correspondence between CA and CCA is much lower for dispersion of transects along the second ordination axes in both diagrams (Kendall's τ_b= -0.61; $p<0.001$). Hence, the combination of travel time, firewood harvesting and proximity to a river can only partly explain the variation accounted by the best fit scenario provided by the second CA axis (figure 2.9). Other environmental variables that were not measured such as soil texture and structure, hydrographic profile, etc. are also expected to have an important impact on species composition.

Table 2.12: Eigenvalues of ordination axes with cumulative percentages of variance they explain for *plants>0.1*. Total variance ("inertia") in the species data is 8.2704.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.771	0.514	0.394
Cumulative % of variance explained	9.3	15.5	20.3
Pearson Corr;, Spp-Envt*	0.994	0.956	0.941
Kendall Corr., Spp-Envt	0.916	0.729	0.729

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables.

Table 2.13: Monte Carlo test of hypothesis that there is no relationship between main and second matrix for *plants>0.1*

MONTE CARLO TEST RESULTS (499 runs)					
eigenvalues			**Species environment correlations**		
Axis	Eigenvalue	p	Axis	Corr.	p
1	0.771	0.01	1	0.994	0.002
2	0.514	0.01	2	0.956	0.0049
3	0.394	0.01	3	0.941	0.176

p = proportion of randomized runs with eigenvalue or species environment correlation greater than or equal to the observed eigenvalue or species environment correlation; i.e., p = (1 + no. permutations >= observed)/(1 + no. permutations)

Table 2.14: Intraset correlations indicating the relations between environmental variables and ordination axes for fitted site scores (CCA) (only values > │0.5│ contribute substantially to the axis)

Variable	Axis 1	Axis 2
travel time	-0.281	**0.784**
altitude	**0.939**	0.152
slope	-0.358	0.061
compass	-0.200	0.185
firewood	0.020	**0.601**
path	-0.039	-0.256
river	-0.148	**-0.544**
plantation	-0.249	-0.476
fire	-0.005	-0.152

(Sub-)woody Plants

Also for case of *(sub-)woody plants*, the eigenvalues of the first two axes (explaining 15.6 of total variance in data) are greater than 0.5, indicating a good dispersion of species scores over the ordination axes (table 2.15). Monte Carlo test results show that the first three axes are significant. However, correlations between species and environmental parameters initially were not significant at the 5% level for the third axis. After removal of the non-significant environmental variables (i.e. *path*, *grazing* and *plantation*) (Monte Carlo test), the correlation between species and environmental parameters for the third axis is significant at the 1% level (table 2.16).

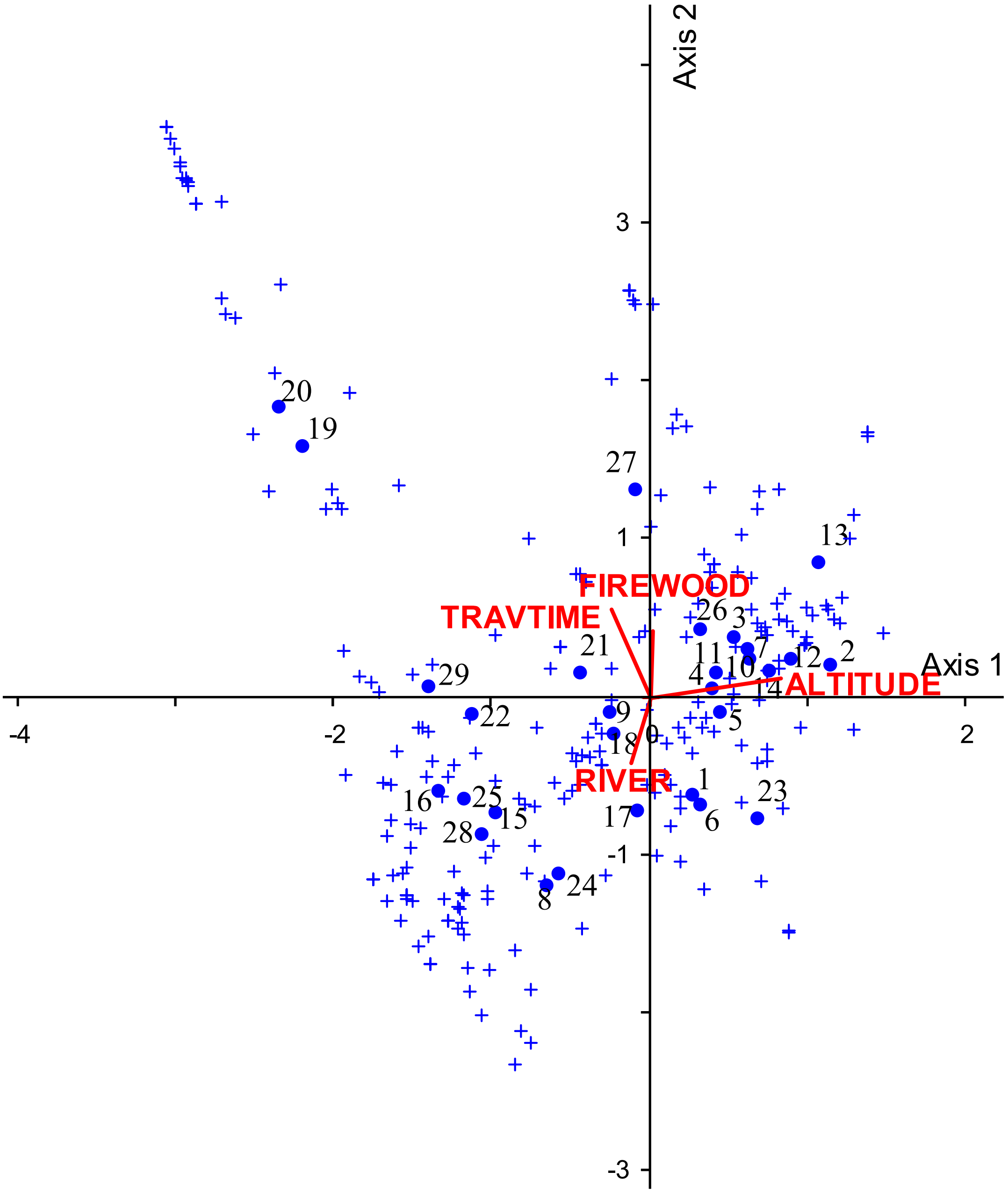

Figure 2.15: Ordination diagram representing the first two axes of a canonical correspondence analysis (CCA) for *plants>0.1 m*. Crosses (+) and dots (•) with numbers represent species and transects, respectively. Transects with high abundance of a species tend to be close to the point of that species. The position of species scores (i.e. +) indicates where species abundance is highest, with (imaginary) concentric circles away from the species score indicating lower abundance of a species (Kindt & Burn, 2002). Environmental variables are represented by vectors that determine additional axes in the diagram and species scores must be projected onto these axis. The overall mean of all environmental variables is represented by the origin of the plot. The inferred weighted average of a species or a transect is higher than average if the projection point (of species or transects) lies on the same side of the origin as the vector-tip and is lower than average if the origin lies between the projection point and the end-point of the vector line. For example, transects 19 and 20 are situated at the largest measured travel times, whereas transect 23 is situated closest to Apillapampa in terms of travel time. Environmental variables with long vectors are more strongly correlated with the axes than those with short vectors (Jongman *et al.*, 1996). Altitude is correlated with the first axis and travel time, firewood harvest and proximity to a river to the second axis. Units on both ordination axes correspond to multiples of variance.

This reduction of environmental variables leads to highly similar eigenvalues as those listed in table 2.15 and therefore they are not repeated here. Similarly to *plants>0.1 m*, altitude correlates best with the first axis, whereas travel time, firewood harvest and proximity to a river are correlated with the second axis (table 2.17). Fire correlates best with the third axis.

Table 2.15: Eigenvalues of ordination axes with cumulative percentages of variance they explain for *(sub-)woody plants*. Total variance ("inertia") in the species data is 7.9012.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.830	0.569	0.452
Cumulative % of variance explained	10.5	17.7	23.4
Pearson Corr;, Spp-Envt*	0.983	0.921	0.883
Kendall Corr., Spp-Envt	0.873	0.594	0.610

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables.

Table 2.16: Monte Carlo test of hypothesis that there is no relationship between main and second matrix for *(sub-)woody plants*

MONTE CARLO TEST RESULTS (99 runs)					
eigenvalues			**Species environment correlations**		
Axis	Eigenvalue	p	Axis	Corr.	p
1	0.830	0.01	1	0.983	0.01
2	0.569	0.01	2	0.921	0.03
3	0.452	0.01	3	0.883	0.009

p = proportion of randomized runs with eigenvalue or species environment correlation greater than or equal to the observed eigenvalue or species environment correlation; i.e., p = (1 + no. permutations >= observed)/(1 + no. permutations)

Table 2.17: Intraset correlations indicating the relations between environmental variables and the ordination axes for fitted site scores (CCA) after removal of three insignificant environmental variables (i.e. grazing, path and plantation). Only values > │0.5│ contribute substantially to the axis.

Variable	Axis 1	Axis 2	Axis 3
travel time	-0.454	**0.742**	0.260
height	**0.928**	0.167	0.075
slope	-0.209	-0.099	0.107
compass	-0.488	-0.046	-0.206
firewood	-0.010	**0.688**	-0.003
river	-0.133	**-0.520**	0.338
fire	0.083	-0.072	**0.554**

The CCA ordination diagram of *(sub-)woody plants*, representing the first two axes (figure 2.16) reveals a similar composition of transect scores as for the CA plot (figure 2.10). Analogous to the result for *plants>0.1 m*, rankings of transect score projections on the first ordination axes in the CCA and CA plots (Kendall's τ_b= -0.86; p<0.001) correspond somewhat better than the projections on the second axes (Kendall's τ_b= -0.81; p<0.001). However, transect score projections on the first two CCA and CA axes give a better match for *(sub-)woody plants* as compared to *plants>0.1 m*. Hence, the combination of travel time, firewood harvest and proximity to a river explain the variation accounted by the best fit scenario, provided by the second CA axis, better for *(sub-)woody plants* than for *plants >0.1 m*. In figure 2.17, the first and third CCA ordination axes are depicted. Transects with evidence of recent burning activity are grouped in the upper part of the plot. As predicted from its eigenvalue (<0.5), dispersion of transects scores is much more reduced along the third axis.

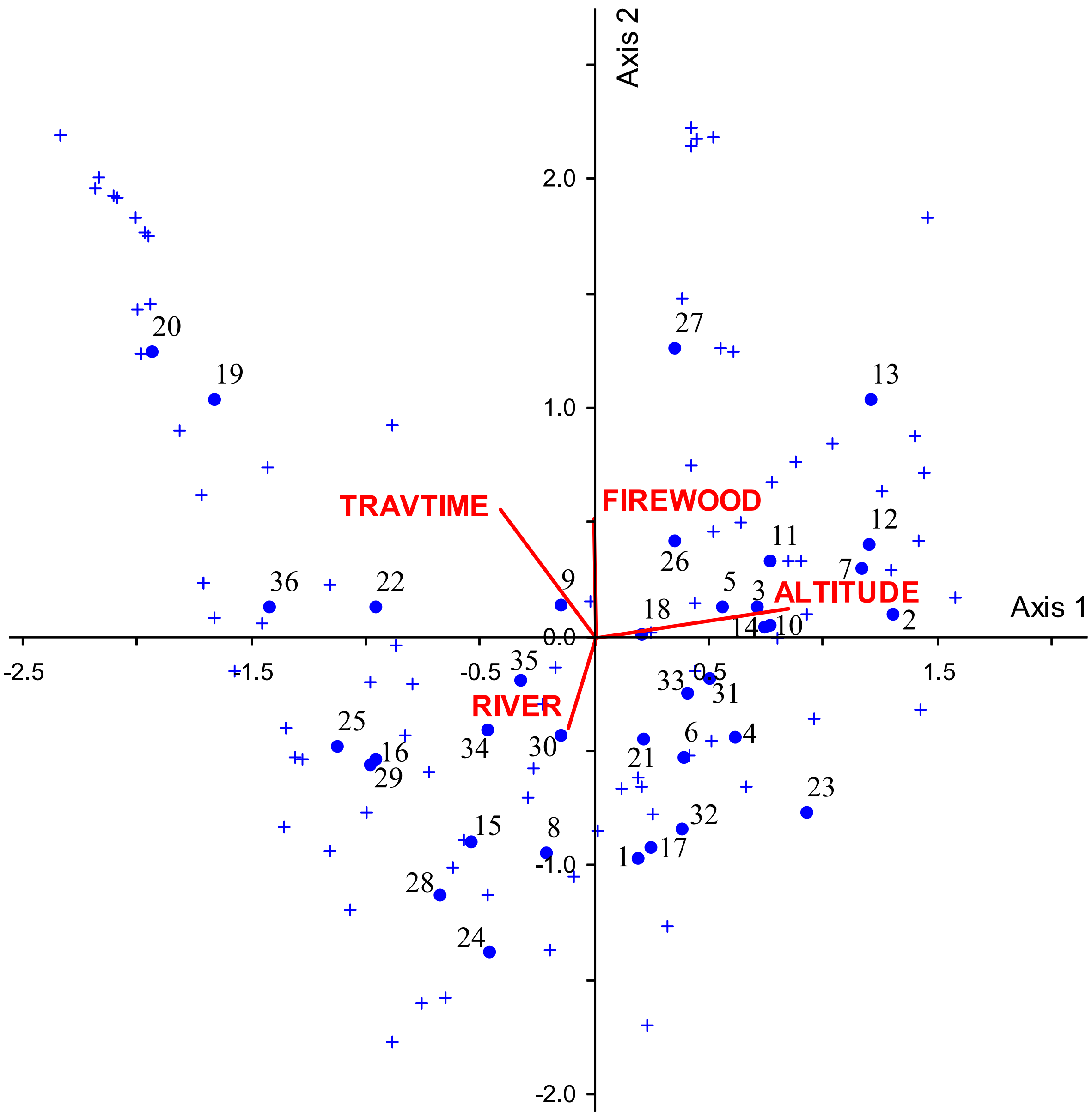

Figure 2.16: Ordination diagram representing the first two axes of a canonical correspondence analysis (CCA) for *(sub-)woody plants*. Crosses (+) and dots (•) with numbers represent species and transects, respectively. Altitude is correlated with the first axis and travel time, firewood harvest and proximity to a river to the second axis. Units on both ordination axes correspond to multiples of variance. For interpretation of the plot, see legend figure 2.15.

In sum, the CCA analyses for *plants>0.1 m* and *(sub-)woody plants* suggest that much of the variance in species abundances and distributions is explained by a combination of natural and anthropogenic variables. These variables are altitude, travel time, proximity to a (temporal) river or stream, evidence of firewood harvest and evidence of recent burning activity. Of the measured variables, travel time from the village centre (a measure of accessibility) appears to be the dominant human factor to explain variation in species abundance data, but also firewood harvest and burning practices contribute significantly.

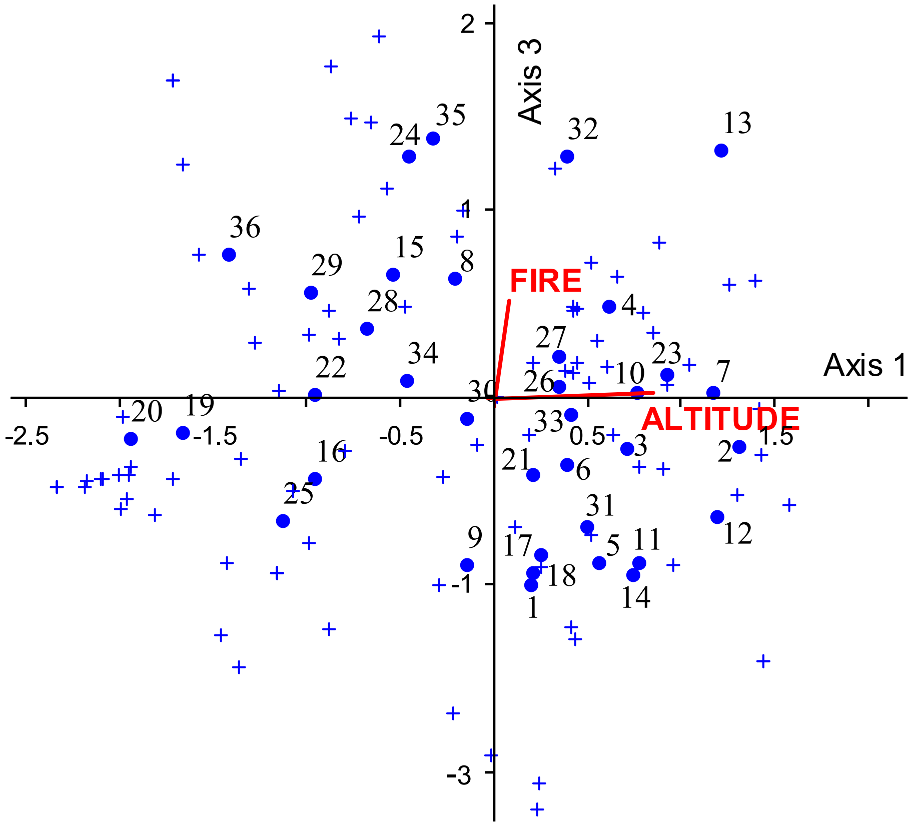

Figure 2.17: Ordination diagram representing the first and third axis of a canonical correspondence analysis (CCA) for *(sub-)woody plants*. Crosses (+) and dots (•) with numbers represent species and transects, respectively. Fire is best correlated with the third axis. Evidence of recent burning activity was observed in transects 4, 13, 15, 24, 32, 35 and 36. Units on both ordination axes correspond to multiples of variance. For interpretation of the plot see legend figure 2.15.

2.3.6. Predicting Diversity in Transects Based on Measured Environmental Variables

Now that the measured environmental variables have been identified that best explain variation in the transect abundance data (i.e. height above sea level, travel time, firewood harvest, proximity to a river and evidence of recent burning), it will be explored to what extent diversity in transects can be predicted from these variables. We therefore exposed our data to various statistical techniques (correlation and regression analysis, t-test, ANOVA) to investigate several null hypotheses that test the contribution of each environmental predictor variable to the observed diversity in transects.

Ho = diversity in transects is random with respect to height above sea level, travel time, slope and compass direction

Plants>0.1 m

Linear correlation demonstrates that diversity of *plants>0.1 m* in sampled transects correlates with height above sea level. Alpha and Shannon diversity significantly decrease with altitude, while the density of all individual plants in transects increases (Table 2.18). The decrease in diversity on the altitude gradient is essentially linear (Alpha diversity = -0.019 * altitude + 104.135 ($R^2=0.17$; p=0.028) and Shannon diversity = -0.001 * altitude + 4.337 ($R^2=0.11$; p=0.047)) and hence corroborates the findings of Gentry (1988b). The latter author uncovered a linear trend of decreasing diversity for plants ≥ 2.5 cm dbh with increasing altitude for the

South American Andes as a whole. Similarly, Galindo *et al*. (2003) found that species richness (for plants ≥1 cm dbh) was inversely related to altitude in the Colombian Andes.

Table 2.18: Pearson correlations between diversity indices and environmental variables for *plants>0.1 m*

		travel time	altitude	slope	compass bearing
Alpha diversity	Pearson Correlation	0.187	**-0.408(*)**	0.294	-0.017
	Sig. (2-tailed)	0.331	0.028	0.121	0.931
Shannon diversity	Pearson Correlation	0.270	**-0.371(*)**	0.233	0.005
	Sig. (2-tailed)	0.157	0.047	0.223	0.978
Number of individuals	Pearson Correlation	-0.006	**0.380(*)**	**-0.408(*)**	-0.132
	Sig. (2-tailed)	0.976	0.042	0.028	0.495

*** = correlation is significant at the 0.05 level (2-tailed)**

Higher numbers of individuals in transects at higher altitudes might be explained by a combination of several underlying factors, such as:

1. Size. Because of their smaller size, more plants are able to grow per square meter.
2. Precipitation and evapotransporation. At higher altitudes, precipitation is higher and evapotransporation lower.
3. Agriculture. Negative influence of agriculture is smaller since terrains at higher altitudes are less suitable for crop production.
4. Pasture activity. There is less pasturing at higher altitudes due to a lower fodder biomass per unit surface area (also see paragraph 4.3.4, chapter 4).

Furthermore, results show that the total number of individuals in transects correlates negatively with site slope (Table 2.18). Since such a trend is not observed for *(sub-)woody plants* (see Table 2.19), lower numbers of plant individuals on sites with steeper slopes might be related to the fact that herbaceous plants establish less easily on steeper slopes. Generally, they have less extended roots systems and are more susceptible to erosive forces than *(sub-) woody plants*.

(Sub-)woody Plants

Intriguingly, the diversity of *(sub-)woody plants* does not decrease with increase in altitude (table 2.19). As Gentry (1988b) demonstrated, one would expect such a trend particularly for *(sub-)woody plant* diversity. There might be at least two hypothetical explanations for this outcome. First, the diversity of woody plant species at lower altitudes could be lower than the potential (climax) situation as a consequence of higher anthropogenic pressure (firewood harvest, grazing, agriculture, etc.). Second, the altitudinal range of our monitoring effort and/or numbers of transects sampled at different altitudes could be too restricted for such patterns to become apparent in the (sub-)woody flora.

Support for the first explanation is provided by the fact that Alpha and Shannon diversity, as well as the total number of individual *(sub-)woody plants* per transect, increase with travel time (significantly at 5% level for Alpha diversity and numbers of individuals and at the 10% level for Shannon diversity; see table 2.19). Indeed, the observation that less accessible transects (measured as travel time) show higher *(sub-)woody plant* diversity and density, might be a consequence of higher anthropogenic pressure in areas that are more accessible. Various publications that report on increasing woody species richness and densities with increasing distance from human settlements have supported this hypothesis (Codron *et al.*, s.d.; Beck *et al.*, 2001; Williams-Linera, 2002; Veach *et al.*, 2003; Mahamane and Mahamane, 2005).

Diversity in transects also increases with site slope (significant at 5% level for Alpha and at 10% level for Shannon diversity; table 2.19). Since site slope is also an important parameter determining site accessibility (cf. Veach *et al.*, 2003), this result also seems to confirm our hypothesis that diversity of woody plant species in transects is negatively correlated with anthropogenic pressure. Other authors have come to similar conclusions. For example, Kessler (2002 and 2006) demonstrated that the restricted distribution of Bolivian *Polylepis* forests to steep rocky mountain slopes and cliffs with very limited accessibility is not due to these species' preference for such habitats. Rather, it is a consequence of thousands of years of human activity in the high Andes that led to the disappearance of these forests on easy accessible sites.

Table 2.19: Pearson correlations between diversity indices and environmental variables for *(sub-)woody plants*

		travel time	altitude	slope	compass bearing
Alpha diversity	Pearson Correlation	**0.379(*)**	-0.194	**0.334(*)**	-0.024
	Sig. (2-tailed)	0.023	0.256	0.046	0.888
Shannon diversity	Pearson Correlation	**0.284(s)**	0.008	**0.305(s)**	-0.021
	Sig. (2-tailed)	0.094	0.962	0.071	0.902
Number of individuals	Pearson Correlation	**0.348(*)**	0.101	-0.040	**-0.300 (s)**
	Sig. (2-tailed)	0.037	0.556	0.818	0.076

*** = correlation is significant at the 0.05 level (2-tailed); s = correlation is significant at the 0.10 level**

Ho = diversity in transects is random with respect to plantation or cultivation of exotic species in transects

Plants>0.1 m

In 5 of 29 sampled transects, exotic tree (*Eucalyptus globulus* and *Pinus radiata*) or shrub (*Spartium junceum*) species had been planted. An independent sample t-tests shows that Alpha diversity is significantly lower (t=2.1; p=0.046) in transects with planted exotic species (31.2±13.5 (s.d.)) than in transects without plantations (43.4 ±11.5 (s.d.)). The total number of individuals and Shannon diversity are significantly equal for both groups. One could ask whether this result is not more a consequence of the fact that exotics are cultivated at higher altitude sites with lower natural species richness, than of the negative influence of exotics. However transects with planted or cultivated exotics are relatively evenly distributed over the altitudinal interval we sampled (2,960-3,530 m.a.s.l.)

(Sub-)woody Plants

In 5 of 36 sampled transects, exotic trees (*Eucalyptus globulus* and *Pinus radiata*) or shrubs (*Spartium junceum*) had been planted. Independent sample t-tests show that Shannon diversity and the total number of individuals in transects with planted trees and/or bushes are significantly equal than in other transects. However, mean Alpha diversity is considerably lower (but only significant at 10% level: t=1.76; p=0.09) in transects with planted exotic species (9.6±3.9 (s.d.)) than in transects without plantations (13.8 ±5.1 (s.d.)).

The lower species numbers in exotic tree stands in Apillapampa are not a real surprise. The negative allelopathic impacts of *Eucalyptus globulus* and *Pinus radiata* on understorey vegetation are well known and studied (Molina *et al.*, 1991; Mahboubi *et al.*, 1997; Souto *et al.*, 2001; Ibisch, 2003e). Participants in Apillapampa are aware of this problem and know that these trees do not combine well with agriculture because they deteriorate soil quality. In Andean Ecuador (3,000-4,000 m), Hofstede *et al.* (2002) observed regeneration of Andean woody species in some pine (*Pinus radiata*) plantations, while understorey was completely lacking in other sites. This made the authors conclude that the impact of pine plantations cannot be generalized but should be evaluated case by case. Results from the present study would suggest that the impact of exotic species on the diversity of native species is rather negative.

Ho = diversity in transects is random with respect to burning activity

Plants>0.1 m

Evidence of (recent) burning activity was observed in 4 of 29 sampled transects. Mann-Whitney non-parametric tests show that diversity (total number of individuals, Alpha and Shannon diversity) is significantly equal in transects with or without observed burning activity. Therefore, fire does not seem to have effect on the plant diversity available in the sites we sampled. However, in view of the small number of transects with observed recent burning activity this finding needs to be interpreted very cautiously.

(Sub-)woody Plants

In 7 of 36 sampled transects, evidence of (recent) burning activity was observed. Independent sample t-tests show that diversity (total number of individuals, Alpha and Shannon diversity) is significantly equal in transects with or without observed burning activity. However, mean Shannon diversity is lower (although only significant at 10% level: t=1.89; p=0.07) in transects with marked signs of burning activity (1.40±0.77 (s.d.)) than in undisturbed transects (1.85±0.50 (s.d.)).

Although not corroborated by our results, the negative effects of fire on woody plant diversity have been demonstrated repeatedly (Davis *et al.*, 1997; Veach *et al.*, 2003). According to Kessler and Driesch (1993), particularly the frequent burning of vegetation is responsible for reducing forest cover in the high Andes. The main objective of burning is to improve fodder quality (figure 2.18) but in the past this activity probably was also part of hunting practices. Mature *Polylepis* trees (i.e. the dominant native tree species in large part of the Central Andes between 3,500-4,400/5,000 m.a.s.l. (Kessler, 2006)) generally survive fires, but this is not the case for plantlets and young trees (Kessler and Driesch, 1993). In the same line, Sax (2002) demonstrated in the Chilean Andes that the number of woody taxa in plots increased significantly with the number of years that had passed since the most recent fire.

Figure 2.18: Example of recently burned vegetation and regrowth of grasses

Ho = diversity in transects is random with respect to firewood harvest, grazing activity, paths crossing transects and presence of nearby (seasonal) river

The null hypothesis is accepted for all of the above binary environmental variables. The number of transects where firewood harvest, grazing activity, crossing paths or the vicinity of a (temporary) river or stream have been observed, are given in table 2.20.

Table 2.20: Numbers of transects sampled for *plants>0.1 m* and *(sub-)woody plants* with observed incidence of firewood harvest, grazing activity, crossing paths and nearby (seasonal) rivers or streams

	Plants >0.1 m		*(Sub-)woody Plants*	
	observed	Not observed	observed	Not observed
firewood harvest	11	18	14	22
grazing activity	24	5	31	5
presence of path	12	17	14	22
presence of river	5	24	6	30

The previous analyses show that variables that explain most variation in species abundance data (identified by CCA), do not necessarily overlap with statistically significant predictor variables for diversity, such as Alpha, Shannon and the number of individuals in transects. Firewood harvest and presence of a river were identified as significant environmental variables by CCA for both *plants>0.1 m* and *(sub-)woody plants*, but they do not detect differences in diversity (i.e. Alpha, Shannon and number of individuals) between transects. On the other hand, plantation of exotic species and site slope were not selected by CCA but do explain significant variation in diversity between transects.

2.3.7. Local Perspectives on Vegetation Degradation and its Causes

The vegetation in our research area is severely fragmented as a consequence of past and present human activities, and relicts of what is supposed to be the climax condition are rather scarce. In order to verify whether participants are conscious of possible short-term changes in abundances of individual plant species, and to determine which species might potentially be facing population decline, a question specifically addressing this topic was included in the ethnobotanical interview (see chapter 3, section 3.3.1. for methodology used). For every plant species shown, participants were asked if they felt its abundance had increased, decreased or stagnated as compared to their furthest memories. Information regarding abundance according to at least two participants, was obtained fro 344 species.

As such, 72 species (21%) were identified that were claimed to have "decreased in abundance" by at least two participants. Most of these are shrubs (42%), and herbs (33%), but there is also mention of 9 trees, 4 grasses, 3 cacti, 1 epiphyte, 1 hemi-parasite and 1 parasite. However, consensus about the status of these species was rather low, and only for thirteen species declining abundances were confirmed by more than half of all questioned participants. Since all but one of these species are used for fuel, they will be discussed more in detail in chapter 5 which deals with harvest of fuel species. One species that is worth noting here is *Krameria lappacea*. It is a highly esteemed medicinal plant (Vandebroek *et al.*, 2003) that is often harvested with root included. Although this small bush produces good quality firewood, it is not used for this purpose. However, it does not regenerate well and is gradually disappearing according to some participants. The bad regeneration potential of this plant may be related to the fact that it is a hemi-parasite that resides on the roots of other plant species (Carlquist, 2005).

In the case that species were reported as "decreasing in abundance", participants were asked to name possible causative factors. As shown in figure 2.19, participants ascribed declining plant resources mainly to excessive harvesting (51% of responses), and the impact of increased erosion (30%). Also climate change (8%), manifested by strongly altered precipitation patterns, and overgrazing (8%) were identified as important causal factors. Bad plant reproduction (2%), damage by leaf-cutting ants (1%), fire (0.4%) and natural pests and diseases (0.4%) are other minor causes that were claimed to cause species degradation (figure 2.19).

Most of the factors identified by participants in Apillapampa, have also been outlined in the scientific literature. Some major relevant threats to biodiversity in the Bolivian Andes have been documented by Calvo (2003a), including (1) increasing territory restriction; (2) demographic growth; (3) climatic change; and (4) loss of traditional knowledge and management practices related to the sustainable use and conservation of biodiversity. These fundamental threats result in and are accompanied by a number of unsustainable practices that unavoidably lead to degradation of the vegetation, such as overgrazing, fire, (over)harvest of firewood species, erosion and the continuous expansion of cultivated areas (Codron *et al.*, s.d.; Kessler and Driesch, 1993; Davis *et al.*, 1997; Pestalozzi, 1998; García and Beck, 2006; Kessler, 2006; Hjortsø *et al.*, 2006; Bentley and Valencia, 2003).

Based on the qualitative information gathered in the present study we were not able to quantify (potential) overharvesting of wild plant biomass, as this would require long-term measurements of biomass growth rates in combination with studying harvest regimes. However, the fact that accessibility is an important variable for determining diversity of plants with (sub-)woody growth forms in transects might be an indication of unsustainable harvest of wild plant populations. Although human-induced burning of vegetation is only of marginal importance according to participants, it does have an important negative impact on woody vegetation, as indicated by literature, and partly by our transect data. The influence of fire is intensified by grazing, which is practiced in most parts of the Andes with livestock densities well above the ecosystem's carrying capacity (García and Beck, 2006; Kessler, 2006) and leads to ecosystem degradation and changes in vegetation composition and structure (Beck *et al.*, 2001; Ibisch, 2003d). Overgrazing is especially detrimental for the reproduction of native tree species, but people cannot afford to discontinue pasturing in order to allow the vegetation to recover (cf. Bentley & Valencia, 2003). The fact that grazing was not identified as a factor controlling diversity in our transects is probably because our observations of grazing activity represent only snapshots and it is very likely that all transects had been exposed to pasturing.

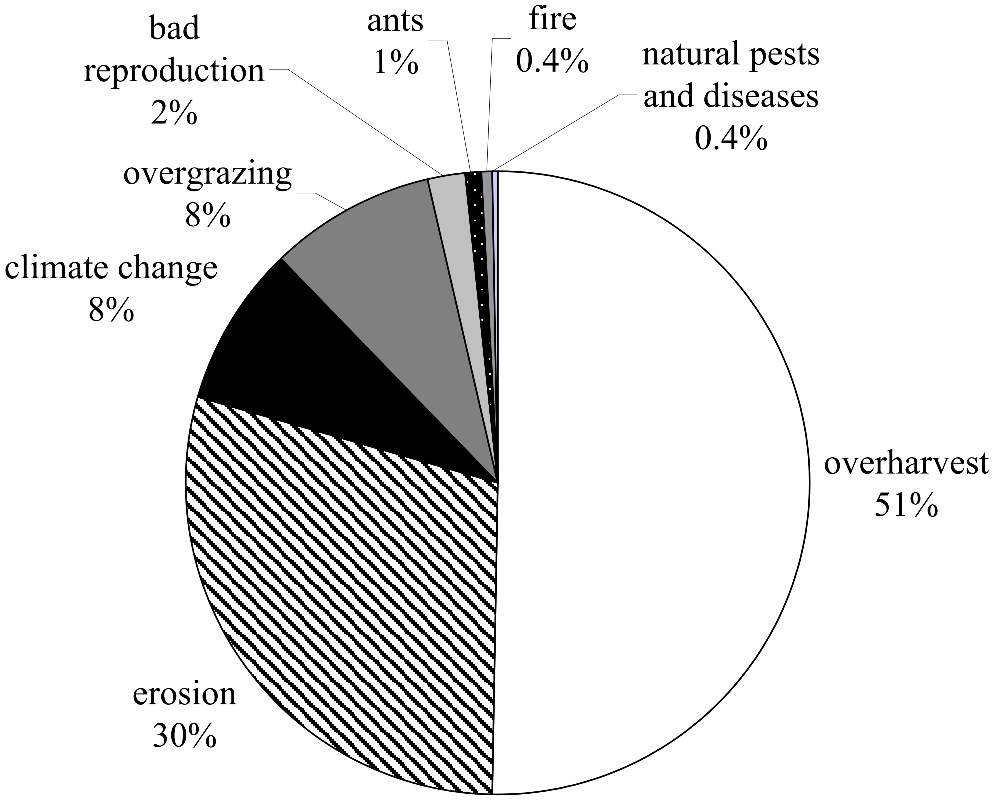

Figure 2.19 Proportional presentation of causal factors ascribed to decreasing species' abundances by participants.

Both indigenous participants and personnel of the NGO FEPADE (1998) agree that erosion has increased strongly over the last decades. Soil loss in the region has been estimated between 51-100 tons per hectare and per year (MDSMA, 1996). The causal factors of erosion are multiple and include overgrazing (Ibisch, 2003d), climate change (Calvo, 2003a) and overharvesting (FEPADE, 1998). Soil erosion has unmistakably been linked to ecosystem degradation (Ibisch, 2003d).

2.4. Conclusions

In this chapter, we have provided a general introduction to the wild and anthropogenic flora of Apillapampa. We believe that our collection of 441 different plant species is highly representative for the flora of Apillapampa between 2,700-3,800 m.a.s.l. Qualitative and quantitative floristic data collected correspond well with other relevant studies that were conducted in the Bolivian Andes, and contribute significantly to the still severely understudied Bolivian flora. In addition, our ecological data will allow for a continuing adjustment of the existing vegetation map of Navarro and Ferreira (2007b) which is based on limited data.

From the literature, it is known that Apillapampa is situated on the border between the *prepuna* and *puna* ecological zones, the occurrence of which is controlled by an altitudinal gradient. We have been able to confirm this for our own transect data by means of different statistical techniques which allowed us to establish the hypothetical border between both zones in our research area at about 3,200 m.a.s.l. Interestingly, the locally used indigenous vegetation classification system corresponds surprisingly well with the phytosociological division between *prepuna* and *puna*.

Vegetation in the study area is highly fragmented, partly as a consequence of historical human activities that continue until today. Our interview data demonstrate that people in Apillapampa are conscious of the short-term decrease of several local wild plant populations, which they ascribe mainly to human factors such as overharvesting and overgrazing. The negative impact of anthropogenic disturbance on the local vegetation is corroborated by the ecological findings of the present study. We demonstrated that apart from altitude, which is the predominant ecological variable in the Andes, other variables associated with anthropogenic pressure determine species abundance data in the sampled transects. In particular, site accessibility (measured as travel time from the village centre), proximity to a river or stream, and evidence of firewood harvesting and/or recent burning are factors that significantly explained abundance data of species.

In addition, analysis of the impact of environmental variables on the local flora in terms of species richness, Shannon diversity and/or the number of individual plants, revealed that mainly anthropogenic disturbance variables (negatively) control diversity in transects. No consistent results were obtained for the otherwise well-established inverse relationship between altitude and species diversity. The only other measured non-human variable influencing plant diversity in transects was site slope. However, the fact that diversity of (sub-)woody plants tended to increase with increasing site slopes can probably also be explained from an anthropogenic point of view. Site slope is inversely correlated with site accessibility. Therefore, a higher diversity of (sub-)woody plants at steeper sites might be related to the fact that harvesting pressure is lower in such places. Support for the hypothesis that diversity of (sub-)woody plant species in transects is negatively correlated with anthropogenic pressure is also provided by the fact that less accessible transects showed a higher diversity and density of (sub-)woody plants. Other anthropogenic disturbance variables that have an apparent negative impact on plant diversity are plantation or cultivation of exotic tree or shrub species, as well as burning of vegetation. However, low significance levels were obtained for the latter variables and therefore their validity in the entire research area remains questionable.

The impact of anthropogenic pressure on wild plant species in Apillapampa is further discussed in chapter 5, where we will deal with the local impact of firewood harvest on wild populations of fuel species.

3.

Plant Use in Apillapampa[1]

3.1. Introduction

The Andes cover approximately 35% of the Bolivian territory and are home to four main ethnic groups: Aymaras, Quechuas, Kallawayas and Urus (Vidaurre *et al.*, 2006). Ethnobotanical studies have been conducted in representative communities of these groups (e.g. Bastien, 1987a; Torrico *et al.*, 1994; Vandebroek *et al.*, 2003; Pestalozzi, 1998; Rios and Rocha, 2002b). The Quechuas and Aymaras are the largest ethnic groups in Bolivia, accounting for 31 and 25% of the Bolivian population, respectively (Calvo, 2003c). The relatively small Kallawaya community (13,000 people (Bastien, 1987a)) is probably the best studied. They speak mostly Quechua and have been classified as a special cultural subgroup of Aymaras. In origin they were most likely a distinct ethnic group (Bastien, 1987a). The Urus represent the eldest, but also smallest ethnic group (0.02% of Bolivian population) of the Andes (Calvo, 2003c). Unfortunately they have received considerably less attention than other

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[1] The medicinal uses and ethnopharmacological properties of the most important medicinal plants collected in Apillapampa are described in the book "*Plantas medicinales para la atención primaria de la salud. El conocimiento de ocho médicos tradicionales de Apillapampa (Bolivia)*" (Vandebroek, Thomas and AMETRAC, 2003)

Andean societies (Vidaurre *et al*., 2006). Both Kallawaya and Uru languages are on the verge of extinction (Raymond, 2005).

Most ethnobotanical publications in the Bolivian Andes have focused on different aspects of medicinal plants (Patzi, 1984; Girault, 1984 and 1987; Bastien, 1987a; Oblitas Poblete, 1992; De Lucca and Zalles, 1992; Zalles and De Lucca, 1993; Alba and Tarifa, 1993; Alba, 1994; Abdel-Malek *et al*., 1996; Sagaseta, 1996; Arrazola, 1999; Vidaurre, 2000 and 2006; Muñoz *et al*., 2000c; Sikkink, 2000; Ureña, 2001; Prado, 2001; Vandebroek *et al*., 2003, 2004a and 2004b; Macía *et al*., 2005). Much fewer studies have recorded overall plant use and/or knowledge of Bolivian Andean communities and regions (e.g. Cardenas, 1989; Hensen, 1991; Torrico *et al*., 1994; Pestalozzi; 1998; Beck *et al*., 2001; Rios and Rocha, 2002b). Nonetheless, also non-medicinal plant uses are of central importance to the economies of rural Andean communities (Ibisch, 2003b; Vidaurre *et al*., 2006). These include wild foods, food additives, flavouring agents, sources of fuel, dyes, handicrafts, house construction, fodder, environmental uses such as hedges, etc. (Pestalozzi, 1998; Beck *et al*., 2001; Øllgaard *et al*., 2006; Ulloa, 2006; Vidaurre *et al*., 2006; Kessler, 2006; García and Beck, 2006; Macía, 2006).

The objective of the present chapter is to provide a detailed description and analysis of *overall* uses of the flora in Apillapampa. Special attention is given to the extraordinary high number of medicinal plants used. Throughout this chapter, a quantitative approach was followed to present data and to reinterpret some of the indices commonly used in ethnobotany research.

3.2. Methodology

3.2.1. Interviews and Participants

Ethnobotanical information related to sampled plant species was gathered *ex situ* by means of semi-structured interviews with eight male and five female participants between December 2002 and December 2003. Pressed and dried plant specimens were used as props during interviewing. Six participants (five men and one woman) are traditional healers who are organized in a semi-formal healers' association called "*Asociación de Jampiris de Apillapampa*". Other participants were selected through peer recommendations as described by Davis and Wagner (2003). Interviews were conducted on an individual basis and included questions about local name(s), use(s), and preparation of plant species.

Plant uses were grouped into the following use categories according to Cook's (1995) Economic Botany Data Collection Standard:

- *animal food*;
- *medicines,* including human and veterinarian medicines;
- *food,* including beverages;
- *materials,* including handicrafts, dyes, construction materials, roof thatch, hygienic substances, and toys;
- *fuel;*
- *social uses,* including ritual and religious uses, smoking materials/drugs and other unspecified social uses;

- *environmental uses,* including erosion control, shade/shelter, soil improvers, ornamentals, hedges; and
- *poison*.

We adapted Cook's classification (1995) by re-organizing plants used as *food additives* under *food,* and plants used for female sterility under *medicine*. Allocating uses to use categories can be ambiguous. The often unclear borderline between different categories is perhaps most obvious for food and medicinal plants. Pieroni *et al.* (2002a) described a continuum, ranging from plants that are exclusively used as food, through multipurpose food medicines, to predominantly medicinal plants. For the case of Apillapampa, Vandebroek and Sanca (2006) mentioned 43 plant species with overlapping food and medicinal uses. Although use categories do not necessarily coincide with local classifications, the use of a standardized classification is a prerequisite for data processing and comparison of research results with data available from other ethnobotanical studies (Prance *et al*., 1987; Boom, 1987; Phillips and Gentry, 1993a; De Walt *et al*., 1999).

3.2.2. Informant Indexing Technique

3.2.2.1. Use Values

The usefulness of plants to humans is highly variable depending on the point of view. From an ecological perspective, all plants have an unmistakable role to play in ecosystem functioning, and hereby contribute directly and indirectly to man's well-being and survival. From a utilitarian perspective, the plant kingdom represents an enormous gene pool from which humans can take direct benefit. Likewise, the perceived usefulness of plants varies from one ethnic group to another. Plants that are highly appraised by one ethnic group for subsistence may be regarded as 'useless' by another group (Prance *et al*., 1987; Phillips *et al*., 1994; Balée, 1994). Throughout this thesis, plant usefulness is therefore understood from a local ethnic perspective. More specifically, it represents the usefulness of plants as perceived by the participants we interviewed.

To make a quantitative assessment of the cultural importance of individual plant species, various criteria can be used. One of the most straightforward ways is to sum the total number of different uses per species, mentioned by all participants interviewed. However, the informant indexing technique proposed by Phillips & Gentry (1993a) offers a much broader statistical potential and has been used consistently throughout this work. We calculated estimates of the total use value of each species *s* according to the simplified formula of Phillips & Gentry (1993a):

$$UV_s = \frac{\sum_{i}^{n} U_{is}}{n_s}$$

where U_{is} equals the number of uses of species *s* mentioned by informant *i*. This approach has the advantage that, given a sufficient number of informants interviewed, minor uses or even mistakes will only minimally influence use values (Phillips & Gentry, 1993a). Use values (UV_S) can be calculated for all different use categories (i.e. medicine, food, material…), whereby the overall use value corresponds to the sum of use values per category. In the following, we will use the term *categorical use values* to address use values that are calculated per use category (e.g. $UV_{medicine}$, UV_{food}, $UV_{material}$…). To illustrate the calculation of categorical and overall use values the example of *Prosopis laevigata* is given in Box 1.

An additional advantage of working with use values is that it allows comparing (categorical) plant use knowledge among participants. As such, Relative Use Values were calculated for each participant, according to the formula proposed by Phillips and Gentry (1993b):

$$RUV_i = \frac{\frac{UV_{is}}{UV_s}}{n_i}$$

Where n_i equals, for each participant i, the number of plant species that correspond with data obtained from at least two other participants.

3.2.2.2. Quality Use Values

One important aspect that is overlooked by the technique proposed by Phillips and Gentry (1993a) is the quality of individual plant uses. Indeed, some plants are more useful than others for similar purposes in the same use category (Prance *et al.*, 1987; Byg *et al.*, 2006). Resource use preferences are often related to purpose-specific characteristics, such as durability and ease of handling for roof thatch, strength of stems used in house construction, etc. (Byg *et al.*, 2006). Similarly, a plant that burns fast and produces little heat can be used as firewood but its perceived quality will obviously be lower than that of a slowly burning fuel species with a high caloric value. Balée (1994) described how Ka'apor people show preferences for certain firewood species for particular purposes and that some species are not used at all, because they 'stink' when burned or because the wood is simply too hard and does not produce a good flame. Analogous observations have been made by van Andel (2000) for her Guyanese study population. The concept of incorporating use quality in ethnobotanical indices was probably first proposed by Turner (1988). The latter author assigned qualities *a priori*, with the specific use type as only criterion. For example, food uses receive a score of 5 because they are considered more important than medicinal uses that are assigned a quality score of 4. Also Prance and co-workers (1987) indirectly included quality of uses in their calculations of species' use values by subjectively assigning a value of 1 to each major use and a value of 0.5 to each minor use.

However, since these methods rely on subjective decisions by the researcher(s), it is unlikely that they are applied consistently by different researchers (Phillips, 1996). Therefore, we prefer a different approach whereby participants themselves are encouraged to assess individual plant use qualities. Other researchers have done the same. Carretero (2005) calculated 'multiple values' for Bolivian palm species by combining use quality and frequencies of use explicitly assigned by local participants and not by researchers. Also Stagegaard *et al.* (2002) encouraged participants to rate the usefulness of plants as either "usable but sub-optimal" (0.5), "suitable" (1.0) or "near optimal" (1.5) for each of five use categories. As such, summing the different use category scores yielded total scores in the range of 0-7.5 for each species. The downside of the latter method is that it does not allow for more than one quality assessment per use category, independently of the different potential uses and their respective qualities in each category. For example, according to the methodology of Stagegaard *et al.* (2002), a particular plant species that is reported to be a good remedy for treating three different health conditions will receive an identical quality assessment for the medicinal use category as a plant that is a good remedy for treating just one health condition.

Box 1: Categorical and Overall Use Values of *Prosopis laevigata* (Humb. & Bonpl. ex Willd.) M.C. Johnst. according to twelve participants in Apillapampa

Participant	Medicine	Food	Material	Environ Uses	Social Uses	Fuel	Animal Food	Poison	All Uses	
1	0	2	1	1	0	2	1	0	7	$\mathbf{UV_1}$
2	0	1	2	0	0	2	1	0	6	$\mathbf{UV_2}$
3	0	2	1	1	0	2	1	0	7	$\mathbf{UV_3}$
4	0	1	2	1	0	1	1	0	6	$\mathbf{UV_4}$
5	0	1	1	1	0	2	1	0 **2**	6	$\mathbf{UV_5}$
6	0	1	0	0	0	1	1	0	3	$\mathbf{UV_6}$
7	1 **1**	2	2	1	0	2	1	0	9	$\mathbf{UV_7}$
8	0	0	0	0	0	1	1	0	2	$\mathbf{UV_8}$
9	1	1	1	1	1	2	1	0	8	$\mathbf{UV_9}$
10	0	1	0	0	0	1	1	0	3	$\mathbf{UV_{10}}$
11	2	1	3	2	0	2	1	0	11	$\mathbf{UV_{11}}$
12	0	1	0	1	0	2	1	0	5	$\mathbf{UV_{12}}$
3	0.33	1.17	1.08	0.75	0.08	1.67	1	0	6.08	**4**
	$\mathbf{UV_{med}}$	$\mathbf{UV_{food}}$	$\mathbf{UV_{mat}}$	$\mathbf{UV_{env\ use}}$	$\mathbf{UV_{soc\ use}}$	$\mathbf{UV_{fuel}}$	$\mathbf{UV_{an\ food}}$	$\mathbf{UV_{poison}}$	$\mathbf{UV_{all\ uses}}$	

Use Values per participant

Categorical Use Values

Overall Use Value

1 The food use value according to participant 7 ($UV_{7,food}$) is 2 because he declared that the pulp surrounding the seeds of *Prosopis laevigata* is consumed as a snack food whereas the seeds themselves are grinded into an edible flour

2 The overall use value of *Prosopis laevigata* according to participant 5 (UV_5) corresponds to the sum of all categorical use values recorded for this participant (i.e. the total number of uses reported by participant 5):

$$UV_{5,all\ uses} = UV_{5,med} + UV_{5,food} + UV_{5,mat} + UV_{5,env\ uses} + UV_{5,soc\ uses} + UV_{5,fuel} + UV_{5,an\ food} + UV_{5,poison}$$
$$= 0 + 1 + 1 + 1 + 0 + 2 + 1 + 0 = 6$$

3 The medicinal use value (UV_{med}) which represents one of the categorical use values, consists of the mean number of medicinal uses assigned to *Prosopis laevigata* by 12 participants:

$$UV_{med} = \frac{\sum_{i=1}^{12} UV_{i,med}}{12} = \frac{0+0+0+0+0+0+1+0+1+0+2+0}{12} = 0.33$$

4 The overall use value ($UV_{all\ uses}$) of *Prosopis laevigata* equals the sum of all categorical use values:

$$UV_{all\ uses} = UV_{med} + UV_{food} + UV_{mat} + UV_{env\ uses} + UV_{soc\ uses} + UV_{fuel} + UV_{an\ food} + UV_{poison}$$
$$= 0.33 + 1.17 + 1.08 + 0.75 + 0.08 + 1.67 + 1 + 0 = 6.08$$

But it can also be expressed as the use value averaged over all participants:

$$UV_{all\ uses} = \frac{\sum_{i=1}^{12} UV_i}{12} = \frac{7+6+7+6+6+3+9+2+8+3+11+5}{12} = 6.08$$

For the present study, we "extended" or reinterpreted the use value index proposed by Phillips and Gentry (1993a) by incorporating the quality of all individual plant uses. The "quality use value" of each species *s* for each informant *i* can be defined as:

$$QUV_{is} = \frac{\sum_{1}^{n_{is}} QU_{is}}{n_{is}}$$

where (1) QU_{is} equals $\sum Q_{is}$, or the sum of the qualities of all uses assigned to species *s* by informant *i* during an interview event (i.e. one informant being interviewed on one species on one day) and (2) n_{is} equals the number of events for species s with informant *i*. This implies that the quality of each use mentioned is to be assessed by each individual participant. In the present investigation, qualities were appraised on an ordinal scale, choosing between (a) good to excellent, (b) fair, or (c) bad, to which values of 1, 0.5 and 0.25 were attributed, respectively. Our estimate of the overall quality use value for each species *s*, QUV_s is then:

$$QUV_s = \frac{\sum QUV_{is}}{n_s}$$

Where n_s equals the number of participants interviewed for species s.

Calculating QUV_s values of species is particularly relevant for those specific use categories where participants can ascribe different qualities to uses, such as medicine and fuel. Analogously, some species can be more useful as food than others. For example, Prance *et al.* (1987) argued how the Ka'apor from Brazil distinguish between "quite edible" and "less edible". For people in Apillapampa, assessing the quality of plant foods was somewhat problematic. When asked to appraise the quality of each food source participants systematically answered: "we just eat [or drink] it that's all". Therefore, food quality use values will in most cases equal food use values since most or all food uses receive a quality score of 1. The relevance of calculating QUV_s values will be properly motivated and discussed later on for individual use categories.

3.2.2.3. Use Diversity and Use Equitability Values

To estimate for how many use categories a plant species is used and how evenly these use categories contribute to its total use value, we calculated use diversity values for individual species (UD_s), following Byg and Balslev (2001). However, we used the Shannon-Wiener diversity index instead of Simpson's index for calculating UD_s values, as suggested by Carretero (2005) and Paniagua Zambrana (2005):

$$UD_s = -\sum P_c * \ln(P_c).$$

Hereby P_c is the contribution of use category *c* to the total utility of a species *s* (i.e. the number of times species *s* was mentioned by all participants within each use category, divided by the total number of use-reports of species *s* across all use categories. If a species is used in many use categories and its uses are evenly distributed over these categories, then its UD_s value will be high. Based on the UD_s values of a species, the use equitability value can be calculated as follows: $UE_s = UD_s / UD_{s\max}$ whereby $UD_{s\max}$= ln(C) and C is the number of different use categories species *s* is used for. UE_s measures how evenly different use categories contribute to the total use of a species, independently of the number of use categories.

3.2.2.4. Factor of Informant Consensus (F_{ic}) and Informant Agreement Ratio (IAR)

To calculate the consistency of participant responses about the use of medicinal plants for different categories of health conditions we applied the Factor of Informant Consensus, F_{ic} (Trotter and Logan, 1986; Heinrich *et al.*, 1998b; Leonti *et al.*, 2001). F_{ic} gives the relationship between the number of responses in each disease category (n_{resp}) minus the number of plant taxa used to treat that specific disease category (n_t) and the number of responses in each category minus 1. Thus, the F_{ic} is determined as follows:

$$F_{ic} = \frac{n_{resp} - n_t}{n_{resp} - 1}$$

A value close to 1 indicates a high intra-cultural consensus (i.e. most participants use the same species for the same ailment category) and a value close to 0 indicates a high variation in the use of species.

The Informant Agreement Ratio is calculated in a similar way and represents the consensus between participants about individual health conditions. In its original form as defined by Trotter and Logan (1986) it is determined as follows:

$$IAR = \frac{n_a - n_{ra}}{n_a - 1}$$

Whereby n_a is the number of times a particular ailment was reported by all participants and n_{ra} the total number of reported remedies used to treat this ailment. In the scope of this study we interpreted n_{ra} simply as the number of plant species that was reported for treating each ailment. IAR varies between 0 and 1. A value of 0 indicates that every time an ailment was reported, a different plant species for treatment of this ailment was mentioned. By contrast, a value of 1 is obtained when all participants mention only one species for treating an ailment.

3.2.2.5. Regression Residual Analysis

In order to evaluate the local importance of different plant families, we applied the regression technique proposed by Moerman (1991 and 1996). Moerman regressed the total number of native North American medicinal and food species on the total number of species listed in the North American flora and calculated regression residuals for each family. Families with positive residuals (i.e. above the regression line) contain more useful species than predicted by the number of species in the family; families with negative residuals have fewer. For a given family size, residuals of more than 1.96 standard errors from the regression line are significantly (at 5% level) different than expected from the number of species in the family. All statistical calculations were performed in SPSS 12.0.

3.3. Results and Discussion

3.3.1. Overall Usefulness of All Collected Plant Species

A total of 387 different botanical species was shown to at least one and maximum 13 participants. Each species was shown to 8.4 (±0.2 (s.d.)) participants on average. A total of 4899 responses (or citations) and 1871 different plant uses were recorded. A *response* or *citation* is defined here as an answer from a participant with regard to a use of a particular plant species. If the use of species A as firewood is reported by two participants and a third participant uses it solely for its edible fruits, then the total number of recorded responses for species A is three. On average, 12.7 (±9.3 (s.d.)) responses were reported per useful plant species. A *plant use* is defined here as a well-defined use of a particular plant species for one particular goal by one or more participants. In the former example, the total number of plant uses for species A is two (firewood and edible fruits). On average, 4.9 (±3.3 (s.d.)) uses were reported per plant species (cf. figure 3.1A).

Figure 3.1B shows the wide range in use values for the 387 useful species, illustrating that only a few species are outstandingly useful, at least in terms of use values. In fact, the most useful species depicted in figure 3.1B, *Prosopis laevigata*, is 30 times more useful than *Tillandsia capillaris* (use value: 6.1 versus 0.2). The average overall use value for any plant species is 1.4 (±0.7 (s.d.)). The overall UV (i.e. UV related to all use-categories) of a particular species is positively correlated with the number of participants to which it was shown (Kendall's τ_b= 0.30; $p<0.001$). Therefore, species shown to higher numbers of participants tend to have higher use values. Hence, our data could be slightly biased since not all species were shown to the same number of participants. However, the low correlation coefficient indicates that the number of participants alone explains only a small portion of the variance in total UV, justifying the validity of our analyses.

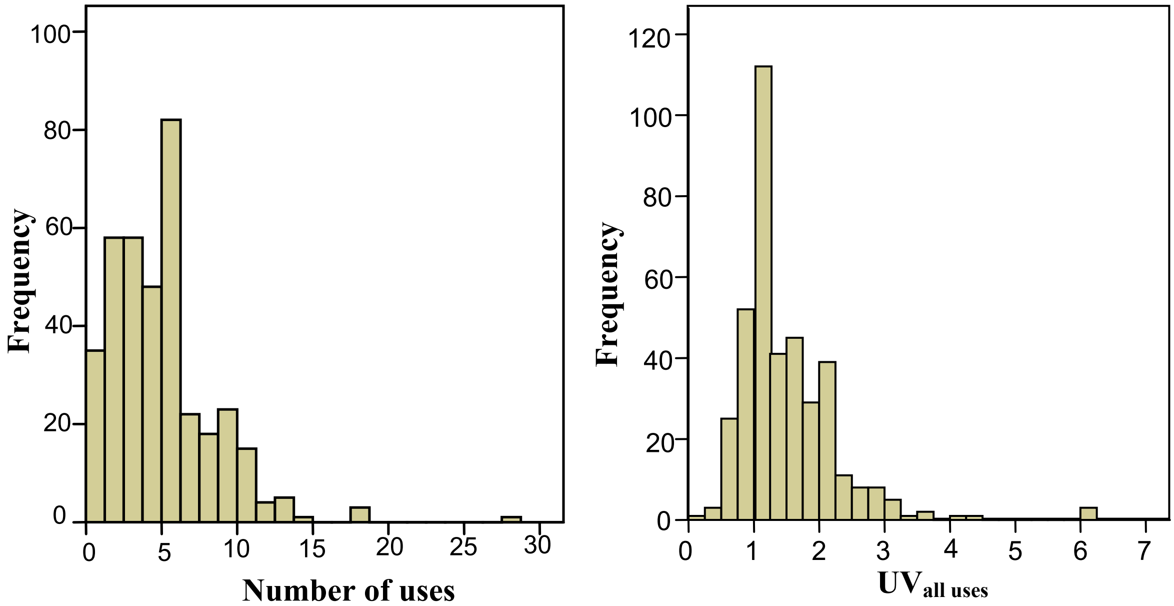

Figure 3.1 Frequency diagrams (number of species) for number of uses (A) and overall use values per species (B)

To demonstrate that calculating UV values of plant species incorporates more information about the relative importance of a species than a simple count of uses, Phillips and Gentry (1993a) regressed each species' UV on the number of uses per species. Linear regression of UV on the number of uses per species for our data shows that less than half (45%; R^2=0.45) of the variance in UV values is explained by simply totalling the number of uses per species. The remaining 55% is accounted for by the process of indexing each use by its relative importance. In table 3.1, the fifty most useful species are ranked according to decreasing use values. It shows that species with the highest number of reported uses do not necessarily have the highest use values.

Table 3.1: Top fifty most useful species based on use values. For each species, the number of participants to whom the species was shown, the number of different types of uses, as well as the number of use categories are given. The ten highest values of each 'usefulness' index are underlined. Only species that were shown to at least three participants are included.

Species	Family	# participants	# uses	# categories	UD_s	UE_s	$UV_{\text{all uses}}$	$QUV_{\text{all uses}}$
Prosopis laevigata	Fabaceae	12	18	8	1.53	0.74	6.1	5.9
Schinus molle	Anacardiaceae	12	28	7	1.57	0.81	6.0	5.6
Eucalyptus globulus	Myrtaceae	3	6	4	1.24	0.90	6.0	6.0
Acacia visco	Fabaceae	10	12	6	1.36	0.76	4.3	4.0
Spartium junceum	Fabaceae	12	18	8	1.65	0.79	3.7	3.5
Tipuana tipu	Fabaceae	9	9	7	1.50	0.77	3.6	3.0
Schinopsis haenkeana	Anacardiaceae	12	11	6	1.32	0.74	3.3	3.2
Kageneckia lanceolata	Rosaceae	11	11	7	1.33	0.68	3.2	3.1
Trichocereus tunariensis	Cactaceae	4	3	4	1.24	0.90	3.0	3.0
Aspidosperma quebracho-blanco	Apocynaceae	10	8	6	1.27	0.71	3.0	3.0
Minthostachys andina	Lamiaceae	12	10	4	1.23	0.89	2.9	2.8
Polylepis besseri	Rosaceae	11	9	6	1.31	0.73	2.9	2.5
Trixis aggregata	Asteraceae	11	13	3	0.98	0.89	2.8	2.7
Berberis commutata	Berberidaceae	11	7	6	1.42	0.79	2.8	2.5
Kentrothamnus weddellianus	Rhamnaceae	13	12	7	1.43	0.73	2.8	2.6
Populus nigra	Salicaceae	8	8	5	1.44	0.90	2.8	2.0
Agave americana	Agavaceae	12	9	5	1.35	0.84	2.8	2.5
Agalinis lanceolata	Scrophulariaceae	12	9	5	1.29	0.80	2.8	2.6
Baccharis salicifolia	Asteraceae	10	6	6	1.41	0.79	2.7	2.1
Cestrum parqui	Solanaceae	12	13	6	1.27	0.71	2.6	2.3
Adesmia miraflorensis	Fabaceae	12	7	6	1.24	0.69	2.6	2.3
Poa buchtienii	Poaceae	10	4	4	1.10	0.80	2.5	2.3
Otholobium pubescens	Fabaceae	12	14	4	1.20	0.86	2.5	2.2
Ipomoea dumetorum	Convolvulaceae	4	4	4	1.22	0.88	2.5	2.5
Cupressus sp.	Cupressaceae	10	8	6	1.44	0.80	2.5	2.3
Ambrosia arborescens	Asteraceae	12	9	4	1.24	0.90	2.5	2.2
Pinus radiata	Pinaceae	11	7	5	1.30	0.81	2.5	2.2
Calamagostris sp.	Poaceae	10	5	4	1.11	0.80	2.4	2.4
Hyaloseris quadriflora	Asteraceae	6	3	4	1.23	0.89	2.3	2.1
Vassobia fasciculata	Solanaceae	13	10	4	1.22	0.88	2.3	2.0

Table 3.1 continued

Species	Family	# participants	# uses	# categories	UD_s	UE_s	$UV_{all\ uses}$	$QUV_{all\ uses}$
Tessaria fastigiata	Asteraceae	10	9	5	1.27	0.79	2.3	1.9
Salix humboldtiana	Salicaceae	10	7	6	1.40	0.78	2.3	1.6
Tecoma ternuiflora	Bignoniaceae	8	4	5	1.31	0.81	2.3	2.1
Dodonaea viscosa	Sapindaceae	12	10	5	1.29	0.80	2.3	2.3
Satureja boliviana	Lamiaceae	13	13	6	1.28	0.71	2.2	2.1
Helogyne straminea	Asteraceae	11	4	5	1.29	0.80	2.2	1.9
Baccharis pentlandii	Asteraceae	11	9	7	1.45	0.75	2.2	1.8
Stipa ichu	Poaceae	12	5	3	1.03	0.94	2.2	2.1
Baccharis sagittalis	Asteraceae	12	18	6	1.23	0.69	2.2	1.9
Aloysia triphylla	Verbenaceae	7	7	4	1.22	0.88	2.1	1.9
Tessaria dodoneifolia	Asteraceae	8	5	5	1.38	0.85	2.1	1.8
Tripodanthus acutifolius	Loranthaceae	10	12	7	1.52	0.78	2.1	2.1
Inga cf. *striata*	Fabaceae	10	5	5	1.30	0.81	2.1	1.9
Festuca boliviana	Poaceae	11	3	3	1.04	0.95	2.1	2.0
Gnaphalium gaudichaudianum	Asteraceae	12	6	3	1.03	0.94	2.1	2.0
Ephedra americana	Ephedraceae	12	13	5	1.17	0.73	2.1	2.0
Acacia aroma	Fabaceae	13	6	6	1.22	0.68	2.1	2.0

Table 3.2: Kendall's τ_b correlation coefficients and significance levels for combinations of different plant use indexes (N=387)

	Number of uses	UD_s	UE_s	UV_s
UD_s	0.610***			
UE_s	-0.379***	-0.300***		
UV_s	0.562***	0.481***	-0.263***	
QUV_s	0.510***	0.436***	-0.241***	0.900***

***= $p<0.0001$; UD_s= use diversity; UE_s= use equitability; UV_s=use value; QUV_s= quality use value

Table 3.1 also shows that quality use values (QUV_s) are generally slightly lower than use values (UV_s), indicating that even for the most useful species not all plant uses are equally appreciated. Nevertheless, a ranking based on QUV_s values largely coincides with one based on UV_s values, as confirmed by the high correlation coefficient between both variables (0.9) in table 3.2. The positive correlations between the number of uses reported for a species and its UV_s and QUV_s are also confirmed in table 3.2.

Ranking of useful plant species based on use diversity ($UD_{s)}$ or use equitability (UE_s) values shows different results in comparison with ranking based on UV_s and QUV_s (table 3.1). This implies that species with high use values are not necessarily used within most use categories, nor that the different use categories contribute evenly to the total usefulness of a species. However, table 3.2 shows that a species' UD_s value is positively correlated with its UV_s and QUV_s values. Hence, if a species is used in a high number of use categories and its uses are distributed evenly over these categories, then expected UV_s and QUV_s values for this species will be high. The opposite seems to be valid for UE_s: it is negatively correlated with all other "usefulness" parameters. This indicates that for species with a high number of recorded uses and/or higher UV_s and QUV_s values, different use categories contribute less evenly to their total use as compared to species with few uses and/or low UVs and QUVs values.

3.3.2. Categorical Plant Uses and Mean Use Values

Nearly all plant species (96%) shown to participants are used as animal food (figure 3.2). More than three quarter of plant species is used in traditional medicine (79%). Almost one third of species is used as food (32%) and/or fuel (29%), while about one fifth are sources of materials. Minor use categories include social uses, environmental uses and poisons (figure 3.2). In the following paragraphs, all use categories except animal food will be discussed in detail. The use of plants as fodder is relatively straightforward and does not require much further elucidation. Aerial parts of plants with herbaceous life forms are often grazed completely, while for most trees and bushes only leaves, young shoots and occasionally (fresh) spines are palatable to livestock. Noteworthy animal food plants include nearly all Cactaceae species that are first burned to remove their spines and then fed to livestock. Also the stems of *Vasconcellea quercifolia* are chopped into pieces and fed to pigs.

A ranking of use categories based on mean use values (figure 3.3) results in a similar ordering as when based on the number of species used per category (figure 3.2). This is because the number of species in a use category is strongly correlated with its mean categorical use value (R^2=0.95; p<0.001).

3.3.3. Variation in Plant Use Knowledge in Relation to Demographic Characteristics of Participants

To evaluate the use knowledge of participants who participated in the research, relative use values (RUV_i) were calculated (Phillips and Gentry, 1993b). A comparison of mean UV_{is}/UV_s ratios between participants shows that overall and categorical plant use knowledge differs significantly among participants ($p \leq 0.01$ for all categories; Kruskal-Wallis tests).

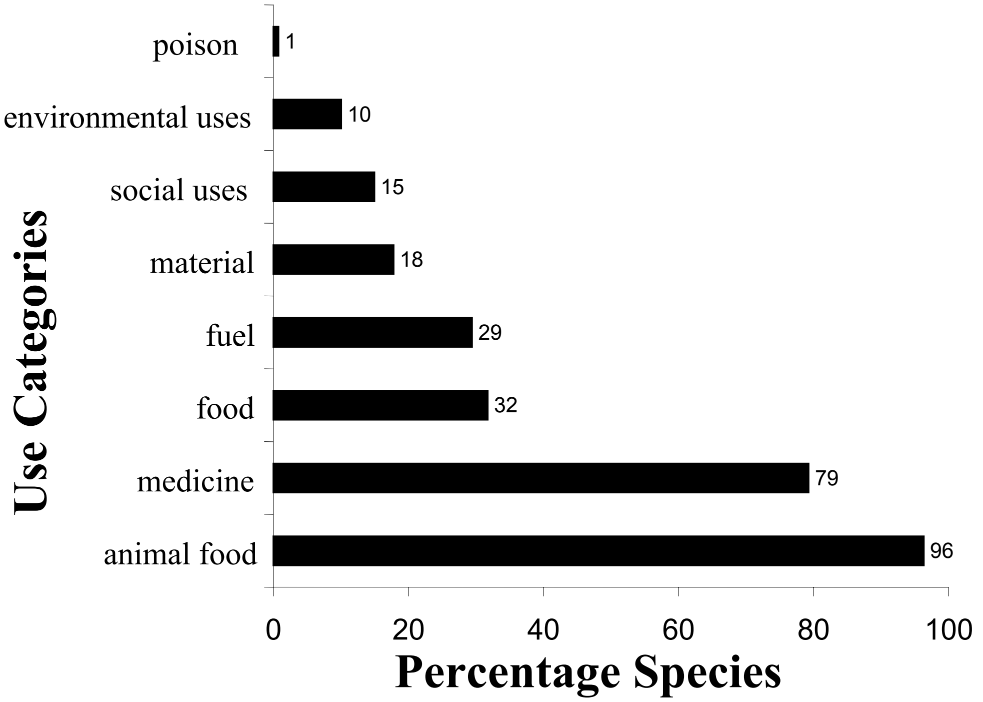

Figure 3.2: Proportional distribution of plants species over different use categories

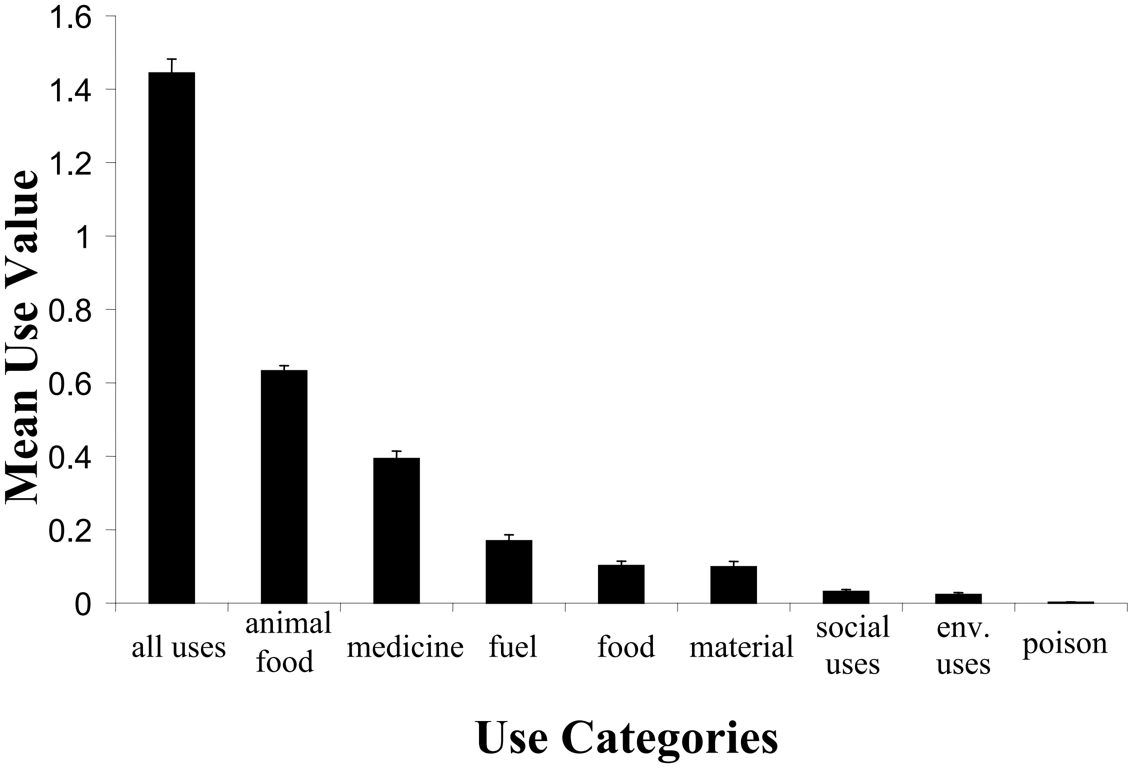

Figure 3.3: Mean categorical use values of plant species. Error bars represent standard errors of the mean (env. uses= environmental uses)

Next, it was verified whether participant's mean RUV_i was related to gender. RUV_i values of the five female participants were compared with those of the eight male participants. Test results statistically confirm that differences in categorical plant use knowledge can not be ascribed to gender ($p>0.3$ for all categories; independent sample t-tests).

Six participants are recognized in Apillapampa as traditional healers. Therefore, we examined whether plant use knowledge was higher for healers as compared to non-plant specialists ($n=7$ people). Contrary to what was expected, the results did not demonstrate a significant difference (all $p>0.18$), not even for medicinal relative use values (Mann-Whitney-test for $RUV_{i,\ medicine}$ and $RUV_{i,\ material}$; independent t-tests for all other categorical RUV_i).

Another demographic variable that may influence categorical relative use values is age. Age of participants ranged from 14 to 66. In figure 3.4 (A-F), relative plant use knowledge (i.e. RUV_i values) is plotted against participant age for different categories of plant use. Plant use knowledge is significantly correlated with age for *all uses* (i.e. overall use category), *medicine*, *food* and *social uses* (5% level). Material use knowledge and age are also related but this correlation is only significant at the 10% level. There does not exist a significant correlation between plant use knowledge about fuel and environmental uses and age.

Overall plant use knowledge increases with age, but age alone explains 31% of the variance in participants' relative use values. Young people hold significantly less knowledge about medicinal plants than elder people. Age explains nearly half (46%) of the variance in relative knowledge about medicinal plants. Knowledge about social uses (mainly comprising spiritual uses) is also held primarily by elder people. Intriguingly, the best fit regression line for relative food use values is not a linear but quadratic, explaining 61% of the variation in data. According to this scenario, mainly elder and younger people possess significantly more knowledge about edible plants than middle-aged people (see the food uses plot in figure 3.4 C). However, it is possible that a quadratic regression is a too theoretical representation of reality. No significant relationship was detected between participant age and relative food use knowledge with linear correlation analysis.

The latter finding is in correspondence with the findings of Phillips and Gentry (1993b) who did not detect a significant linear relationship between age and knowledge about food plants either. The latter authors argued that much learning of what is edible starts at an early age, whereas the preparation and use of medicines is a process that is more complex and undoubtedly takes longer to learn since learning and experimenting with medicinal plants can be a life-long process (Phillips and Gentry, 1993b).

However, Vandebroek *et al.* (2004b) found that among the healers from Apillapampa also a combination of personal and social variables can lead to increased medicinal plant knowledge. The latter authors demonstrated that that medicinal plant knowledge of healers was not related to the age of initiation or the number of years of practicing experience. Instead, medicinal knowledge scores were strongly correlated with a combination of practicing years and the number of family members practicing traditional medicine.

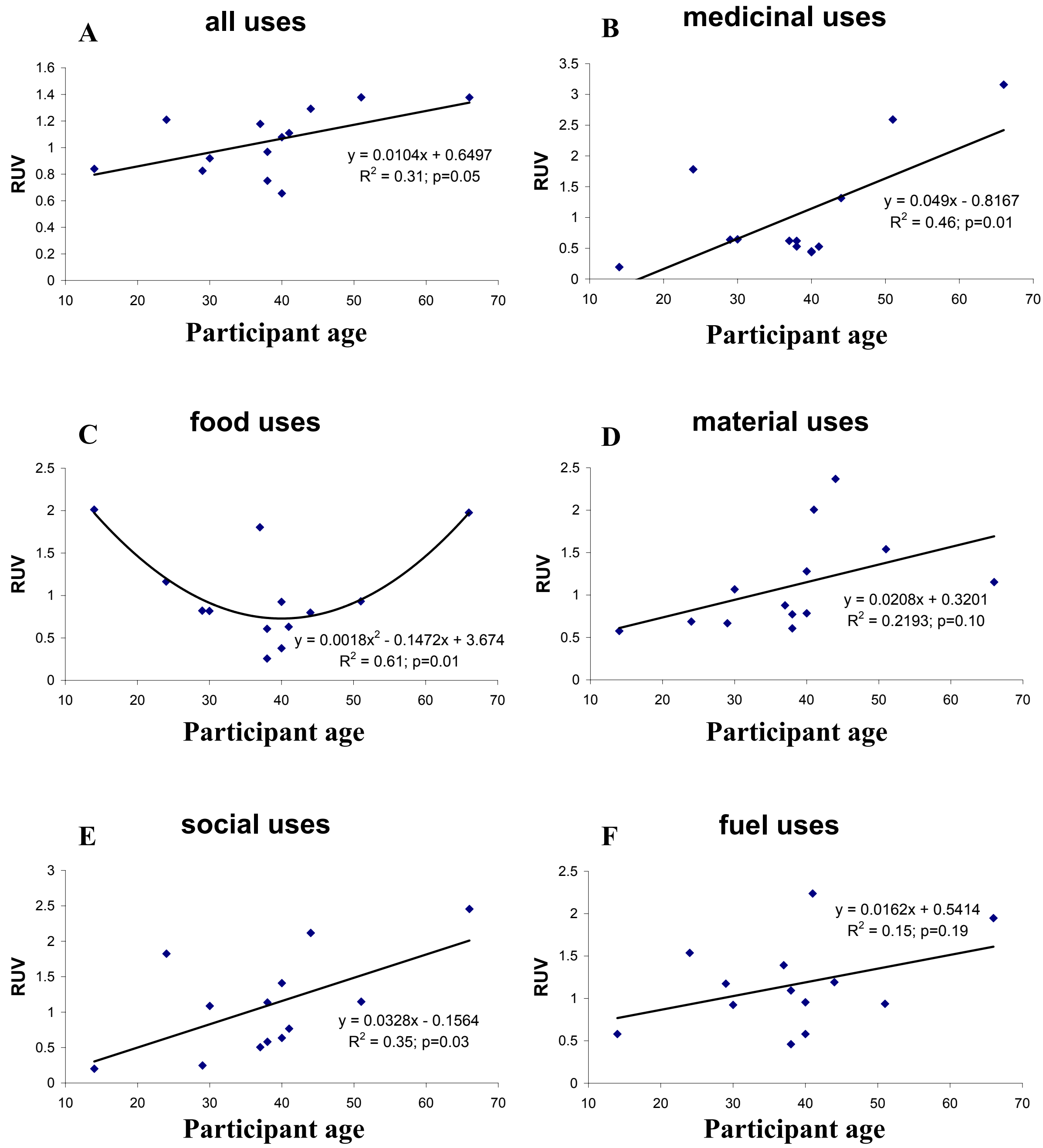

Figure 3.4: Regressions of relative knowledge of participants versus participant age with Pearson correlation coefficients and significance levels. A: all uses; B: medicinal uses; C: food uses; D: material uses; E: social uses; F: fuel uses

Also, regression lines for relative values of material and fuel use have positive slopes (figure 3.4D&F), indicating that knowledge about fuel and material producing plants is learned as one gets older. However, for these use categories age does not explain much of the variance in relative informant knowledge.

In sum, these findings support the notion that local knowledge is neither evenly distributed nor random among traditional societies, but patterned (D'Andrade, 1987). Antweiler (1998) called local knowledge a "social product" that is part of a specific cultural system. Division of knowledge by age, gender or social status has been reported quite widely in literature (Ellen, 1979; Berlin, 1992; Phillips & Gentry, 1993b; Bernstein *et al.*, 1997; Begossi *et al.*, 2002; Ladio and Lozada, 2004). Women (Kainer and Duryea, 1992; Begossi *et al.*, 2002; Stagegaard *et al.*, 2002; Howard, 2003; Deda and Rubian, 2004; Lawrence *et al.*, 2005) or children (Ros-Tonen *et. al.*, 1998; Setalaphruk and Price, 2007) often hold extensive knowledge about plant use, but this knowledge often remains largely invisible to outsiders. Vandebroek *et al.* (2004b) provide various examples of knowledge distribution for the specific case of medicinal plants. Based on our data, participant age seems to be the only variable that significantly explains part of the variation in use knowledge data. This might be due to the fact that our participant sample is too small and not random enough to represent the entire population of Apillapampa.

3.3.4. Medicinal Plant Use

3.3.4.1. Most Important Medicinal Plant Families

A total of 307 medicinal plant species was recorded during the present study, covering 79% of all species shown to participants. In a previous study that focused on the medicinal plants of Apillapampa, the medicinal use of 181 plants species was reported (see Vandebroek, Thomas and AMETRAC*,* 2003). Twenty three of these species (including six unidentified lichens and mosses) were not inventoried during the present investigation and eleven additional species were not included in the ethnobotanical interviews due to lack of voucher specimens (table 3.3). To ensure a representative image of overall medicinal plant use in Apillapampa, the results presented here apply to the total of 341 (=307+23+11) reported medicinal plants, except when indicated differently. In absolute numbers, medicinal plant use in Apillapampa is not unusually high, since pharmacopoeias of more than 300 species have been reported for various societies around the world (e.g. Girault, 1984; Bastien, 1987a; Frei *et al.*, 1998; Ankli *et al.*, 1999a; Leonti *et al.*, 2001; Etkin, 2002; Shepard, 2004). Most notable here are undoubtedly the Bolivian Kallawayas whose pharmacopoeia is composed of approximately one thousand different medicinal plant species (Girault, 1987; Bastien, 1987a). However, it is important to note in this respect that Apillapampa is just one settlement of Quechua people, whereas most of the studies previously mentioned encompass several communities of people with a similar ethnical background.

Table 3.3: Number of medicinal species and responses recorded during the present study in comparison to the study of Vandebroek *et al.* (2003)

	Present study	**Vandebroek *et al.*, 2003**	**Overlapping species or responses**
medicinal species	307	181	147
medicinal responses	1319	1105	157

Only six of the eight traditional healers that participated in the study of Vandebroek *et al.* (2003) were involved in both investigations since two male participants no longer lived in Apillapampa at the time the author conducted field research for the present study. Hence, information about the medicinal use of plants was provided by a total of fifteen participants (i.e. the 13 participants from the present study plus the two traditional healers who only participated in the study of Vandebroek *et al.* (2003)).

Number of participants interviewed per medicinal plant varied between 1 and 15 with an average of almost ten (9.5 ± 3.5 s.d.). During the present investigation, a total of 1319 different medicinal responses were recorded. Vandebroek *et al.* (2003) listed 1105 responses. Of those 1105 responses, 589 correspond with the 147 species for which ethnomedical information was collected during both investigations. In total, 157 overlapping medicinal responses were counted between both studies. Hence, about one fourth (27%) of the responses that were documented during the study of Vandebroek *et al.* (2003) on the 147 overlapping species were actually repeated during the present research. Moreover, a comparison of both studies shows that the proportional number of responses shared by both studies is independent of participant's age. Between 18 and 37 percent of the responses made by the six participants during the first study were repeated during the second study.

The 341 medicinal plants are distributed over 80 botanical families. One fourth of all species are Asteraceae (85 species; 25%) followed by Fabaceae (27 species; 8%), Solanaceae (22 species; 6%), Lamiaceae (14 species; 4%) and Scrophulariaceae (10 species; 3%). The popularity of Asteraceae has been linked to (1) the wide array of bioactive components they contain (Heinrich *et al.*, 1998a) and (2) the higher likeliness of people to experiment with members of this family as a consequence of the typical bitter phytochemicals they often contain (Casagrande, 2002). However, it is also no coincidence that the botanically most diverse families (leaded by Asteraceae) also provide the highest numbers of medicinal species. Regression analysis shows that the number of medicinal plant species in a family (NMS) is a function of the total number of species inventoried for that family (NSF) in Apillapampa:

$$\text{NMS} = 0.761 \times \text{NSF} + 0.101 \ (r^2=0.98 \text{ and } p<0.001)$$

The high significance and correlation coefficient obtained for this regression, based on data from Apillapampa, confirm Moerman's (1991 and 1996) argument that in a random universe (one of) the best predictor(s) of the number of medicinal species would be the size of the family. While Moerman (1991 and 1996) used published checklists of vascular plants to quantify family size, we based our analysis on the total number of collected species per family, since checklists are currently nonexistent for our study area. However, as one of the goals of the present study consisted of elaborating an inventory of *all* plant species growing in the surroundings of Apillapampa, we believe our family size estimates realistically approach the actual number of species available to local people.

In figure 3.5, the distance between the observed and predicted value of each NMS is displayed graphically, based upon our data from Apillapampa. Figure 3.5 shows that participants under- and overuse one and two families, respectively. Poaceae is underused with only 5 medicinal species (while 17 species were inventoried and its predicted species number is 13). By contrast, 22 of 23 Solanaceae species and 14 of 15 Lamiaceae species were mentioned to have a therapeutic value, explaining their statistical overuse, as the predicted species numbers are 17.5 and 11.5, respectively.

Ever since Moerman (1991) pointed out the usefulness of regression residual analysis for interpretation of ethnobotanical use data, it has been applied by various authors (e.g. Phillips and Gentry, 1993a; Moerman *et al.*, 1999; Leonti *et al.*, 2003b Treyvaud Amiguet *et al.*, 2006). These studies support the general observation that indigenous pharmacopoeias around the world are far from random assemblages, as always some families have more medicinal species than predicted by chance (Moerman, 1996). For the case of Apillapampa, the numbers of overused and underused medicinal families are rather restricted with two and one family, respectively.

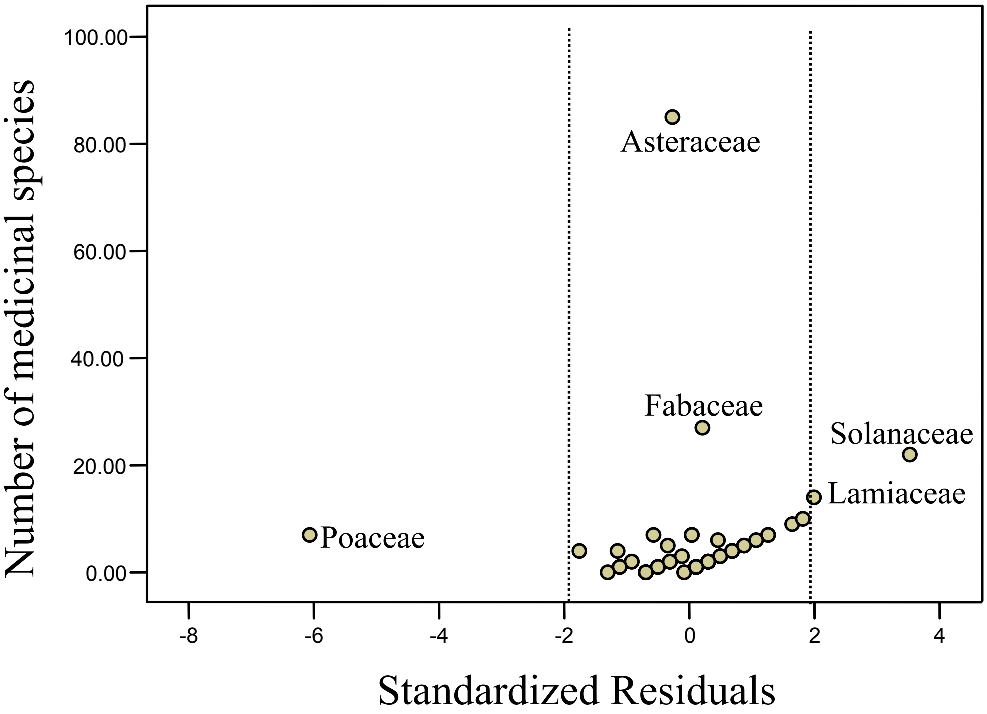

Figure 3.5 Number of medicinal species (NMS) vs. standardized residuals of the regression of NMS on family size (NSF). Families with standardized residuals >1.96 or <-1.96 (p=0.05) have significantly higher, respective lower NMS than expected from their size.

To verify whether over/underutilization of certain plant families for medicinal purposes corresponds to "global patterns of human knowledge" (Moerman *et al.*, 1999), Treyvaud Amiguet *et al.*, 2006 compared the results of their regression residual analysis based on medicinal species from Belize with similar studies from three northern temperate regions (Kashmir, North America, and Korea (original data from Moerman *et al.*, 1999)) and three southern Neotropical regions (Veracruz and Chiapas in Mexico and Ecuador (original data from Moerman *et al.*, 1999 and Leonti *et al.*, 2003b)). Here we compare the results obtained for Apillapampa with these studies. As shown in table 3.4, the most frequently and widely overused plant family, as medicines, is the Asteraceae. In Apillapampa, the Asteraceae is the most important medicinal family in terms of species used (85 out of 112), but it is not overused. Based on the studies listed in table 3.4, the significant overuse of Lamiaceae and Solanaceae recorded for Apillapampa seems less universal and these families are only among the most overused families in Chiapas, Mexico (Moerman *et al.*, 1999). The Lamiaceae or mint family produces a wide range of aromatic volatile oils, such as menthol and thymol, which are appreciated for their therapeutic values, as well as for their culinary use as condiments and aromatic teas. The Solanaceae is known to be a highly bioactive family which in many cases can be related to presence of alkaloids (Moerman, 1996; Gurib-Fakim, 2006). The Poaceae figures among the three most underutilized families of nearly all studies mentioned in table 3.4. Analogously, in Apillapampa it represents the only significantly underutilized family.

Table 3.4: The three top ranking overused and underused families of medicinal plants in Apillapampa and seven other locations based on standardized residuals

	Most overused families			Most underused families		
	1	2	3	1	2	3
Apillapampa	Solanaceae	Lamiaceae	Scrophulariaceae*	Poaceae	Bromeliaceae*	Polygalaceae*
TIPNIS	Solanaceae	Piperaceae	Rubiaceae	Sapotaceae	Lauraceae	Chrysobalanaceae
Toledo[1] (Belize)	Piperaceae	Rubiaceae	Asteraceae	Orchidaceae	Poaceae	Cyperaceae
Veracruz[2] (Mexico)	Asteraceae	Piperaceae	Fabaceae	Orchidaceae	Poaceae	Rubiaceae
Chiapas[3] (Mexico)	Asteraceae	Lamiaceae	Solanaceae	Poaceae	Orchidaceae	Cyperaceae
North America[3]	Asteraceae	Apiaceae	Ericaceae	Poaceae	Cyperaceae	Fabaceae
Kashmir[3]	Asteraceae	Euphorbiaceae	Ranunculaceae	Poaceae	Urticaceae	Anacardiaceae
Ecuador[3]	Araceae	Fabaceae	Bignoniaceae	Orchidaceae	Moraceae	Lauraceae
Korea[3]	Asteraceae	Lamiaceae	Ranunculaceae	Cyperaceae	Poaceae	Orchidaceae

[1] Treyvaud Amiguet *et al.*, 2006; [2] Leonti *et al.*, 2003b; [3] Moerman *et al.*, 1999
*: only significant at the 10% level

3.3.4.2. Life Form, Habitat and Origin

More than half (51%) of all medicinal plants are herbs, while about one fourth (26%) have a shrub habit (fgure 3.6). In accordance with their representation in the entire inventoried flora, a far lower number of vines, trees and ferns are used as medicinals with 18 (5.3%), 16 (4.7%) and 12 (3.5%) species, respectively. All parasites (3 species) and hemi-parasites (8 species) and nearly all (6 out of 7 species) Cactaceae that were inventoried have a therapeutic value. Six unidentified medicinal lichens and mosses were collected in the study of Vandebroek *et al.* (2003). According to Bennett and Prance (2000), parasitic plants have the reputation to be utilized more commonly as medicines as compared to other life forms.

The number of medicinal plants used per growth is correlated with the number of species inventoried for each growth form. However, regression standard residual analysis shows that, based on the number of plant species inventoried per growth form (NSGF), shrubs are overrepresented as medicinal species (regression equation is NMS = 0.757* NSGF +0.543; $r^2=0.98$ and $p<0.001$). Ninety (90) out of 95 inventoried shrub species are used medicinally, while the predicted number from the regression equation is 72.

The prevalence of herbaceous plants in the pharmacopoeia of Apillapampa is not a surprise. As we will discuss in detail in chapter 10 (section 10.4.3), various authors have linked the popularity of herbs in traditional medicine to their higher likeliness to contain bioactive phytochemicals than woody growth forms (e.g. Stepp and Moerman, 2001; Voeks, 2004). The fact that nearly all inventoried shrub species are used medicinally is therefore less expected and we hypothesize that the local therapeutic importance of this growth form is guided by (a combination of) different factors. In paragraph 3.3.4.7., this finding will be discussed in detail. Of all the factors discussed in the latter paragraph, seasonal availability is probably most relevant. During the dry season, nearly all annual herbs disappear (except on irrigated land and in humid places) and mainly only woody plants persist. Woody plants persist during the dry season and therefore they are the only medicinal alternative during half of the year. Therefore, they are more likely to be better known by people, also as providers of herbal medicines.

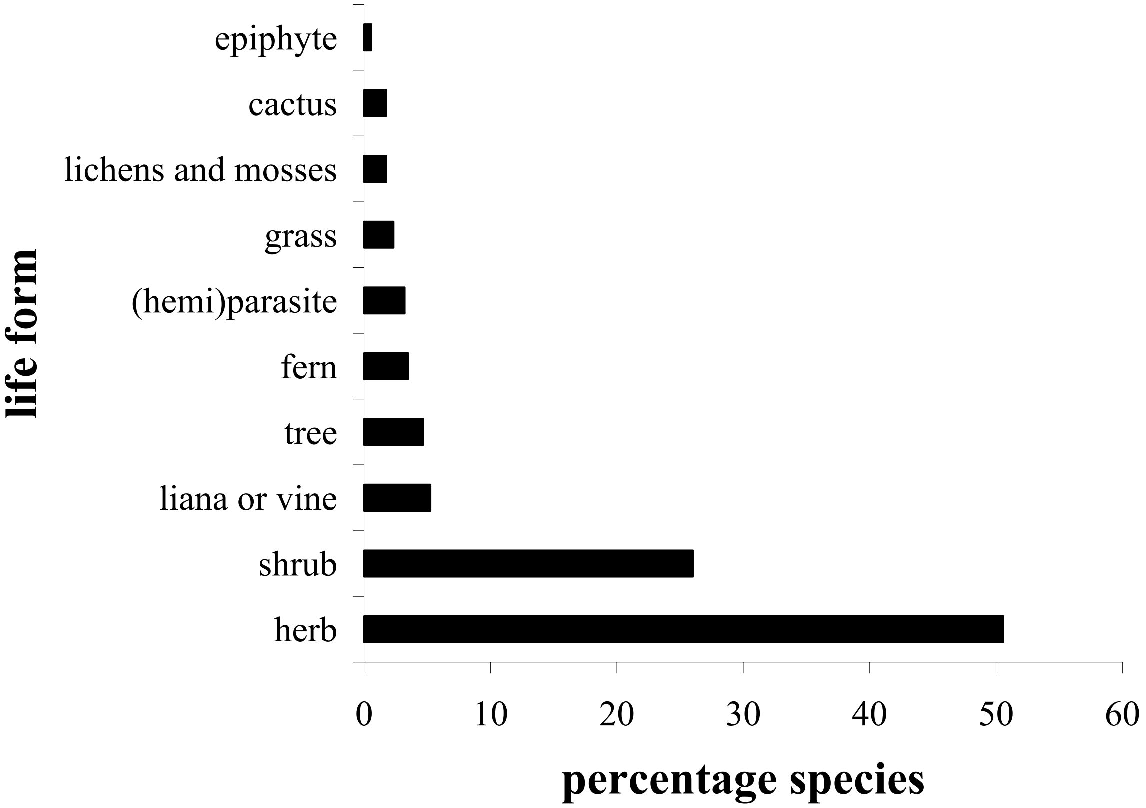

Figure 3.6: Proportional distribution of life forms of medicinal plants in Apillapampa

Most medicinal species grow wild in natural environments (79%), i.e. outside cultivation fields, homegardens, ruderal places, etc. However, the term natural is not really appropriate since nearly all vegetation has undergone significant change, as a consequence of present and past human disturbance regimes, including agriculture, pasturing, burning activities and firewood harvesting (cf. chapter 2). Forty three species (13%) are weeds that grow typically, but not exclusively, on agricultural fields. Homegardens are relatively less important sources of medicines with a total of 25 inventoried cultivated plants (7%). Herein are also included the planted exotics *Eucalyptus globulus*, *Pinus radiata* and *Spartium junceum*. Six medicinal plants (2%) are ruderals, typically growing along roads in or outside the village. Forty one medicinal plants (12%) are introduced, half of which are agricultural weeds.

3.3.4.3. Ailment Categories

To provide a general idea of medicinal plant use in Apillapampa, all recorded medicinal uses of the 341 inventoried plant species were classified according to general ailment categories defined by Cook (1995) and whereto we added the category of 'Culture-Bound Syndromes'. Figure 3.7 shows that most medicinal plant use and knowledge seems to be situated in seven categories for which more than 200 medicinal responses were documented. These categories are (in order of importance): *Digestive Disorders*, *Infections/Infestations*, *Injuries*, *Culture-Bound Syndromes*, *Muscular-Skeletal Disorders*, *Pain* and *Respiratory Disorders*. Within each category more than 100 medicinal species are used, except for Respiratory *Disorders* which contained 85 species.

Data presented in figure 3.7 were used to calculate consistency of responses within a category using the Factor of Informant Consensus, F_{ic} (Trotter and Logan, 1986; Heinrich *et al.*, 1998b; Leonti *et al.*, 2001). This analysis shows that the highest consensus is not necessarily found for ailment categories with the highest number of responses and species used. High F_{ic} values are obtained for *Injuries* (0.61), *Skin/Subcutaneous Cellular Tissue Disorders* (0.61), *Nutritional disorders* (0.61), *Respiratory Disorders* (0.61) and *Digestive Disorders* (0.59).

These results are in agreement with literature where *Dermatological Disorders* (including injuries of the skin), *Gastrointestinal Disorders* and *Respiratory Ailments* generally yield the highest number of species used and the highest consensus among indigenous participants (Frei *et al.*, 1998; Oths, 1998; Heinrich *et al.*, 1998b; Ankli *et al.*, 1999a; Leonti *et al.* 2001; Bourdy *et al.*, 2000 and 2004; Begossi *et al.*, 2002). In the Andes, particularly respiratory, musculoskeletal and gastrointestinal disorders are most salient (Donahue, 1981; Bastien, 1987a; Carey, 1990; Mitchell, 1991; Oths, 1998).

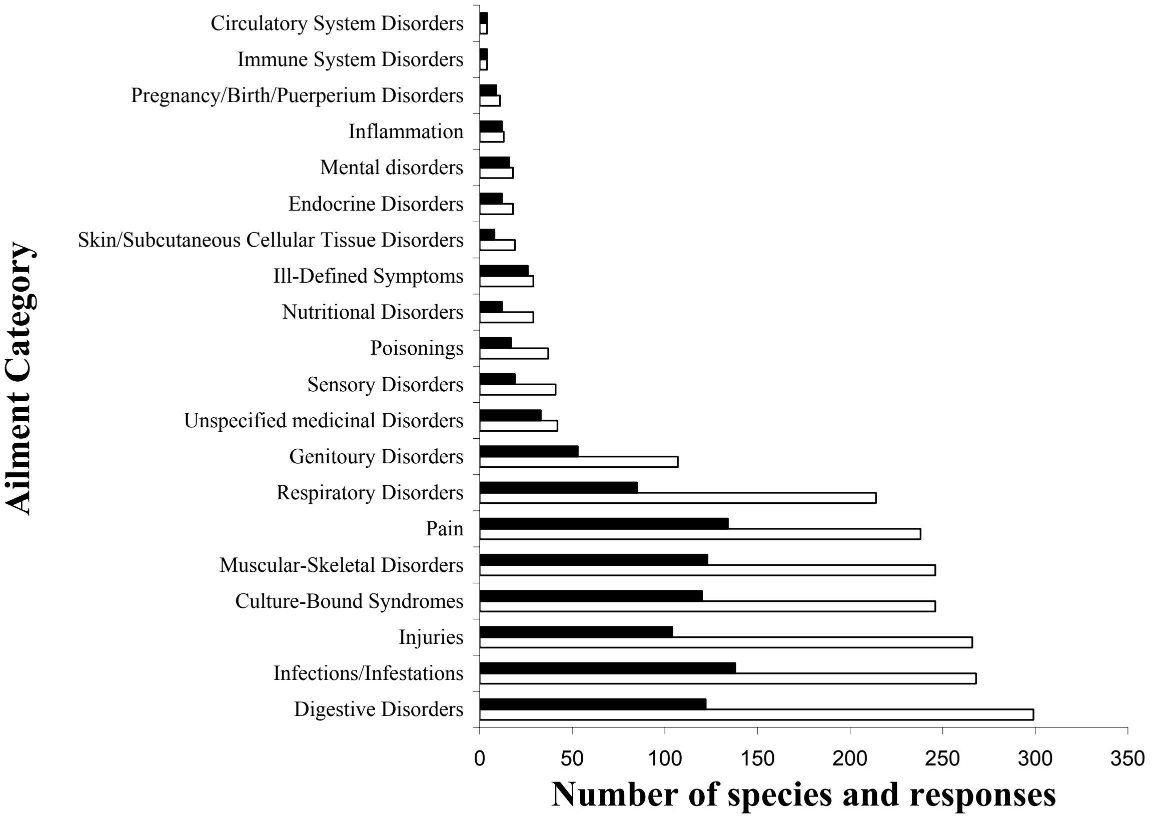

Figure 3.7: Distribution of medicinal species and medicinal responses over ailment categories defined by Cook (1995). Many plant species have multiple medicinal uses and therefore are classified under various corresponding ailment categories (white bars: number of responses; black bars: number of species).

3.3.4.4. Informant Consensus: Agreement about Health Conditions

A total of 108 different health conditions (including 9 veterinary disorders) were reported during ethnobotanical interviews. Seven of these are related to pain in different body parts (e.g. backache, abdomen, etc.). The highest diversity of medicinal plants was recorded for pain as a general symptom (131 species), followed by rheumatism (119 species), fever (87 species), bad wind or *wayra* (87 species) and bruises (75 species).

Two noteworthy folk illnesses (classified as culture-bound symptoms) are *wayra* and *madre*. *Wayras* are wind- or airborne diseases that can cause symptoms varying from stiff muscles to (facial) paralysis, including Bell's palsy (Bastien, 1987a; Larme, 1998; Vandebroek *et al.*, 2008). Alba (1993) confirms that *wayra* is equivalent to neuralgia, neuritis and paralysis. *Madre* is associated by local participants with heavy labour on agricultural fields. Several of its symptoms correspond with the biomedical definition of a hernia, but according to Vandebroek *et al.* (2008) it is probable that this illness is associated with megacolon and intestinal volvulus (abnormal twisting of the intestine) occurring in Chagas' disease or American trypanosomiasis, a serious human parasitic disease (Brandt de Oliveira *et al.*, 1998).

Health conditions with Informant Agreement Ratio (IAR) values higher than 0 are listed in table 3.5. High consensus is documented for hair loss, female sterility, warts, toothache, fractures and sprains, and cough. Three health conditions have IAR values of 1. The exclusive use of *Spathantheum orbignyanum* against snake bites in livestock is confirmed by four participants while unanimity (3 participants) also exists on the use of roots of *Kentrothamnus weddellianus* for treating hair loss. *Ephedra americana,* on the other hand, is the only species that is reported as a tonic (2 participants). The latter use might be related to the bioactive amphetamine ephedrine that is a known secondary metabolite of this species (Hegnauer, 1969).

3.3.4.5. Quality of Medicine[2]

The fact that a plant species is used to treat a particular health condition does not necessarily mean that it is effective in alleviating symptoms or eliminating causal factors. To quantify the proportion of less potent herbal remedies in ethnomedicine in Apillapampa, participants were encouraged to systematically assess the quality of each remedy on an ordinal scale, choosing between (1) good to excellent, (2) fair or (3) bad. Remedy quality was assessed for a total of 1119 responses. "Good to excellent" scored highest with 64%, followed by "fair" (35%). Only 1% (10 responses) referred to the rather bad quality of herbal remedies. Of those remedies classified as "fair", participants often declared that they are sometimes effective in alleviating particular symptoms, but on other occasions do not help at all. Likewise, it was frequently reported (without further specification) that the therapeutic power of a number of such "fair" remedies is patient-dependent: in some people they are effective, while in others they are not.

For no less than fifty health conditions, at least one of the responses referred to a remedy that was rated as "fair". Health conditions with the highest percentages of remedies rated to be of

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[2] Results described in this section apply only on the present study and not on Vandebroek *et al.* (2003)

"fair" quality are conjunctivitis (5 responses; corresponding with 45% of the responses for this health condition), bad wind or *wayra* (45 responses; 45%), rheumatism (53 responses; 44%), colds (7 responses; 44%), stomach-ache (18 responses; 43%), toothache (9 responses; 43%), colic (9 responses; 39%) and fever (18 responses; 39%) (only health conditions with more than 10 responses are given).

Table 3.5: IAR values for reported health conditions in Apillapampa. Only those health conditions for which the number of responses was higher than 3 and IAR > 0 are listed. Animal medicine is not included here.

Health Condition	# resp	# spp	IAR
hair loss	3	1	1.00
female sterility	14	4	0.77
wart	13	5	0.67
toothache	35	13	0.65
fracture/sprains	31	12	0.63
cough	150	56	0.63
malnutrition	27	11	0.62
biliary colic	36	15	0.60
labour	28	12	0.59
snake bite	15	7	0.57
pain (muscle/back...)	35	16	0.56
madre	96	45	0.54
bruises	154	75	0.52
wounds	104	51	0.51
constipation	19	10	0.50
otitis	19	10	0.50
flatulence	17	9	0.50
hematuria	3	2	0.50
heartburn	3	2	0.50
diarrhoea	26	14	0.48
ophthalmia	21	12	0.45
rheumatism	207	119	0.43
bad wind (*wayra*)	150	87	0.42
colic	45	27	0.41
measles	6	4	0.40
pain (general)	211	131	0.38
fever	142	87	0.39
diabetes	18	12	0.35
skin fungus	13	9	0.33
allergic skin reactions	10	7	0.33
pain (breast)	4	3	0.33
uterus ailments	4	3	0.33
pneumonia	62	42	0.33
kidney ailments	35	24	0.32
insect stings	11	8	0.30
urinary retention	22	16	0.29
pain (abdomen)	79	57	0.28
common cold	57	42	0.27
scabies	31	23	0.27
cataract	9	7	0.25
puerperium	9	7	0.25
exhaustion	5	4	0.25
haemorraghe	5	4	0.25
vitamin deficiency	5	4	0.25
gall bladder ailments	67	53	0.21
depression	12	10	0.18
conjunctivitis	13	11	0.17
alcohol intoxication	7	6	0.17
pain (headache)	50	42	0.16
stomach-ache/gastritis	64	54	0.16
pain (backache)	21	18	0.15
dizziness	15	13	0.14
purgative	8	7	0.14
sore throat	9	8	0.13
intestinal parasites	11	10	0.10

resp= number of responses; # spp = number of species

3.3.4.6. Culturally Most Relevant Medicinal Remedies and Species

Medicinal Plant Remedies

A total of 1400 different plant remedies (i.e. medicinal plant uses) have been documented in Apillapampa. A *plant remedy* or a *medicinal plant use* is defined as the use of one particular plant species for one particular health condition, irrespective of preparation or plant part used and as mentioned by one or more participants. In figure 3.8, the number of remedies is plotted against the number of participants who confirmed them. On average, remedies are confirmed by 1.6 (±1.4 (s.d.)) participants. Nearly one third of all reported remedies (i.e. 29% or 406 remedies) were confirmed by at least two participants. Such low level of consensus may seem surprising, especially when taking into account that nearly half of our participants are traditional healers. Nonetheless, the inverted J-shaped curve of figure 3.8 corresponds to a widespread pattern (e.g. Friedman *et al.*, 1986; Barrett, 1995; Alexiades, 1999; Casagrande, 2002). The curve indicates that the distribution of knowledge about plant remedies follows a pattern in which few remedies are known by almost everyone while most knowledge is idiosyncratic, i.e. significant only at the level of the individual. Casagrande (2002) hypothesized that this phenomenon reflects the existence of an upper limit to the amount of medicinal plant knowledge that can be transferred and distributed throughout pre-literate communities. On the other hand, it is possible that knowledge of medicinal plants is more difficult to learn as compared to food, material and environmental uses (cf. Phillips and Gentry, 1993b). The fact that we have demonstrated earlier (section 3.3.3) that participant age did not correlate with RUV for *food*, *materials* and *environmental uses*, whereas a highly significant positive correlation was found between participant age and RUV for medicine might testify to this possibility. A third explanation for the idiosyncratic nature of medicinal knowledge could be that the population is progressively losing its medicinal plant knowledge due to modernization.

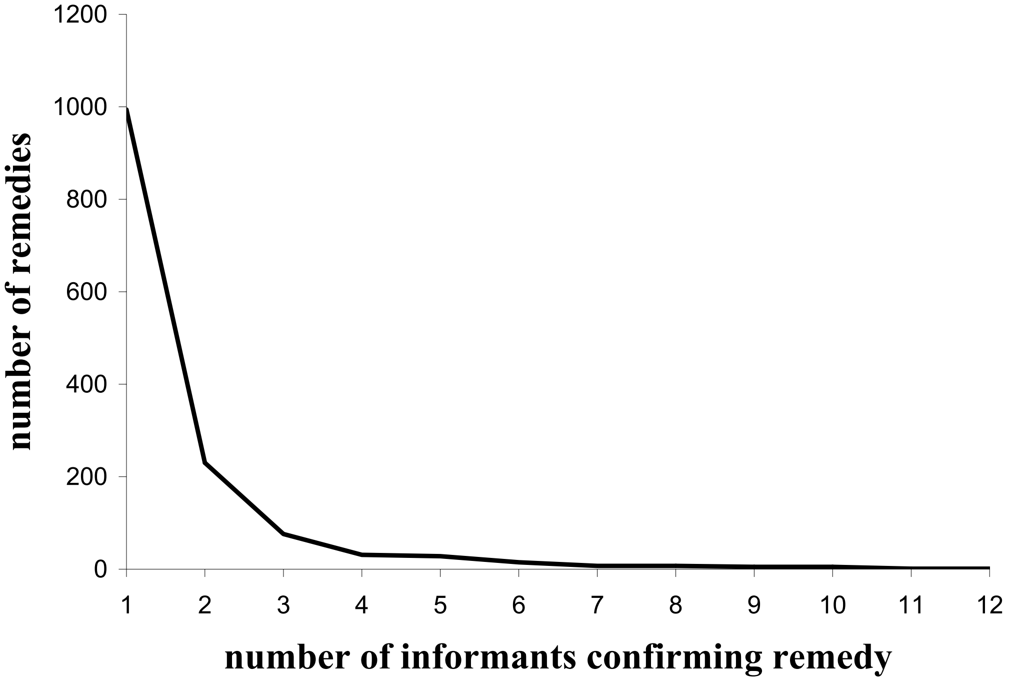

Figure 3.8: Numbers of remedies versus the numbers of participants confirming them

Highest consensus was recorded for the remedies listed in table 3.6. The majority of the participants agrees on these uses and therefore the chance that these plants are bioactive may be higher than for other species. It is interesting to note that all these remedies consist of native plant species.

Medicinal Plant Species

On average, 4.3 (±1.4 (s.d.)) participants provided ethnomedicinal information on a medicinal plant species. The medicinal use of 86 (25% of the total number of medicinal plants) and 147 species (43%) was confirmed by only one and two participants, respectively. Species with the most diverse ethnomedical applications are listed in table 3.7. The majority of species in this list are also native ones.

Table 3.6: Medicinal plant remedies with highest participant consensus

Scientific name	Health condition	Number of confirming participants
Trixis aggregata	bruises	12
Krameria lappacea	madre	11
Schinus molle	rheumatism	10
Echeveria sp.	otitis	10
Achyrocline ramosissima	cough	10
Gnaphalium gaudichaudianum	cough	10
Passiflora umbilicata	bruises	10
Tessaria fastigiata	malnutrition	9
Calceolaria engleriana	fracture/sprains	9
Mutisia ledifolia	cough	9

The species from table 3.7 also score high for medicinal use values and quality use values (table 3.8), partly because medicinal UV_s and QUV_s values are correlated with the number of medicinal applications per species (Kendall's τ_b=0.75 and 0.62, respectively; $p<0.001$ for both). As shown in table 3.8, medicinal quality use values are consistently lower than use values due to the fact that not every reported ethnomedical application of species is of "good" quality. Regressing medicinal quality use values of species on their medicinal use value results in a R^2 value of 81.6, which indicates that assigning a quality to medicinal uses explains nearly one fifth (18.4%) of the variance in QUV_s values.

Table 3.7: Medicinal plant species with highest number of different medicinal applications

Scientific name	# part	# med uses	Scientific name	# part	# med uses
Schinus molle	12	17	*Ephedra americana*	12	12
*Medicago sativa**	9	17	*Sonchus asper**	10	12
Trixis aggregata	13	13	*Caiophora canarinoides*	12	11
Schkuhria pinnata	12	13	*Satureja boliviana*	5	11
Baccharis sagittalis	10	13	*Lepechinia meyenii*	9	11
Otholobium pubescens	12	12	*Rosa* x *noisettiana* cf.*	10	11
Cestrum parqui	11	12	*Valeriana decussata*	10	11
Tripodanthus acutifolius	10	12	*Cheilanthes scariosa*	10	11
Agalinis lanceolata	11	12	*Ephedra rupestris*	10	11
Solanum nitidum	12	12	*Calceolaria parvifolia* ssp. *parvifolia*	8	10

part= participants; # med uses= medicinal uses
*= introduced species

A weakness of UV_s, possibly less so of QUV_s, is that it does not satisfactorily incorporate consensus among participants. For example, if three participants each name two different medicinal uses for species A, then its medicinal use value equals two ((2+2+2)/3) and the number of reported health conditions six. If these participants unanimously agree that species B is used for treating two different health conditions it would also result in a medicinal use value of two, while consensus for species A is zero and for species B it is 100%.

QUV_s values might express participant consensus better than UV_s. It is noticeable how ranking based on QUV_s values (table 3.8) combines species that have the highest consensus for particular remedies (table 3.6) together with species that have the most diverse ethnomedical applications (table 3.7). Ranking based on $\mathrm{UV_S}$ values seems to favour the latter species more. This property of $\mathrm{QUV_S}$ to partially incorporate participant consensus might be related to the fact that a higher consensus about remedies parallels a higher frequency of responses related to remedies that are considered to be of “good quality”. A technique that takes into account participant consensus and thus can be used to evaluate the latter assumption is the informant agreement ratio (IAR) for medicinal species. We interpreted the formula originally proposed by Trotter and Logan (1986) as follows:

$$0 < IAR_s = \frac{n_r - n_a}{n_r - 1} < 1$$

wereby n_r is the total number of medicinal responses registered for species *s* and n_a is the number of ailments or health conditions that are treated with this species. The $\mathrm{IAR_S}$ of a medicinal species varies between 0, when the number of health conditions treated equals the number of medicinal responses, and 1, whereby all participants agree upon the exclusive use of the species for a particular health condition.

Table 3.8: Medicinal plant species with the highest medicinal use value (UV) and quality use value (QUV). The top fifteen of species according to UV and QUV values are underlined in the corresponding columns. The top five of species with the highest $\mathrm{IAR_s}$ values are marked in bold.

scientific name	**# medicinal uses**	**# participants**		**$\mathrm{UV}_{s\ \mathrm{medicine}}^{1}$**	**$\mathrm{QUV}_{s\ \mathrm{medicine}}^{2}$**	**IAR^{2}_{s}**
		Combined[1]	Present[2]			
Trixis aggregata	13	13	11	2.46	2.00	0.61
Schinus molle	17	14	12	2.14	1.42	0.45
Otholobium pubescens	12	14	12	2.00	1.17	0.59
Chenopodium ambrosioides	7	8	1	1.88	-	0.57
Cestrum parqui	12	14	12	1.86	1.15	0.56
Agalinis lanceolata	12	14	12	1.79	1.04	0.54
Equisetum giganteum	7	8	0	1.75	-	0.54
Tessaria fastigiata	5	12	10	1.75	1.00	**0.80**
Minthostachys andina	8	14	12	1.71	1.10	**0.70**
Baccharis genistelloides	9	8	0	1.63	-	0.33
Flourensia riparia	7	8	0	1.63	-	0.50
*Medicago sativa**	17	15	13	1.60	0.65	0.30
Tripodanthus acutifolius	12	14	10	1.57	0.55	0.48
Solanum tripartitum	6	9	3	1.55	0.83	0.62
Solanum nitidum	12	13	10	1.54	1.10	0.42
Krameria lappacea	9	14	12	1.43	1.14	0.58
Solanum palitans	7	9	9	1.44	1.33	0.62
Baccharis sagittalis	13	12	12	1.50	1.29	0.29
Passiflora umbilicata	4	12	9	1.33	1.22	**0.80**
Gnaphalium gaudichaudianum	5	12	12	1.25	1.21	**0.71**
Achyrocline ramosissima	2	10	6	1.30	1.17	**0.92**
Calceolaria engleriana	7	14	12	1.29	1.17	0.65
Geranium soratae	5	8	8	1.13	1.13	0.50
Mentzelia fendleriana	5	5	5	1.20	1.10	0.20

[1]: based upon combined results from the present research and Vandebroek *et al.* (2003)
[2]: based upon the results from the present research
***= introduced species**

When applied on our data set, species' IAR_s values correlate positively (but weakly) with the number and proportion of "good quality" responses per species (Kendall's τ_b= 0.30 ($p<0.001$) and 0.14 ($p=0.004$), respectively), confirming our hypothesis that species for which participant consensus is higher also yield more "good quality" responses. Hence, as a species' QUV_s is also positively correlated with the number of "good quality" medicinal responses per species (Kendall's τ_b=0.64; $p<0.001$), this may explain in part why QUV_s expresses consensus better than UV_s.

Table 3.9 lists medicinal species with the highest IAR_s values. Although both medicinal UV_s and QUV_s correlate with IAR_s (Kendall's τ_b= 0.41 and 0.30, respectively; $p<0.001$ for both cases), ranking of species based on IAR_s values gave different results as compared to ranking based on medicinal UV_s and QUV_s values (table 3.8). The only species that occur in both tables are *Achyrocline ramosissima*, *Tessaria fastigiata, Passiflora umbilicata, Gnaphalium gaudichaudianum* and *Minthostachys andina*. This outcome is, at least in part, due to the fact that rankings based on UV_s and QUV_s values favour plant species with multiple medicinal applications, whereas IAR_s is less sensitive to the number of different medicinal applications. For example, a plant with only one medicinal application that is known to all interviewed participants will receive UV_s and QUV_s values of maximally 1, and therefore has little chance of being listed among the most important medicinal species. On the other hand, its IAR_s value would also be 1, acknowledging the maximum level of consensus. In line with this observation, the number of different medicinal uses per species is significantly higher ($p<0.001$; Mann- Whitney) for species with high medicinal UV_s and QUV_s values (table 3.8) than for species with high IAR_s values (table 3.9).

Table 3.9: IAR_s values for medicinal plant species in Apillapampa. Only those species are listed for which the number of responses is higher than 3 and for which ethnobotanical data was collected during both investigations.

Scientific name	# participants interviewed	# responses	# medicinal uses	IAR_s
Tessaria dodonaeifolia	8	3	1	1.00
Achyrocline ramosissima	10	13	2	0.92
Dunalia brachyacantha	8	7	2	0.83
Passiflora umbilicata	12	16	4	0.80
Tessaria fastigiata	12	21	5	0.80
Bidens mandonii	8	5	2	0.75
Dodonaea viscosa	14	17	5	0.75
Echeveria sp.	13	13	4	0.75
Gamochaeta americana	10	9	3	0.75
Trichocereus tunariensis	8	9	3	0.75
Plantago orbignyana	11	9	3	0.75
Hypseocharis pimpinellifolia	13	13	4	0.75
Vassobia fasciculata	15	19	6	0.72
Gnaphalium melanosphaeroides	9	8	3	0.71
Margyricarpus pinnatus	10	8	3	0.71
Spathantheum orbignyanum	13	15	5	0.71
Gnaphalium gaudichaudianum	12	15	5	0.71
Rumex conglomeratus	8	11	4	0.70
Cosmos peucedanifolius	12	11	4	0.70
Minthostachys andina	14	24	8	0.70

Nonetheless, similar to UV_s and QUV_s, a plant species' IAR_s is positively correlated with its number of medicinal uses (Kendall's τ_b=0.37; $p<0.001$). However, regression analysis shows that the number of medicinal uses per species explain only 4% of the variation in IAR_s values (R^2=0.04; p=0.002), but 57% of the variation UV_s values (R^2=0.57; $p<0.001$) and 26% of the variation of QUV_s (R^2=0.26; $p<0.001$). Hence, IAR seems to be less sensitive to the reported numbers of different medicinal uses per species as compared to UV_s and QUV_s.

Medicinal UV_s, QUV_s and IAR_s values of plants are significantly correlated with the number of participants interviewed (Kendall's τ_b=0.16, 0.13 and 0.27 respectively; $p<0.001$ for all three cases). Although these correlations are weak, they indicate that probably higher UV_s, QUV_s and IAR_s values would have been obtained if the number of interviewed participants per species would have been higher and equal for all species.

Use values imply that the local importance of a plant is primarily determined by its number of medicinal uses. Although this proposition has rarely been tested, Byg and Balslev (2001) were able to show a positive correlation between the perceived importance of palm species by local participants in Madagascar and their use values and number of uses. In spite of this finding, we believe that assessing the local importance of a plant should be based on a combination of (1) the number of uses/use value and (2) the level of consensus between participants, precisely because QUV_s and IAR_s focus on different aspects of ethnobotanical data. Medicinal QUV_s values appear to be more sensitive to the number of ethnomedical applications per plant species and additionally incorporate emically (i.e. culture-specific) perceived therapeutic qualities, whereas IAR_s values address informant consensus. We herewith propose to combine both parameters into the 'quality use agreement value' (QUAV), which is defined as:

$$\mathrm{QUAV_s} = \mathrm{QUV_s} * \mathrm{IAR_s}$$

$QUAV_s$ values range from 0 (no consensus) to QUV_s (complete consensus) or UV_s (complete consensus and all responses of good quality). In table 3.10, ranking of the twenty highest scoring medicinal species according to $QUAV_s$ values shows that species from the top twenty ranking according to IAR_s and QUV_s, respectively are represented in a relatively equal way (10 and 13 species, respectively).

3.3.4.7. Explaining High Numbers of Medicinal Plants per Health Condition

As indicated in table 3.5, various health conditions are treated with a high diversity of medicinal plants. Rheumatism alone accounts for one third of all inventoried medicinal plants. Likewise, cough is treated with up to 56 different plant species. However, based on participant consensus *Achyrocline ramosissima, Gnaphalium gaudichaudianum* and *Mutisia ledifolia* (see table 3.6) are considered to be the most efficient to alleviate the latter symptom. One could ask why Apillapampeños use so many more species. Although it is difficult to formulate a straightforward answer, we propose several possible explanatory factors for plant selection that can be relevant separately, but also additively or synergistically. These include: (1) availability of medicinal plants in time and space; (2) characteristics of specific health conditions; (3) the dynamic and specialized nature of traditional medicine in Apillapampa; (4) inability to empirically test the efficacy of plants used in mixtures; (5) sensory perception; and (6) other minor factors. In the following paragraphs, each of these factors will be discussed into detail. In chapter 12 (section 12.6.), the high overall number of medicinal plants used in

Apillapampa is additionally linked the contact history and traditional lifestyle of Quechua people.

Table 3.10: Ranking of medicinal species according to decreasing quality use agreement values (QUAV$_s$). Species from the top twenty ranking of QUV$_s$ and IAR$_s$, respectively, are marked in bold in the corresponding columns.

Scientific name	# disorders	# participants interviewed	UV_{med}	QUV_{med}	IAR_s	QUAVs
Trixis aggregata	13	13	2.46	**2.00**	0.61	1.23
Achyrocline ramosissima	2	10	1.29	**1.17**	**0.92**	1.08
Passiflora umbilicata	4	12	1.33	**1.22**	**0.80**	0.98
Gnaphalium gaudichaudianum	5	12	1.25	**1.21**	**0.71**	0.86
Tessaria fastigiata	5	12	1.75	1.00	**0.80**	0.80
Minthostachys andina	8	14	1.71	**1.10**	**0.70**	0.77
Calceolaria engleriana	7	14	1.29	**1.17**	0.65	0.75
Otholobium pubescens	12	14	2.00	**1.17**	0.59	0.69
Krameria lappacea	9	14	1.43	**1.14**	0.58	0.66
Cestrum parqui	12	14	1.86	**1.15**	0.56	0.64
Vassobia fasciculata	6	15	1.27	0.88	**0.72**	0.64
Schinus molle	17	14	2.14	**1.42**	0.45	0.64
Dodonaea viscosa	5	14	1.21	0.83	**0.75**	0.63
Tetraglochin cristatum	7	14	1.29	0.96	0.65	0.62
Gnaphalium cheiranthifolium	5	11	1.09	0.91	0.64	0.58
Agalinis lanceolata	12	14	1.79	**1.04**	0.54	0.56
Geranium soratae	5	8	1.13	**1.13**	0.50	0.56
Gamochaeta americana	3	10	0.9	0.75	**0.75**	0.56
Gnaphalium melanosphaeroides	3	9	0.89	0.78	**0.71**	0.56
Solanum palitans	8	9	1.44	**1.33**	0.42	0.56
Hypseocharis pimpinellifolia	4	13	1.00	0.73	**0.75**	0.55

Availability, Accessibility and Ecological Edge

Availability and accessibility have (at least) two dimensions: one in time and one in space. Many potent herbaceous medicinal plants are only available during the rainy season. If one has not built up a (dried) stock of these plants, during the dry season one necessarily has to count on other (mainly woody) species that are available during that season. Apart from season, another important factor that influences plant availability and accessibility in Apillapampa is the uneven spatial distribution of vegetation. Most Apillapampeños own cropping fields along vertical and horizontal gradients with ecological variation. Accessibility to these fields is rather low due to long travel times, bad or nonexistent roads or steep slopes that require significant climbing effort. To optimize time investment, people tend to build small houses (figure 3.15C) along the edges of these agricultural lands, which allow them to work and stay on-site during various periods of the year. Especially during planting and harvesting seasons, whole families temporarily live in these dwellings. Pasturing of livestock is also one of the motivations for these periodical movements. When humans or animals get afflicted by ailments while temporarily residing on these distant cultivation fields away from the village, people will look for herbal remedies in their close reach first before considering returning to the village to fetch remedies that may be more familiar to them. As we have shown in chapter 2, populations of wild plants (including medicinals) vary considerably according to the location of sites. This uneven distribution of vegetation in terms of time and space urges people to acquire knowledge about different medicinal plant species from diverse ecological niches for treating similar health conditions (cf. Bastien, 1987a). Due to the inability to consistently track down and collect particular species when needed, knowing alternative ones with (comparative) therapeutic powers certainly is an advantage and can be interpreted as a kind of risk management.

In addition, as indicated in chapter 2, Apillapampa is situated on the ecological edge between *prepuna* en *puna* zones, which contain different vegetation. It has been suggested that societies that live in environments with high ecological variation, such as on ecological edges, favour the development of extensive (wild plant) knowledge bases through a maximized access to different ecosystems (Bastien, 1987a; Milliken and Albert, 1997; van Andel, 2000; Turner *et al*. 2003). This would enable societies to respond more flexibly to threats that afflict them (Turner *et al*. 2003). In a broad sense such threats might also include diseases.

Similar observations have been made elsewhere as well (e.g. Alcorn, 1984; Bastien, 1987a; Alexiades, 1999; Leonti *et al*., 2002; Casagrande, 2002). For example, Mexican Popoluca people consider it essential that certain medicinal species are available in each ecological zone where they go, work or live in order to treat common ailments. Therefore, encountering substitutes or alternative treatments if certain species are not available is crucial to these people (Leonti *et al*., 2002). Accessibility or availability of plants have frequently been reported to be among the primary considerations of indigenous people when selecting between different treatment options, at least during the early stages of an illness episode (Alexiades, 1999; Casagrande, 2002). From her work among the Huastec Maya, Alcorn (1984) argued that availability of plant species can have profound consequences for their medicinal use in the sense that less effective but more abundant plant species may be favored instead of better (but less available) remedies. This observation has recently been confirmed by Lawrence *et al*. (2005) based on a study among various indigenous and *mestizo* groups in Amazonian Peru. However, this hypothesis does not seem universally valid (Casagrande, 2002) and in Apillapampa various plant species that are relatively rare and inaccessible are still renowned for their therapeutic powers.

Characteristics of Health Conditions

Apart from availability, characteristics related to specific health conditions might also influence the number of medicinal plants used. We support the suggestion made by other authors that the number of medicinal plants used to treat health conditions is related to the prevalence of these conditions (e.g. van Andel, 2000; Vandebroek *et al*., 2008). In Apillapampa, the high number of plant species reported for bruises is most likely linked to the high incidence of bruises in the area due to the traditional agricultural lifestyle. Wounds and bruises also figure among the most frequently treated ailments in the logbook of the community's primary health care centre (PHC) which is managed by the local NGO, FEPADE (Vandebroek *et al*., 2008). PHC data, based on diagnosis of 324 outpatients that were treated during a period of eight months between July 2000 and April 2001, showed that respiratory infections (including pneumonia, cough, otitis and sore throat) and fever were among the most frequently reported ailments or symptoms. These health conditions also rank high in terms of the number of plants used for treatment (table 3.5).

Likewise, the high number of plant remedies recorded for rheumatism is probably related to its high local incidence. Rheumatism has been identified as the most prevalent degenerative disease in Apillapampa (FEPADE, 1998) and in the Bolivian Andes, especially in older women who work on the land in skirts while cold wind quickly cools off their legs (Bastien, 1987a). Nevertheless, it is not mentioned as frequently in the PHC logbook since people tend to rely on traditional steam baths for treatment rather than on Western medicine (Vandebroek *et al.*, 2008).

The high incidence of particularly respiratory, musculoskeletal and gastrointestinal disorders in Andean communities is well-documented in literature (Donahue, 1981; Bastien, 1987a; Carey, 1990; Mitchell, 1991; Oths, 1998). To stress the high local incidence of these disorders in the Peruvian Andes community of Chugurpampa, which is situated at the same altitude as Apillapampa, Oths (1998) documented that ‘in spite of cultural interventions such as immunization, pure water and adequate sanitation and diet these Andeans are hardly ever illness free’.

Another characteristic that may affect the number of plant species used pertains to the causal factors of different health conditions. As illustrated by table 3.5, there seems to be a tendency for using more medicinal plants to treat health conditions or symptoms that are provoked by a wide array of causal agents as compared to disorders or symptoms that are caused by one (or a restricted number of) causal factor(s). Here, we refer to health conditions of the first type as “multiple causal agent disorders” (MCAD) and those of the latter type as “single causal agent disorders” (SCAD). We define MCAD as *any kind of disorder or ailment altering a patient’s physical or psychological wellbeing that is difficult to diagnose based on mere symptoms because of the wide array of potential causal agents that may provoke its symptoms*. A SCAD is on the other hand *any kind of disorder or ailment altering a patient’s physical (or psychological) wellbeing that is relatively straightforward to diagnose because of the restricted number of causal agents that provoke its symptoms*.

Fever, as an example of a MCAD, can be the body’s response to a viral, bacterial or parasitological infection, but it can be caused just as well by a poisoning or tumour. Diarrhoea is another example: Casagrande (2002) identified at least 23 different pathogens in Mexican Tzetlal Maya communities that may cause diarrhoea, including bacteria, protozoans, viruses and worms. Chronic disorders such as rheumatism are a special case of these MCADs. Rheumatism itself covers a wide range of medical problems and may have many causal factors. On the other hand, trauma is the only causal factor for fractures or sprains which are therefore classified as a SCAD. While the diagnosis and evaluation of the efficacy of a remedy is generally relatively straightforward for SCADs, this is often more complicated for MCADs. According to our participants, treatment of MCADs (and to a far lesser extent of SCADs) in Apillapampa usually involves a trial-and-error approach, in analogy with (most) other medical systems (e.g. Ryan, 1998; Heinrich *et al.*, 1998b; Cocks and Dold, 2000; Sumner, 2001; Casagrande, 2002), including the Western medical tradition. Different herbal remedies are subsequently administered to patients who suffer from MCADs (or SCADs), until the appropriate remedy is found for the specific causal agent, or until the body’s defense mechanisms have defeated self-limiting diseases such as common colds (Waller, 1993). Therefore, in theory, MCADs such as diarrhoea will require a higher number of different remedies to ensure efficient treatment as compared to disorders with one or a restricted number of causal factors (SCAD), such as fractures. It may therefore not be a surprise that in many, if not most, ethnobotanical studies, MCADs consistently figure among the health conditions for which the highest number of remedies or medicinal plants are reported (e.g. Milliken and Albert, 1996 and 1997; Frei *et al.*, 1998; Heinrich *et al.*, 1998b; van Andel, 2000; Bourdy *et al.*, 2000; Leonti *et al.*, 2001; Thomas, 2001; Geissler et al., 2002; Etkin, 2002; Bourdy *et al.*, 2004).

Dynamic and Specialized Nature of Traditional Medicine

Traditional medicine (TM) has an important cultural tradition in the Bolivian Andes and in Apillapampa. Its importance may be attributed to (1) TM being an adaptation strategy to a hostile and unpredictable environment (Bastien, 1982 and 1987a; Larme, 1998; Vandebroek *et al.*, 2004b), (2) a long history of contact with western society and its diseases, and (3) a long-standing sedentary agricultural lifestyle (see chapter 12, section 12.6.). Traditional medicine is not static and traditional healers in Apillapampa frequently experiment with “new” plant species. One well-respected healer declared that “in fact every plant has medicinal properties”; according to healers the tricky part lies in successfully matching the plants to the disorders they are able to treat. Similar assertions by indigenous healers have also been reported by Leonti *et al.* (2002). Moreover, experimentation with medicinal plants seems to be characteristic for societies all over Latin America and beyond (Bastien, 1987a; Milliken *et al.*, 1992; Gessler *et al.*, 1995; Milliken and Albert, 1997; Milliken, 1997a; Heinrich *et al.*, 1998b; Alexiades, 1999; Bennett and Prance, 2000; Leonti *et al.*, 2002; Casagrande, 2002; Voeks, 2004).

In view of the overall limitation to the amount of medicinal plant knowledge that can be transmitted and distributed throughout preliterate communities (Casagrande, 2002), experimentation in the medicinal plant context might also help explaining the low consensus rates in Apillapampa: 71% of all reported remedies and 25% of all collected medicinal plants were confirmed by one participant only. However, these proportions are so high that it would be improper to simply regard them as a result of experimentation. Other underlying factors such as specialist knowledge, mistakes, scattered remnants of ancient knowledge and practices may be contributors as well.

Another relevant characteristic of the ethnomedical system in Apillapampa is the humoral (hot/cold) classification system, a legacy of Hippocrates (Foster, 1994). In line with indigenous believes throughout Latin America (Foster, 1994; Bastien, 1987a; Pestalozzi, 1998), in Apillapampa most health conditions are classified into the humoral states *fresco* (cold) or *caliente* (hot). Traditional healers evaluate the humoral state of patients through interpretation of their pulse. For example, fever is conceived as a hot condition, characterized by a fast pulse, while a common cold is perceived as cold and is said to be accompanied by a slow pulse. A similar dichotomy is applied to medicinal plant species, whereby cold plants are used to treat hot health conditions and vice versa. Alcorn (1984) argued that in actual usages, all available “cold” plants may not be used to cure a “hot” disease, but only (a series of) particular “cold” plant(s) for a particular “hot” disease. Although the present investigation was not focused on studying the humoral system, our interview data strongly suggest that a similar assertion is valid in Apillapampa. Hence, bearing in mind the haphazard availability and accessibility of many plants in Apillapampa, people are “forced” to know plenty of alternative “humoral antagonist’ plants for treating humoral health conditions of a particular “hot” or “cold” state. This is in line with Brett’s (1994, cited by Casagrande, 2002) suggestion that among the Yzeltal Maya people, humoral concepts could be a factor guiding medicinal plant selection and experimentation. Casagrande (2002) likewise argued that humoral principles could be particularly important to expert curers who are likely to experiment with new plants and who hold more detailed knowledge about medicinal plants. However, it should be noted that some authors have hypothesized that the humoral classification may serve as a *post hoc* mnemonic function, providing (lay) people first and foremost with an explanation of plant use and selection for certain illnesses when the type of therapy is already known (Ankli *et al*., 1999b; Casagrande, 2002).

Emic Plant Efficacy and Biomedically Inactive Plants

Efficacy of medicinal plants is judged primarily by a participant’s perception of a plant’s ability to correct deleterious symptoms. These perceptions are mostly based on firsthand experiences and may have a pharmacological basis, but perceptions can also be heavily influenced by social persuasion (Casagrande, 2002) or may represent “cultural constructs of efficacy” (Etkin, 1988) whereby direct biomedical correlations can be absent. Emic perception of plant efficacy has been shown to be strongly correlated with the distribution of knowledge about medicinal plant species, whereby some plants are known by more people because they are more effective than other for correcting illness symptoms (Casagrande, 2002). Here we argue how the problematic approach of emically-guided testing of the efficacy of plant species in mixtures is expected to contribute to an increase in the number of different medicinal plant species used to treat particular health conditions in Apillapampa.

In most, if not all ethnomedical systems, the efficacy of at least some medicinal plants can be demonstrated relatively unambiguously through empirical testing (Moerman, 1991; Heinrich *et al*., 1998b; Leonti *et al*., 2001; Shepard, 2004; Waldstein and Adams, 2006). This is also the case for Apillapampa. For example, the efficacy of plants used to expel intestinal parasites can be evaluated directly through examination of faeces, and plants with potent antiseptic properties will generally heal infected wounds rapidly. However, it is far less straightforward to assess the therapeutic potential of medicinal plants used in mixtures wherein plants can act individually, additively or synergistically (Hernández Canoa and Volpato, 2004; Gurib-Fakim, 2006).

Plant mixtures are sometimes used in Apillapampa for preparation of herbal teas, plasters or compresses, but they are particularly common in steam baths that can contain twenty or more different plant species at once. Nearly one third of all recorded medicinal plants is used in steam baths. The composition of the plant mixtures used in steam baths strongly varies throughout the year, depending – among other factors – on (seasonal) plant availability. In addition, participants declared to experiment frequently with these mixtures by adding “new” plants. Such an approach facilitates the (unconscious and/or unintended) inclusion of inactive plants in the pharmacopoeia. Plant mixtures can undoubtedly be highly effective in alleviating symptoms. However, pinpointing the therapeutic power of individual plants through observation is practically impossible, as empirical testing is focused on the mixture and not on the individual plant. The inability to distinguish between active and non-active plants could therefore promote the local belief that all plants in mixtures are good medicines and hereby contribute to the high numbers of medicinal species used to treat particular health conditions.

Other causal factors for the inclusion of non-active plants in ethnopharmacopoeia have been identified in literature and some of these may be valid in Apillapampa as well. Some ethnomedical preparations are simply placebos and used to treat self-limiting diseases such as minor influenza or a simple cold (Waller, 1993; Stepp and Moerman, 2001). The placebo effect is a complex cultural phenomenon that exists in all medical systems (Moerman, 2000 and 2003). As such, the placebo effect and emically perceived efficacy of plants that are used in the context of self-limiting diseases might lead to the inclusion of potentially biologically inactive plants in the local pharmacopoeia.

Literature supports the hypothesis that not all medicinal plants in Apillapampa are necessarily biologically active. It has been argued that, although theoretically all plants are potential sources of biologically active molecules (Fellows, 1991), far from all plants used in TM evocate biomedical effects in humans (e.g. Davis & Yost, 1983a; Milliken *et al*., 1992; Waller, 1993; Rates, 2001; Sumner, 2001; Massé, 2002). Davis & Yost (1983a) stated that: "*In no area of ethnobotany is the challenge greater than in the search for new medicines, for in no area is there a greater mixture of fact and fiction*". In the same line, Sumner (2001) argued that: "*ethnobotanists have estimated that perhaps half the folk uses of medicinal plants are valid*." The famous Bolivian Kallawaya healers employ about a thousand medicinal plants of which Girault (1984) claimed 25-30% are effective cures (Bastien, 1987a).

Another way to test our hypothesis is by comparing the proportion of plants used medicinally in Apillapampa with data available in literature. Seventy-nine percent (79%) of all inventoried species in Apillapampa is used as medicines. Since one of our research goals was to make an inventory of the vegetation in Apillapampa that is as complete as possible, we believe that this proportion corresponds well with the actual situation. Hence, if this estimation is correct, it would mean that the proportion of medicinal plants in the flora of Apillapampa is significantly higher than the estimated world average. Farnsworth and Soejarto (1991) have estimated that 35-70,000 of the approximately 250,000 angiosperms (i.e. 14-28%) on earth have been used – at one time or another – in some culture for medicinal properties. In Bolivia, up to present at least 3,000 plants species have been identified as being used in TM (Giménez and Ibisch, 2003). This is 15% of the estimated total number of vascular plant species (20,000) in Bolivia (Ibisch and Beck, 2003).

Higher proportions than the world mean are scarcely reported in literature. Hensen (1991) found that in Chorojo, a rural Bolivian Andes community, 56% of the 204 species encountered in *Polylepis* forests was used in traditional medicine, whereas Birk (1995) showed that 75% of all 290 species used by the Bolivian Chiquitanos had a local therapeutic value. Also Bourdy *et al.* (2004) recorded medicinal plant use within the same order (61% of all 305 species inventoried) among the Izoceño-Guarani. However, more frequently, reported proportions of medicinal plant use fall within the range proposed by Farnsworth and Soejarto (1991). Gimenez *et al*. (1996) found that the Raqaypampeños, Quechua people living at altitudes between 2,100 and 3,200 m.a.s.l., used 37% of the 532 species inventoried in traditional medicine. Bye (1993) estimated that 15% of the Mexican flora is used medicinally.

Leonti *et al*. (2001 and 2002) reported that 614 of the 2,500-3,000 species (i.e. 20-25%) prevailing in the Mexican Popoluca habitat are used as medicines. Finally, Moerman (1996) calculated that native North-Americans use(d) 11.8% of the available flora for medicinal purposes.

Hence, it seems unlikely that the proportionally higher medicinal use of the available flora in Apillapampa would be due to a significantly higher bioactivity of the local vegetation as compared to other areas in the world. Therefore, it is more plausible that the pharmacopoeia in Apillapampa contains a number of inactive plants. Future ethnopharmacology studies into the bioactivity of these plants are necessary to corroborate or refute this hypothesis.

Sensory Perception

The importance of sensory cues in the selection of medicinal plants is only recently receiving increased attention (Heinrich *et al*., 1992; Leonti *et al*., 2002; Casagrande, 2002; Shepard, 2002 and 2004). Although we did not explicitly investigate this aspect of TM, we believe that it is relevant to some extent in Apillapampa. Medicinal plant properties can be selected and classified according to their main sensory and organoleptic characteristics involving taste, detection of irritation, odour, and visual/tactile properties (Milliken and Albert, 1997; Ankli *et al*., 1999b; Chaumeil, 2000; Shepard, 2002 and 2004). Bitter plants are often used to treat diarrhoea or to expel intestinal parasites, while plants with pungent odours are frequently inhaled to treat respiratory conditions (Heinrich *et al*., 1992; Van Damme *et al*., 1992; Milliken and Albert, 1997; Ankli *et al*., 1999a; van Andel, 2000; Shepard, 2004). In Apillapampa, most resinous plants are generally identified as good remedies for curing muscular-skeletal system pains, including rheumatic complaints (Vandebroek *et al*., 2003).

In most, if not all, societies around the world there also exist plants with “medicinal” properties attributed through morphological (and physiological) association, known as the ‘doctrine of signatures’ (e.g. Milliken *et al*., 1992, Balée, 1994; Plotkin, 1994; Pestalozzi, 1998; Sumner, 2001; Dafni and Lev, 2002; Grenand *et al*., 1987 and 2004; Leonti *et al*., 2002; Casagrande, 2002; Shepard, 2002 and 2004). This visual perception also appears to be relevant in Apillapampa. The fact that *Spathantheum orbignyanum*, locally called *katari sara* (“snakes’ maize”), is locally used for treating snake-bites, corresponds with a world-wide phenomenon whereby members of the Araceae family are used for snake-bites, based on their morphological and visual resemblance to snakes (e.g. Grenand *et al*., 2004).

On the other hand, it has been suggested that sensory cues, including the doctrine of signatures, could serve an important mnemonic function: plants that are both effective (in terms of emic perception) and easy to remember are more likely to be retained in oral traditions (Ankli *et al*., 1999b; Leonti *et al*., 2002; Shepard, 2002 and 2004).

An example whereby sensory cues and humoral characteristics of plants are combined is provided by Villagrán *et al*. (2003). The latter authors documented that people in the Chilean Andes predict the medicinal quality of plants based on the colours of their flowers whereby yellow flowered plants are perceived as hot remedies and white or blue flowered plants as cold remedies.

Minor Factors

A minor factor that contributes to an increase in the number of medicinal species is the linking of different species from the same genus to similar ethnomedical applications. For example, although *Plantago tomentosa* is locally recognized as the best wound healing plant from this genus, all other local *Plantago* species were ascribed an identical use, while being perceived as less useful. Some plants that belong to different genera or families are sometimes also ascribed similar therapeutical value, which is probably due to association based on morphological and organoleptic similarities with better known or more potent species (cf. Hernandez Canoa and Volpato, 2004).

3.3.4.8. Modes of Plant Preparation

The most commonly reported method of preparing medicinal plant remedies consists in making herbal teas by soaking or boiling specific plant parts in (hot) water (figure 3.9). The resulting infusion or decoction is sometimes ingested with sugar to improve taste. Teas are mainly prepared to treat coughs (17%), pain (of teeth, abdomen, body, back, breast, head and limbs, 16%), gall bladder ailments (8%), gastritis and stomach-ache (8%), *madre* (7%) and pneumonia (4%). The second most cited mode of application is the use of compresses (cataplasms) to treat bruises (35%), wounds (14%), fever (8%), bad wind or *wayra* (5%), snake bites (4%), fractures and sprains (4%), pain (of back, head, limbs and body, 4%) and rheumatism (2%). Compresses are prepared by placing fresh, dried or boiled plant parts (that may be grinded and occasionally mixed with urine, alcohol, salt, oil or raw eggs) on the afflicted part of the body by means of a piece of cloth. Plasters are prepared in a similar way by boiling resinous plants in little water until a sticky residue remains. This residue, which is sometimes mixed with honey, is placed on the afflicted body part by means of a piece of (news)paper (see also Vandebroek *et al.*, 2003).

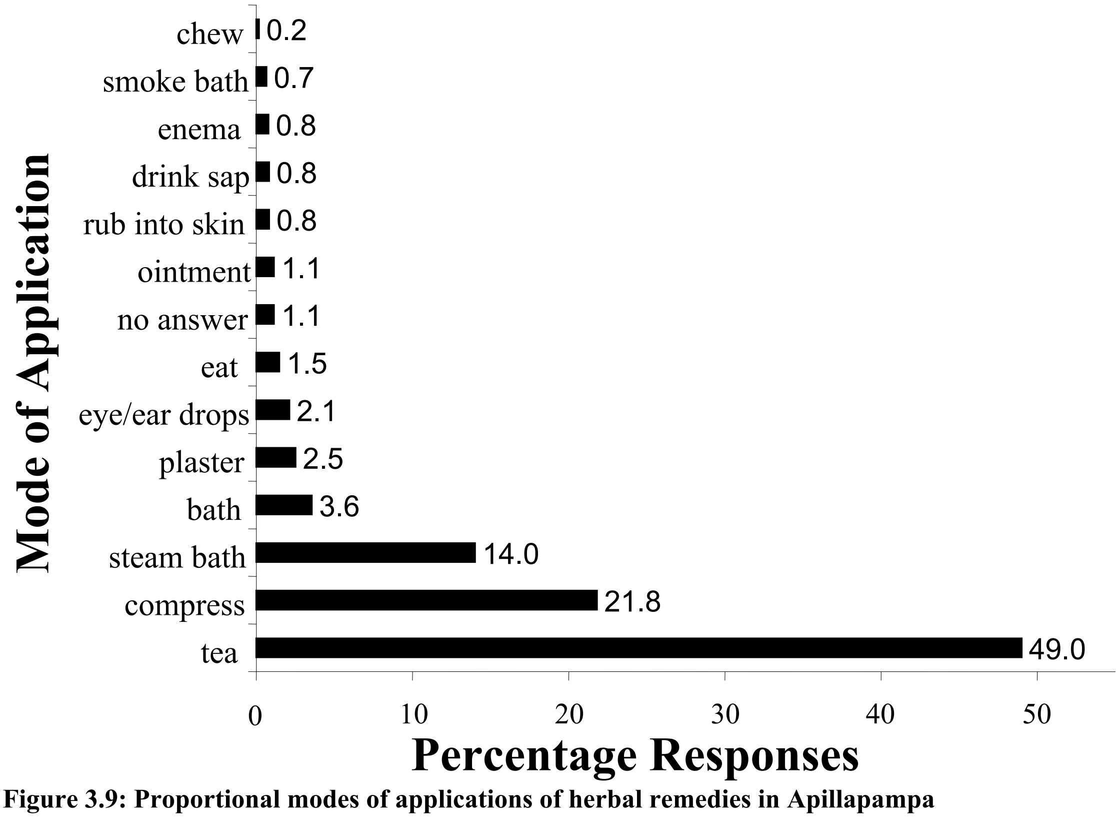

Figure 3.9: Proportional modes of applications of herbal remedies in Apillapampa

The use of steam baths is also relatively important in Apillapampa. They are principally prepared to treat rheumatism (53%) and bad wind or *wayra* (42%) and, as said earlier, contain mixtures of up to twenty different species. The whole plants or plant parts are boiled in water and after some 20-30 minutes the recipient is placed under the patient who is sitting on a chair and is covered with a blanket or a piece of plastic so that the steam produced underneath is inhaled and has maximal contact with the body (Vandebroek *et al.*, 2003). A total of 101 different medicinal species was reportedly used in steam baths. Ointments and therapeutic oils (used for rubbing into the skin) are prepared by boiling various plants (or their parts) in water for at least half an hour. Next, melted animal fat, liquid Vaseline and/or vegetal oil are added. Then, the liquid floating on top of the mixture is decanted and used as an ointment or therapeutic oil. Ointments and oils are mostly used to treat rheumatism, scabies, skin inflammation, wounds and different body pains (Vandebroek *et al.*, 2003).

3.3.4.9. Plant Parts Used

Nearly half of all cited herbal preparations were based on preparation of leaves (44.4%). This ranking was followed by use of the entire plant (14.2%, comprising almost all herbs, (hemi-) parasites and epiphytes), stems (13.1%), roots (6.8%) and flowers (6.6%) (see figure 3.10). Other studies of Andean medicinal plant use in Bolivia (e.g. Macia *et al.*, 2005; Vidaurre, 2000; Girault, 1987) confirm the dominant use of plant leaves in traditional medicine. Plant exudates are most commonly applied externally in Apillapampa. For example, latex of *Asclepias barjoniaefolia* and *Vasconcellea quercifolia* are used to treat warts. In the latter plant, this property might be due the presence of papain, a protein-disintegrating enzyme which is also present in the latex of the related species *Carica papaya* (Grenand *et al.*, 2004; Thomas and Vandebroek, 2006).

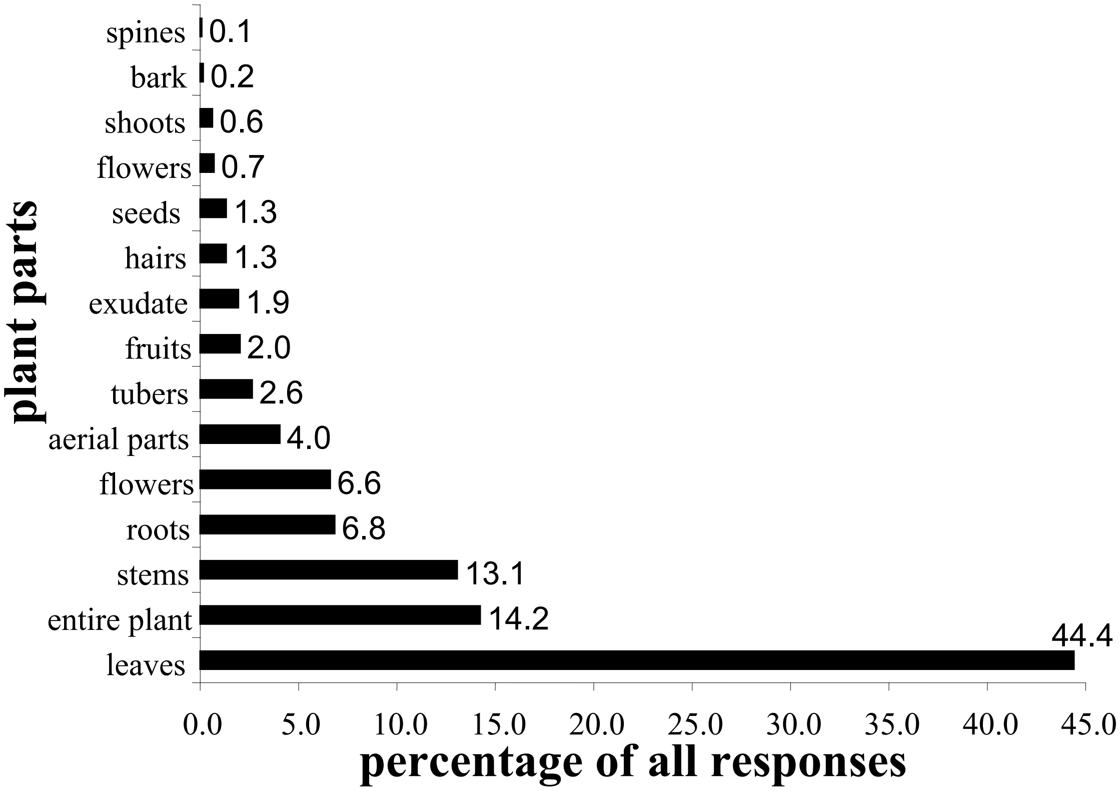

Figure 3.10: Plant parts used to prepare herbal remedies in Apillapampa

The small hairs of all local *Plantago* species are used in compresses to treat wounds. The virtue of *Plantago* in wound healing is well known and was already described in Dioscorides's *Materia Medica* 2,000 years ago (Voeks, 2004).

3.3.5. Food Plant Use

3.3.5.1. Most Important edible families

During research, in particular during transect sampling, it was observed how accompanying participants would constantly pick plant parts and put them in their mouths. Hence, it seemed as if they were continuously testing the taste of plants. Therefore, most people have good knowledge regarding edibility, taste and toxicity of plants. Likewise, people also dispose of profound knowledge about the plants that are favoured, disliked or toxic to livestock (cf. Bentley *et al*., 2005). We will discuss this in more detail later on in this chapter when we report on the negative properties of plants (see section 3.3.11).

Thirty two percent of all plants shown to participants are used as food (i.e. 123 different species). Vandebroek and Sanca (2006) described the food use of six additional species that were not inventoried during the present study, which brings the total of all food species discussed in this work to 129. Food species are distributed over a total of 46 botanical families and 94 genera, whereby Asteraceae (25 species; 19%), Fabaceae (11; 9%), Lamiaceae (9; 7%), Solanaceae (8; 6%), Cactaceae (7; 5%) and Verbenaceae (6; 5%) are the best-represented families. Genera with the highest number of edible species are *Salvia* (5 species), *Solanum* (5) and *Tagetes* (4).

Regression analysis shows that in Apillapampa the number of food species per family (NFS) can be predicted from the family size (the latter is represented here as the total number of inventoried species in a family or NSF) (NFS = 0.229 x NSF + 0.257; r^2=0.84 and $p<0.001$). There are no families with a NFS lower than expected from their respective NSF. Figure 3.11 depicts the families that have data points well above the NFS-NSF regression line. These are Lamiaceae (9 out of 14 species), Cactaceae (all 7 species), Verbenaceae (5 out of 9 species) and Rosaceae (4 out of 6 species) (figure 3.11). In Moerman's (1996) analysis of the food flora of native North Americans, Cactaceae and Rosaceae figure among the top ten families that contain more food species than would be predicted based on their relative sizes. Lamiaceae are, as mentioned before, widely used as medicine and food (Moerman, 1996). The substantial overlap between medicinal and food plants in the Lamiaceae in Apillapampa has also been shown by Vandebroek and Sanca (2006).

The majority of food plants are herbs (64 species; 50%) and shrubs (36; 28%), followed by vines or lianas (9; 7%), cacti (7; 6%) and trees (6; 5%). One epiphyte, three hemiparasites and one grass are also regarded as edible by local participants.

More than two thirds of all edible plants (90 species; 70%) are harvested from natural environments. Homegardens and agricultural fields possess a relative equal importance in providing food with 19 and 18 species, respectively. Only two ruderal plants are edible. Nineteen of all inventoried edible plants are (sporadically to systematically) cultivated in homegardens or agricultural fields, whereas fourteen species are exotics.

3.3.5.2. Plant Parts Used

A total of 170 different food uses were recorded for the 129 edible species inventoried. Most often, the plant part used are leaves (24%), which are – in the same way as young shoots (8%) – used as condiments or to prepare salads and infusions/teas (figure 3.12). One fifth (19%) of species produce fruits that are eaten raw, processed in a hot sauce or used to prepare infusions/teas. Branches (12%) and entire plants (9%) are almost exclusively used in infusions/teas. The flowers of 19 (11%) different plant species are sucked for the sweet nectar they produce, drunk in infusions/teas or refreshing beverages, or eaten cooked. Plant tubers or bulbs, representing 10% of all food uses, are mostly eaten raw or cooked, but some serve also as condiments or to curdle milk.

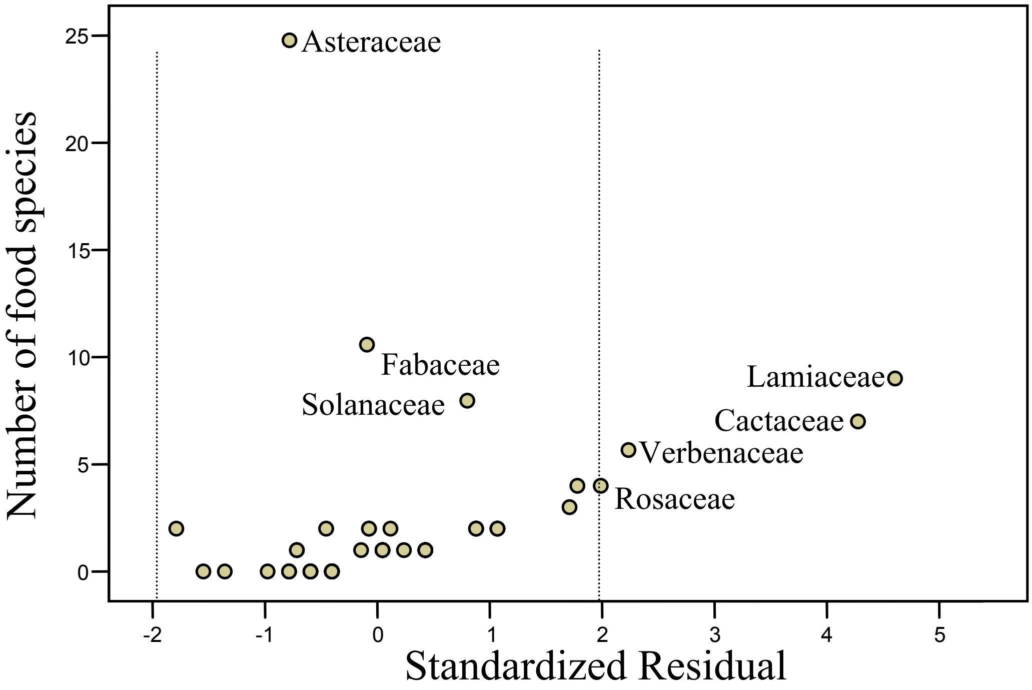

Figure 3.11 Numbers of food species (NFS) vs. standardized residuals of the regression of NFS on family size (NSF). Families with standardized residuals >1.96 or <-1.96 (p=0.05) have significantly higher, respectively lower NFS than expected from their size.

3.3.5.3. Modes of Consumption

More than one third of all food species (38%) is consumed in infusions/teas after soaking or boiling the plant or its parts in (hot) water (figure 3.13). Some teas are aromatic, especially when prepared with *Aloysia gratissima*, *A. triphylla* (both species possess a lemongrass-like taste), *Mentha* cf. *viridis, Schkuhria pinnata, Minthostachys andina, Satureja boliviana* or *Salvia* spp. *Ephedra americana* and *E. rupestris* are drunk in stimulating teas comparable to coffee, which is probably related to the presence of ephedrine in these plants (Hegnauer, 1969). The roots of the grass *Elionurus tripsacoides*, as well as entire young plants of the epiphyte *Tillandsia hirta,* are drunk in teas.

Twenty-six species produce edible fruits or fruit parts (figure 3.13). These are all consumed raw, except for the cultivated *Lupinus mutabilis* of which seeds require boiling and washing for several days in running water to remove a toxic alkaloid (cf. Vandebroek and Sanca, 2006). The seeds of *Prosopis laevigata* possess sweet arils that are consumed as a snack food.

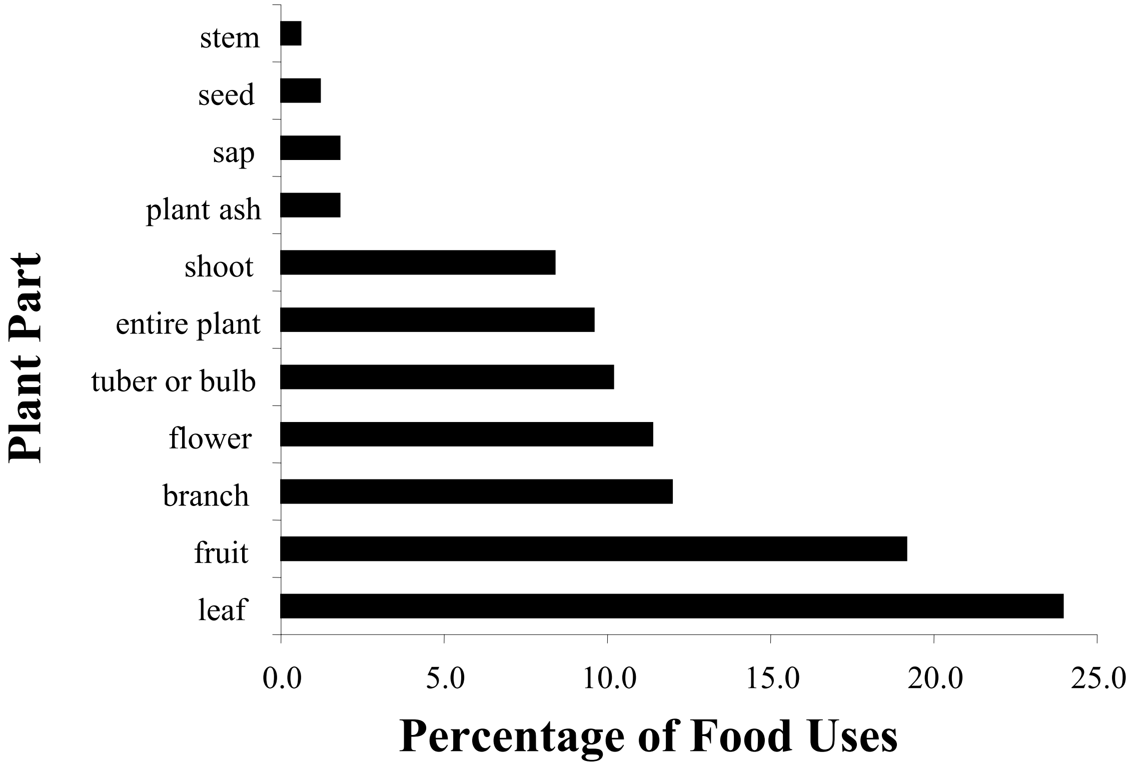

Figure 3.12: Proportional distribution of edible plant parts in Apillapampa

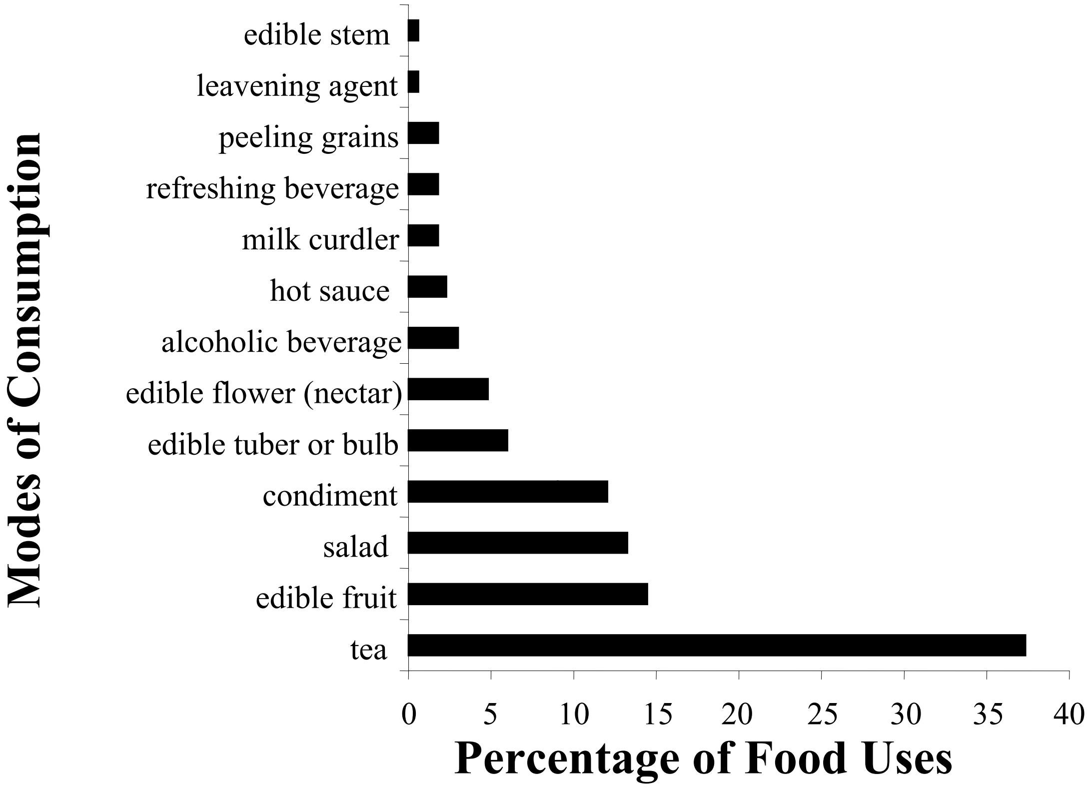

Figure 3.13: Proportional modes of consumption of edible plants in Apillapampa

The seeds themselves are ground into (sweet) edible flour, locally called *pito*, which is consumed raw as well. According to Cardenas (1941), historically these fruits used to be processed into an alcoholic beverage, locally called "*chicha de algarrobo*". The best-represented plant family that produces edible fruits is Cactaceae with seven species, followed by Solanaceae with four species, and Passifloraceae and Berberidaceae with three species each. Although the edibility of *Solanum sisymbriifolium* fruits is confirmed by literature (Vasquez & Coimbra, 2002), one participant warned that they can cause nauseas and hallucinations.

The young shoots and leaves of 22 species are eaten in salads. Intriguingly, these include spiny bushes that might seem unappetizing at first sight, including *Adesmia miraflorensis*, *Berberis boliviana*, *B. commutata* and *B. rariflora.* The young shoots of the latter species were eaten especially during times of famine according to participants. Species that are more widely used to prepare salads are *Amaranthus hybridus*, *Erodium cicutarium*, *Medicago sativa*, *Mimulus glabratus*, *Sonchus asper*, *S. oleraceus*, *Taraxacum officinale* and *Ullucus tuberosus* subsp. *aborigineus* (see Vandebroek and Sanca (2006) for a review of the literature).

A number of aromatic plants are used as condiments in the preparation of bread, soups, salads or main dishes. Two species possess a marked mint odour (*Satureja boliviana* and *Minthostachys andina* (cf. Ulloa, 2006)), while *Hedeoma* cf. *mandoniana* is called *pampa oregano* due to its oregano-like taste. *Tagetes pulsilla* has a characteristic anise aroma and is used as a condiment in preparing soups, bread or *rosquete*, a local biscuit made of flour, eggs, fat and sugar. As confirmed by Ulloa (2006), its aromatic relatives *T. minuta*, *T. multiflora* and *T. terniflora* are only used in soups or main dishes, in analogy with the introduced and cultivated *Ruta graveolens*. The bulb of *Zephyranthes challensis* is also used in the preparation of *rosquete*, while the leaves of *Porophyllum ruderale* are used to season salads, as has also been documented by Ulloa (2006).

Ten species produce edible tubers or bulbs. These include wild relatives of native agricultural tuber crops (*Solanum tuberosum*, *Oxalis tuberosa* and *Tropaeolum tuberosum* (Cadima Fuentes, 2006)). *Solanum megistacrolobum*, *Solanum* sp. 1 and *Tropaeolum pentaphyllum* subsp. *megapetalum* produce small but edible tubers that need cooking, while the sweet tubers of *Oxalis eriolepis* and *O. pinguiculacea* are consumed raw. Interestingly, it is claimed that eating too much *O. eriolepis* tubers causes bed-wetting in children. Participants also mentioned the edibility of the bulbs of *Alstroemeria pygmaea* and the tubers of *Ipomoea dumetorum* (a relative of sweet potato, *Ipomoea batatas*) and *Bidens andicola*.

Children, constantly in search of sweets, suck nectar from the flowers of some eight different taxa. Popular species are *Castilleja pumila*, *Salvia haenkei* and *S. orbignaei*. The sticky fluid contained in the bracts of *Commelina elliptica* is also appreciated. On the other hand, the flowers of the allochthonously-cultivated tree *Erythrina falcata* are prized by grown-ups. They are cooked or processed in sauces or main dishes, as a floral vegetable.

Alcohol is consumed frequently in Apillapampa, especially by the male population. During festivities, home-made beer (*chicha*) is prepared from maize, wheat, barley or mixtures of these. Sometimes, alcoholic beverages are also prepared from the fruits of either *Schinus molle*, *Opuntia ficus-indica* or *Passiflora mollissima* (Vandebroek and Sanca, 2006). Fruits of *Schinus molle* were particularly important in the old days for the elaboration of *chicha de* *molle* (Ulloa, 2006). When no *chicha* is prepared, people use to drink pure (97%), imported alcohol that is often diluted with herbal teas or soft drinks. Sometimes, aromatic plants like *Tripodanthus acutifolius* or *Tagetes pusilla* are macerated in the alcohol for a few days or weeks to flavour it.

As elsewhere in Bolivia, *llajwa* hot sauce is indispensable on the menu in Apillapampa. It is typically prepared by grinding the fruits of the cultivated *Capsicum pubescens* and mixing them with water and salt (cf. Ulloa, 2006). When available, tomatoes or tree tomatoes (*Solanum betaceum*) are added, as are the leaves of *Porophyllum ruderale*. The fruits of the wild *Capsicum eximium* bush are highly esteemed as an alternative for *C. pubescens*. Its small fruits are extremely hot, a characteristic people seem to love since they are fonder of these than of those of *C. pubescens*. However, *C. eximium* is restricted to altitudes lower than the village centre, which explains why its use is rather limited in Apillapampa. Participants declared that people living at lower altitudes often cultivate *C. eximium* instead of *C. pubescens*.

During the dry season, the limited amount of milk produced by livestock is exclusive privilege of the offspring. However, during the rainy season nursing animals can be milked as a consequence of the increased availability of fodder. Yet, even then the amount of extracted milk is limited and people often prefer to curdle it and process it into cheese, rather than 'simply' drinking it. Nowadays, many people say to use "pills" that are imported from the city as curdling agents, but some stick to the traditional practice of using plants. The sap from the tubers of *Begonia baumannii*, *Oxalis eriolepis* and *O. pinguiculacea* can be mixed with milk; after one night, the residue that has formed is separated from its liquid and squeezed into fresh cheese, called *quesillo*. Sometimes, entire tubers of *B. baumanii*, washed and chopped, are put in the milk, in stead of mere sap for the same purpose of making cheese.

Refreshing beverages are occasionally prepared from the sweet ripe fruits of *Schinus molle*, *Prosopis laevigata* or the flowers of *Cosmos peucedanifolius* after grinding and mixing them with water. The mixture is sieved before consumption.

In some cases, it is not the living plant itself that is of interest, but its ashes. The ashes of a considerable number of plants are used with respect to coca insalivation as will be discussed under paragraph 3.3.8. In a food context, plant ashes of *Helogyne straminea*, *Kentrothamnus weddellianus* and *Schinus molle* are boiled together with wheat grains to "tenderize" the hulls so that they can be removed more easily in a mortar.

Two additional food reports are worth mentioning. Interestingly, the stems of the cactus *Echinopsis obrepanda* var. *calorubra* are eaten after removal of its spines, whereas the bulbs of *Nothoscordum* cf. *andicolum* are used as a leavening agent to make dough rise when baking bread.

3.3.5.3. Most Valued Food Plants

As indicated before (3.2.2.2.), assigning qualities to food uses was less relevant in Apillapampa than in the case of medicinal plants. Therefore, food QUV_s values generally equaled UV_s values. In spite of the fact that most species in table 3.11 have one to four different food uses, their use values hardly exceed 1. This implies that not all edible species are appreciated or actually consumed by all participants. Knowledge of a number of (historical) food uses is disappearing, such as those related to famine foods (e.g. young shoots of spiny bushes) and traditional preparations (e.g. *chicha de molle*). Eight out of twenty species that have high food use values are cultivated. Cactaceae is the family that possesses most food species.

Table 3.11: Highest scoring food species based on use values

Scientific name	family	# resp	# uses	$QUV_{food}=UV_{food}$
Satureja boliviana	Lamiaceae	13	4	1.23
Prosopis laevigata *	Fabaceae	12	3	1.17
Schinus molle *	Anacardiaceae	12	3	1.00
*Opuntia ficus-indica**	Cactaceae	6	2	1.00
Oxalis eriolepis	Oxalidaceae	7	2	1.00
Trichocereus tunariensis	Cactaceae	8	1	1.00
*Aloysia triphylla**	Verbenaceae	7	1	1.00
Ipomoea dumetorum	Convolvulaceae	2	2	1.00
*Amaranthus hybridus**	Amaranthaceae	12	1	1.00
Capsicum eximium	Solanaceae	12	3	1.00
Opuntia sulphurea	Cactaceae	2	1	1.00
*Passiflora mollissima**	Passifloraceae	8	2	1.00
Minthostachys andina	Lamiaceae	12	2	0.92
Inga cf. *striata**	Fabaceae	10	1	0.90
Echinopsis obrepanda var. *calorubra*	Cactaceae	12	2	0.83
Tagetes pusilla	Asteraceae	11	3	0.82
Berberis commutata	Berberidaceae	11	2	0.82
Hedeoma cf. *mandoniana*	Lamiaceae	10	1	0.80
*Passiflora umbilicata**	Passifloraceae	9	1	0.78
Echinopsis cochabambensis	Cactaceae	11	1	0.73

resp= responses; *= cultivated species

3.3.6. Fuel Plant Use

A total of 114 different botanical species belonging to 32 families are used as sources of kindling-wood and fuel. Most species are Asteraceae (34 species; 30%) followed by Solanaceae (13; 11), Fabaceae (11; 10), Lamiaceae (7; 6); Euphorbiaceae (5; 4) and Verbenaceae (5; 4). Practically all (sub-)woody plants are used as fuel. Mostly stems and branches are burned, but also the dried leaves of *Eucalyptus globulus* and *Agave americana* are frequently used. Fourteen species, half of which are Fabaceae, are reported as sources of charcoal (see table 3.12). A more detailed account on fuel species is provided in chapter 5.

3.3.7. Material Plant Use

This use category broadly groups all species that are used in construction, technology and handicrafts. At least 69 different species are used as sources of materials in Apillapampa, representing 24 families and 59 genera. Important families are Asteraceae (22 species; 32%), Poaceae (10; 15%), Fabaceae (6; 9%), Anacardiaceae (3; 4%), Loranthaceae (3; 4%), Rosaceae (3; 4%) and Solanaceae (3; 4%). Genera with most material species are *Baccharis* (4 species), *Eupatorium* (3) and *Ophryosporus* (3), which all belong to Asteraceae.

Table 3.12: Plant species used to make charcoal with respective numbers of confirming participants

scientific name	family	growth form	# participants
Schinus molle	Anacardiaceae	tree	2
Mutisia acuminata	Asteraceae	bush	1
Acacia aroma	Fabaceae	tree	2
Acacia visco	Fabaceae	tree	2
Adesmia miraflorensis	Fabaceae	bush	6
Prosopis laevigata	Fabaceae	tree	8
Schinopsis haenkeana	Fabaceae	tree	6
Senna aymara	Fabaceae	bush	1
Tipuana tipu	Fabaceae	tree	1
Kentrothamnus weddellianus	Rhamnaceae	bush	1
Kageneckia lanceolata	Rosaceae	tree	5
Polylepis besseri	Rosaceae	tree	4
Dodonaea viscosa	Sapindaceae	bush	1
Escallonia millegrana	Saxifragaceae	bush	2

The number of material species in a family (NMaS) can be predicted from the total number of species collected in these families (NSF). The regression is highly significant and explains 85% of variation in data (NMaS = 0.209 x NSF - 0.177; r^2=0.85 and $p<0.001$). Analysis of standardized residuals for individual families shows that Lamiaceae is significantly underutilized since none of the 14 species that were inventoried have a material value. Families that contain significantly higher NMaSs than expected from the regression equation are Poaceae (especially useful as roof thatch and mattress stuffing), Loranthaceae and Anacardiaceae.

Most material species have (sub-)woody habits: 43% are shrubs and 25% trees. Grasses rank third as growth form (15%). The list is completed by six herbs, three hemi-parasites, two lianas and one cactus. However, native tree species are clearly the most useful: among the ten species with highly diverse material uses are nine native tree species.

For the 69 material species that were inventoried, a total of 129 different uses was recorded (figure 3.14). Nearly half of these species have more than one material use. Species with highly diverse uses are *Acacia visco* and *Schinus molle;* their wood is used as construction material and to manufacture ploughs, planks or boards, handles and musical instruments. In addition, the wood of *A. visco* is used for fabricating looms.

House Building and Furniture

Walls of houses in Apillapampa are traditionally made with rocks or sun-dried adobe blocks elaborated from a mixture of soil, water and grass. When fresh, the latter mixture is also used as mortar to “cement” individual adobe blocks together or to fill holes between rocks during wall construction. The small simple dwellings that are built near crop fields are always made of rocks. They are round whereas houses in the village are mostly rectangular (figure 3.15B & C). In comparison, houses in the village generally have one or exceptionally two floors and larger dimensions. Larger houses and floors are a consequence of increased availability of large plank wood obtained from cultivated timber species such as *Eucalyptus globulus* and *Pinus radiata*. In times prior to the existence of these plantations, houses were much smaller since most native trees remain relatively small and do not grow straight. A similar trend towards bigger houses has also been reported for other Bolivian Andes communities (e.g. Bentley and Valencia, 2003).

Most material plants are used in house construction and more specifically for roof construction (figure 3.14). The roofs of the small, round huts are typically conical. They are built with an inner layer of branches and stems from trees or bushes such as *Polylepis besseri*, *Acacia visco*, *Schinopsis haenkeana*, *Tipuana tipu*, *Schinus molle, Nicotiana glauca, Gynoxys glabriuscula* and *Lophopappus cuneatus*. The giant peduncle of *Agave americana* is also used here. The outer roof layer is formed by dried stems of mostly *Viguiera australis,* various Poaceae species and less frequently *Viguiera tucumanensis*, *Eupatorium* spp., *Ophryosporus* spp., *Senecio clivicola* or *Stevia galeopsidifolia* (figure 3.15C).

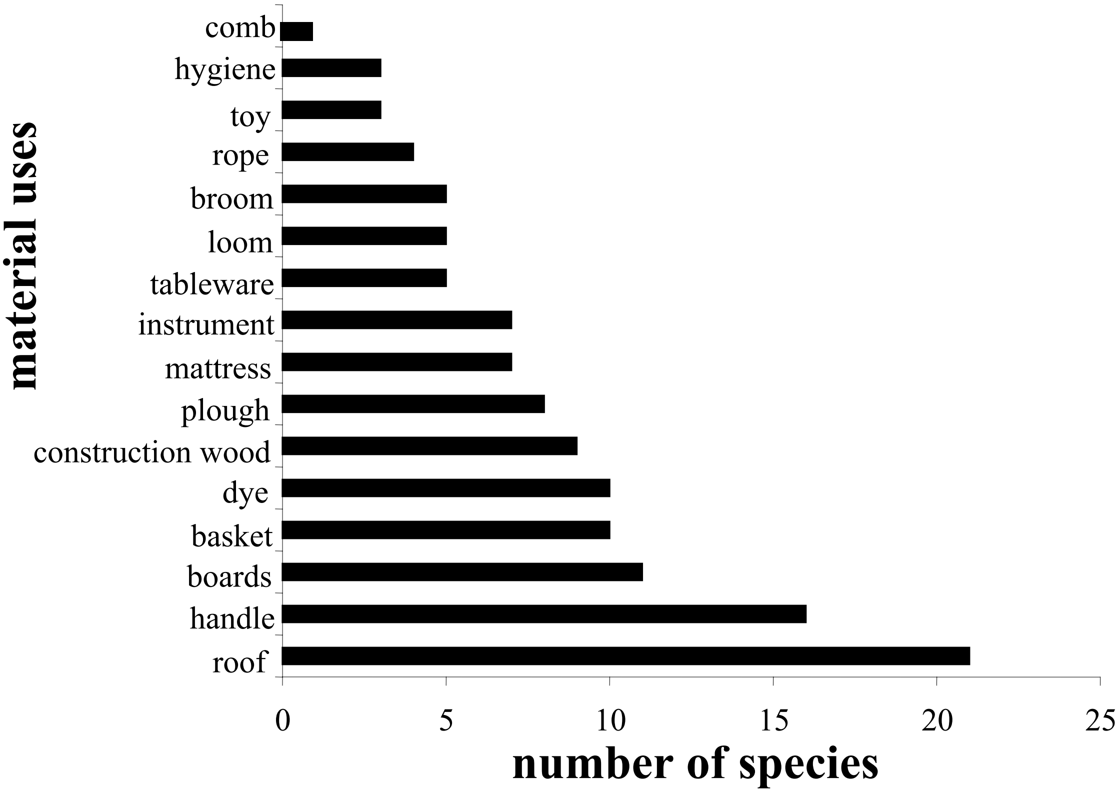

Figure 3.14: Reported material uses with numbers of species

For the roofs of rectangular houses, a frame is built first, either with branches of the same native trees mentioned for the small huts, or with planks from timber species. In most cases, one layer of *Arundo donax* stems, held in place with ropes, is placed on top. Traditionally, these ropes were manufactured from the leaves of the tall grass *Cortaderia rudiuscula* (figure 3.15D), but now purchased alternatives may be used. Since *Arundo donax* does not grow well at Apillapampa altitudes, it is mostly bought in the neighbouring town of Capinota which is situated some 800 m lower. A layer of *Viguiera australis* stems is put on top of the *Arundo donax* stems (figure 3.15B). The outer roof layer consists of bundles of grass that are placed imbricately. For this purpose, large quantities of *Festuca* spp., *Calamagostris* spp. and less frequently *Lamprothyrsus hieronymi*, *Stipa ichu* (both confirmed by Macía, 2006) or *Muhlenbergia rigida* are harvested as whole plants, including roots (figure 3.15A). According to García and Beck (2006), the large and flexible leaves of *Festuca dolichophylla* are highly preferred in high Andean Bolivia for roof thatching. Prior to placing the bundles on the roof, their lower part is “dipped” into a liquid mixture of earth and water to improve durability.

Doors, windows and furniture such as beds, chairs, tables, etc. are now largely made out of planks from timber species (for these purposes, *Salix babylonica, S. humboldtiana*. and *Populus nigra* are also used). However, in line with tradition, *Schinus molle*, *Schinopsis haenkeana*, *Polylepis besseri*, *Maytenus flagellata* and *Acacia visco* are also used. According to one participant, in the old days people used to make coffins out of *Schinus molle*.

Agriculture

Sixteen woody species are used to fabricate handles of axes, pickaxes, shovels, forks etc. (figure 3.15G). Not all wood is useful for this purpose: only wood of species that is somewhat flexible and does not break or splinter easily is chosen. Apart from tree species that are also used in house building, several shrub species are used, including *Berberis commutata*, *Gymnanthes schottiana*, *Mutisia acuminata*, *Tripodanthus acutifolius*, *Spartium junceum*, etc.

Agricultural lands are still ploughed with a pair of oxen and wooden ploughs (figure 1.4B). All men learn to manufacture the latter, but only well after a certain age. Bentley and Valencia (2003) made the same observation for Apharumiri, another Quecha community of the Cochabamba department in Bolivia (also see Bentley *et al*., 2005). According to participants, only eight tree species produce wood that is resistant enough to fabricate durable ploughs: *Acacia aroma*, *A. visco*, *Aspidosperma quebracho-blanco*, *Kageneckia lanceolata*, *Prosopis laevigata*, *Schinopsis haenkeana*, *Schinus molle* and *Tipuana tipu*.

Wool Spinning, Colouring and Weaving

Whereas the role of men in agriculture is primarily focused on crop production, animal husbandry is more a daily occupation of women and children who spend a lot of time herding sheep and goats. While watching over the animals, women often dedicate free time to spin wool that is cut of or left behind by sheep when grating against spiny bushes. For spinning wool, people use a simple instrument, locally called *phusqa* that consists of a wooden stick of about 30-40 cm long with a transversally located disk at about one fourth of its length (figure 3.15F). Wool is turned into thread by making the *phusqa* spin on the ground while standing or being seated. The sticks of the *phusqa* are typically manufactured from *Proustia cuneifolia*, as according to participants the wood of this species is most appropriate for this use.

Once enough thread is produced to process it into a *poncho* (figure 1.4D) or a simple rectangular cloth called *awayu*, it is dyed. *Awayus* are used to carry almost anything on one’s back, including babies. They represent a very characteristic cultural good of Quechua people. Nowadays, more frequently commercial dyes are imported from the city of Cochabamba as they are relatively cheap and come in all possible bright colours. However, ten different species were mentioned as source of natural dyes. Plant parts are boiled in water together with the thread to fix the colour. Green is obtained from the branches of *Dodonaea viscosa* while the bark and wood of *Berberis commutata* and the flowers of *Coreopsis* sp. provide yellow dyes. *Baccharis torricoi* is somewhat positioned in between since it produces yellow to green colours, depending on the quantity of branches used and hence the concentration of the liquid

Figure 3.15 A: Tying bundles of *Festuca* sp. for roof thatch together, prior to transportation to the village on the back of donkeys; B: House in the village manufactured from adobe blocks. The lower roof layer consists of cylindrical *Arundo donax* culms with dried stems from *Viguiera australis* on top. The outer roof layer (bundles of grass species such as in A) is not yet applied in this picture; C: Small house typically built near crop fields by means of rocks; D: Rope made from *Cortaderia rudiuscula*; E: small broom manufactured from the stems of *Muhlenbergia rigida* F: *Phusqa* used for spinning wool; G: Four-pronged fork, manufactured locally

obtained. The flowers of the small cactus *Opuntia vestita* give a red colour and the bark of *Prosopis laevigata* a brown one. Finally, the hemiparasites *Tristerix penduliflorus* and *Ligaria cuneifolia* colour threads black, just like *Eupatorium tunariense.* One participant also mentioned using the flowers of the cultivated rose *Rosa* x *noisettiana* cf. for dying but no colour was specified. After dyeing, threads are dried in the sun and then they are ready to be woven. Five species were mentioned for the construction of looms (figure 1.4E): *Acacia visco*, *Escallonia millegrana*, *Kageneckia lanceolata*, *Lophopappus cuneatus* and *Proustia cuneifolia*.

Handicrafts

Ten different species are used for manufacturing baskets, with a clear dominance of Asteraceae species (6 out of 10). Most popular and durable are *Baccharis salicifolia*, *Hyaloseris quadriflora*, *Tecoma ternuiflora* and *Tessaria dodonaeifolia*, but *Baccharis pentlandii*, *Kageneckia lanceolata*, *Maytenus flagellata*, *Plazia daphnoides* and *Salix humboldtiana* are also used. According to participants, baskets always have been, and still are, favourite trading goods. It is still common practice for Apillapampeños to trade baskets with people living at lower altitudes for the quantity of potatoes they can contain. The basic motive is that the best basket plants typically grow at higher altitudes, while the traded potatoes can only be cultivated at lower heights. This example corresponds to Bastien's (1982) argument that the Andean economic system was characterized by specialization, verticality and reciprocity. According to the latter author, Andeans specialize in extracting natural resources at different altitudes of mountain zones (verticality) and exchange them for those produced by people living at other altitudes (reciprocity; cf. section 1.2.1). The splendid quality of the branches of *Tecoma ternuiflora* for manufacturing baskets is confirmed by Beck *et al*. (2001), while Cárdenas (1989) reported the use of *B. salicifolia.* Finally, Torrico *et al*. (1994) validate the use of *Plazia daphnoides*, *Kageneckia lanceolata* and *Salix humboldtiana* in basket making.

Nowadays, mattresses are fabricated by sowing synthetic potato sacks together and stuffing them with grass. *Bothriochloa barbinoides*, *Calamagostris* sp*.*, *Cortaderia rudiuscula*, *Festuca boliviana*, *Lamprothyrsus hieronymi*, *Poa buchtienii* and *Stipa ichu* are used for this purpose, among others.

In the old days, all tableware was carved from local wood, including cups, plates, spoons, etc. This tradition is rapidly disappearing with the invasion of plastics and cheep metal cutlery. Nevertheless, most participants still remember and can name species that are best suited for these purposes: *Aspidosperma quebracho-blanco*, *Escallonia millegrana*, *Maytenus flagellata*, *Polylepis besseri* and *Schinopsis haenkeana*.

A simple but practical tool that is present in all houses is the broom. *Muhlenbergia rigida* (Poaceae) (figure 3.15E) is considered the single best species to manufacture brooms (cf. Macía, 2006). Its popularity is far from restricted to Apillapampa and even the cleaning services of the major Bolivian highland cities (e.g. Cochabamba and La Paz) use it. However, in times of need, other species, such as *Calamagostris* sp. or *Stipa ichu* (confirmed by Macia, 2006) are also used. For cleaning yards, branches of *Baccharis dracunculifolia* or *Lophopappus cuneatus* are simply bound together.

Combs are locally made out of the peduncle of *Puya glabrescens* (Bromeliaceae) by double folding a 30 cm long section of the coarse fibres it contains, hereby forming a kind of rigid brush.

Miscellaneous Uses

A kind of shampoo or soap can be prepared by rubbing the roots of *Kentrothamnus weddellianus*, or the leaves of *Cestrum parqui* or *Eupatorium hookerianum*, in water.

Important musical instruments in Apillapampa are panpipes, flutes and drums (figure 3.19E). On occasion, a small stringed instrument called *charango* is played but this one does not appear to be manufactured locally. Drums are made from animal skin and the wood of one of the following tree species: *Acacia visco*, *Aspidosperma quebracho-blanco*, *Escallonia millegrana*, *Maytenus flagellata*, *Prosopis laevigata*, *Schinus microphyllus* and *S. molle*.

In past days, the leaves of *Agave americana* were processed into cords, a practice that is still common in Latin America (cf. Macia, 2006). *Prosopis laevigata* spines are so incredibly hard that they are sometimes used as nail substitutes to repair people's sandals that are made of old automobile tires.

Most Valued Material Plants

In table 3.13, the twenty most important material species are ranked according to their quality use value. Nearly all species in this list are used for at least two different material applications. However, consensus regarding these uses is low since UV_{mat} and QUV_{mat} values are always lower than two, except for *Eucalyptus globulus* and *Acacia visco*. Low values may point to a gradual loss of traditional practices concerning the use of natural materials.

Table 3.13: Ranking of material plants according to quality use values

Scientific name	family	# part	# uses	QUV_{mat}	UV_{mat}
*Eucalyptus globulus**	Myrtaceae	2	2	2.00	2.00
Acacia visco	Fabaceae	10	6	1.90	2.00
Aspidosperma quebracho-blanco	Apocynaceae	10	4	1.60	1.60
Calamagostris sp.	Poaceae	10	3	1.40	1.40
Poa buchtienii	Poaceae	10	2	1.25	1.40
Stipa ichu	Poaceae	12	4	1.21	1.25
Kageneckia lanceolata	Rosaceae	11	4	1.18	1.18
*Agave americana**	Agavaceae	12	4	1.17	1.25
Prosopis laevigata	Fabaceae	12	4	1.08	1.08
Schinopsis haenkeana	Anacardiaceae	12	5	1.08	1.08
Festuca boliviana	Poaceae	11	2	1.05	1.09
Maytenus flagellata	Celastraceae	5	5	1.00	1.00
Muhlenbergia rigida	Poaceae	12	2	1.00	1.00
*Arundo donax**	Poaceae	2	1	1.00	1.00
Viguiera australis	Asteraceae	12	2	0.96	1.00
*Pinus radiata**	Pinaceae	11	3	0.95	1.00
Tecoma ternuiflora	Bignoniaceae	8	1	0.88	0.88
Schinus molle	Anacardiaceae	12	6	0.71	0.88
Polylepis besseri	Rosaceae	11	4	0.64	0.64
Proustia cuneifolia	Asteraceae	11	3	0.64	0.64

part= number of participants interviewed
* introduced species

3.3.8. Social Plant Use

Plant applications categorized as social uses include ritual, religious and spiritual uses, as well as smoking materials and drugs. At least 58 different species are used within this category in Apillapampa. They are distributed over 24 families and 47 genera. The families with most species are Asteraceae (18 species; 31%), Lamiaceae (5; 9%), Fabaceae (4; 7%) and Solanaceae (4; 7%). The most diverse genera in terms of number of species are *Baccharis* (6 species) and *Salvia* (3 taxa).

The number of species with social uses in a family (NSoS) can be predicted from the number of species collected in that family (NSF) (NSoS= 0.154 x NSF- 0.084 (r^2=0.88 and $p<0.001$). Standardized residuals analysis shows that Asclepiadaceae are significantly underutilized based on the number of inventoried species. On the other hand, within Lamiaceae, Loranthaceae, Berberidaceae and Rhamnaceae more species are used than expected from the regression equation. Most plants with a social use value are shrubs (33 species; 57%), followed by herbs (11 species; 19%) and trees (6 species; 10%).

Quite a number of species (22) are used to treat *maldiciones* or curses (Figure 3.16). Especially plants with spines (fourteen species or 64%) are prevalent for this use. Curses are believed to induce a series of symptoms, including pains in any body part, weak pulse, general fatigue and listlessness. In general, this condition is diagnosed by a traditional healer through consultation of dried coca leaves, but patients can also be warned about having this condition by their dreams (Vandebroek *et al.*, 2003). *Maldición* is nearly always treated with herbal teas, but sporadically herbal baths or compresses are also prepared. Among the most popular species there are: *Chuquiraga parviflora*, *Barnadesia macrocephala*, *Colletia spinosissima*, *Spartium junceum*, *Kageneckia lanceolata*, *Berberis rariflora*, *B. boliviana*, *B. commutata* and *Caiophora canarinoides*.

Three plant species are used preventively to avert curses or other spiritual threats. Charcoal prepared from *Heterophyllaea lycioides* is thrown in the air or worn in a small bag around one's neck. Branches of *Spartium junceum* are hung at the entrance of houses and *Acicarpha tribuloides* is drunk in teas.

As shown in figure 3.16, six plant species have been or are still used in a ritual-religious context. Various participants confirmed that in the past sheep that suffered from an unspecified disease where treated by traditional healers or *jatiris* by means of a ritual ceremony. While reciting ritual texts, sheep were guided with branches of *Bomarea dulcis* through an arc made of palm leaves (probably *Parajubaea torallyi* (Wood, 2005)). Another ritual is related to lack of rainfall. When rain keeps off too long, all men in the village are encouraged to participate in ritual singing and lamentations that can go on for various days and nights, as we have been able to witness ourselves. During these ceremonies, people drink (imported, 97%) alcohol and chew coca leaves. One of the practices in the ritual rain calling ceremony includes transporting water from one well to another, as well as transplanting the tubers of *Begonia baumannii* (called: *granisu t'ika* or hail flower) from one place to another.

Schinus molle, *Cupressus* sp., *Rosa* x *noisettiana* cf. and *Tillandsia usneoides* (figure 3.19F) are used as decorative elements during festivities such as marriages, at Christmas, etc.

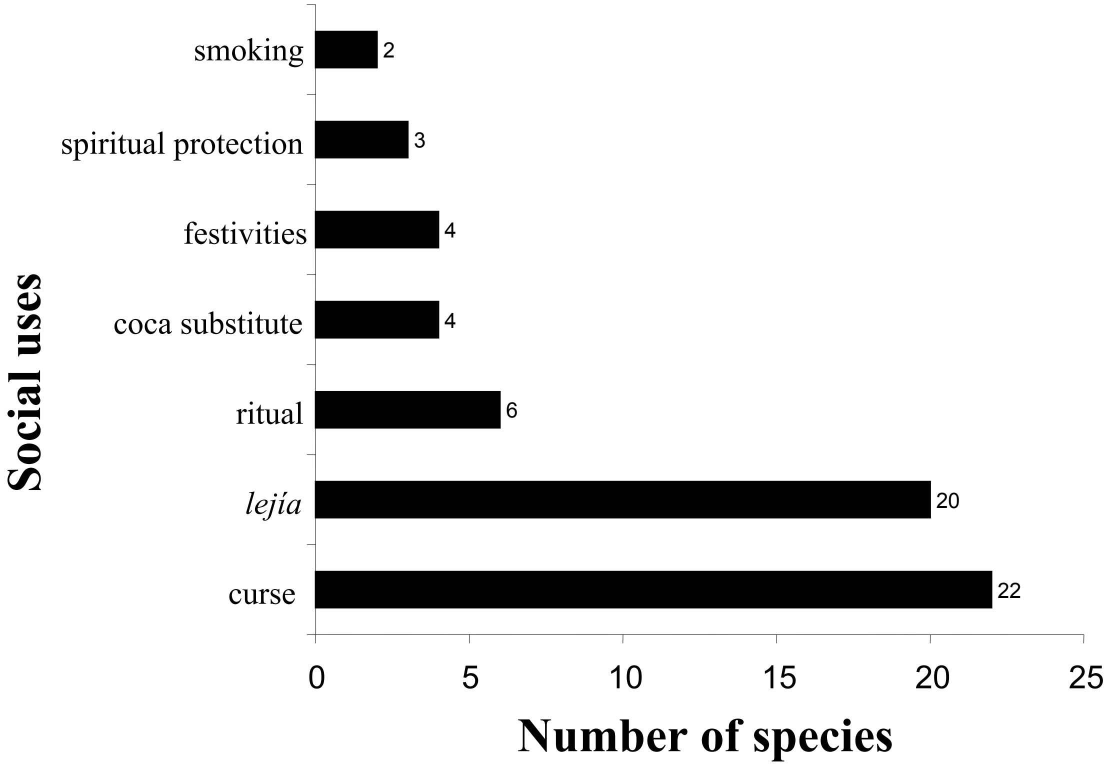

Figure 3.16: Numbers of reported species for different social uses

Tea prepared from *Tetraglochin cristatum* and/or *Glandularia aristigera* has a religious connotation and is typically drunk during the holy week (*Semana Santa*) before Easter. The latter plant is locally called *mamanchipaj thuqani* (Quechua) which translates into "the spit of our holy mother" due to the belief that the plant appeared where the mother of Christ spat on the ground. *Apium leptophyllum* is believed to cure envy, whereas *Muhlenbergia rigida* is drunk in teas when someone wants to separate from his or her partner.

Coca (*Erythroxylum coca*) insalivation is a nearly daily practice for the larger part of the adult male population in Apillapampa. Most coca leaves are imported from the city of Cochabamba, but some producers import and sell them personally. Coca consumed in town is produced in Chapare, the province where the second part of this study was executed (chapters 6-11). Various families in Apillapampa own terrains there on which they grow coca as a cash crop among other, less marketable, crops such as bananas, plantains, citrus fruits, mangos, etc. A few times per year these people return to Apillapampa to work the lands they still own there. During these short stays, they bring along part of the coca harvest to sell it to other villagers.

The use of coca leaves is not addictive and is basically practiced to promote endurance, relieve fatigue and overcome the effects of hunger and thirst while walking, climbing and working on the steep Andean slopes (Vandebroek and Sanca, 2006). It is common practice to chew the leaves together with plant ash, or *lejía*, which is prepared by mixing the ashes of some particular plant species with water and baking this mass in an oven like bread. Plant ash of the selected species consists of alkaline substances that are responsible for the transformation of stimulating coca alkaloids to free bases, thus promoting physiological effects (Hilgert *et al.*, 2001). As an alternative, sometimes commercial sodium carbonate ($NaHCO_3$) is used.

Twenty different plant species were mentioned to be used in the preparation of *lejía*. Nine are Asteraceae and species with the highest degree of consensus are *Baccharis linearifolia* subsp. *polycephala*, *B. prostrata*, *B. torricoi*, *Cestrum parqui*, *Cleistocactus buchtienii*, *Helogyne straminea*, *Ligaria cuneifolia*, *Tristerix penduliflorus* and *Salvia haenkei*.

Participants also named four species of which leaves can be chewed as a local alternative for coca. These comprise *Tipuana tipu*, *Jatropha gossypiifolia*, *Tithonia* aff. *tubiformis* and *Satureja boliviana*. For smoking, basically the leaves of the cultivated *Nicotiana otophora* are used, but also those of the small herb *Hedeoma* cf. *mandoniana* have been mentioned.

All but three species only possess one social use. Nonetheless, variation in quality use values is rather large, indicating that most social uses of plants are not practiced (anymore), nor remembered by most participants. Assigning qualities to social uses is not very relevant, as evidenced by UV and QUV values in table 3.14 which are nearly equal.

Table 3.14: Ranking of social use plants according to (quality) use values

Scientific name	family	# resp	# uses	$UV_{soc\ uses}$	$QUV_{soc\ uses}$
Nicotiana otophora	Solanaceae	12	1	0.92	0.92
Helogyne straminea	Asteraceae	11	1	0.82	0.77
*Spartium junceum**	Fabaceae	12	3	0.67	0.67
Ligaria cuneifolia	Loranthaceae	12	1	0.67	0.63
Cleistocactus buchtienii	Cactaceae	11	2	0.64	0.55
Baccharis linearifolia subsp. *polycephala*	Asteraceae	12	1	0.50	0.50
Chuquiraga parviflora	Asteraceae	11	1	0.45	0.41
Baccharis prostrata	Asteraceae	12	1	0.42	0.38
Berberis rariflora	Berberidaceae	6	1	0.33	0.33
Tipuana tipu	Fabaceae	9	1	0.33	0.33
Tristerix penduliflorus	Loranthaceae	11	1	0.36	0.32
Colletia spinosissima	Rhamnaceae	11	1	0.36	0.27
Salvia haenkei	Lamiaceae	11	1	0.27	0.27
Cestrum parqui	Solanaceae	12	1	0.25	0.25
Cupressus sp.*	Cupressaceae	10	1	0.20	0.20
Baccharis torricoi	Asteraceae	11	1	0.18	0.18
Eupatorium tunariense	Asteraceae	11	1	0.18	0.18
Bomarea dulcis	Alstroemeriaceae	11	1	0.18	0.18
Kageneckia lanceolata	Rosaceae	11	1	0.18	0.18
Ophryosporus charua	Asteraceae	11	1	0.18	0.18

resp.= number of responses; *= introduced species

3.3.9. Environmental Plant Use

At least 39 different species, distributed over 15 families, possess (an) environmental use(s) in Apillapampa. Asteraceae (15 species; 38%), Fabaceae (7 species; 18%) and Rosaceae (4 species; 10%) are the families that contain most species related to this use category.

More than half of all species mentioned in this category are used as organic fertilizer (figure 3.17). Under the impulse of the NGO FEPADE, farmers are encouraged to produce organic compost from wild plants to fertilize crop species as an alternative for imported chicken dung or other chemical fertilizers. Compost heaps are produced by alternating layers of cut wild plant biomass with layers of dung from livestock mixed with ashes from the fire. Probably more species than the ones cited here are actually used for this purpose, because some participants claimed to use about any herbaceous plant for this purpose.

Another initiative that is stimulated by the NGO FEPADE is the production of plantlets of useful plant species such as *Eucalyptus globulus*, *Passiflora mollissima* or *Spartium junceum* in small-scale plant nurseries. These plants are cultivated in a substrate that is a mixture of two parts of sand, one part organic fertilizer or mulch and one so-called part of black earth (rich in organic substance) (Bentley and Valencia, 2003). The mulch is collected under trees such as *Acacia visco*, *Schinopsis haenkeana, Tipuana tipu, Schinus molle* and *Prosopis laevigata*. The latter two species are locally recognized as active soil improvers and are tolerated in crop fields because of this quality (figure 3.19A). This practice is confirmed by Bentley and Valencia (2003).

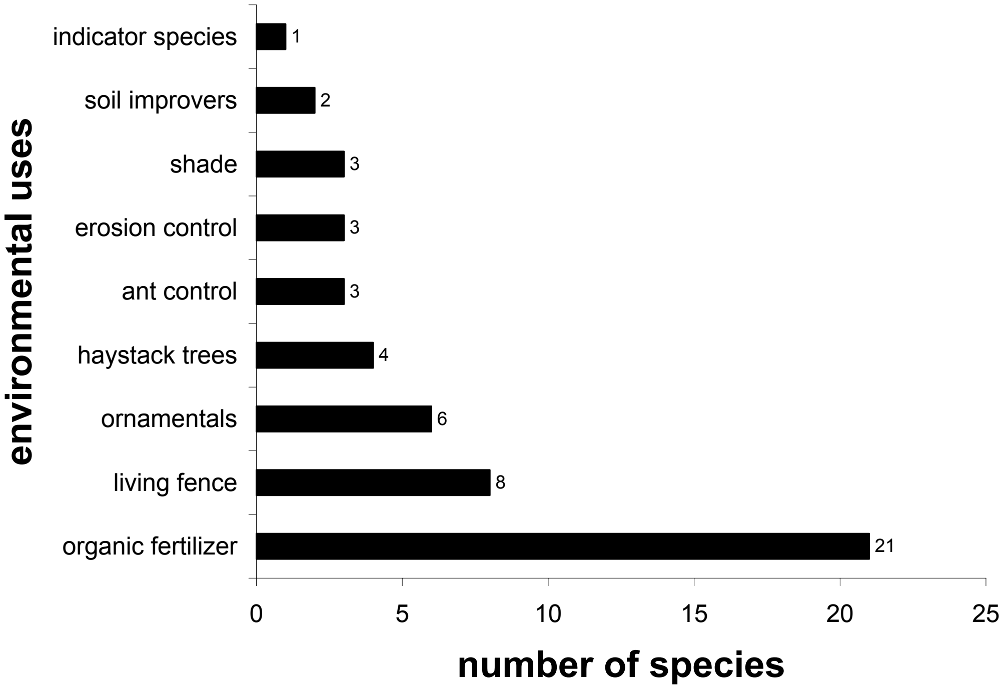

Figure 3.17: The number of reported plant species according to different types of environmental uses.

We have been able to observe first hand how wheat was indeed growing at least 10 cm higher within a radius of 3-5 meters around a *Prosopis laevigata* tree. Soil enrichment of the latter species is probably related to symbiosis with nitrogen-fixing *Rhizobium* bacteria (Olalde Portugal and Aguilera Gómez, 1998), apart from other beneficial services provided by the tree such as the production of leaf litter, the creation of a micro-climate and the reduction of the negative impact of rain.

A number of species are planted or transplanted in order to form living fences that prevent animals from trespassing. Most of these species have spines, e.g. *Caesalpinia spinosa, Adesmia miraflorensis, Agave americana, Rubus* cf. *ulmifolius* or *Berberis boliviana*. Cut pieces of *Cleistocactus buchtienii* stems are typically laid horizontally on stone walls together with some soil substrate, where they grow steadily. Closely planted rows of *Spartium junceum* and *Cupressus* sp. also serve as living fences. For erosion control, *Spartium junceum, Agave americana* and *Calamagostris* sp. are planted along contour lines.

To prevent livestock from eating crop residues (mostly dried maize or wheat stalks), the latter are stored in crowns of native trees. Starting from the sapling stage, tree branches are manipulated in a way that forces them to spread out. Each year a larger bundle of maize stalks is stored between the branches of these living haylofts. *Schinus molle* and *Prosopis laevigata* are most used as haystack trees (figure 3.19D), but *Acacia visco* and *Schinopsis haenkeana* have also been reported. The use of haystack trees is also described by Bentley and Valencia (2003) and has even been documented from China, *inter alia* (P. Van Damme, pers. comm.).

An interesting practice to prevent leaf-cutter ants from attacking crop species consists in leading them away by deliberately placing cut off branches of their favourite wild plants (e.g. *Heliotropium microstachyum*, *Senna aymara* and *Vasconcellea quercifolia*) around crop fields. Main motivation is that by feeding the ants wild plants, they will not disturb crops. A more drastic alternative is to burn the ant nests as we have observed on various occasions.

One environmental indicator species, *Barbaceniopsis boliviensis*, is used to predict rain. It is said that the leaves of this plant turn yellow when it is going to rain in the next couple of days.

Environmental Services Provided by Wild Plants

In order to assess local people’s awareness of the environmental services wild plants provide to the local ecosystem, participants were asked whether they felt the plants under scrutiny contributed to natural ecosystem functioning (including wild fauna) in any kind of way. According to participants, eighty-seven percent of all inventoried plant species (i.e. 337 species) provide at least one environmental service (figure 3.18). Seventy nine percent of these species provide two or more services. Most species (324) were reported to protect the soil against erosion through their root system (figure 3.19B&C). Two hundred and twenty four species were said to improve soil fertility through the production of leaf litter. According to participants, wild mammals and birds find refuge in at least 186 species to build nests and/or breed, and 46 species provide them with edible plant parts.

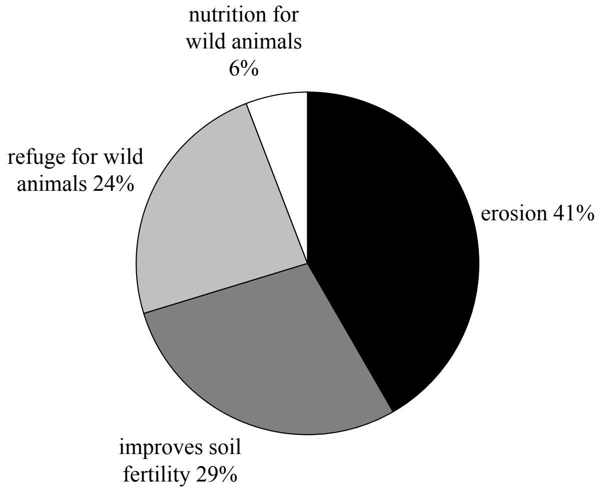

Figure 3.18: Proportional distribution of all environmental services provided by wild plant species

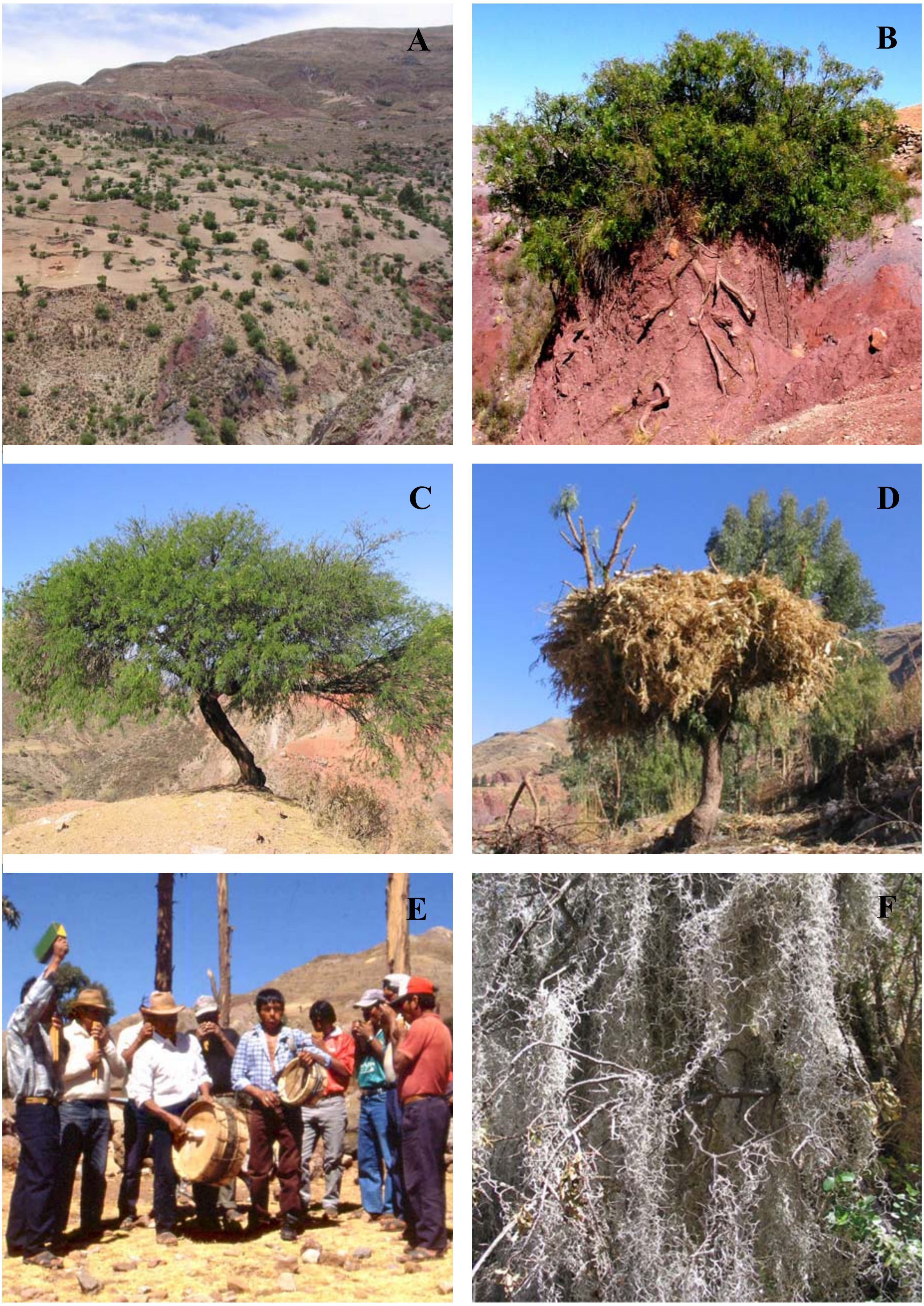

Figure 3.19 A: View of the agricultural landscape in Apillapampa, illustrating the popularity of combining multipurpose trees (here mostly *Schinus molle*) with crop production; B Image illustrating (i) high local erosion rates and (ii) the impressive potential of *S. molle* for erosion control; C: The multipurpose tree *Prosopis laevigata*; D: Use of *S. molle* as a haystack tree; E: Musical instruments used in Apillapampa; drums are manufactured locally (photograph courtesy of I. Vandebroek); F *Tillandsia usneoides* is harvested and sold as a decorative element at Christmas

3.3.10. Poison Plants

At least three species are used as insecticides and repellents. The leaves of *Calceolaria engleriana* are ground and macerated in water for two days. The extract is then used to fumigate crops. An aqueous extract prepared from the bark of *Aspidosperma quebracho-blanco* is used to kill bugs, locally called *vinchucas* (probably *Triatoma infestans*), one of the vectors of the Chagas' parasite (*Trypanosoma cruzi*). Chagas' disease remains a serious public health problem in Bolivia. The dry Interandean valleys of the Cochabamba department to which our study area belongs is considered the center of dispersion of the Chagas' parasite vector (Albarracin-Veizaga, 1999; Vandebroek *et al*., 2008). Finally, the pungent *Schkuhria pinnata* is said to be an effective repellent against flees. Therefore people often put various plants under their beds to ensure a good night's sleep.

3.3.11. Negative Properties of Plants

In spite of the numerous goods and services plants provide to man, quite a number of species also possess negative properties. Some plants compete with agricultural crops (i.e. weeds), while others are poisonous to people and/or livestock (figure 3.20). Negative properties were reported for 175 different species (45 % of all the plant species that were presented to participants), belonging to 43 families. A strong correlation exists between the number of species with negative properties (NNeS) in a family and family size (NSF) (NNeS = 0.507 x NSF - 0.329; r^2= 0.97 and p<0.001 (linear regression). Standardized residuals analysis shows that based on family size, Solanaceae and Euphorbiaceae are statistically overrepresented in the group of species with negative properties, while Lamiaceae is underrepresented.

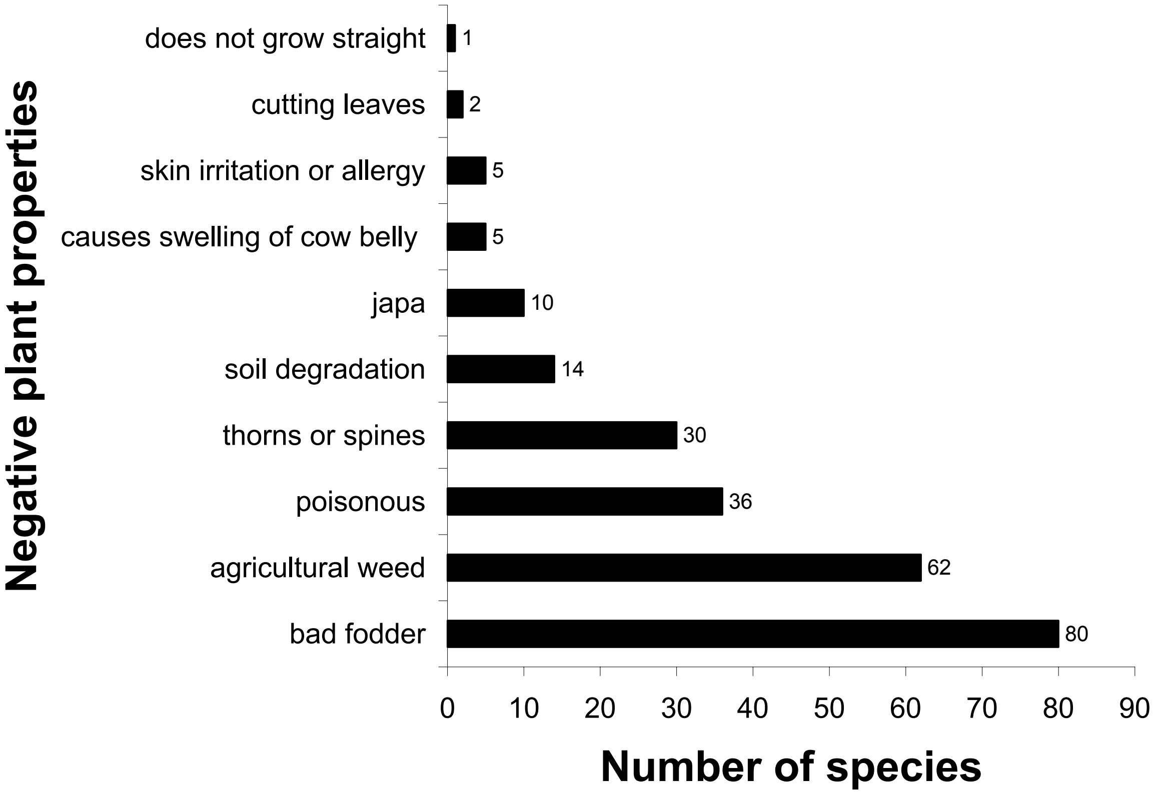

Figure 3.20: Locally perceived negative plant properties with respective numbers of plant species

When evaluating negative properties of individual plant species, Apillapampeños show a tendency to partly base their judgment on utilitarian motives. Plants that are neither harmful nor useful are often regarded as negative. For example, although not necessarily toxic, many plant species (80) are not appreciated by livestock. Farmers relate this to the bad taste of these plants and therefore often consider them as negative. Likewise, participants explained that some native trees or shrubs, such as *Schinus microphyllus*, would provide good construction material if they would grow straight rather than curvy, which is therefore considered to be a negative property. Thorns, spines and sharp leaf edges are also viewed as a negative property of plants. It makes plants less palatable and attractive to livestock. Moreover, they cause people and animals to cut themselves when walking through vegetation or harvesting firewood (Bentley *et al*., 2005).

Sixty two species have been identified locally as agricultural weeds. While disliked for their tendency to compete with agricultural crops, many weed species provide good fodder and human food, as well as herbal medicines. More harmful for crop production are species that actually degrade soil. Fourteen species are believed to deteriorate soil fertility, such as *Eucalyptus globulus*, *Pinus radiata*, *Cupressus* sp., *Agave americana* and *Otholobium pubescens*. Participants declared that some of these species “suck” the soil, depriving it from its nutrients (e.g. *Agave americana*), while the leaf litter produced by others is toxic to crop species (e.g. *Eucalyptus globulus*).

According to participants, forty-three species are poisonous to livestock to a varying extent. Ten of these species are said to cause *japa*. *Japa* is a health condition in animals evidenced by bloodshot swollen opaque bluish eyes. It is claimed that, if not cured in time, this condition can lead to blindness. Bentley and Valencia (2003) recorded a similar description of *japa* in their study area in Apharumiri. It occurs when animals eat or grate against the branches of some particular bushes (*Astragalus garbansillo*, *Dalea pazensis*, *D. boliviana, Gymnanthes schottiana*, *Heterophyllaea lycioides*, *Menodora pulchella*, *Lupinus erectifolius* and *L. tatei* among others), or when they are stung by an insect that is appropriately called *japa* as well. The toxicity of *Astragalus garbansillo* has been pointed out by Pestalozzi (1998) who ascribed it to the plant’s high selenium and alkaloid content. Excessive consumption may lead to death in sheep. In the Chilean Andes, *Astralagus cryptanthus*, is said to be toxic for livestock (Villagrán *et al*., 2003).

Other poisonous plants might also cause death among livestock. Although the fresh leaves of *Kageneckia lanceolata* do not cause adverse effects in goats, extreme caution is taken to prevent them from eating wilting leaves as these are lethal. The same accounts for the wilted leaves of *Cestrum parqui* and even of peach (*Prunus persica*). Again, Bentley and Valencia (2003) made the same observations in the Quechua community of Apharumiri. Other reported poisonous plants include: *Cestrum atroxantum*, *Lycianthes lycioides*, *Passiflora umbilicata* and *Spathantheum orbignyanum*.

Five plants were claimed to make a cow’s belly swell and, when eaten excessively, they might even cause it to burst. Intriguingly, also the cultivated fodder species *Medicago sativo* appears in this list. According to participants, care is taken not to feed animals with freshly cut shoots, but only after they have been dried for a few hours.

A few species have a negative connotation because they cause skin irritation or allergy. Included here are: the nettle species *Urtica urens*, *Caiophora canarinoides*, *Heterophyllaea lycioides* and *Schinopsis haenkeana*. Especially touching the latter species can cause severe allergic reactions over the entire skin as we have witnessed personally in a participant who accompanied us during transect sampling. People believe that little organisms called "*khapas"* that live on the tree are responsible for this reaction.

3.4. Conclusions

In this chapter we have provided a general overview of plant use in Apillapampa. It is shown that people in Apillapampa still know and use a wide variety of wild plant species for important aspects of their daily life. Most plant species are used in the categories of animal food, medicine, fuel and food. The importance of different use categories, both in terms of the number of species and average use values, reflects the relative importance of different types of plant uses in people's daily life. In Apillapampa, animal husbandry is an essential part of life and the use of medicinal plants has an excelling tradition. As demonstrated in chapter 5, also the use of wild fuel plants is highly important for people's subsistence.

We have demonstrated that plant knowledge of participants in Apillapampa is largely controlled by age. Particularly, the acquisition of knowledge about the medicinal and social uses of plants seems to be a life-long process. However, also in Apillapampa modernization is spreading and many traditional customs are no longer practiced. The knowledge of many historical plant uses is therefore mainly held by elder people and is prone to permanent loss if not recorded.

In line with studies in other Andean communities, traditional medicine in Apillapampa is a highly important cultural tradition. Over the centuries, Andeans have developed a specialized ethnomedical system as an adaptation strategy to a hostile and unpredictable environment where illness is always on the brink. We mentioned several factors that might contribute to the impressive level of medicinal plants use in Apillapampa. First, we argued that the limited availability of plants in time and space stimulates people's knowledge of a broad range of (medicinal) plants from every ecological unit where they travel, live and work. Second, we related the number of medicinal plants used for different health condition to the local prevalence of these conditions. Also, the tendency of traditional healers to experiment with 'new' medicinal plants may be a relevant contributor. Fourth, we hypothesized that the inability to empirically test the efficacy of plants used in mixtures could lead to the inclusion of a number of biologically inactive plant species in the pharmacopoeia of Apillapampa. Furthermore, sensory perception has some importance for selecting medicinal plants in Apillapampa. Finally medicinal properties may also be ascribed to plants through association with other, very similar plants. In chapter 12, the high number of medicinal plants used in Apillapampa is put in light of the contact history and traditional life style of Andean peoples in general.

Throughout this chapter, it was shown that the taxonomic classification of plants at the family level is an important factor in determining the usefulness of species. Some families are clearly more useful for certain use categories than others. The superior usefulness of several plant families is restricted to one or few different use categories, and apparently not one single family is significantly more useful for *all* different categories than other families. For example, the mint family is significantly overused as medicines and food, but significantly underused as source of materials.

The applicability of the technique to incorporate the quality of plant use (i.e. quality use values; QUV_s), proposed by us in this chapter, depends upon the type of use category. In the category of medicines it provides a 'novel' way to approach and interpret plant use data, whereas in the food category its significance is as good as nil for the case of Apillapampa. In addition, we have shown that a combination of QUV_s with a reinterpreted consensus index regarding the medicinal use of species (IAR_s), might represent the cultural significance of medicinal plants better than existing indexes. This is particularly because such an approach – as opposed to other indexes – takes into account (1) the average number of medicinal uses; (2) the perceived quality of those medicinal uses; and (3) participant consensus about those medicinal uses.

4.

Some Factors Guiding the Usefulness of Plant Species and Vegetation Units in Apillapampa[1]

4.1. Introduction

Ethnobotanical research combined with quantitative ecological sampling methods using plots or transects has gained considerable importance over the past twenty years. Quantitative ecological and ethnobotanical data have been used to calculate the proportion of *useful plant species* over *available species* (Prance *et al.* 1987; Balée and Gély, 1989; Boom, 1989; Bennett, 1992; De Walt *et al.*, 1999; van Andel, 2000; Galeano, 2000) and to distinguish "more useful" forest types from others (Phillips *et al.* 1994; see also chapter 9). Such quantitative ethnobotanical data can enhance our understanding of human-environment interactions (Begossi, 1996; Galeano, 2000; Benz *et al.*, 2000) and help design more efficient

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[1] Data from this chapter have been used in the articles *Why are More Diverse Vegetation Units "Less Useful" to People? Indigenous Valuation of Vegetation in the Bolivian Andes: the Example of Apillapampa* and *Examining the Relationship between Plant Use and Plant Diversity in Apillapampa, a Bolivian Andean Community*, which have been submitted for publication in *Journal of Arid Environments* and *Human Ecology*, respectively.

biodiversity management and conservation plans (Phillips *et al.*, 1994; Begossi, 1996; Sheil *et al.*, 2003; Da Cunha and Albuquerque, 2006). In South America, most studies have focused on Amazonia. To the best of our knowledge, quantitative ethnobotanical studies in the (Bolivian) Andes using transects or plots are underrepresented in literature.

Quantitative ethnobotanical research has repeatedly demonstrated that inhabitants of the most diverse ecosystems on earth use the vast majority of plant species growing in these habitats (e.g. Balée, 1986; Prance *et al.*, 1987; Boom, 1989; Bennett, 1992; Phillips *et al.*, 1994; van Andel, 2000; Stagegaard *et al.*, 2002). It is often hypothesized that there exists a positive correlation between plant use/knowledge and habitat diversity (Berlin, 1992; Bennett, 1992; Milliken and Albert, 1997; Bernstein *et al.*, 1997; Ellen, 1998 and 1999; Vandebroek *et al.*, 2004b). If this hypothesis is correct, then inventories of useful plant species would generally contain more species for tropical forest populations than for societies that reside in areas with other, less diverse vegetation types. Ladio and Lozada (2004) have shown that knowledge and consumption of edible wild plants among Mapuche communities from Patagonia follow a pattern in agreement with the ecological conditions of the gathering environments. The latter authors demonstrated that the species richness of known and consumed plants was higher in botanically more diverse than in less species-rich environments. A quantitative ethnobotanical investigation was undertaken to verify if such a trend could also be observed at a micro-scale level in Apillapampa.

We used linear regression analysis to examine how different categories of plant use (including materials, food, medicine…) vary with plant diversity in plots. The usefulness of regression analysis for hypothesis testing in ethnobotanical research has been demonstrated before (e.g. Phillips and Gentry, 1993b; Vandebroek *et al.*, 2004b). However, apart from simply demonstrating causal relations between variables, some additional features of regression analysis can also be used successfully to detect trends in data. For example, Moerman (1991 and 1996) applied regression residual analysis for identifying statistically over- and underused families. This method has been used by other ethnobotanists as well (e.g. Phillips and Gentry, 1993a; Galeano, 2000; Treyvaud Amiguet *et al.*, 2006). Here, regression slope analysis is applied to analyze use patterns in ethnobotanical data.

Ethnobotanists have frequently linked plant usefulness to a number of phylogenetic, ecological, physiognomic, morphological and organoleptic (taste, smell, optical) parameters (Johns, 1990; Phillips and Gentry, 1993b; Alexiades, 1999; Galeano, 2000; Casagrande, 2002; Leonti *et al.*, 2002; Voeks, 2004; Shepard, 2004; Lawrence *et al.*, 2005). In this chapter we will additionally explore whether such correlations are also valid for Apillapampa. We hypothesize that if the use value of plant species can be predicted from variables that characterize these species, perhaps also the usefulness of entire vegetation units (as combinations or associations of plant species) occurring at different sites throughout the landscape can be predicted from a number of variables that characterize these sites. We test this hypothesis through a two-tiered process. First, environmental variables that best explain variance in the usefulness of vegetation units available at different sites are selected. Second, the power of each variable to predict the usefulness of vegetation units occurring at different sites is tested separately. This will allow us for example to investigate if intensity of plant use in Apillapampa diminishes with travel distance from human settlements (Martin, 1995).

4.2. Methods

Measuring the “Usefulness” of Transects

The transect data set used in this chapter is the same as the one described in chapter 2 (see this chapter for an overview of the sampling methodology). In the following analysis, it is assumed that transects are representative samples of the vegetation occurring at the respective study sites. The usefulness of transects was assessed by calculating (1) the proportion of useful species and individuals present in each transect; and (2) use values that are averaged for individual plants in transects. For a more detailed account on local participants, interviews and the calculation of use values, the reader is referred to chapter 3. Calculation of proportions of useful species in transects clearly holds limitations and can only be considered as a general guide to the cultural importance of vegetation units (Phillips *et al*., 1994). However, we believe it can provide useful information when studying trends in plant use across different landscape elements, as will be shown in the following analyses. Additionally, we followed the method developed by Phillips *et al.* (1994) for comparing the usefulness of vegetation sample units (here transects) based on the calculation of use values. These authors summed the use values of all individual plants occurring in each sample unit and then divided the resulting sum by the total number of plant individuals in the corresponding unit. As such, for each transect one overall use value was obtained for each use category, hereafter referred to as *the averaged categorical use value of a transect*.

Presentation of Results

As already highlighted in chapter 2, the research area is characterized by a strong seasonal climate. During the rainy season, annual and perennial species flourish, but once the rain stops and soil dries nearly all annual plants disappear completely, with exception of plants growing in humid areas such as wells or stream banks. During the dry season only (sub-)woody plants, Cactaceae and some epiphytes remain visible. This has important implications for the availability of plants to people throughout the year. During the rainy season people have access to practically *all* plant species, whereas during the dry season basically only perennial plants remain.

In view of this clearly marked seasonal variation in the vegetation, we also quantified the usefulness of transects on a biannual basis. The situation in the rainy season is represented by the first twenty nine transects (section 2.2.1.2.) wherein all plant species of 0.1 m and larger (except Poaceae) were sampled. We will refer to the situation in the rainy season as *plants >0.1 m*. The situation in the dry season is represented by the sub-sample of (sub-)woody plants (including Cactaceae) of the same twenty-nine transects sampled in the rainy season plus seven additional transects that were sampled during the dry season. The dry season situation will be referred to as *(sub-)woody plants*.

Diversity Indices

As indicated in chapter 2, diversity in transects is expressed as Alpha diversity (α, the species number or richness) and Shannon-Wiener diversity (H, hereafter called Shannon diversity). Examination of the number of plants species used in any use category in relation to Alpha diversity in transects provides a direct estimation of the relationship between the number of species used to the number of available species. On the other hand, Shannon diversity considers both species richness and evenness. Hereby, increases in species richness as well as a more even abundance of individual species both lead to a higher Shannon index. Therefore, two different sample sites with equal Shannon diversity can have a different richness and evenness.

Statistics

General Statistics

Throughout this chapter, a number of standard statistical tests and procedures have been applied, such as ANOVA, t-tests, linear regression and correlation, Kruskal Wallis tests, Mann-Whitney tests, rank correlation, etc. All these calculations were performed in SPSS 12.0. The statistical programme Prism was used to test for significant differences in regression line slopes, based on an equivalent ANCOVA method as discussed by Zar (1984) and Sokal and Rohlf (1995).

Redundancy Analysis

Redundancy analysis (RDA), an unimodal direct gradient analysis, was applied to identify which of the environmental variables that were measured best explain variation in the usefulness of plants in transects. Use of RDA is justified as the lengths of gradients in our analyses were consistently smaller than 2 s.d. (Jongman *et al.,* 1996). We used the statistical programme CANOCO 4.0 (cf. Ter Braak, 1988a and 1988b) for RDA, and both CanoDraw 3.1 and CanoPost 1.0 for generating ordination diagrams. Significance of ordination axes and species environment correlations was evaluated by means of Monte Carlo Permutation tests. Ordination plots were centred and standardized for samples (transects) and scaling was focused on inter-sample (i.e. transect) distance.

4.3. Results and Discussion

4.3.1. Usefulness of Vegetation Sampled in Transects

Plants>0.1 m: *Situation in the Rainy Season*

An average number of 8.6 (± 3.2) participants (range: 1-13) provided information on the use of *plants>0.1 m*. Overall use values of *plants>0.1 m* range from 0.33 (*Stevia boliviensis*) to 6 (*Schinus molle*). On average, 99% of plants species and 99% of plant individuals in transects have at least one kind of use. Most species and individuals (98% in both cases) are used as fodder. Eighty percent of plant species and 76% of plant individuals is used in traditional medicine; 36% of species and 31% of individuals as fuel; and 36% of species and 38% of individuals as food. Social uses, materials and environmental uses are represented by lower proportions of species and individuals in transects: 19 and 18; 16 and 17; and 14 and 17 percent, respectively (see figure 4.1).

Figure 4.2 shows that a similar ranking of use categories is obtained for mean categorical use values of transects with the sole difference that *material* and *social uses* switch places in the ranking according to importance. The relevance of calculating averaged use values of transects in addition to the proportion of species and individuals used is demonstrated by comparing their ranges for the sampled transects. While the percentage of useful species and individuals are remarkably uniform between transects (94-100% and 92-100%, respectively), transects' averaged use values differ by a factor of almost four (0.61-2.22).

(Sub-)woody Plants: Situation in the Dry Season
An average number of 9.7 (± 3.0) participants (range: 2-13) provided information on the use of plant species. Overall use values of *(sub-)woody plants* range from 0.45 (*Heterophyllaea lycioides*) to 6.08 (*Prosopis laevigata*). All species collected in the 36 transects have at least one use that is not related to animal food (an average of 96% of species and 98% of individuals are used as fodder). On average 95% of species and 94% of individuals in transects are used as fuel; 88 and 86% of species and individuals have a medicinal value, respectively; whereas 39 and 49% of species and individuals fulfil a role in providing food. Social uses, materials and environmental uses represent 39 and 43; 45 and 42; and 22 and 18 percent of plant species and individuals in transects, respectively (figure 4.1).

Figure 4.2 shows that an equivalent ranking is obtained for transects' mean categorical use values with the sole difference that *material* and *social uses* switch places in the ranking according to importance. The percentage of useful species and individuals is 100% in all transects, whereas transects' averaged use values differ by a factor of nearly two (1.45-2.81).

Data from both the dry (*(sub-)woody plants*) and rainy (*plants<0.1 m*) season support the general observation made by most ethnobotanical investigations: indigenous people are dependent upon an impressive number of plant species for every aspect of their physical, cultural and spiritual lives (Milliken *et al.*, 1992).

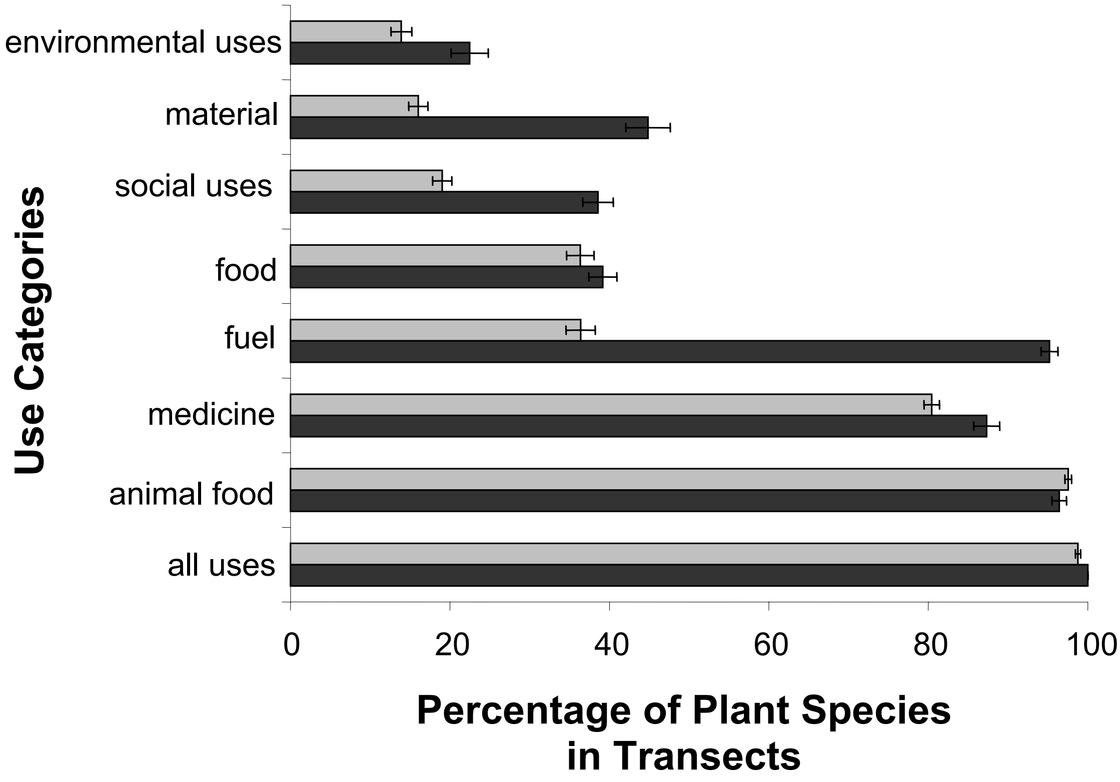

Figure 4.1: Mean percentages of plant species in transects per use category (grey: *plants>0.1 m*; black: *(sub-)woody plants*) (error bars represent standard errors of the mean)

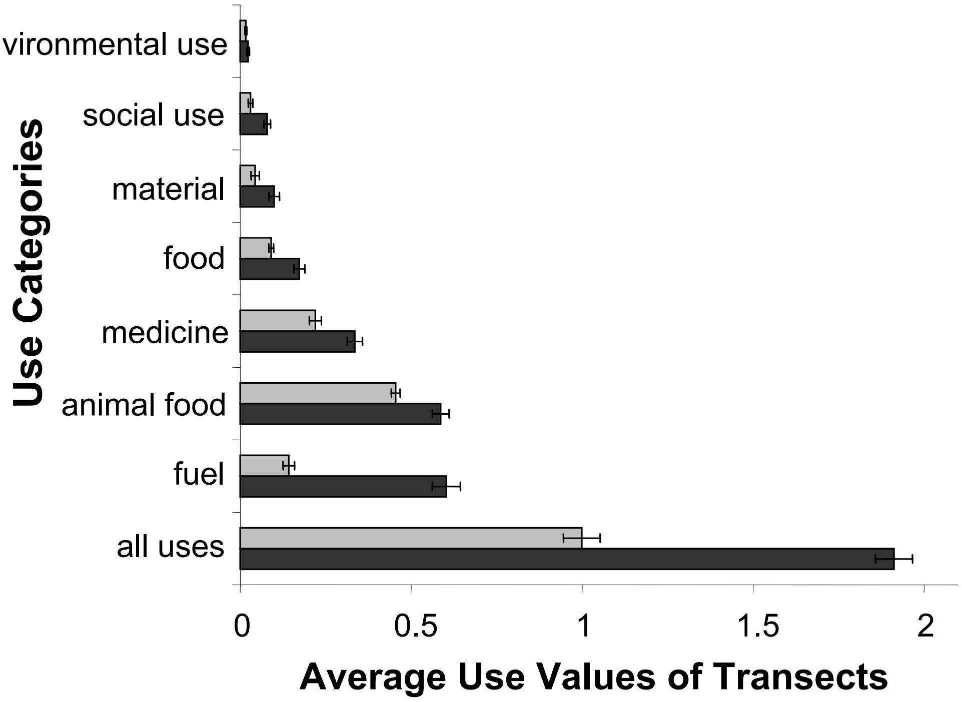

Figure 4.2: Transects' mean categorical use values (grey: *plants >0.1 m*; black: *(sub-)woody plants*) (error bars represent standard errors of the mean)

Traditionally, quantitative ethnobotanical studies have been conducted in Amazonia by means of one hectare plots. Estimates of useful tree and liana species with dbh ≥ 10 cm revealed percentages ranging from 49 to 100 percent (Balée, 1986 and 1987; Prance *et al.*, 1987; Milliken *et al.*, 1992, Phillips *et al.*, 1994; Boom, 1987, Piñedo-Vasquez *et al.*, 1990; De Walt *et al.*, 1999; Galeano, 2000; van Andel, 2000). In these plots, the reported proportion of species used as food or medicine is relatively consistent and ranges between 17-40% and 7-35%, respectively.

Hence, plant use in Apillapampa is situated in the upper margins of the breadth of plant uses cited in literature, in spite of the fact that these literature studies used different sampling strategies and sampled other vegetation types. In particular, the proportion of medicinal plants in Apillapampa is exceptionally high and scores are more than double as compared to those from plots and transects mentioned in the literature. Possibly, this difference could partly be ascribed to the vegetation type, since Hensen (1991) also found that more than half of the 204 plant species prevailing in *Polylepis* forests was used in traditional medicine by people from the rural Bolivian Andes community of Chorojo. However, in the Chilean Andes Villagrán *et al.* (2003) found that, although 90 % of nearly 150 (randomly?) inventoried plants was useful to people, "only" 36% was used as animal food, 31% as herbal medicines, 10% as food and 4% as fuel. These values fall within the range of comparative studies in Amazonia. Therefore, further research in other communities in the (Bolivian) Andes using a similar sampling strategy as ours is necessary to test this hypothesis.

4.3.2. Relation between Plant Diversity and Use in Different Use Categories

In this section, trends in (1) the percentage of used plant species; (2) the number of used species; and (3) mean use values will be evaluated as a function of Alpha and Shannon diversity for both *plants>0.1 m* and *(sub-)woody plants* by means of correlation and regression analysis. Data points in figures 4.3, 4.4, 4.5 and 4.7, depicting regression lines for various use categories at once, are not shown for clarity.

The main null hypotheses are:

- H_0^1: there exists a random distribution of the proportion of plant species used in transects with respect to plant diversity; and
- H_0^2: averaged categorical use values of transects are random with respect to plant diversity.

Plants>0.1 m

Use Categories Versus Alpha Diversity

Proportion of Used Species

The proportion of used plant species and plant individuals in transects is not correlated with Alpha diversity for most use categories. For plant species used as *food* ($R^2=-0.24$, $p<0.01$) and for *social uses* ($R^2=-0.31$, $p<0.01$) there exists a negative correlation with Alpha diversity. Hence, transects that contain more species will have proportionally fewer species that are used as food or for social purposes. Therefore, H_0^1 is accepted for all use categories, except for *food* and *social uses*. The proportion of species and individuals with any kind of use (overall use category) does not correlate with Alpha diversity in transects.

However, a closer look at the relationship between Alpha diversity (i.e. species richness) and the number of useful plant species within each use category in transects reveals certain trends. As indicated in figure 4.3, in a transect with Alpha diversity equal to “X”, the proportion of medicinal plants would be “B/X”, whereby “A+B=X”. The line indicated with “*maximum number of plant species that can be used*” represents the equation y=x. In each use category, a constant proportion of used to available plants implies that their regression lines are parallel to the y=x line. In other words, it entails that regression line slopes have to be statistically equal to 1. A prerequisite for this type of evaluation is that regression lines are highly significant ($p<0.01$) and have high correlation coefficients (R^2 should be at least 0.4 (Höft *et al.*, 1999). This is the case with most of our results.

Correlations between the absolute number of used species and Alpha diversity in transects are highly significant and positive for all use categories (see figure 4.3 for individual Pearson correlation values). When comparing all regression lines, slopes turn out to be significantly different ($F=173.1$, $p<0.01$). Pairwise comparison distinguishes two groups with equal slopes: regression lines for *food* and *fuel* (first group, $F=1.3$, $p=0.26$) and regression lines for *materials*, *social uses* and *environmental uses* (second group, $F=0.33$, $p=0.72$). Since the slopes of regression lines are significantly lower than 1 for all use categories, the proportion of plant species used decreases in relation to the number of plant species in transects for all use categories, thus rejecting H_0^1.

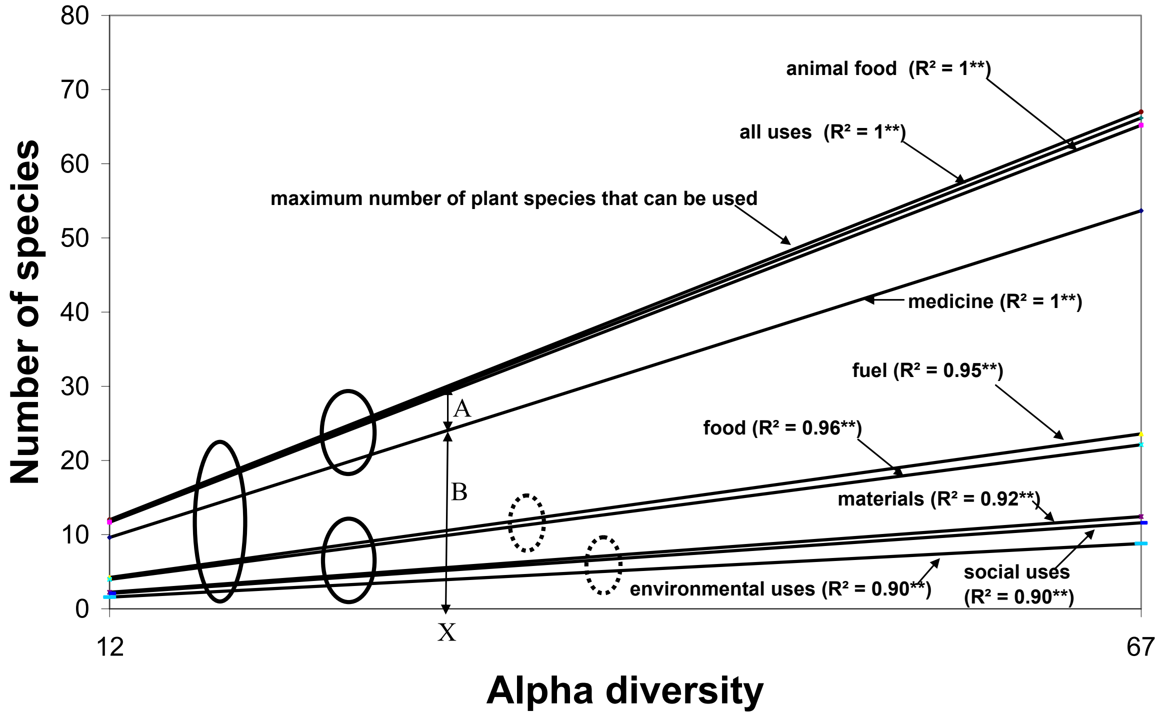

Figure 4.3: Regression lines that represent the number of *plants>0.1 m* per use category in relation to Alpha diversity in transects. Solid oval lines encircle regression lines with significantly different slopes, dotted oval lines encircle regression lines with significantly equal slopes (= p<0.01).**

In addition, figure 4.3 shows two general clusters of regression lines: a cluster with slopes that tend to trend towards 1 (*all uses* (0.99), *animal food* (0.97) and *medicine* (0.80)) and a cluster with slopes that are lower than half this value (<0.5), trending towards 0 (*fuel* (0.35), *food* (0.33), *materials* (0.18), *social uses* (0.17) and *environmental uses* (0.13)).

Categorical Use Values

Likewise, linear regression was applied to examine whether a transect's mean categorical use values can be predicted from the level of Alpha diversity. Although at the margin of statistical significance, results show that the averaged overall use value of transects decreases with increasing Alpha diversity (R^2=-0.13; p=0.059). Significant negative correlations are observed between Alpha diversity and transects' mean use values for *fuel* (R^2=-0.15; p=0.039), *environmental uses* (R^2=-0.28; p<0.01) and *social uses* (R^2=-0.21; p=0.01). Transects' averaged *medicinal, food* and *material* use values are not influenced by Alpha diversity.

Use Categories Versus Shannon Diversity

Proportion of Used Species

The Shannon-Wiener index is considered a better representation of actual plant diversity than Alpha diversity and therefore its impact on plant use was also evaluated. Both Shannon and Alpha diversity are strongly correlated for *plants>0.1 m* since the regression line "*maximum number of plant species that can be used*" in figure 4.4 has an R^2=0.64 (p<0.01). Therefore, similar trends are expected as in the case of Alpha diversity. Our calculations show that the proportion of used plant species in transects is not correlated with Shannon diversity, except for one use category. Only the proportion of plant species used as food is negatively correlated with Shannon diversity (R^2=-0.29, p<0.01). H_0^1 is accepted for all other use categories.

Similar to Alpha diversity, correlations between the number of plant species used and Shannon diversity in transects are highly significant and positive for all use categories. However, correlation coefficients are lower for Shannon diversity as compared to Alpha diversity (see figure 4.4 for individual Pearson correlation values). When comparing all regression lines, slopes are significantly different (F=17.5, p<0.01). Pairwise comparison of the slopes distinguishes three groups with significantly equal slopes. Slopes of regression lines of *maximum number of plant species that can be used, all uses, animal food* and *medicine* (first group, F=0.68, p=0.51) are significantly higher than those of *fuel* and *food* (second group, F=1.1, p=0.31). Regression line slopes of *social uses*, *materials* and *environmental uses* (third group, F=0.18, p=0.84) are significantly lower than those from the first and second group. The fact that these three groups of regression lines with equal slopes are obtained for Shannon, but not for Alpha diversity is probably related to the lower Pearson correlation coefficients that were obtained for Shannon diversity.

Again similar to Alpha diversity, the three groups of regression lines with equal slopes can be reduced to two general clusters of (1) regression lines that run parallel to the "*maximum number of plant species that can be used*" line (i.e. *all uses*, *animal food* and *medicine*) and (2) regression lines with slopes lower than half the value of the "*maximum number of plant species that can be used*" line and trending towards 0 (i.e. *food*, *fuel*, *social uses*, *material* and *environmental uses*). Hence, H_0^1 is accepted for use categories with regression lines belonging to the first cluster and rejected for use categories with regression lines that fall within the second cluster.

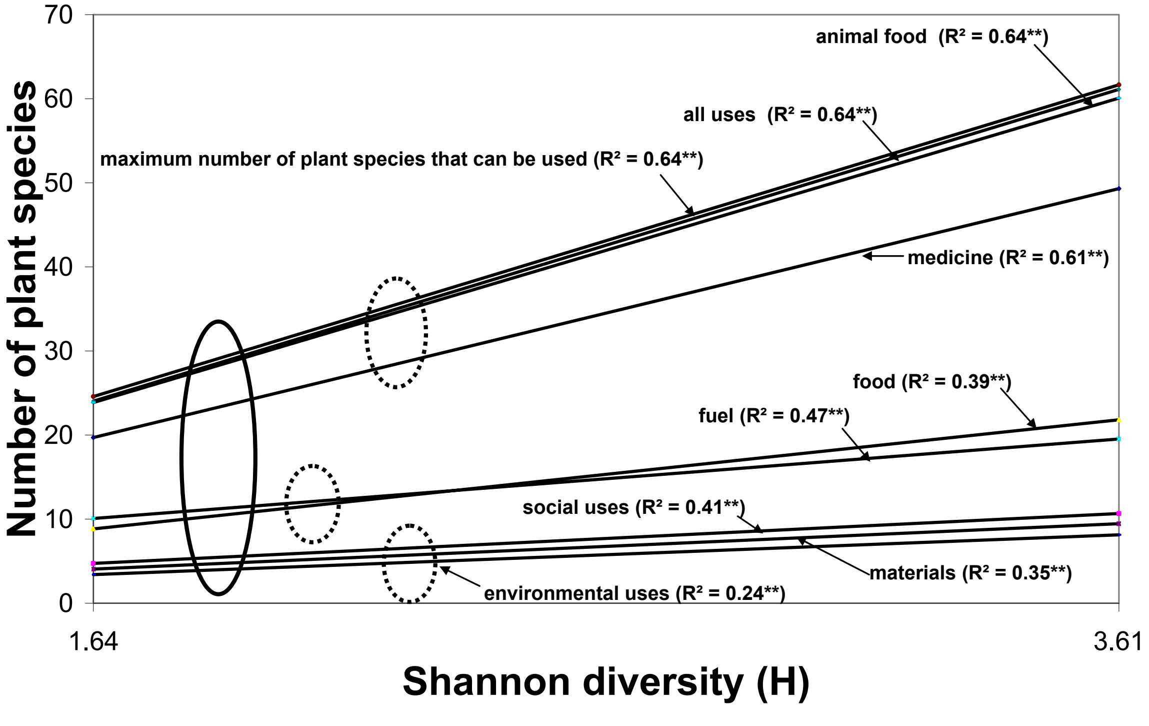

Figure 4.4: Regression lines representing number of *plants>0.1 m*, used per use category in function of Shannon diversity in transects. Solid oval lines encircle regression lines with significantly different slopes, dotted oval lines encircle regression lines with significantly equal slopes (= p<0.01).**

Categorical Use Values

None of the transects' mean categorical use values correlates with Shannon diversity. This implies that mean categorical use values of transects are invariable of Shannon diversity, thus accepting H_0^2.

(Sub-)woody Plants

Use Categories Versus Alpha Diversity

Proportion of Used Species

The proportion of used plant species in transects correlates with Alpha diversity just in the case of two use categories only. Negative significant correlations are detected for the percentage of plant species used for *materials* (R^2=-0.13, p=0.03) and *social uses* (R^2= - 0.12, p=0.04), rejecting H_0^1 for these categories.

Similar to *plants>0.1 m*, we scrutinized the relationship between Alpha diversity and the absolute number of useful plant species per category to detect possible trends. Correlations are highly significant and positive for all use categories (see figure 4.5 for specific Pearson correlation values). Slopes of regression lines are significantly different (F=92.2, p<0.01). Only regression line slopes related to *materials* and *food* are equal (F= 1, p= 0.32), together with those for *all uses* and *animal food* (F= 2.3, p= 0.14). Because every *(sub-)woody plant* is useful in at least one way, the regression line for *all uses* coincides with the line that depicts the maximum number of plant species that can potentially be used (representing the equation y=x). The slopes of all regression lines are significantly lower than 1 for all categories except for *animal food*. Therefore, the proportion of used plant species for all other use categories decreases in relation to the number of plant species in transects, thus rejecting H_0^1.

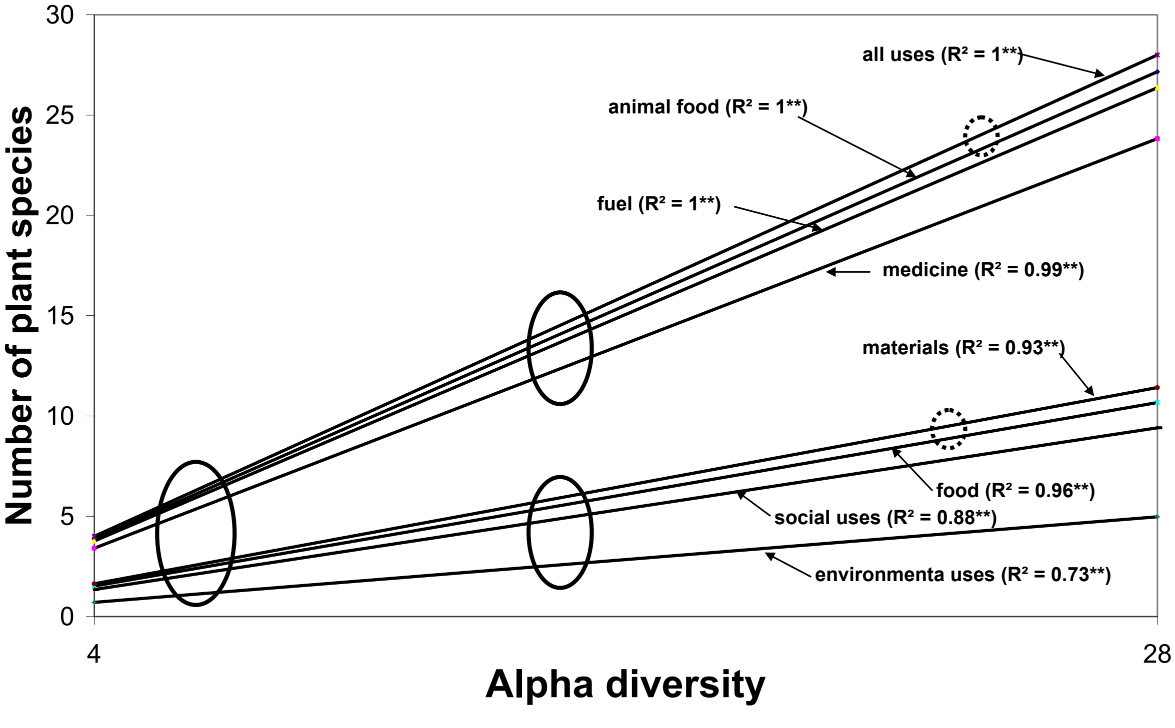

Figure 4.5: Regression lines representing number of *(sub-)woody plants*, used per use category in function of Alpha diversity in transects. Solid oval lines encircle regression lines with significantly different slopes; dotted oval lines encircle regression lines with significantly equal slopes (: p<0.01).**

Again similar to *plants>0.1 m*, there are two general clusters of regression lines: a cluster with slopes that tend to trend towards 1 (i.e. *all uses* (1), *animal food* (0.97), *fuel* (0.94) and *medicine* (0.85)) and a cluster with slopes that are lower than half this value (i.e. <0.5), trending towards 0 (i.e. *materials* (0.40), *food* (0.38), social uses (0.33) and *environmental uses* (0.18)).

Categorical Use Values

Transects' mean use values do not correlate with Alpha diversity for most use categories. Only the averaged *overall* and *fuel* use value of transects can partly be predicted from Alpha diversity (R^2=-0.27 and p<0.01 for both cases; figure 4.6A). Hence, whereas transects with higher species richness have lower averaged *overall* and *fuel* use values, mean use values for all other use categories are independent of Alpha diversity.

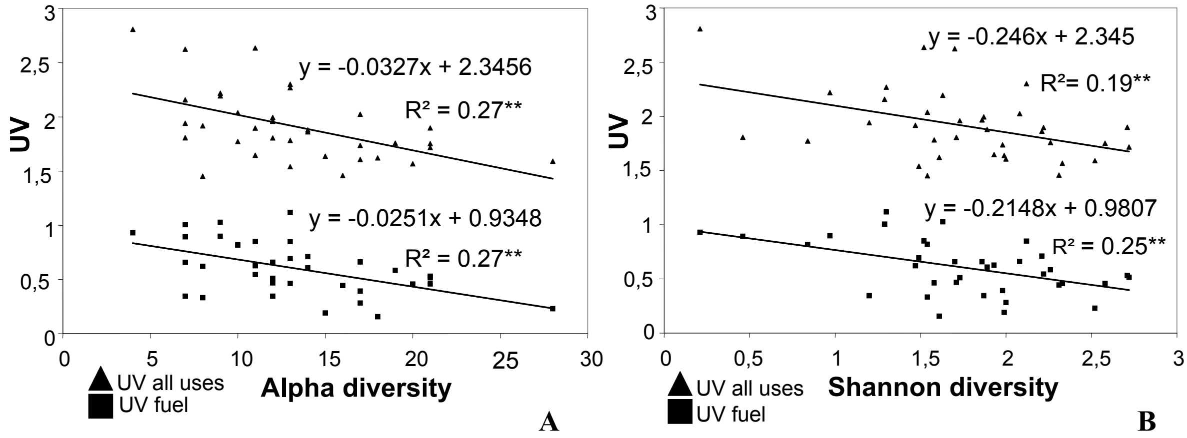

Figure 4.6: Regression analysis of transects' mean overall and fuel use values in function of Alpha (A) and Shannon (B) diversity.

Use Categories versus Shannon Diversity

Proportion of used species

Similar to *plants>0.1 m*, Shannon and Alpha diversity correlate strongly with each other in the case of *(sub-)woody plants* (see regression line "*maximum number of plant species that can be used*" in figure 4.7, R^2=0.68; p<0.01). Therefore, similar results are expected as for Alpha diversity. The proportions of used plant species in transects are not correlated with Shannon diversity for every use category except one. There exists a significant negative correlation for the percentage of plant species used as *materials* (R^2=-0.24; p<0.01), rejecting H_0^1 for this use category only.

Correlations between the absolute number of plant species used and Shannon diversity in transects are highly significant and positive for all use categories (for specific Pearson correlation values, see figure 4.7). When comparing all regression lines, slopes are significantly different (F=14.2, p<0.01). Pairwise comparison distinguishes two groups with equal slopes. Slopes of regression lines for *all uses*, *animal food*, *fuel* and *medicine* (first group, F=0.52, p=0.67) are significantly higher than those of *materials*, *food, social uses* and *environmental uses* (second group, F=2.1, p=0.13). Here, a statistically significant division is made between those use categories with slopes that are significantly equal to the "*maximum* *number of plant species that can be used*" and use categories with slopes that are lower than half this value (trending more towards 0). Therefore, H_0^1 is accepted for use categories from the first cluster, and rejected for use categories from the latter cluster.

Categorical Use Values

Mean use values of transects do not correlate with Shannon diversity for most use categories. Only a transect's averaged *overall* and *fuel* use value per plant individual can be partly predicted from Shannon diversity (R^2=-0.19 and $p<0.01$ and R^2=-0.25 and $p<0.01$, respectively; figure 4.6B).

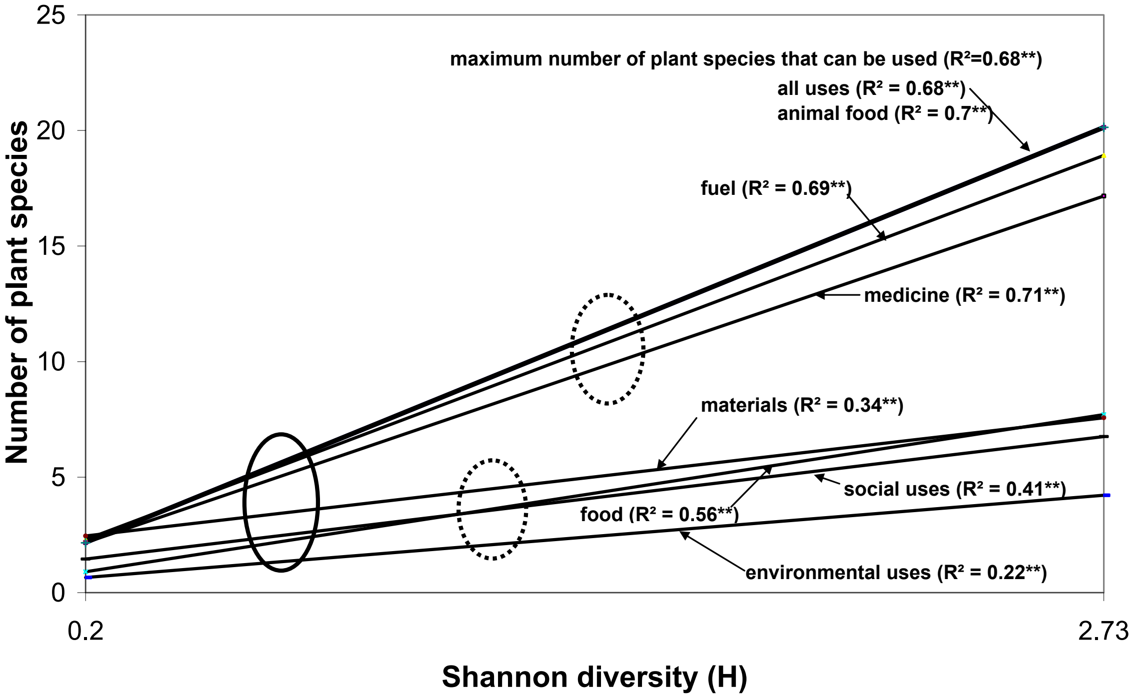

Figure 4.7. Regression lines representing number of *(sub-)woody plants*, used per use category in function of Shannon diversity in transects. Solid oval lines encircle regression lines with significantly different slopes; dotted oval lines encircle regression lines with significantly equal slopes (= p<0.01).**

4.3.2.1. What Distinguishes Diversity Followers from Diversity Laggards?

In the previous paragraphs we have shown that regressing the proportion of used species in relation to plant diversity in transects is inadequate for predicting trends in plant use based on diversity. Better results are obtained by analyzing the slopes of regression lines that represent the number of species used in relation to Alpha and Shannon diversity. Regression lines with slopes significantly lower than slopes of the line that represents the maximum number of species that *can* be used at any given level of diversity imply that fewer species are used with increasing diversity. The summary in table 4.1 shows that regression slope analysis detects 23 negative correlations between plant use and diversity, whereas simply regressing the proportion of species that is used detects only 6 correlations.

An additional strength of regression analysis is that pairwise comparison of slopes of regression lines can be used to detect clusters in use categories. Here, independent from the chosen sampling strategy (*plants>0.1 m* or *(sub-)woody plants*) and type of diversity index

(Alpha or Shannon diversity), two groups of use categories can be distinguished which we call *diversity followers* and *diversity laggards*. Regression line slopes of diversity followers tend to be equal to the curve that represents the maximum number of species that can potentially be used at a given diversity. Regression line slopes of diversity laggards tend to be less than half this value. The following use categories can be considered diversity-followers: *all uses*, *animal food* and *medicine.* On the contrary, *food*, *material*, *social uses* and *environmental uses* are diversity laggards. The *fuel* use category is a diversity laggard for *plants>0.1 m* and a diversity follower for *(sub-)woody plants*.

Table 4.1: Significance levels of correlations between the proportion of species used in transects and diversity based on (1) calculated proportions and (2) slopes of regression lines

	Calculated Proportions of Used Species				**Regression Slope Analysis**			
	Plants <0.1		***(Sub-)woody Plants***		***Plants <0.1***		***(Sub-)woody Plants***	
	α	**H**	α	**H**	α	**H**	α	**H**
all uses	n.s.	n.s.	n.s.	n.s.	- **	n.s.	n.s.	n.s.
animal food	n.s.	n.s.	n.s.	n.s.	- **	n.s.	n.s.	n.s.
medicine	n.s.	n.s.	n.s.	n.s.	- **	n.s.	- **	n.s.
food	- **	- **	n.s.	n.s.	- **	- **	- **	- **
fuel	n.s.	n.s.	n.s.	n.s.	- **	- **	- **	n.s.
material	n.s.	n.s.	- *	- **	- **	- **	- **	- **
environmental use	n.s.	n.s.	n.s.	n.s.	- **	- **	- **	- **
social uses	-**	n.s.	- *	n.s.	- **	- **	- **	-**

- = negative correlation; **= p<0.01; *= p<0.05; n.s.= not significant

Diversity Followers

All (*sub-)woody plants* and 99% of *plants>0.1 m* have at least one use. Therefore, the proportion of plants with any kind of use (overall use category) is obviously invariable to diversity in transects. The same accounts for *animal food*: nearly all plant species in transects were reported to be palatable to livestock.

However, the most intriguing category of diversity-follower is *medicine.* Whereas the number of useful plant species increases only moderately with increasing plant diversity for diversity laggards, the number of medicinal plants keeps abreast with diversity. The question arises as to why medicine is a diversity follower, or in other words, why Apillapampeños use so many medicinal plant species. The mean proportion of plants used medicinally (79% of *plants>0.1 m* and 85% of *(sub-)woody plants*) in comparison with the occurrence of these species is indeed surprisingly high. We suggest that the factors mentioned in chapter 3 (section 3.3.4.7.) regarding the use of medicinal plant species for treating particular health conditions may be valid here as well. These include:

(1) availability of medicinal plants in time and space;
(2) characteristics related to specific health conditions such as prevalence and their causal factors;
(3) the dynamic and specialized nature of traditional medicine in Apillapampa that nourishes experimentation with "new" plants;

(4) inability to empirically test the efficacy of plants used in mixtures which could be particularly relevant here since one third of *plants>0.1 m* and nearly two thirds of *(sub-) woody plants* are used in steam baths;
(5) sensory perception; and
(6) other minor factors.
For a more detailed account on these topics the reader is referred to chapter 3.

Although probably several of the abovementioned factors contribute partially to the high and more or less constant percentage of medicinal plants found in sites with varying levels of diversity, the first factor might be the most relevant here. We hypothesize that the principal difference between diversity laggards and medicine, as a diversity follower, is related to the fact that plants used in traditional medicine are often needed on a short notice. Illness generally does not announce its arrival and herbal remedies have to be obtained rapidly whenever and wherever it strikes. We suggest that in such a context of immediacy, emic perception of the efficacy of medicinal plants may be of subordinate importance.

Plants that are abundant at one site might be completely absent at another, and most herbs that flourish during the rainy season are impossible to obtain during the dry season. This uneven distribution of vegetation in terms of time and space (see chapter 2) throughout the ecological units where people live and work stimulates a profound knowledge of a wide medicinal flora in every site as a strategy to respond rapidly to emerging illnesses (cf. chapter 3, section 3.3.4.7.). High densities and short distances appear to be decisive factors in plant collection (Grenand, 1992; van Andel, 2000; Byg *et al.*, 2006). Various authors have shown that availability and accessibility are primary factors for determining the initial selection and use of medicinal plants. Casagrande (2002) demonstrated that in Tzeltal Maya communities, people often start with plants that are easier to obtain and resort to less accessible plants if the first treatments do not achieve expected effects. Adu-tutu *et al.* (1979) found that availability of dental treatments was a more important factor than efficacy for choosing plant species to use among Ghanaians. Alexiades (1999) observed that among the Esse Ejja of Amazonia "accessibility is a primary consideration when selecting between different treatment options, at least during the early stages of an illness episode." These publications confirm that medicinal plant selection and use does not seem to be based solely on emic perception of their efficacy for curing illness symptoms.

The various potential factors listed in chapter 3 (section 3.3.4.7.) that may contribute to the pattern of selection of medicinal plants by users, lead to a considerable variation in medicinal plant use and knowledge at the individual level (cf. figure 3.8). A consequence of this variation is that medicinal plant knowledge is much more idiosyncratic as compared to knowledge of plants in other use categories (see also chapter 3, section 3.3.4.6.). Indeed, whereas food, material and environmental uses of plants in transects are generally known by several (if not most) participants, consensus related to medicinal plant use was much lower. About one third (35% and 34%, respectively) and half (54% and 49% respectively) of *plants>0.1 m* and *(sub-)woody plants* was confirmed as having a medicinal use by just one or up to two participants, respectively.

It was verified to what extent the idiosyncratic character of medicinal plant knowledge can explain the high regression line slope of *medicine*. For *plants>0.1 m*, Shannon diversity correlates positively with the proportion of plants mentioned by one or two participants, respectively (r=0.44; p=0.02 and r=0.57; p=0.001 respectively). By contrast, neither for Alpha diversity, nor for *(sub-)woody plants* such significant correlations were found. Hence, the relatively high regression slope for “medicine” as compared to other use categories can be attributed only in part and only for *plants>0.1 m* to the high proportion of species known to at most two participants.

Fuel may be a diversity follower for *(sub-)woody plants* for the same reason as *medicine* in that it is often needed for immediate use. The fact that people (temporarily) live in different ecological units throughout the landscape (as explained in chapter 3) obliges them to know and use the firewood available at each site. When asked why they use so many thin-stemmed plants rather than sticking to good quality firewood, participants unanimously declared that combustion quality is not a primary preoccupation when collecting firewood for cooking a “quick” meal. Nevertheless, emic perception of fuel quality was mentioned as a major selective factor when trips are purposefully organized for collection of firewood. Surely, the degraded nature of vegetation in Apillapampa plays a significant role here. As discussed in chapter 2, the original forest cover has gradually been replaced by secondary vegetation throughout the history of human occupation in the Bolivian Andes. This seems to oblige people to use plant species with an inferior firewood quality.

In sum, diversity followers are often used in a context of urgency or immediacy, whereby the quality or (emic perception of) efficacy of plants for fulfilling certain needs may be of secondary importance. Therefore, the use of species in these categories does not seem to be constricted by user-defined boundaries. Theoretically, *all* plants occurring in the Apillapampa living environment could be used in traditional medicine, although it is highly unlikely that they would all be biomedically activity. Likewise, nearly all (sub-)woody plants found in transects are used as fuel, although many of these are considered to provide poor quality firewood. We believe that it are precisely these characteristics that make that proportions of plants used in diversity followers are (fairly) constant in transects with different levels of diversity.

Diversity Laggards

For diversity laggards, an increase in the number of useful species in a particular use category lags behind the increase in the number of available species in transects. As opposed to *medicine* and *fuel*, plant use of diversity laggards (*food*, *materials*, *environmental* and *social uses*) has a less “urgent” nature. For example, in Apillapampa, the basic source of food comes from local agriculture. Although some previously used famine foods were mentioned (cf. chapter 3, section 3.3.5.3), nowadays wild food plants do not possess a real subsistence role anymore. Wild edible plants are eaten as snack foods and are only occasionally harvested, but no special collection trips seem to be organized to gather them. Likewise, plants used as sources of materials or for environmental uses, are harvested and used in a more relaxed, trivial context. For example, wooden ploughs are typically manufactured during periods when there is not much work on the land, well in advance of their use. Therefore, the need to know and use many alternative plants for similar applications in different ecological units seems less relevant for diversity laggards.

Plant use in diversity laggard categories in Apillapampa seems to be driven by emic perception of plant quality or efficacy to fulfil certain uses rather than being determined primarily by accessibility or availability (cf. Byg *et al*., 2006). Much learning of what is edible seems to take place early in life (Setalaphruk and Price, 2007) through a process of trial-and-error (Phillips and Gentry, 1993b). Logically, the basic prerequisite for a plant to be used as food would be that its ingestion does not cause adverse (acute or chronic) effects on human health. Taste and the pleasure associated with eating also determine whether something is used as food, but these factors may be less important. According to Moerman (1996) "*foods* are to be understood by observation – one can observe human beings or other animals eating and infer that the things they eat are food." Johns' (1999) definition is more refined and considers as a food "any substance that is ingested for the primary purpose of obtaining nutrient". Johns (1999), citing Bell *et al*. (1998) and Rozin (1976), adds that although a more immediate motivation behind ingestion may be to eliminate hunger or thirst, or the hedonic effect of food, appetite and thirst are determined by a metabolic requirement for energy and water, respectively. Hence, from this it is clear that – at least in non-industrialized societies – only a limited portion of the flora can potentially be used as food. The proportion of edible species at a worldwide scale has been estimated at 5% (12,000 species) (Lewington, 1990). Ethnobotanical inventories in other regions (with diverse vegetation types) list similar percentages of edible species for the total flora: 8% for Bolivian *puna* vegetation (Pestalozzi, 1998); 6% for southern Ecuador (Van Den Eynden, 2004); 6.6% for Tehuacán-Cuicatlán in Mexico (Casas *et al*., 2000); 6% for Ethiopia (Cotton, 1996); 6% for the Namib desert (Van den Eynden *et al*., 1993); 7.5% for the humid Mexican forests (Toledo *et al*., 1995); and 7.5% for the North American flora (Moerman, 1996). Also in Apillapampa there may exist an empirically determined upper limit, although it seems to be considerably higher than the abovementioned figures from the literature. This is probably because a large part (38%) of edible plants in Apillapampa is consumed in herbal teas (see chapter 3, section 3.3.5.3.), whereas in the studies from literature the proportion of teas was considerately smaller.

The same philosophy pertaining to the diversity laggard characteristics of food plants may be valid for other use categories of diversity laggards as well. Only the category of social uses is an exception. Plants or their parts will only be used as *materials* if they can satisfy certain requisites that are user-defined. Wood that breaks easily and/or does not last longer than a day will probably not be used for fabricating handles. Good handles are valued and rather than obtaining them on the spot, tools with handles are generally brought over to the place where they will be used. Analogously, there are many vegetal substances or extracts that stain, but for these to be used as plant dyes, durability and colour are essential characteristics. Also, selection of plants with *environmental uses* is generally based on empirical criteria For example, plants that are grown as ornamentals should have at least some (culturally defined) aesthetic characteristic(s), whereas plants used for erosion control preferably have extensive root systems.

If the former reasoning is correct, then two important properties of (most) diversity laggards are that (1) their usefulness can in most cases be demonstrated unambiguously by means of empirical testing; and (2) the number of useful species is restricted by an approximate use-defined upper limit that may vary according to the cultural and ecological setting.

Contrary to the previous diversity laggards, the category of *social uses* also includes magico-ritual or religious uses of plants that are less prone to empirical testing (cf. Balée, 1994). However, apart from being a small category in terms of the number of species used, magico-ritual or religious uses can also partly be defined by certain culturally defined prerequisites. For example, in Apillapampa a strong tendency exists for using plants with spines or thorns to treat curses (see chapter 3, section 3.3.8.). Therefore, plants are not necessarily selected randomly either for the social uses they fulfil.

Fuel is a diversity laggard for *plants>0.1 m* because in transects with high species richness, proportionally fewer (sub-)woody plant species prevail. Fuel plants are exclusively (sub-) woody in growth form. Therefore, proportionally fewer fuel plants are present in more diverse transects.

In summary, in categories that are diversity followers plants are partly selected and used in an immediacy context, whereby emic perception of efficacy may be less important. By contrast, selection of plants used in diversity laggard categories is principally driven by emic perception of efficacy, because plants or their parts are generally not needed on a short notice.

4.3.2.2. Why do Mean Categorical Use Values of Some Transects Vary with Diversity and Others Do not?

Categorical use values are a better representation of the actual usefulness of transects as opposed to the proportion of useful species (Phillips *et al*., 1994). The mean overall use value of transects decreases with increasing diversity in Apillapampa, although this trend is only statistically significant for *(sub-)woody plants* and less conclusive for *plants>0.1 m* (table 4.2). This implies that areas with a higher diversity of (sub-)woody plants are considered relatively less useful by local people than less diverse sites. Lower mean overall use values of transects for (sub-)woody species in more diverse sites may be caused by the fact that a number of those species and their uses are not known by every respondent. We have already demonstrated that proportionally fewer (sub-)woody species are used for *food*, *materials*, *environmental uses* and *social uses* in more diverse transects (see table 4.1). Yet, the same observation was made for *plants>0.1 m*. Then, why does the mean overall use value of a transect not decrease with increasing diversity for *plants>0.1 m*?

Accessibility of sample sites might be an explanation to this question. In chapter 2, we have shown that species richness in transects correlates negatively with accessibility for *(sub-) woody* plants, but not for *plants>0.1 m*. Further on in this chapter, we also demonstrate that the mean use value of a transect is positively correlated with accessibility for *(sub-)woody* plants, but not for *plants>0.1 m* (see tables 4.3 and 4.4). Hence, in spite of being less species-rich, more accessible sites have a higher overall use value to people than less accessible sites (cf. Martin, 1995). As such, species-rich sites might owe their higher (sub-)woody plant diversity to a lower harvest pressure that is concomitant with lower site accessibility and the lower perceived usefulness of some of the species they harbour. Alternatively, in sites that are better accessible less useful (sub-)woody species might disappear more easily as compared to species that have high use values and which people might tend to conserve more. If this is true, then it could explain the higher overall usefulness and lower diversity of more accessible sites.

Table 4.2: Significance levels of correlations between transects' averaged use values and Alpha and Shannon diversity for both sampling strategies (*plants>0.1 m* and *(sub-)woody plants*)

	Plants>0.1 m		***(Sub-)woody***	
	α	**H**	α	**H**
all uses	-(s)	n.s.	-**	-**
animal food	n.s.	n.s.	n.s.	n.s.
medicine	n.s.	n.s.	n.s.	n.s.
food	n.s.	n.s.	n.s.	n.s.
fuel	-*	n.s.	-**	-**
material	n.s.	n.s.	n.s.	n.s.
environmental use	-**	n.s.	n.s.	n.s.
social uses	-**	n.s.	n.s.	n.s.

- = negative correlation; **= $p<0.01$; *= $p<0.05$; s= $p<0.1$; n.s.= not significant

Also, the average fuel use value of a transect tends to decline with increasing species richness for both sampling strategies (table 4.2). In chapter 2, we have shown that both density and species richness of *(sub-)woody plants* increase with travel time (i.e. decrease with accessibility). Further on in this chapter, we also demonstrate the negative relationship between travel time and the average fuel use value of *(sub-)woody plants* in transects (see table 4.4). Nonetheless, the proportion of fuel plants is relatively invariable to diversity in transects. Therefore, these findings suggest that more species-rich (and thus less accessible) sites contain relatively more (sub-)woody individuals with lower fuel use values as compared to less species-rich sites. In line with the hypothesis cited above, this observation is probably related to the fact that less accessible fuel plants are less known and used and therefore receive lower fuel use values (cf. Martin, 1995).

On the other hand, decreasing average fuel use values with increasing species richness for transects with *plants>0.1 m* is probably due to the fact that in transects with higher species richness proportionally fewer plant species with (sub-)woody growth forms prevail. The same can be said for the average social and environmental use values of transects (table 4.2) because social and environmental uses are almost exclusively fulfilled by (sub-)woody plants.

In summary, while diversity-rich areas may be having a lower *overall* and *fuel* usefulness, the (sub-)woody plants that prevail in them have similar mean medicinal, food, material, environmental and social use values as those growing in sites with lower diversity. Hence, decreasing proportions of (sub-)woody plant species that are used for food, material, environmental and social uses in relation to increasing diversity are not reflected in the average use values for these categories in transects. This indicates that in more diverse areas, species from these use categories have (1) higher categorical use values and/or (2) are proportionally represented by more individuals.

4.3.3. Which Environmental Variables Can Explain Variation in the usefulness of vegetation sampled in transects?

In chapter 2, it was demonstrated that variation in the diversity of *plants>0.1 m* and *(sub-) woody plants* in transects can be explained in part by some of the environmental variables that were measured during this study. In the previous section (4.3.2.), it was shown how quantitative plant use in transects correlates with plant diversity for most use categories. Hence, there are serious indications that the variation in quantitative plant use can also be partly explained by some selected environmental variables. In this section, quantitative plant use (or 'usefulness') is represented by (1) the proportion of used plant species and plant individuals in transects; and (2) the average use values of transects.

Proportion of Plant Species and Plant Individuals Used in Transects

A direct gradient analysis can help to identify the environmental variables that significantly control variation in the usefulness of transects. Hereby, the main ("species") matrix consists of columns containing percentages of individuals and species used per category and rows corresponding to transects. In the second ("environmental") matrix, columns are environmental variables and rows are transects. To determine which ordination technique is best suited (linear or unimodal), a DCA was performed to determine the length of the gradient. The latter was smaller than 2 s.d. for both *plants>0.1 m* (first axis: 1.611) and *(sub-) woody plants* (first axis: 1.146), thus a constrained linear model (i.e. redundancy analysis, RDA) seemed best-suited.

Plants>0.1 m

RDA ordination axes are highly significant (p=0.005; Monte Carlo test), but the first two axes explain only 19.6% of variation (13.1%+6.5%). By means of the feature "forward selection" in the CANOCO programme (Ter Braak, 1988a and 1988b), only those environmental variables that are significant (Monte Carlo Permutation test) were selected. These variables consisted of altitude (p=0.005) and small-scale plantation of exotics (p=0.03). Altitude correlates best with the first axis (correlation coefficient = -0.59). Plantation and altitude are weakly, but evenly correlated with the second axis (0.292). In figure 4.8, the ordination diagram of the first two axes is plotted. The directions of the arrows indicate the directions in which the percentage of used species or individuals pertaining to different use categories in transects increase most, and the length of the arrows equal the rate of change in that direction. The cosine of the angle between the arrows of the percentage of used species or individuals in transects and the environmental variables approximates the correlation coefficient between both. In other words, arrows pointing roughly in the same direction indicate a highly positive correlation while arrows pointing in roughly opposite directions indicate a highly negative correlation. Arrows crossing at right angles point out near zero correlation (Jongman *et al.*, 1996). In general, one can be more confident of correlations between arrows (pertaining to percentages species or individuals used in transects and environmental variables) that are situated far from the origin as compared to those that are situated near the centre. For example, from figure 4.8 it can be concluded that the percentage of individuals and species in transects that are used as food increases with altitude, while proportions of individuals that serve as fuel or material are higher in transects that contain planted exotic trees or shrubs.

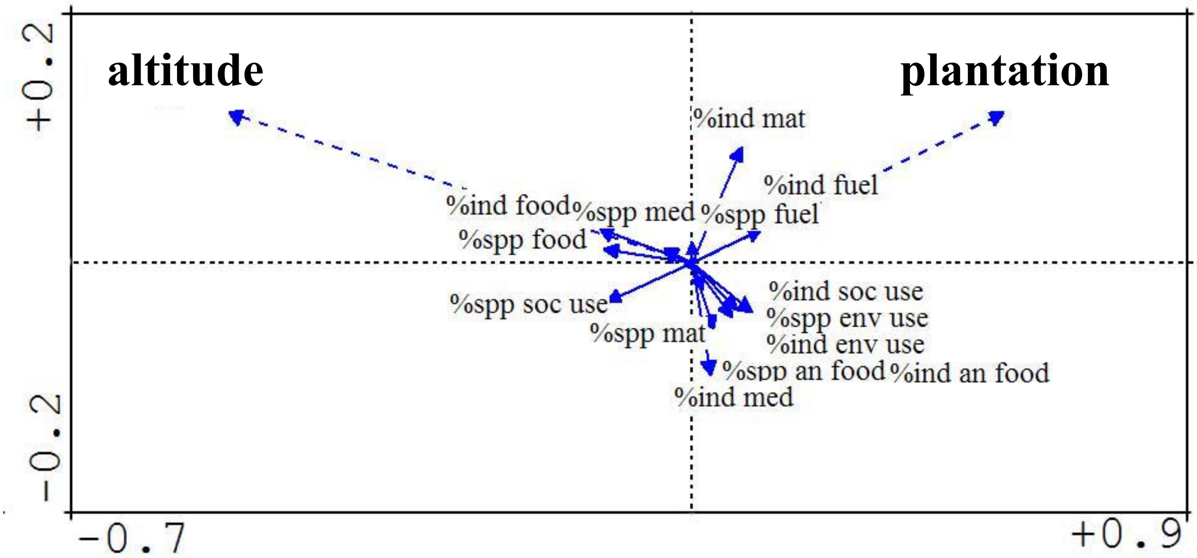

Figure 4.8: Redundancy analysis (RDA) of the percentage of used species and individuals in transects for *plants>0.1 m*. Transect scores are not presented. Dotted arrows represent significant environmental variables. For interpretation of the diagram the reader is referred to the text (mat= material; med= medicine; soc use= social uses; env use= environmental uses; an food= animal food).

(Sub-)woody Plants

The same procedure as described for *plants>0.1 m* was followed for *(sub-)woody plants*. Ordination axes are highly significant (p=0.005; Monte Carlo). The first two axes explain a similar amount of variation as was also the case for *plants>0.1 m* (21.6%), although here the contribution of the two axes is more evenly (12.1% and 9.5% for axis 1 and 2 respectively). By means of the “forward selection” feature in the CANOCO programme, only altitude (p=0.005), travel time (p=0.025) and fire (p=0.025) were withheld as significant environmental variables. Fire correlates most with the first axis (correlation coefficient = -0.53). Altitude and travel time correlate evenly but inversely with the second axis (-0.514 and 0.555, respectively). Figure 4.9 indicates that the percentage of (sub-)woody individuals used as fodder correlates perfectly with travel time. The proportion of medicinal plant individuals in transects decreases in relation to travel time, while the proportion of medicinal (sub-)woody species increases with altitude.

Average Use Values of Transects

Ordination analysis can likewise be used to examine which measured environmental variables explain the variation in categorical use values of transects. For this analysis, the main matrix consists of columns with transects’ mean categorical use values, whereas rows represent transects. The length of gradient was much smaller than 2 for all axes and for both *plants>0.1 m* and *(sub-)woody plants* (first axis: 0.569 and 0.675, respectively). This justifies the use of a linear model. Redundancy analysis was applied, using a second matrix with environmental variables as columns and transects as rows. However, ordination axes were not significant for *plants>0.1 m*, nor did there exist a correlation between any of the measured environmental variables and the ordination axes (Monte Carlo Permutation test, p>0.1 for all variables). For *(sub)woody plants* better results were obtained. Altitude (p=0.005), fire (p=0.01) and travel time (p=0.0015) are the only significant environmental variables (Monte Carlo Permutation test). All canonical axes are significant and the first axis explains 34.3% of the variation in use value data. The second axis contributes very little to explaining variation (3.4%). The first axis correlates with altitude (correlation coefficient is -0.55) and travel time (0.47), and the second axis correlates with fire (0.45).

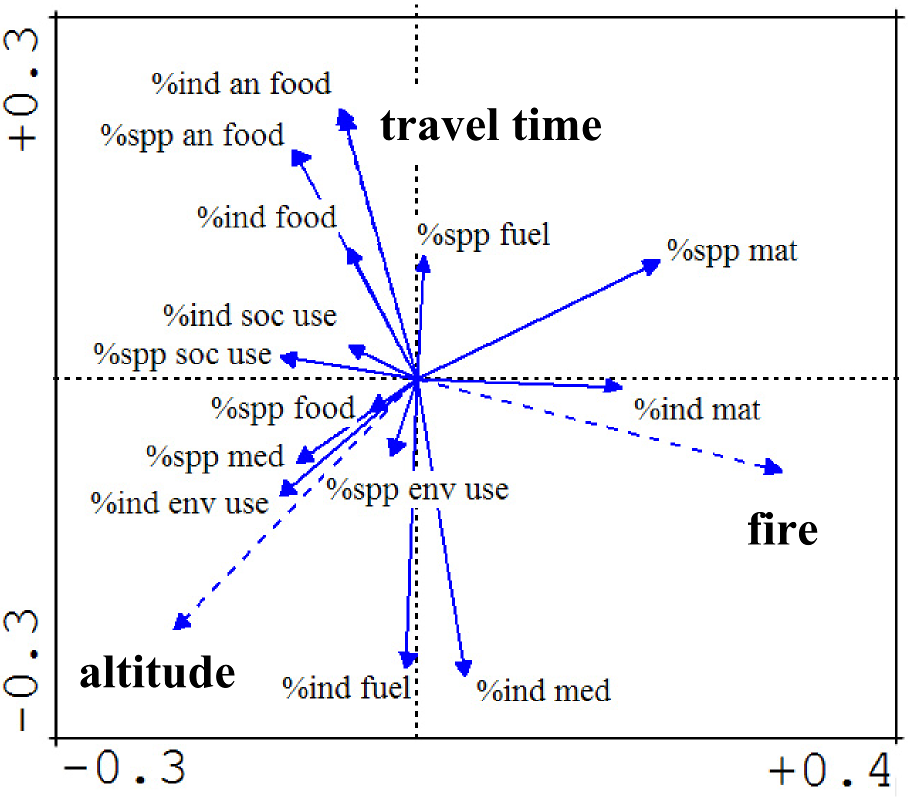

Figure 4.9: Redundancy analysis (RDA) of the percentage of individuals and species used to available in transects for *(sub-)woody plants*. Dotted arrows represent significant environmental variables. Transect scores are not presented. For interpretation of the diagram the reader is referred to the legend of figure 4.8 and the text.

According to figure 4.10, the mean medicinal and fodder use values of transects decrease with travel time and altitude, respectively. On the other hand, the mean food use value is higher in transects without evidence of burning activity. Nevertheless, these observations do not hold strong power because most arrows of the categorical mean use values are located near the origin of the diagram, which implies that less confidence is obtained for these correlations (cf. Jongman *et al*., 1996).

4.3.4. Predicting Average Categorical Use Values of Transects Based on Measured Environmental Variables

Altitude, travel time, planted exotic trees or shrubs, and evidence of recent burning have been identified as the measured environmental variables that explain best the variation in the usefulness of vegetation in transects. Here, we will explore to what extent average categorical use values of transects can be predicted from these variables by exposing our data to various statistical techniques (correlation and regression analysis, t-test, ANOVA and Mann-Whitney test).

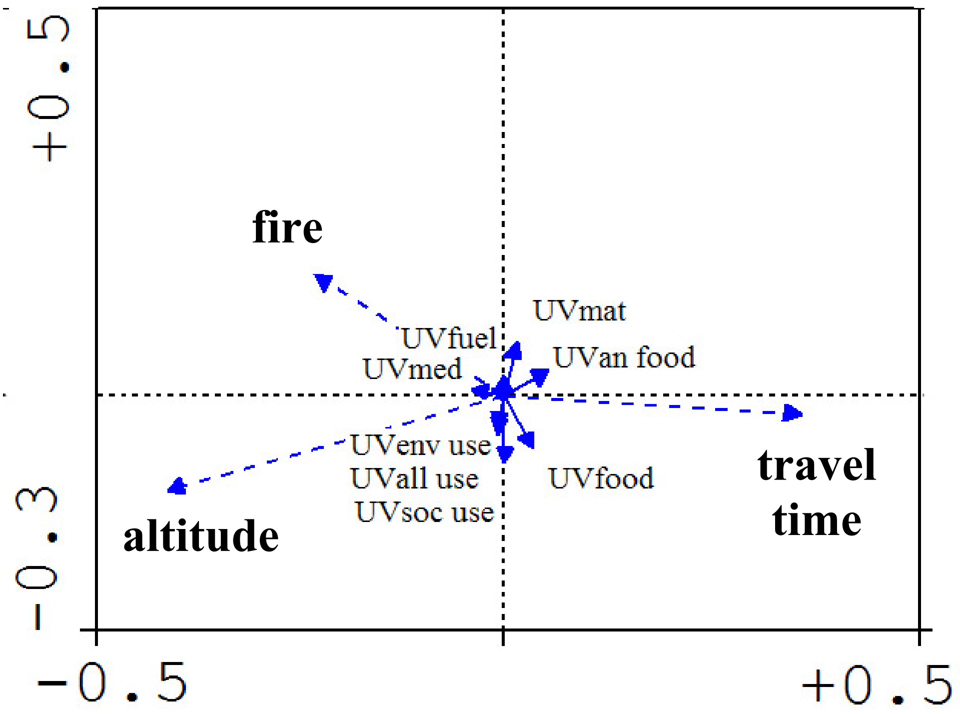

Figure 4.10: Redundancy analysis (RDA) ordination diagram of transects' mean categorical use values for *(sub-) woody plants*. Transect scores are not presented. For interpretation of the diagram the reader is referred to the legend of figure 4.8 and the text.

Ho = average categorical use values of transects are random with respect to altitude, travel time, slope and compass direction

Plants>0.1 m

Pearson correlation was used to examine between transects' averaged use values and travel time, altitude, slope and compass bearing. Correlations are not significant for slope and compass bearing. Table 4.3 shows that significant correlations exist with travel time and altitude. Mean medicinal use value of *plants>0.1 m* does only correlate negatively with travel time and the mean food use value of transects increases with travel time and altitude, but all these correlations are only significant at the 10% level. Transect's mean animal food use value decreases significantly with altitude at the 1% level. Similar trends in the percentage of species and individuals used as food and fodder in relation to altitude can also be observed in figure 4.8.

(Sub-)woody Plants

Only travel time and altitude correlate with mean categorical use values. For slope and compass bearing no significant values were obtained. The mean categorical use values of *(sub-)woody plants* in transects decrease significantly with travel time for *overall uses*, *medicine*, *environmental uses* and *fuel* (table 4.4). Although only significant at the 10% level, similar results were obtained for *plants>0.1 m* regarding medicinal uses. These findings suggest that more accessible sites (lower travel time) are more useful to people for various categorical plant uses (cf. Martin, 1995). This corroborates the hypothesis that "the more accessible or abundant vegetal resources are more useful to people" might not only be valid for individual plant species (Adu-Tutu *et al.*, 1979; Johns *et al.*, 1990; Phillips and Gentry, 1993b; Alexiades, 1999; Frei *et al.*, 2000; Casagrande, 2002; Bonet and Vallès, 2002; La Torre-Cuadros and Gerald, 2003; Byg *et al.*, 2006), but also for entire vegetation units.

Table 4.3: Pearson correlations between transects' mean categorical use values and environmental variables for *plants>0.1 m*; only significant combinations are given

Categorical use values	**Correlation parameters**	**travel time**	**altitude**
$UV_{medicine}$	Pearson Correlation	**-0,335(s)**	-0,035
	Sig. (2-tailed)	0,076	0,856
UV_{food}	Pearson Correlation	**0,337(s)**	**0,342(s)**
	Sig. (2-tailed)	0,074	0,070
$UV_{animal\ food}$	Pearson Correlation	0,274	**-0,494(**)**
	Sig. (2-tailed)	0,150	0,006

**: p<0.01; s: p<0.1

The mean *animal food* use value of *(sub-)woody plants* is negatively correlated with altitude (table 4.4). This implies that the general usefulness of plants used as fodder increases with decreasing altitude. This trend is also evidenced in figure 4.10. Transects situated at higher altitudes possess higher mean fuel and social use values, although the significance level for these correlations are relatively low (p=0.049 and p=0.08, respectively). Not all significant correlations listed in table 4.4 can be observed in the ordination diagram in figure 4.10. This is probably due to the fact that the arrows pertaining to most categorical use values are situated too close to the plot centre. Nevertheless, figure 4.9 depicts similar results for the percentage of plant individuals used as *medicine* and *fuel*.

Table 4.4: Pearson correlations between transects' mean categorical use values and environmental variables for *(sub-)woody plants*; only significant combinations are given

Categorical use values	**Correlation parameters**	**travel time**	**altitude**
$UV_{all\ uses}$	Pearson Correlation	**-0,361(*)**	0,002
	Sig. (2-tailed)	0,030	0,991
$UV_{medicine}$	Pearson Correlation	**-0,431(**)**	0,115
	Sig. (2-tailed)	0,009	0,503
UV_{fuel}	Pearson Correlation	**-0,447(**)**	**0,330(*)**
	Sig. (2-tailed)	0,006	0,049
$UV_{envuses}$	Pearson Correlation	**-0,350(*)**	0,249
	Sig. (2-tailed)	0,037	0,143
$UV_{socuses}$	Pearson Correlation	0,006	**0,292(s)**
	Sig. (2-tailed)	0,970	0,084
$UV_{animal\ food}$	Pearson Correlation	0,143	**-0,577(**)**
	Sig. (2-tailed)	0,404	0,000

envuses= environmental uses; socuses= social uses
**= p<0.01; *=p<0.05; s= p<0.1

The fact that travel time and altitude were selected by RDA as environmental variables that significantly explain variation in the usefulness of transects is reconfirmed here by means of correlation analysis. More significant correlations were found for *(sub-)woody plants* than for *plants>0.1 m*. This observation explains partly why the RDA of transects' mean categorical use values for *plants>0.1 m* failed to yield significant results.

Ho = mean use values of transects sampled in the prepuna ecological zone are equal to those of transects sampled in the puna ecological zone

In the previous paragraphs it was demonstrated that altitude is a significant predictor of several averaged categorical use values of transects. Since the geographical position of the *prepuna* and *puna* ecological zones is predominantly based on altitude, we examine here whether the average categorical use values of transects are significantly different between the *prepuna* and *puna* ecological zones, respectively.

Plants>0.1 m

Independent sample t-tests and Mann-Whitney non-parametrical tests demonstrate that mean use values of transects sampled in *prepuna* (13 transects) and *puna* (16 transects) zones are equal for all use categories, except food. The mean food use value of transects from the *puna* ecological zone (0.10) is significantly higher than from the *prepuna* (0.07) (p=0.02; t-test). This result is in agreement with the positive correlation between altitude and mean food use values of transects demonstrated before.

(Sub-)woody Plants

T-tests and Mann-Whitney non-parametrical tests demonstrate that the mean use value of transects sampled in the *prepuna* (17 transects) and *puna* (19 transects) zones are equal for all use categories, except for fuel and animal food. The mean fuel use value of transects from the *prepuna* ecological zone is significantly higher than from the *puna*, whereas the opposite is observed for mean animal food use values (p=0.03 and p=0.003, respectively; t-tests). This outcome is rather surprising, given that we previously demonstrated that the mean fuel use value of transects correlates positively with altitude, whereas the opposite is true for mean fodder use values. Possibly this discrepancy is an artefact of a too small sample size.

Ho = transect use values are random with respect to planting of exotic species in transects

Plants>0.1 m

In 5 of 29 sampled transects, planted exotic trees (*Eucalyptus globulus* and *Pinus radiata*) or shrubs (*Spartium junceum*) were present. Mean categorical UVs of transects with and without planted species were compared by means of independent sample t-tests (for $UV_{medicine}$, UV_{food}, $UV_{animal\ food}$ and $UV_{pesticide}$) and Mann-Whitney tests (for $UV_{all\ uses}$, $UV_{material}$, $UV_{env\ use}$, $UV_{soc\ use}$ and UV_{fuel}). Test results show that $UV_{animal\ food}$ (p=0.04), $UV_{material}$ (p<0.01), $UV_{env\ use}$ (p=0.01) and UV_{fuel} (p=0.049) are significantly higher in transects with planted exotic species than in other transects. This trend is supported by figure 4.8 for the percentage of individuals used as *material* and *fuel*.

(Sub-)woody Plants

In 5 of 36 sampled transects, exotic tree or shrub species had been planted. Independent sample t-tests show that the mean $UV_{all\ uses}$ (p<0.01) and $UV_{medicine}$ (p=0.02) are significantly higher for transects with planted exotic species than for other transects. All other average categorical UVs are independent of planted exotics in transects (p-values all ≥ 0.11).

Planting of exotic species was also selected as a significant variable that explains variation in the proportion of used species and plant individuals in transects for *plants>0.1 m* (figure 4.8). This shows that the presence of exotic species plays a role in predicting certain mean categorical use values in transects, both for *plants>0.1 m* and *(sub-)woody plants*. For *plants>0.1 m* this might be related to the combined effect of a lower richness of herbaceous plants found in transects with planted exotics as compared to other transects (see chapter 2, section 2.3.6.) and the higher usefulness of these exotics. Indeed, although actual species numbers are lower, higher proportions of species and individuals that grow in transects with planted exotics are useful as compared with transects without exotics. For *(sub-)woody plants*, higher overall and medicinal use values of transects with exotics is probably related to the higher use values obtained for these exotics (*Eucalyptus globulus*, *Spartium junceum* and *Pinus radiata* score third, fifth and twenty seventh, respectively, in the listing of the most useful plant species; see table 3.1 chapter 3).

Ho = mean use values of transects are random with respect to burning activity

Plants>0.1 m

In 4 of 29 sampled transects, evidence of burning activity was observed. Independent sample t-tests demonstrate that evidence of burning activity does not influence categorical use values of transects (p-values all ≥0.21).

(Sub-)woody Plants

In 7 of 36 sampled transects, evidence of burning activity was observed. Independent sample t-tests demonstrate that all but one use values are independent of burning activity (p-values all ≥0.08). The mean food use value of transects without burning activity was significantly higher as compared to transects where burning was observed ($p<0.01$). The fact that mean food use value is higher in transects without (recent) burning is also visualized in the RDA diagram for *(sub-)woody plants* (figure 4.10).

Ho = use values of transects are random with respect to the presence of a nearby (temporary) stream

Plants>0.1 m

Five of 29 sampled transects are situated in the vicinity of (temporary) streams. Independent sample t-tests demonstrate that all transects' mean categorical use values (except UV_{food}) are independent from the presence of (temporal) streams (p-values all ≥0.16). Mann-Whitney test shows that the mean food use value of transects in the vicinity of a (temporary) stream is significantly lower ($p=0.04$) than for transects without a stream. This is a rather unexpected outcome and probably represents an artefact of a too small sample size.

(Sub-)woody Plants

Six of 36 sampled transects are characterized by the presence of (temporary) streams in the direct vicinity. Results show that mean $UV_{all\ uses}$ ($p<0.01$; t-test), UV_{fuel} ($p<0.01$; t-test) and $UV_{material}$ ($p= 0.02$; Mann-Whitney test) are significantly higher in transects that are located near (temporary streams) than in other transects.

Although not selected by RDA as a significant environmental variable, (temporary) streams might partly influence the usefulness of transects for some use categories, possibly as a consequence of the different hydrographical profile near (temporary) streams.

Ho = the mean use values of transects are random with respect to firewood harvest, grazing activity and paths crossing transects

This null hypothesis is accepted for every one of these binary environmental variables. The numbers of transects in which firewood harvest, grazing activity, crossing paths were observed, are listed in table 4.5.

Table 4.5: Numbers of transects sampled for *plants>0.1 m* and *(sub-)woody plants* with observed incidence of firewood harvest, grazing activity and crossing paths

	Plants>0.1 m		***(Sub-)woody Plants***	
	observed	**not observed**	**observed**	**not observed**
firewood harvest	11	18	14	22
grazing	24	5	31	5
presence of paths	12	17	14	22

In summary, up to here, we have shown that in Apillapampa the average usefulness of *plants>0.1* and *(sub-)woody plants* in transects can be predicted in part by the altitudinal position of vegetation sites, site accessibility (expressed as travel time from the village centre), planting of exotic species, evidence of recent burning activity and the presence of a (temporary) river or stream. All variables except presence of a stream were selected by RDA. Finally, comparison of the average categorical use values of transects also allowed to demonstrate that *prepuna* and *puna* ecological zones are equally useful to Apillapampeños, in terms of their overall use value, even though significant differences were found for certain individual use categories.

4.3.5. Predicting Categorical Use Values of Plant Species

In this section we will investigate the extent to which use values of individual species (instead of transects) can be predicted from a number of phylogenetic, morphological, ecological, and anthropological variables.

Ho = species' use values are random with respect to their classification at the family level

To test this hypothesis, all plant species belonging to families that are represented by at least 7 species are selected (representing a total of 280 species). Mean use values show a large variation among plant families for different use categories. For example, overall FUV_S values vary from 0.42 (Bromeliaceae) to 2.14 (Cactaceae). To test whether this variation in FUV_S values is statistically significant, the Kruskal-Wallis test was applied. Results in table 4.6 show that plant family has a significant value in predicting a species' use value for all use categories, except *social uses*. These findings support the well-documented fact that plant family is a dominant factor in determining the use (value) of particular plants (Phillips and Gentry, 1993b; Moerman, 1996; Cotton, 1996; Moerman *et al.*, 1999; Byg *et al.*, 2006). In chapter 3 we already highlighted the families that are significantly overused for different use categories.

Table 4.6: Kruskal Wallis test results for evaluating significant differences between family use values (FUVs) per use category. Only the mean social use value of plant species is independent of plant family.

	FUV $_{all}$	FUV $_{med}$	FUV $_{food}$	FUV $_{mat}$	FUV$_{env}$	FUV$_{soc}$	FUV $_{fuel}$	FUV $_{anim}$
χ^2	**54.105****	**41.576****	**58.941****	**39.513****	**38.043****	14.771	**48.163****	**63.193****
Sig.	0.000	0.000	0.000	0.001	0.001	0.541	0.000	0.000

all= all uses; med= medicine; mat= material; env = environmental uses; soc = social uses; anim= animal food; sig.= significance
**= $p<0.01$

Ho= species' use values are random with respect to their growth form

Growth forms of plant species were divided into six categories: (sub-)woody plants (110 species), herbaceous plants (including ferns; 240 species), vines and lianas (19 species), (hemi-)parasites (9 species), cacti (7 species) and epiphytes (4 species). Only the first three growth forms were included in this analysis due to the small sample sizes of the other growth forms. Mean use values of plant species grouped per growth form are shown in figure 4.11 for all but two use categories: *fuel* and *poison* are not represented here for reasons of clarity. All plants that are used as fuel have a (sub-)woody growth form (mean $UV_{fuel}=0.57$), whereas only 2 herbaceous and 1 (sub-)woody plant species are used as natural poisons. Kruskal Wallis tests reveal that plant growth form has a significant value in predicting a species' use value for all use categories but *medicine* (table 4.7).

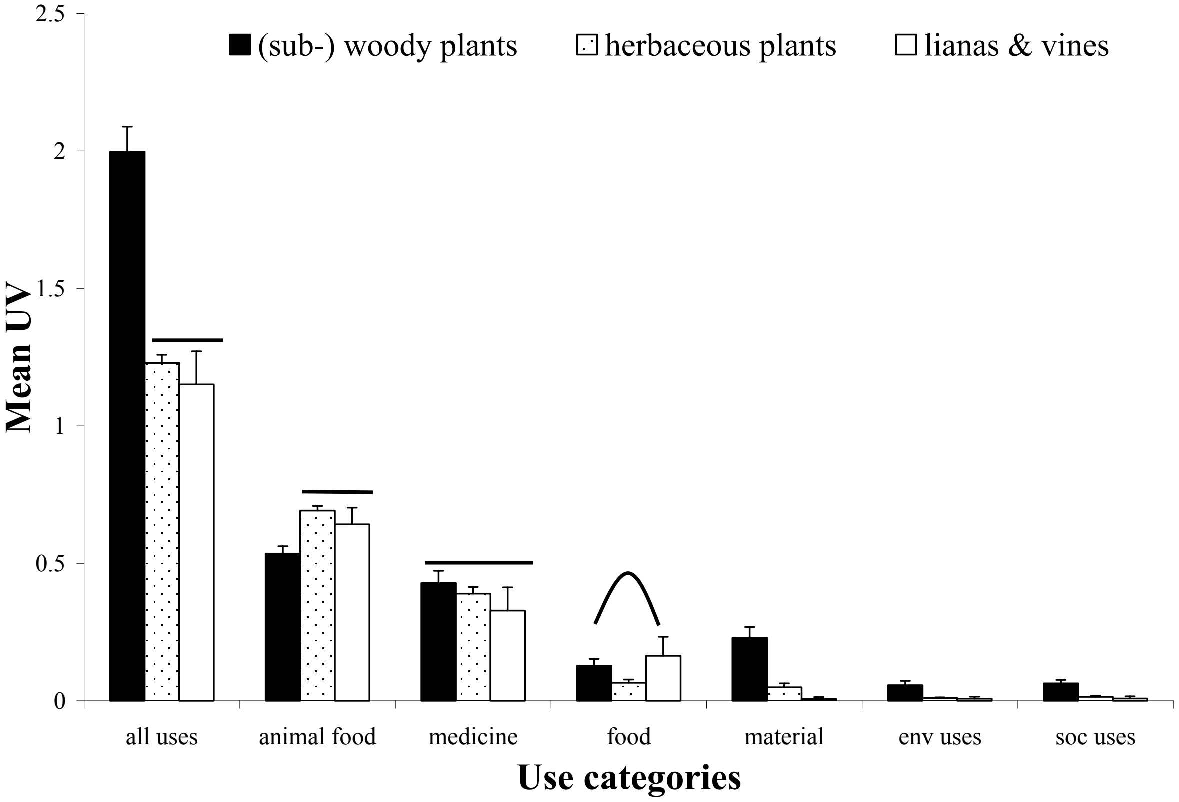

Figure 4.11: Mean categorical use values of plants according to growth form. Growth forms with equal mean (categorical) use values are indicated by horizontal and curved lines (error bars represent standard errors of the mean).

Mann-Whitney tests show that mean use values of (sub-)woody plants are significantly larger than those of herbaceous plants for all but two use categories. The mean medicinal use value of plant species is equal (p=0.99) for (sub-)woody and herbaceous plants, while herbaceous plants have a higher fodder use value. Results of other Mann-Whitney pairwise comparisons between life forms are represented in figure 4.11 by means of horizontal and curved lines, indicating significantly equal (at 5% level) mean categorical use values

Table 4.7: Kruskal Wallis test results for evaluating significant differences between mean categorical use values per growth form. Only the mean medicinal use value is independent of growth form.

	$UV_{\text{all uses}}$	UV_{anim}	UV_{med}	UV_{food}	UV_{material}	$UV_{\text{env uses}}$	$UV_{\text{soc uses}}$	UV_{fuel}
χ^2	**102.66****	**26.314****	3.25	**34.02****	**60.12****	**18.14****	**34.29****	**274.45****
Sig.	0.000	0.000	0.662	0.000	0.000	0.003	0.000	0.000

med= medicine; env uses= environmental uses; soc uses= social uses; sig.= significance
**= p<0.01

Ho= species' use values are random with respect to their cultivation status

As mentioned in chapter 2, at least 44 (non-agricultural crop) plants are cultivated in Apillapampa. To compare the usefulness of cultivated and non-cultivated plants, Mann-Whitney non-parametric tests were used. Test results show that cultivated plants have a significantly higher usefulness (all p<0.001) than wild plants, for all but three use categories: medicine, social uses and animal food. For the latter three categories, use values are equal for cultivated and non-cultivated plants (see figure 4.12).

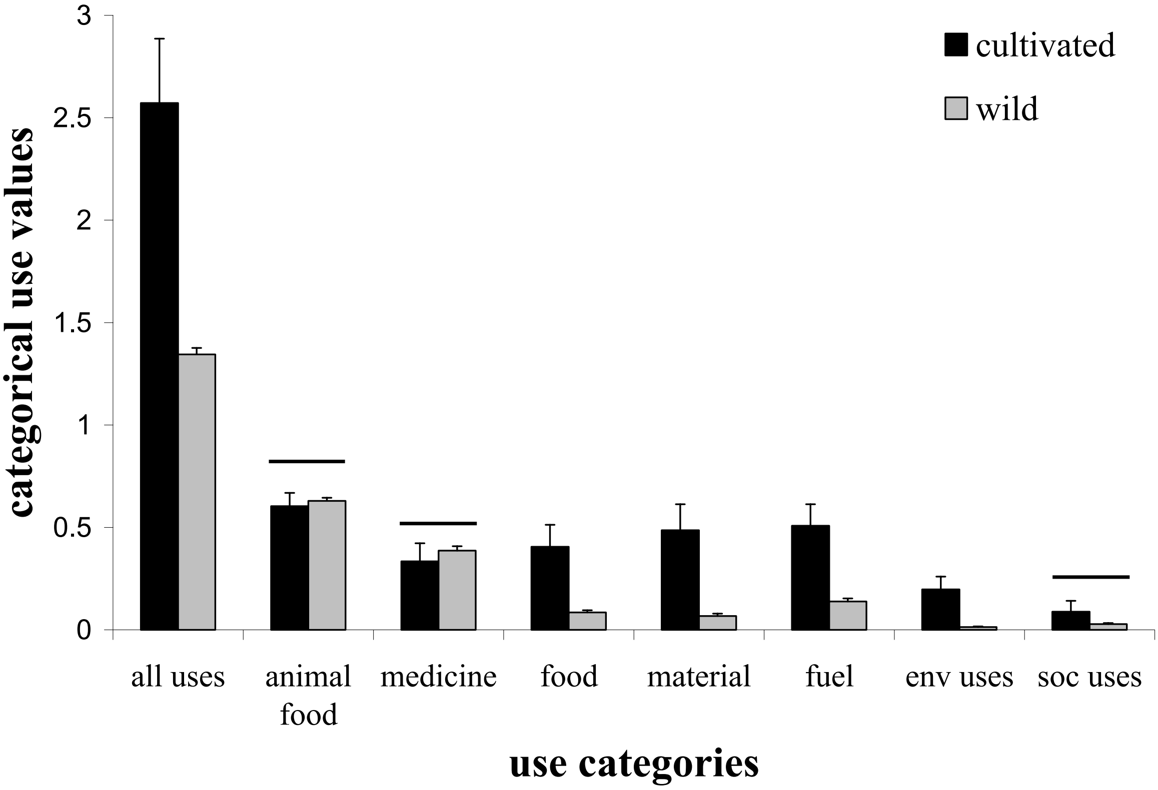

Figure 4.12: Mean categorical use values of cultivated and wild plants (error bars represent standard errors of the mean; significantly equal values are indicated by horizontal lines)

The fact that cultivated plants are more useful for food, material, environmental uses and fuel can be expected since usefulness is generally the driving force behind management of plants (Van den Eynden, 2004). Interestingly, a similar mean medicinal use value is obtained for wild plants as for cultivated plants. In view of the highly different sample size between cultivated and wild species (1:8), this confirms that people in Apillapampa mainly resort to wild plant populations for herbal medicines.

Ho= species' use values are random with respect to their geographical origin

A total of 54 plant species that grow in Apillapampa (25 cultivated and 29 weeds) have been introduced from outside of South America (see chapter 2, section 2.3.1.). Categorical use values of introduced and native species are equal (Mann-Whitney tests, $p>0.05$ for all use categories).

Ho= species' use values are random with respect to plant density and frequency in sampled transects

We calculated the density and frequency of 298 different plant species that were sampled in the first 29 transects. The seven additional transects that were sampled for (sub-)woody plants are not included in this analysis to guarantee that all species' density and frequency measurements are based on equal numbers of transects. In this list we also included eighteen useful plant species with habits smaller than 0.1 m that were sampled in transects but have not been considered in the diversity analysis of transects (as they are not *plants>0.1 m*; see methodological considerations in chapter 2) .

The results presented in table 4.8 show that density only predicts a species' fodder use value. Although density and frequency of plants are correlated (Kendall's $\tau b = 0.55$; $p<0.001$), frequency is a more potent predictor variable of use values. Species with higher frequencies are more likely to have higher overall, food and fodder use values. Hence, the hypothesis that more accessible species are more useful (Adu-Tutu *et al.*, 1979; Johns *et al.*, 1990; Phillips and Gentry, 1993b; Alexiades, 1999; Frei *et al.*, 2000; Casagrande, 2002; Bonet and Vallès, 2002; La Torre-Cuadros and Gerald, 2003; Byg *et al.*, 2006) seems to apply also to plant species in Apillapampa, at least if frequency in transects is an adequate measure of plant accessibility. In the next paragraph we will therefore examine the relationship between frequency and perceived accessibility by local participants.

Table 4.8: Kendall's τ_b correlation coefficients with corresponding significance levels between predictor variables (relative density and frequency) and response variables (categorical use values). Only significant correlations are shown.

		$UV_{\text{all uses}}$	UV_{food}	$UV_{\text{animal food}}$
density	**Corr. Coeff.**	0.04	0.07	**0.12****
	Sig.	0.95	0.13	0.003
frequency	**Corr. Coeff.**	**0.10****	**0.10***	**0.08***
	Sig.	0.02	0.03	0.05

*= $p \leq 0.05$; **= $p \leq 0.01$

Ho= species' use values are random with respect to their perceived accessibility

To the best of our knowledge, the relationship between plant density and frequency on the one hand and plant accessibility on the other hand, has rarely been tested. We hypothesized that one way to test this assumption was by systematically asking participants to assess accessibility of plant species by the following question: "Is this plant easy to find or do you have to look for it? Answers were coded in a binary format, whereby "1" represents easy access, and "0" the opposite. Next, participants' judgments were evaluated per species and only those species that were perceived as easy to find by more than half of the participants were classified as 'easily accessible' A similar procedure was followed for classifying plants that were perceived as difficult to find. As such, 179 species were classified as difficult to find against 168 easily accessible ones.

Our data related to 269 species for which both accessibility data assessed by participants *and* density and frequency data measured in transects were available. They revealed that plant species that were perceived as easy accessible by the majority of participants have significantly higher densities and frequencies than species that were assessed as being difficult to find (8.6 vs. 3.3 individuals per 100 m² and present in 20% vs. 11% of transects, respectively; $p<0.001$, Mann-Whitney tests). These findings suggest that plant density and frequency are indeed good predictors of accessibility, at least in Apillapampa.

Results presented in table 4.9 show that a species' mean overall, material, fuel and animal food use values are significantly higher for species that are easy accessible as compared to species that are difficult to find. All other categories are equal.

Table 4.9: Mann-Whitney test results for evaluating significant differences between mean categorical use values of easily and poorly accessible species. Only plants shown to at least two respondents were included in this analysis.

	$UV_{all\ use}$	UV_{med}	UV_{food}	UV_{mat}	$UV_{env\ use}$	$UV_{soc\ use}$	UV_{fuel}	UV_{anim}
Mann-Whitney U	**10168****	14398	14337	**13281****	14485	14782.5	**12169****	**11999****
Sig.	0.000	0.492	0.359	0.006	0.303	0.672	0.000	0.001

med= medicine; mat= material; env use= environmental uses; soc use= social uses; an food= animal food; **=$p<0.01$

In spite of the positive relationship between plant density and accessibility, density is not a good predictor of usefulness (table 4.8). This might indicate that our transect data are not adequate for quantifying actual densities of plants in the landscape. This assumption will be tested in the following paragraph.

Ho= species' use values are random with respect to their perceived available abundance

The question remains whether 29 transects significantly represent the abundances and frequencies of the sampled species in the entire living environment of Apillapampa. This can, at least in part, be tested by comparing assessments about the abundance of individual plant species by participants with their measured densities and frequencies in transects. To quantify how participants estimate the abundance of individual plant species, they were asked to determine for each species whether it was presented in a large, moderate or small quantity in the local vegetation. The corresponding score (i.e. large, moderate or small) that was confirmed by at least half and the majority of the interviewed participants was assigned to every individual plant species (minimum two participants were interviewed per plant). Ninety five species were excluded from this analysis since no quantity score was confirmed by at least half and the majority of the participants. For twenty five species, half of the respondents confirmed one quantity score and the other half another one and therefore these species were also excluded. In total, 258 species were selected; their quantity was rated as large, moderate and small for 23, 136 and 99 species, respectively.

Our data related to 195 species for which both abundance data (assessed by participants) *and* density and frequency data (measured in transects) were available (table 4.10). The mean frequencies of plants in the three quantity scores are significantly different ($p<0.01$; Kruskall Wallis test). No significant differences were found for the mean density of plants in the three quantity scores. Hence, the measured frequency of a species in transects is a better representation for the abundance of that species perceived by participants as compared to its measured density. This may, as suggested earlier, be related to the fact that our transect data do not sufficiently represent actual densities of plants in the landscape. On the other hand, the observed differences may also be because people's estimations pertain to different spatial scales or to different localities as compared to those of transects (cf. Hellier *et al.*, 1999). In addition, there may exist a large individual variation between participants regarding the scale at which they evaluate plant abundance (Byg *et al.*, 2006).

Table 4.10: Mean densities (# individuals per 100 m²) and frequencies (% transects) of plant species for three different ordinal quantity scores given by more than half of all participants. N is the number of species assessed per quantity score. Combined data on quantity scores, density and abundance were only available for 195 species.

Quantity score	N	Mean density	Mean frequency
large	18	18	26
moderate	104	5	15
small	73	4	11

Kruskal-Wallis non-parametric tests examined whether mean categorical use values are statistically different between species which, according to respondents, are present in large, moderate or small abundances (N=258). The results show that both mean overall and animal food use values of plants in the category "high in abundance" are significantly higher than for plants with moderate or small abundances (Mann-Whitney; $p<0.01$; cf. table 4.11). This observation is in agreement with the correlation found between plant frequency and categorical use values (see table 4.8). Also, the material use value of plants with a high abundance is significantly higher than for plants with moderate or small abundance (Mann-Whitney; $p<0.01$; cf. table 4.11). For UV_{med} the opposite is observed: the mean UV_{med} of plants that are said to have high abundances is significantly lower than that for plants with regular or small abundances (Mann-Whitney; $p<0.01$).

Hence, the measured frequency of plants, as well as the indigenous assessment of plant accessibility and abundance seem to be fair predictors of the overall usefulness of plant species. However, this pattern can not be generalized for every use category. Particularly the medicinal usefulness of plants does not seem to be influenced by any of these variables (except the indigenous assessment of plant abundance), which is probably due to the exceptionally high proportion of available plants that is used in traditional medicine in Apillapampa (see chapter 3).

Table 4.11: Kruskal Wallis test results for evaluating significant differences between mean categorical use values of species that according to participants are represented by respectively large, regular or small abundances (N=258)

	$UV_{all\ uses}$	UV_{med}	UV_{food}	UV_{mat}	U_{envuse}	U_{socuse}	UV_{fuel}	$UV_{an\ food}$
χ^2	**9.294****	**8.798****	2.519	**8.553****	4.089	0.112	4.536	**27.771****
Asymp. Sig.	<u>0.010</u>	<u>0.012</u>	0.284	<u>0.014</u>	0.129	0.946	0.104	<u>0.000</u>

med= medicine; mat= material; env use= environmental uses; soc use= social uses; an food= animal food
**= $p \leq 0.01$

Ho= family use values (FUV) are random with respect to the overall density and frequency of plant species in the sampled transects

To address this null hypothesis, we calculated densities and frequencies of the 15 different plant families that were sampled in the 29 first transects and that are represented by at least seven species. The density of plant families in transects correlates with material FUV values (Pearson R= 0.58; p=0.02), while the frequency of plant families in transects correlates with overall (Pearson R= 0.65; p= 0.01) and medicinal FUV values (Pearson R=0.67; p= 0.01). No families are statistically over- or underused in these categories. These results indicate that in Apillapampa family use values can in part be predicted from their local frequency and density, at least for families with a locally high species-richness. Similar observations have been made by Galeano (2000) for forest used by Afro-American people in Colombia.

4.4. Conclusions

Community members in Apillapampa make extensive use of the surrounding wild flora. The proportion of plants used in transects is clearly situated in the upper margins of the range reported in literature. What determines the usefulness of individual species or vegetation units (sampled in transects) in Apillapampa is clearly not purely controlled by stochastic processes. In this chapter, we have identified several variables that guide the usefulness of plant resources. The variables that determine the usefulness of local vegetation units include: altitude, accessibility (measured as travel time from the village centre), planting of exotic tree or shrub species, evidence of recent burning activity and proximity to a (temporary) river or stream. Although altitude explains a substantial part of the variation in the usefulness of transects, differences in usefulness of altitude-based ecological zones were restricted to few use categories. Regardless of some minor differences in categorical use values, the overall usefulness of the *prepuna* and *puna* ecological zones is equal.

Plant diversity in transects turned out to be a fairly good predictor of the usefulness of the vegetation at sampling sites. Based on regression slope analysis of categorical plant uses plotted as a function of plant diversity, a distinction could be made in Apillapampa between diversity followers (medicine, animal food and/or fuel) and diversity laggards (food, materials, environmental uses, social uses and/or fuel). For diversity laggards, the number of useful plant species increases only moderately with increasing plant diversity, whereas for diversity followers the number of species keeps abreast with plant diversity. The medicinal use category is most notable among diversity followers. It seems that in categories that are diversity followers, plants are partly selected and used in an immediacy context, whereby emic perception of efficacy may be less important. By contrast, selection of plants used in diversity laggard categories is principally driven by emic perception of efficacy, because plants or their parts are generally not needed on a short notice.

In analogy to vegetation units, the use value of individual plant species is guided by several variables, including phylogenetic, morphological, ecological and anthropogenic characteristics of plants such as plant family, growth form, cultivation status, density, frequency and indigenous assessments of accessibility and abundance of plants. In addition, our data allowed us to confirm the hypothesis that the density and frequency of plants in the landscape is correlated with their perceived accessibility by local people.

We have provided support for the notion reported in the literature that "more accessible plant resources are more useful to people". The case of medicinal plants was most noteworthy in this respect. While the average medicinal use value of vegetation occurring at more accessible sites was higher than that of less accessible ones, no such trend was observed for individual medicinal species. In other words, no higher mean medicinal use value was obtained for plant species that were perceived as more accessible than for species that were difficult to find. This difference might be related to different assessments of accessibility to sites (measured as travel time from the village centre) and accessibility to plants (assessed by local participants). However, further research is needed to clarify this.

5.

Human Impact on Wild Populations of Firewood Species in Apillapampa

5.1. Introduction

Firewood is the basic fuel source in rural Bolivia (FAO, 2001; Israel, 2002; Araujo-Murakami and Zenteno Ruiz, 2006). According to the Bolivian National Institute of Statistics (INE, 2007), three quarters of rural households used firewood as a source for cooking between 1998 and 2003. Subsistence consumption of firewood by poor farmers from areas such as the north of the Potosi department and the southeast of the Cochabamba department, to which our study area belongs, is estimated to be about 2.5 kg per person per day (Dünnwald and Vega (1998) cited in Ibisch and Mérida, 2003). For the *altiplano* region, values between 1-2.7 kg per person per day have been calculated (Van Dam, 1988; FAO (1991) cited in Hjortsø *et al.*, 2006). These values are comparable to mean firewood consumption values for South America which have been rated at 2-2.5 kg per person per day (Foley, 1985).

Firewood harvest has been identified as a major causal factor in the continuous degradation of the vegetal (relict) cover in the Bolivian Andes. According to Kessler (2006), direct harvest of firewood for local consumption or to process it to charcoal is a most pressing threat (together with fire, agricultural expansion and overgrazing) for the destruction of *Polylepis* forests (i.e. the dominant Andean forests at altitudes between 3,500-4,400/5,000 m.a.s.l.) in Bolivia. In most cases, the subsequent removal of vegetation cover leads to soil erosion, edaphic desertification, and alteration of the hydrological cycle (Ibisch, 2003a; Rios and Rocha, 2002a; FAO, 2001; Codron *et al*., s.d.).

As elsewhere, habitat destruction in Bolivia basically parallels evolutions in demographic pressure. Increased firewood harvest can thus – at least partly – be attributed to population expansion (Mahamane and Mahamane, 2005). The population in Bolivia increased nearly 800% between 1900 and 2001 (Calvo, 2003c). Even though the Bolivian rural population has been decreasing in comparison to the growth of the urban population, Pacheco (1998, cited by Calvo, 2003c) demonstrated that between 1950 and 1992 the rural population of the Andean valleys (to which the research area belongs) almost doubled from 625,450 to 1,133,953 inhabitants. In spite of the fact that in Bolivia the use of firewood decreases with increasing income and education levels (Israel, 2002), rural poverty continues to nourish the harvest of wild firewood species.

On the village level, Beck *et al.* (2001) have shown that distance to settlement was directly related to woody vegetation density in the *Altiplano* of the Bolivian department of Tarija. In chapter 2 (section 2.3.6.) we obtained similar results for Apillapampa when showing that the density of (sub-) woody plants increases significantly with travel time from the village center. Such tendencies support the notion that harvesting of firewood species from wild population by poor Bolivian farmers is unsustainable. In this respect, Bentley and Valencia (2003) cite a Bolivian forester who declared that "[Andean] farmers think of forests as something to cut down for firewood and to obtain land to cultivate something to eat." Based on their experiences in Apharumiri, a Quechua community that is also situated in the Cochabamba department, the latter authors confirmed indeed that people value farm land and crops more than forest land and trees. Trees are only valued if they can provided added value to farmland (e.g. protection against erosion or encroachment of rivers etc.).

Since people in Apillapampa rely heavily on wild trees and shrubs for firewood, it is particularly important to assess the human impact on wild populations of these species. In this chapter, and drawing upon semi-structured interviews and transect data, we will therefore attempt to identify plant species whose populations are negatively affected in Apillapampa, as a consequence of firewood harvest. Next, mean harvest heights of individual firewood species, as claimed by our participants, are compared with the mean heights of their respective populations as measured in transects. This comparison will provide an indication of the degree of (un)sustainable harvest of certain species. Finally, direct ordination analysis is applied to identify the environmental variables that best explain the variation in the mean height measurements of firewood species in transects.

5.2. Methodology

Ecological and Ethnobotanical Data

Ecological data used in this chapter were obtained following the sampling techniques described in chapter 2. The height of all individual *(sub-)woody plants* was systematically measured during transect sampling. Ethnobotanical data of fuel species were gathered according to the methods described in chapter 3.

Statistical Analyses
A detailed account of the ordination techniques applied in this chapter is provided in chapter 2. Ordination analyses and elaboration of ordination diagrams were conducted by means of the PC-ORD 4.0 program. All other statistical analyses such as Pearson correlation, t-tests and Mann-Whitney tests were carried out with SPSS 12.0.

5.3. Results

5.3.1. Harvest Impact Values

As shown in chapter 3, a total of 114 different botanical species is used in Apillapampa for kindling and as fuel. Firewood is basically used for cooking only (figure 5.6B) and according to our observations, its application as a heating source in Apillapampa is negligible. Owing to the fragmented nature of the research area, and the high pressure on wild vegetation as a consequence of intense firewood harvest, participants were encouraged to assess the evolution of the abundance of individual plant species used for fuel on an ordinal scale. As such, people were systematically asked if they felt that the abundance of each species under scrutiny had increased, decreased or stagnated as compared to the past. This inquiry yielded a list of 34 species for which at least one participant reported a decrease in abundance. Table 5.1 lists 19 species with decreased abundances confirmed by at least two participants. Increased abundance was only reported for few species. Obviously, abundances of introduced species such as *Spartium junceum*, *Eucalyptus globulus, Salix humboldtiana, S. babylonica, Populus nigra, Cupressus* sp. and *Pinus radiata* have increased since the local NGO FEPADE started encouraging their cultivation more than two decades ago. Apart from exotics, species such as *Schinus molle, Agave americana* and *Nicotiana glauca* were also claimed to have increased in abundance over the past few years. Participants ascribed this evolution to increased cultivation of the first two species and a greater reproductive success of the third one. However, *Nicotiana glauca* is a characteristic shrub for eroded soils (Pendrotti *et al*. 1988), and higher abundances are likely to be a consequence of increased erosion in Apillapampa (MDSMA, 1996; FEPADE, 1998).

Participants were queried about possible causal factors for fuel species with reported decreased abundance. They most frequently mentioned excessive harvesting (76% of answers), but the impact of increased erosion was recognized as well (10%). Also, climatic change (6%), manifested by strongly altered precipitation patterns, overgrazing (4%) and damage by leaf-cutting ants (4%) were reported as being the cause of degradation of fuel species (figure 5.1).

As indicated by participants, overexploitation is locally considered the most important threat to conservation of wild fuel species. A factor of crucial importance to resilience of fuel species under heavy harvest regimes relates to the ability of these species to regenerate after being cut (with small axes). Therefore, participants were asked during interview sessions about coppicing potential of fuel species after cutting. Results presented in table 5.2 show that

21 species were claimed never to resprout, whereas two species were said to resprout sometimes. Participants agreed unanimously that all other fuel species used in Apillapampa (not listed in table 5.2) always regenerate. Survival of fuel plants is also strongly affected by the method of harvesting and/or harvesting preferences. For example, when firewood harvest involves extraction of the root, coppicing of the plant is no longer possible. The systematic harvesting of plant roots together with aerial parts (aboveground biomass), was reported for 24 fuel species by at least one participant (table 5.3). In addition, the roots of 14 other species were reported as "harvested on occasion" (not included in table 5.3).

Table 5.1: Native fuel species with decreased abundance as compared to the past, according to at least two participants ("less" refers to less abundant at present than before; "the same" to no changes in abundance; and "more" to currently more abundant than before)

Scientific Name	# participants	Responses		
		% "less"	% "the same"	% "more"
Salvia haenkei	3	100	0	0
Dodonaea viscosa	7	71.4	28.6	0
Acacia visco	3	66.7	33.3	0
Adesmia miraflorensis	7	66.7	33.3	0
Baccharis dracunculifolia	8	62.5	37.5	0
Polylepis besseri	8	62.5	37.5	0
Acacia aroma	5	60	40	0
Aspidosperma quebracho-blanco	5	60	40	0
Gynoxys glabriuscula	6	50	50	0
Prosopis laevigata	6	50	50	0
Kageneckia lanceolata	6	50	50	0
Cestrum parqui	7	42.9	57.1	0
Schinus molle	7	42.9	28.6	28.6
Baccharis papillosa	5	40	60	0
Baccharis buxifolia	11	36.4	63.6	0
Plazia daphnoides	6	33.3	66.7	0
Berberis commutata	7	28.6	71.4	0
Proustia cuneifolia	7	28.6	71.4	0
Senna aymara	8	25	75	0

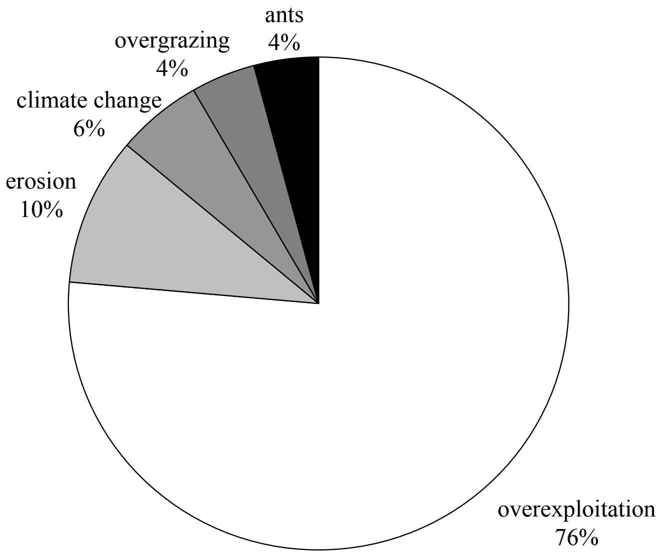

Figure 5.1: Causal factors for decreased abundance of fuel species according to participants in Apillapampa

Table 5.2: Assessment of the regeneration potential of fuel plants. Twenty-one species never coppice after being cut according to at least one participant. Two species occasionally coppice.

Scientific Name	# participants	Responses		
		% "never"	% "sometimes"	% "always"
Jatropha gossypiifolia	2	100.0	0	0
Cupressus sp.	3	66.7	0	33.3
Hyaloseris quadriflora	3	66.7	0	33.3
Pinus radiata	3	66.7	0	33.3
Cestrum atroxanthum	5	60.0	0	40.0
Nicotiana glauca	2	50.0	0	50.0
Salvia haenkei	2	50.0	0	50.0
Acacia visco	5	40.0	20.0	40.0
Baccharis dracunculifolia	5	40.0	20.0	40.0
Otholobium pubescens	3	33.3	0	66.7
Baccharis buxifolia	11	27.3	9.1	63.6
Acacia aroma	4	25.0	0	75.0
Baccharis papillosa	9	22.2	0	77.8
Gymnanthes schottiana	5	20.0	0	80.0
Gynoxys glabriuscula	5	20.0	0	80.0
Aspidosperma quebracho-blanco	6	16.7	0	83.3
Baccharis prostrata	6	16.7	0	83.3
Prosopis laevigata	6	16.7	0	83.3
Helogyne straminea	7	14.3	0	85.7
Polylepis besseri	8	12.5	0	87.5
Schinopsis haenkeana	8	12.5	12.5	75.0
Schinus microphyllus	5	0	20.0	80.0
Tipuana tipu	4	0	25.0	75.0

Participants provided different reasons for extracting roots. Because of the relative ease of extraction as compared to large shrubs and trees, many small shrubs are frequently uprooted by means of small pickaxes. Moreover, aboveground biomass volume of small shrubs is often limited and including the root makes collection worthwhile. When a decision is made to cut down a mature tree (e.g. *Prosopis laevigata*) for its wood, the root is frequently excavated to process it into charcoal. When the goal is to obtain charcoal from shrub species (cf. table 3.12 in chapter 3), preference is given to root biomass because aboveground shrub biomass is usually too limited in size while the root is thicker and better suited. Roots of species that do not coppice are harvested more frequently. However, the twenty-four native species listed in table 5.3 with presumed potential to coppice were also claimed to be harvested with inclusion of the roots by at least one participant.

Yet, not all harvesting is necessarily destructive. For thirty-five fuel species at least one participant claimed to collect them only after they die a natural death. Unfortunately this practice is not really common (anymore?) since only one participant reported this practice for a total of 32 species. Three other participants reported exclusive collection of dead wood for 6, 2 and 1 species, respectively.

Another factor that influences the preferred use of certain species is related to their quality as a fuel source. Although theoretically all (sub-)woody plants can be used for firewood, there exist strong preferences for a limited number of species. A species is considered adequate for use as firewood when it possesses one or more of the following properties: (1) has a high caloric value; (2) produces little smoke; (3) leaves small amount of ashes; (4) burns slowly; or (5) can be lit and burned under wet conditions. During ethnobotanical interviews we systematically inquired about fuel quality (as a multiple choice question with choice of quality between the options "good", "fair", or "bad") when a species was reported "used as firewood". Only those species that were considered to posses a good quality by at least half of all participants are listed in table 5.4.

Table 5.3: Assessment of root harvest for fuel species. Only those species are listed for which roots are systematically harvested according to at least one participant.

Scientific Name	# participants	Responses		
		% "mostly"	% "sometimes"	% "never"
Satureja boliviana	2	100.0	0.0	0.0
Salvia haenkei	3	66.7	0.0	33.3
*Agave americana**	2	50.0	0.0	50.0
Baccharis pentlandii	7	28.6	14.3	57.1
Heterophyllaea lycioides	4	25.0	0.0	75.0
Nicotiana glauca	4	25.0	0.0	75.0
Senna aymara	8	25.0	12.5	62.5
Barnadesia macrocephala	4	25.0	25.0	50.0
Tessaria fastigiata	5	20.0	0.0	80.0
Prosopis laevigata	10	20.0	20.0	60.0
Agalinis lanceolata	6	16.7	0.0	83.3
Cupressus sp.	6	16.7	0.0	83.3
Plazia daphnoides	6	16.7	16.7	66.7
Proustia cuneifolia	6	16.7	33.3	50.0
*Spartium junceum**	7	14.3	0.0	85.7
Acacia aroma	8	12.5	0.0	87.5
Helogyne straminea	8	12.5	12.5	75.0
Kentrothamnus weddellianus	8	12.5	12.5	75.0
Cestrum parqui	8	12.5	37.5	50.0
Schinopsis haenkeana	9	11.1	11.1	77.8
Baccharis buxifolia	10	10.0	20.0	70.0
Baccharis dracunculifolia	10	10.0	20.0	70.0
Baccharis papillosa	10	10.0	20.0	70.0
Schinus molle	11	9.1	9.1	81.8

To simultaneously take into account the effects of decreasing plant abundance, regeneration (i.e. coppicing) capacity, root harvest and firewood quality, we have developed an index that we will name the Harvest Impact Value (HIV). This index allows to estimate to what extent wild populations of particular fuel species may be negatively affected by harvest. Our estimate of the Harvest Impact Value for a species (HIV_S) is as follows:

> HIV_S= [(% answers "less abundant") + (% answers "no or occasional regeneration") + (% answers "systematic or occasional root harvest") + (% answers "good quality wood)]/400

whereby:

1. % answers "no or occasional regeneration" = (% answers no regeneration) + [(% answers occasional regeneration) * ½]; and
2. % answers "systematic or occasional root harvest" = (% answers systematic root harvest) + [(% occasional root harvest) * ½].

Table 5.4: Ranking of fuel species according to the percentage of participants who acknowledges their good fuel quality. Only fuel species considered to be of good quality by at least half of all participants (number of participants queried varied from 3 to 12 are listed. Underscored species were not sampled in the transects, due to their patchy distribution, or because they are cultivated exclusively.

Plant species	# participants	% answers "bad"	% answers "moderate"	% answers "good"
Baccharis dracunculifolia	10	0	0	100
Dodonaea viscosa	6	0	0	100
Eucalyptus globulus	7	0	0	100
Spartium junceum	8	0	0	100
Tripodanthus acutifolius	4	0	0	100
Zanthoxylum coco	5	0	0	100
Prosopis laevigata	12	0	8	92
Acacia aroma	10	0	10	90
Aspidosperma quebracho-blanco	8	0	12	88
Kageneckia lanceolata	7	0	14	86
Schinopsis haenkeana	11	0	18	82
Pinus radiata	9	0	22	78
Cestrum atroxanthum	4	0	25	75
Schinus molle	12	0	25	75
Senna aymara	8	0	25	75
Kentrothamnus weddellianus	11	0	27	73
Acacia visco	7	0	29	71
Gynoxys glabriuscula	7	0	29	71
Barnadesia macrocephala	6	0	33	67
Gymnanthes schottiana	6	0	33	67
Maytenus flagellata	3	0	33	67
Cestrum parqui	9	11	22	67
Proustia cuneifolia	8	0	38	63
Tipuana tipu	8	0	38	63
Acalypha plicata	5	0	40	60
Agalinis lanceolata	5	0	40	60
Baccharis prostrata	5	0	40	60
Baccharis torricoi	5	0	40	60
Nicotiana glauca	7	14	29	57
Adesmia miraflorensis	9	0	44	56
Cupressus sp.	9	0	44	56
Agave americana	8	0	50	50
Aloysia gratissima	4	0	50	50
Baccharis papillosa	10	0	50	50
Escallonia millegrana	6	0	50	50
Eupatorium lasiophthalmum	4	0	50	50
Lippia boliviana	3	0	50	50
Polylepis besseri	10	0	50	50

Occasional regeneration and occasional root harvest are only valued half as much. We reasoned that the harvest impact on resilience of populations of wild firewood species that regenerate occasionally and/or are only occasionally harvested with inclusion of roots is lower than for species that never coppice and for species of which the roots are systematically harvested, respectively. HIV_s values theoretically range from 0 to 1. High values correspond with a higher probability that firewood harvest has detrimental effects on species' local wild populations. Since this index is based on participant consensus it has to be interpreted merely as an indicative instrument for detecting which species are most vulnerable to firewood (over)harvesting. After all, as indicated by participants, many other (ecological and anthropological) factors may determine species resilience to harvesting, such as reproductive success, responses to climatic change or erosion, livestock grazing, pest and diseases, but also vegetation burning practices or accessibility of habitats.

We included only native species (except *Agave americana*) in the calculation of HIVs, since introduced fuel species are all cultivated and thus do not run the risk of being depleted. Cultivated native species such as *Schinus molle*, *Prosopis laevigata*, *Schinopsis haenkeana* and *A. americana* were included since they also occur locally in wild populations. The thirty species with highest HIV_s values are listed in table 5.5. Particularly those species that are not cultivated may actually be undergoing or facing population decline. Interestingly, nine of these species (indicated in bold in table 5.5) are among the twenty most abundant (sub-) woody species in all 36 transects that were sampled during the present study (see table 2.10 from chapter 2). This led us to examine, through Pearson correlation analysis, to what extent the HIV_s of a firewood species co-varies with its density and frequency measured in transects. The results show that a species' HIV_s can partly be be predicted from its mean density ($r=0.34$; $p=0.02$), but not from its frequency in transects ($r=0.23$; $p=0.13$). This finding would suggest that the impact of harvest is more severe on species that are more abundant and thus also more accessible, since in chapter 4 (section 4.3.5.) we have demonstrated that density and perceived accessibility of plants are positively correlated.

5.3.2. Comparing Mean height of Fuel Species in Transects with Mean Reported Harvest Size

When a participant reported to use a particular plant species for firewood, a subsequent question was asked about the mean growth height of that species at the time of harvest. Thereafter, the mean harvest height for every firewood species was calculated by averaging over all participants querried. These data were compared with the mean growth height per species as measured in the thirty-six 50 x 2 m^2 transects. Only for 63 wild species, statistically comparable data of mean harvest and mean growth height were obtained. In 47 cases, mean harvest height equaled measured transect height (p-values >0.05; Mann-Whitney tests), while for 16 species that are listed in table 5.6, height measured in transects was lower than the mean harvest size calculated from participants' assertions (at 1% level; Mann-Whitney tests). Ten of these species figure among the 25 fuel plants with highest HIV_s values. Hence, the majority of species that are harvested at average heights higher than their mean growth height measured in transects, appear to be among the species most negatively affected by harvest. This could indicate that people in Apillapampa, being aware of the negative impact of harvest on these species, try to lower the pressure on them by harvesting only the largest individuals of their local populations.

Table 5.5: Thirty highest harvest impact values of fuel species; species in bold are among the twenty most abundant (sub-)woody species sampled in 36 transects

	Responses				
Scientific Name	% "less abundant"	% "does not resprout"	% "harvest with root"	% "good quality wood"	HIV$_s$
Baccharis dracunculifolia	63	50	20	100	0.58
Salvia haenkei	100	50	67	0	0.54
*Prosopis laevigata**	50	17	30	92	0.47
*Acacia visco**	67	50	0	71	0.47
Acacia aroma	60	25	13	90	0.47
Dodonaea viscosa	71	0	6	100	0.44
Aspidosperma quebracho-blanco	60	17	0	88	0.41
Gynoxys glabriuscula	50	20	6	71	0.37
*Schinopsis haenkeana**	25	19	17	82	0.36
Cestrum parqui	43	0	31	67	0.35
Cestrum atroxanthum	0	60	0	75	0.34
Adesmia miraflorensis	67	0	13	56	0.34
Baccharis papillosa	40	22	20	50	0.33
Nicotiana glauca	0	50	25	57	0.33
Senna aymara	25	0	31	75	0.33
*Schinus molle**	40	0	14	75	0.32
Baccharis buxifolia	36	32	20	40	0.32
Kageneckia lanceolata	40	0	0	86	0.32
*Agave americana**	25	0	50	50	0.31
Polylepis besseri	63	13	0	50	0.31
Proustia cuneifolia	29	0	33	63	0.31
Kentrothamnus weddellianus	17	0	19	73	0.27
Hyaloseris quadriflora	0	67	0	40	0.27
Barnadesia macrocephala	0	0	38	67	0.26
Agalinis lanceolata	25	0	17	60	0.26
Plazia daphnoides	33	0	25	43	0.25
Tipuana tipu	25	13	0	63	0.25
Baccharis pentlandii	17	0	36	43	0.24
Gymnanthes schottiana	0	20	8	67	0.24

* = (occasionally) cultivated

Table 5.6: Firewood species for which mean harvest size as reported by participants is significantly higher than their mean height measured in transects (Mann-Whitney tests; p≤0.01); species listed in bold are among the 25 fuel plants with highest harvest impact values.

Acacia aroma
Adesmia miraflorensis
Agalinis lanceolata
Baccharis dracunculifolia
Baccharis papillosa
Baccharis prostrata
Barnadesia macrocephala
Berberis commutata
Dodonaea viscosa
Kageneckia lanceolata
Lepechinia graveolens
Ophryosporus hepthantus
Proustia cuneifolia
Salvia haenkei
Schinus microphyllus
Verbesina cf. *semidecurrens*

5.3.3. Which Variables can Explain the Variation in Height of Different (Sub-)woody Species Used as Firewood?

The potential impact of human disturbance on wild populations of firewood species can also be tested statistically by means of direct gradient (i.e. ordination) analysis. In a similar way we did in chapter 2, here we will examine whether the variation in plant height of different firewood species is explained by principally anthropogenic or natural factors. The length of the ordination axes is more than 2 s.d. (Detrended Correspondence Analysis; DCA), which justifies the use of restricted or canonical correspondence analysis (CCA) (Jongman *et al.*, 1996). The main matrix consisted of rows with transect data and columns with species data. Individual cells contained data about the mean height of each species in a transect. In the second matrix, rows and columns represented transect data and environmental variables, respectively.

After removal of those environmental variables that were proven to be insignificant, significant correlations (at the 5% level) were obtained between transect scores and environmental parameters for the first two axes. The first two axes are significant at the 1% level (Monte Carlo tests) but explain only 18% (= 11% + 7%) of variation in data. For ensuring a good dispersion of species and transect scores along the ordination axes, eigenvalues larger than 0.5 are generally advisable (Jongman *et al.*, 1996). Therefore, eigenvalues that were obtained indicate that transect and species scores are better dispersed along the first axis (0.734) than along the second axis (0.476). Altitude and travel time correlate best with the first axis, whereas travel time, fire and the presence of cultivated exotic species ("plantation") are correlated with the second axis (table 5.7). Hence, mainly anthropogenic disturbance variables explain the variation in the mean height of (sub-)woody plants in sampled transects. The selection of "plantation" as a significant environmental variable in the CCA does not seem to be related to higher growth height of cultivated exotics because the mean height of (sub-)woody plants in transects with planted exotics does not differ significantly from the average height in transects without these exotics.

Table 5.7: Intraset correlations indicating the relationships between environmental variables and the ordination axes for the fitted site scores (CCA). Only values >│0.5│ contribute substantially to the axis (plantation refers to the presence of cultivated exotic tree or shrub species in transects).

Variable	Axis 1	Axis 2
travel time	**0.525**	**0.690**
altitude	**-0.945**	0.266
slope	0.238	0.205
compass	0.349	0.023
firewood	0.192	0.267
plantation	-0.138	**-0.548**
fire	-0.133	**-0.560**

Some obvious trends can clearly be observed in the ordination diagrams represented by figures 5.2 and 5.3. For example, as expected, most transects characterized by evidence of recent fire activity and/or cultivated woody species ("plantation") occur in the lower side of figures 5.2 and 5.3 (i.e. transects 1, 4, 6, 13, 15, 24, 25, 32, 35 and 36), i.e. near to the vector-tips of the environmental variables fire and plantation.

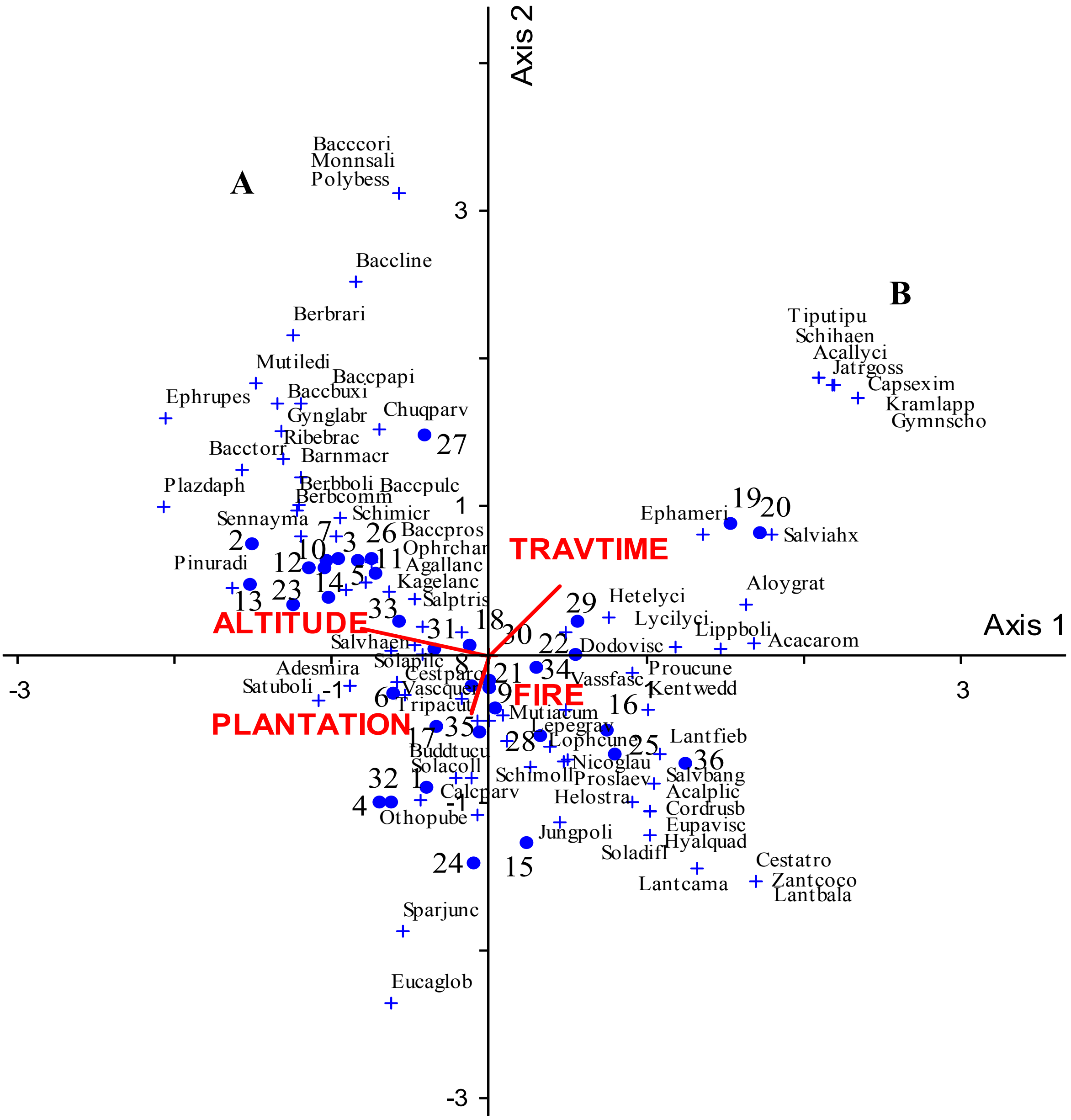

Figure 5.2: Ordination diagram representing the first two axes of a canonical correspondence analysis (CCA) based on the mean height of (sub-)woody plants in transects. Crosses (+) and dots (•) with numbers represent species and transect scores, respectively. Transect scores are situated at the centroid of the scores of species that occur in them. The scores of transects with high densities of a species tend to be close to the point of that species. The position of species scores indicate where the mean growth height of the species is the largest, with (imaginary) concentric circles away from the species position indicating decreasing mean height (Kindt & Burn, 2002). Crosses are accompanied by abbreviated scientific names, whereby the first four letters correspond to the genus and the last four letters to the species. Environmental variables are represented by vectors that determine axes in the diagram whereupon transect scores must be projected. The overall mean of all environmental variables is represented by the origin of the plot. The inferred weighted average of transects or species is higher than average if the projection point lies on the same side of the origin as the vector-tip and is lower than average if the origin lies between the projection point and the vector-tip. Environmental variables with long vectors are more strongly correlated with the axes than those with short vectors (Jongman *et al.*, 1996). Units on both ordination axes correspond to multiples of variance. For the meaning of "A" and "B" the reader is referred to the text.

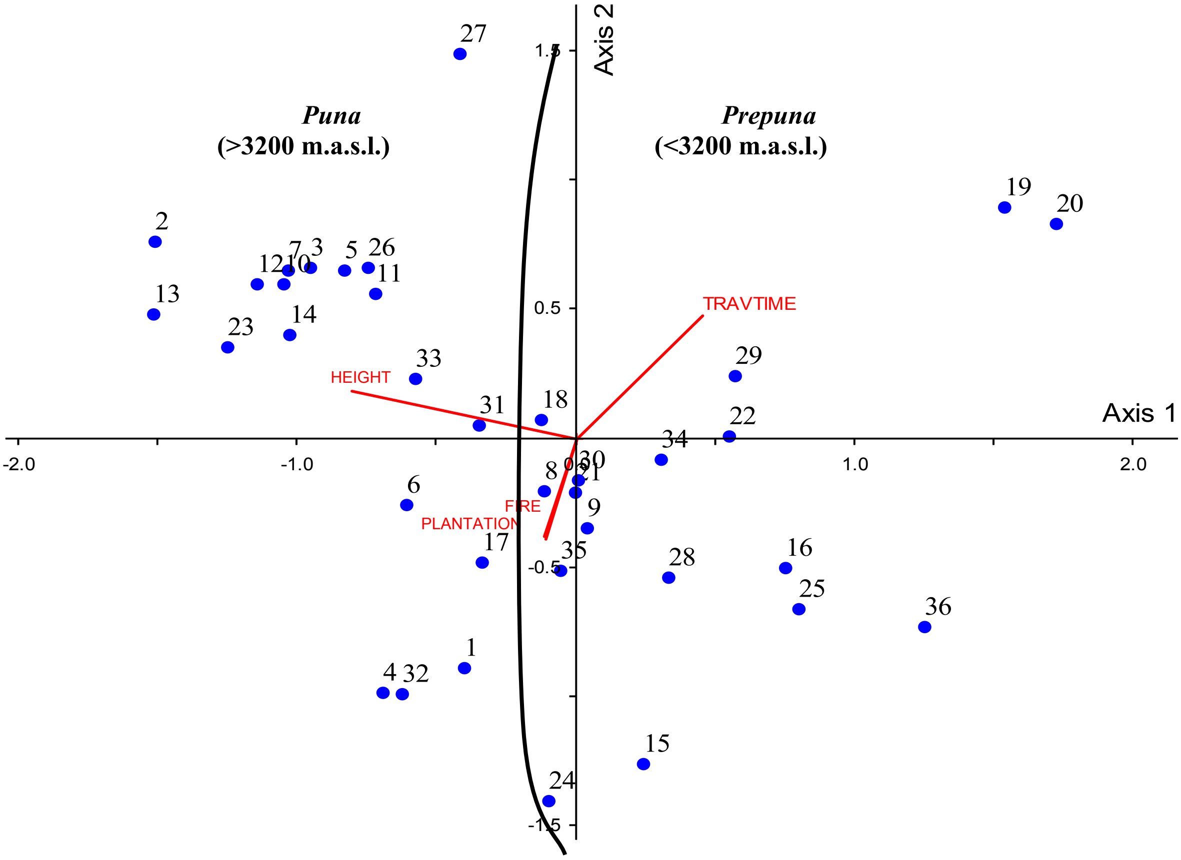

Figure 5.3: Ordination diagram representing the first two axes of a canonical correspondence analysis (CCA) based on the mean height of (sub-)woody plants in transects. This diagram is similar to figure 5.2, with the exception that species scores are not shown. For interpretation, the reader is referred to the legend of figure 5.2 and the text.

Two typically, introduced and cultivated species, *Spartium junceum* and *Eucalyptus globulus*, are situated at the lower edge of the diagram, hereby stressing the anthropogenic nature of their occurrence. Indeed, according to Jongman *et al.* (1996) "species points on the edge of the diagram are often rare species, lying there because they prefer extreme (environmental) conditions or because their few occurrences happen to be at sites with extreme conditions". Exotics are rare in the sense that they only occur at sites through human intervention. Also most other species whose scores are situated on the edges of the diagram in figure 5.2 are relatively rare because most have been sampled in one (or two) transect(s) only.

As can be deducted from figure 5.2, species that grow at high travel times from the village centre include *Schinopsis haenkeana*, *Gymnanthes schottiana*, *Tipuana tipu*, *Krameria lappacea, Polylepis besseri, Baccharis coridifolia, B. linearifolia* and *Monnina salicifolia*. However, it is not entirely clear whether altitude would not be a stronger determinant of the occurrence of these species since the last four species (indicated by "A" in figure 5.2) only prevail in transects at the highest altitudes whereas the first four species (indicated by "B" in figure 5.2) occur in transects situated at lowest locations. Also, the absence of data points between A and B suggests that large travel times are correlated with extremes in altitudes. However, this can also be a consequence of the fact that the travel time spectrum has not been sampled as evenly as the altitude spectrum. Or in other words, there are more repetitions of short and medium travel times than of long travel times.

Although anthropogenic variables explain a considerable portion of variation in the mean height of (sub-)woody plants in transects, altitude seems to be the predominant factor. Grouping of transects according to the ecological *puna* and *prepuna* zones as shown in chapter 2 based on species' abundance data, is also apparent when based on the mean height of (sub-)woody plants (figure 5.3). This is partly related to the fact that the main matrix whereupon the ordination in figure 5.3 is based incorporates also presence/absence data of the species involved.

To evaluate to what extent canonical correspondence analysis (i.e. CCA, whereby the axes are restricted to linear combinations of environmental variables), matches the best fit scenario provided by unrestricted correspondence analysis (i.e. CA), the CA ordination diagram was constructed (figure 5.4). Eigenvalues of CA are slightly higher (0.81 and 0.60 for the first and second axis, respectively) than those of CCA and explain 23% of the variation in the mean height of (sub-)woody plants. Projections of transect scores on the first axes of CCA and CA in figures 5.3 and 5.4, respectively, do not lead to completely identical rankings, but they do not differ too much either (Kendall's τ_b= 0.93; p<0.0001). This comparison indicates that a combination of altitude and travel time explains the "best fit" dispersion of transect scores on the first axis relatively well. Ranking of scores on the second axis of the CA and CCA diagrams correspond with each other to a lesser extent (Kendall's τ_b= 0.80; p<0.0001) than for the first axes, but they are still comparable. This indicates that also a linear combination of the selected environmental variables "travel time", "fire" and "plantation" represents the "best fit arrangement" of the second axis to some extent. Hence, although the variables that were measured can not completely explain the "best fit" arrangement of transects based on the mean height of (sub-)woody plants, they do validate our finding that variation in the mean height of (sub-)woody plants is partly due to anthropogenic disturbance.

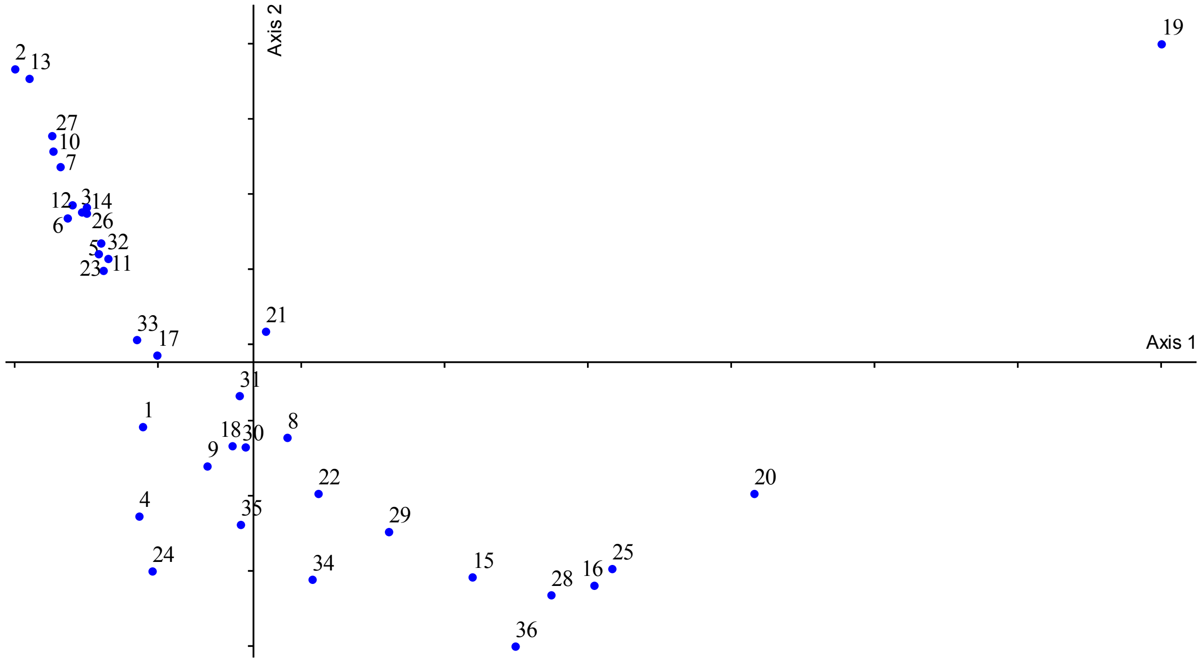

Figure 5.4: Ordination diagram representing the first two axes of a correspondence analysis (CA) based on mean (sub-)woody plant height in transects. Observe how the arch effect (see section 2.2.2.4., chapter 2) manifests itself through arrangement of transect scores in a broad U-form.

5.3.4. Which Variables can Explain the Variation in Height of Good Quality (Sub-) woody Species Used as Firewood?

We already mentioned earlier that it is not because a plant can burn that it will be used as a source of fuel. Table 5.4 lists 38 (sub-)woody plant species that are considered good quality fuel. The abundance, frequency and mean height of 30 of these species was measured in the sampled transects. Analogously to the previous analysis, CCA was conducted to investigate which variables explain the variation in mean height of these species in transects best.

Rows in the main matrix represented transects, while columns accounted for the 30 species listed in table 5.4. Cells contained mean height data for species and transect. Like for the previous analysis, in the second matrix, rows represented transect data while columns represented environmental variables. The eigenvalues of the first two ordination axes (0.76 and 0.51, respectively) are significant at the 1% level and explain 23.4% of the variation in data. Also, the correlation between species scores and environmental parameters is significant (Monte Carlo test; p=0.01).

The first axis is correlated with travel time and altitude above sea level, and the second axis correlates with plantation and fire (table 5.8). These variables turn out to be same as those that came out of the previous analysis which included *all* (sub-)woody species. Also the ordination diagram obtained here (figure 5.5) is almost identical to figure 5.2, apart from some minor shifts in transect and species scores. Therefore, our observations regarding the variation in the mean height of *all* (sub-)woody plants are valid as well for the 30 good quality firewood species.

Table 5.8: Intraset correlations for 30 species (considered to have the “best firewood quality”), indicating the relationships between environmental variables and the ordination axes for the fitted site scores (CCA). Only values >│0.5│ contribute substantially to the axis.

Variable	Axis 1	Axis 2
travel time	**0.681**	0.494
height	**-0.920**	0.254
slope	0.239	0.296
compass	0.387	-0.023
firewood	0.220	0.115
plantation	-0.215	**-0.719**
fire	-0.181	**-0.706**

5.3.5. Predicting the Mean Height of (Sub-)woody Plants in Transects Based on Measured Variables

In a next step, we verified to what extent each of the measured environmental variables can predict the mean height of (sub-)woody species in transects. Therefore, the mean height of all measured individual (sub-) woody plants was calculated per transect. The contribution of each predictor variable to determining the mean height of (sub-)woody plants in transects was then examined by means of Pearson correlation analysis and independent t-tests. The results show that only altitude correlates inversely with the mean height of (sub-)woody plants (r=-0.38; p=0.02). On the other hand, the mean plant height in transects is negatively correlated with the number of (sub-)woody individuals (r=-0.38; p=0.02). However, we suspect this is an effect of altitude rather than a consequence of anthropogenic pressure. Indeed, in chapter 2 we show and discuss that the density of (sub-)woody plants significantly increases with altitude.

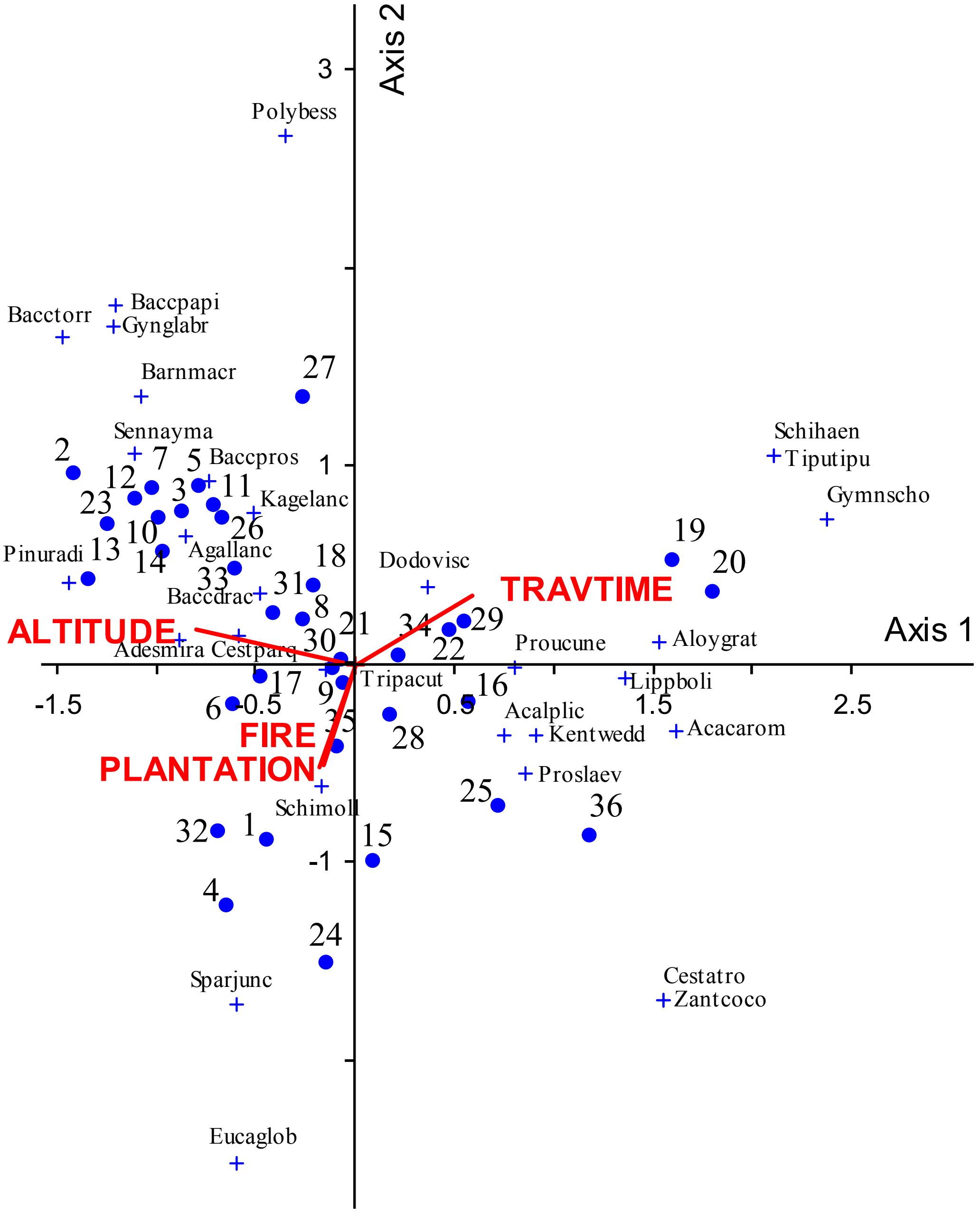

Figure 5.5: Ordination diagram representing the first two axes of a CCA (explaining 14 and 9% of variation in data, respectively) based on mean height of 30 "good quality" firewood species in transects. For interpretation, the reader is referred to the legend of figure 5.2. Altitude above sea level and travel time are correlated with the first axis, while evidence of recent burning and presence of planted wood species are correlated with the second axis.

5.4. Discussion

Although most people in Apillapampa cultivate exotic tree species such as *Pinus radiata* and *Eucalyptus globulus* (figure 5.6C), pressure on wild firewood species remains high. Most exotic species are planted for production of timber that is (1) used in all kinds of constructions; or (2) commercialized to a limited extent. Basically, only woody debris and leaves of these timber species are used as fuel. It is only seldom that the wood is cut into blocks for cooking (figure 5.6D), e.g. in times of festivities when large amounts of the alcoholic beverage *chicha* are prepared with maize. At the time of the present study it was more common instead to see huge bundles of branches and entire plants of different wild shrub or tree species in front of houses (figure 5.6A). Days, or even weeks, before the start of festivities, people generally undertake (long) journeys for harvesting large quantities of wild firewood species that are transported to their houses on the backs of donkeys.

According to Ibisch (2003b), firewood species most appreciated in Andean Bolivia are *tholas* (*Baccharis* spp.) and *kewiñas* (*Polylepis* spp.). Beck *et al.* (2001) add *Acacia aroma*, *Schinus molle* and *Prosopis laevigata* to this list, while a study executed by FAO (2001) reports on the importance of *Kageneckia lanceolata*, *Buddleja* spp. and *Tipuana tipu* as fuel species. All the latter species have also been identified as important sources of firewood in Apillapampa and their good to superior quality of wood has been confirmed by at least half of all interviewed participants.

We have shown that the average size by which most firewood species are harvested equals the mean size at which they prevail in the natural landscape. This result can be interpreted in at least two ways. One possibility is that the mean harvest size of species has decreased with time, paralleling a decrease in their mean height in natural populations, e.g. as a consequence of historical anthropogenic pressure. In a second interpretation, the mean height of wild populations of firewood species could approximate the standing stock as it has always been under human disturbance regimes. While the first interpretation would confirm overharvesting of wild populations, the second one would rather point to the sustainable use of wild firewood species. However, as the baseline situation of these populations of firewood species is not known due to absence of comparative data, it is impossible to know which of these scenarios is actually taking place. The effect of anthropogenic disturbance on wild populations of firewood species should therefore better be estimated by measuring actual changes in biomass over a period of several years in a number of representative demarcated sites throughout the landscape from where people actually harvest firewood.

For 16 firewood species, a significantly higher average harvest size was reported than their mean height measured in transects. Although caution is necessary when interpreting these results, this could mean that only the largest individuals of these species are harvested from local wild populations. If this is true, it would indicate that Apillapampeños practice sustainable harvesting of these species, 10 of which figure among the top 25 fuel plants with high harvest impact values. Harvesting only the largest individuals might be a local response to counter observed resource depletion.

In view of the fact that some people even dig out the roots of fuel species that are known to resprout, it seems nonetheless rather unlikely that any type of general harvest restriction is applied to firewood species. We did find that some people reported applying sustainable techniques such as harvesting only those plants that had died naturally, or only mature ones, or only branches. However, there exists no general agreed social system that obliges everyone to respect certain harvest rules. Farmers are entitled to do as they like on their land. Therefore such practices can hardly be classified as conservation (Smith and Wishnie, 2000).

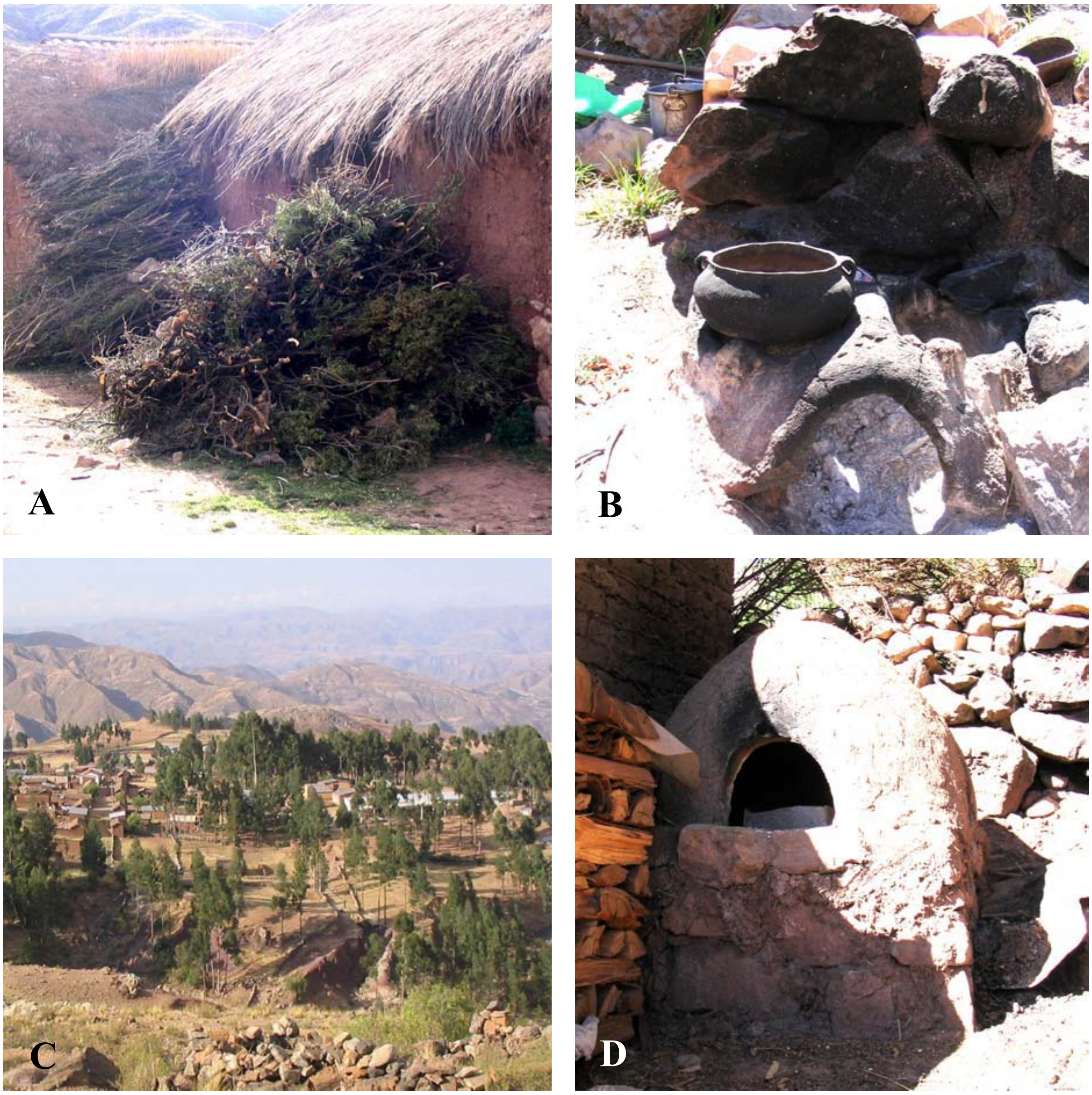

Figure 5.6 A: Bundles of firewood species in front of a house; B: Traditional cooking fire with earthenware pot; C: panoramic view of Apillapampa, illustrating the high abundance of cultivated *Eucalyptus* species; D: Traditional oven with stack of *Eucalyptus* wood

Calculating harvest impact values (HIV$_S$), based on interviews with multiple participants, can provide an indication of which species are more likely to being harvested unsustainably. Our findings strongly indicate that populations of various firewood species are negatively affected by anthropogenic pressure. People from Apillapampa are aware of decreasing populations of wild firewood species and they realize that overharvesting is one of the principal causes. Numerous studies have supported this notion by linking biomass extraction through harvesting of firewood (in combination with grazing) with detrimental effects on vegetation structure and diversity in the Bolivian Andes (Davis *et al*., 1997; García and Beck, 2006; Kessler, 2006; Hjortsø *et al*., 2006; Bentley and Valencia, 2003; Kessler and Driesch, 1993;

Codron *et al.*, s.d.). The fact that a species' HIV_s is likely to increase with its density in transects might indicate that anthropogenic pressure is higher on more abundant firewood species. In chapter 4 we have analogously demonstrated that the fuel use value (UV_{fuel}) of plants that are perceived as easily accessible is significantly higher than the UV_{fuel} of plants that are difficult to find. These results seem to support the hypothesis that anthropogenic pressure is strongest on more accessible species.

It is, however, important to note that our assessment about the use and conservation status of wild firewood species in Apillapampa is based upon the perception of local people and not on actual measurements. Therefore, it is difficult to make irrefutable conclusions about the (un)sustainable harvest of these species. Nevertheless, the relevance of this study has been confirmed by various authors who argued that local people are often better placed than outsiders to assess environmental change and that local people recognize all too well the consequences of decreasing biodiversity (e.g. Martin, 1995; Hellier *et al.*, 1999; Ellen *et al.*, 2000; Etkin, 2002). As such, ethnobotanically oriented assessments of local diversity and/or decline of natural resources can provide valuable alternative information sources whereupon to base conservation policies, as compared to monitoring programs. Moreover, the latter are much more expensive and less time-efficient, as they generally run over a number of years (Hellier *et al.*, 1999).

Also ordination analysis suggested that anthropogenic variables are responsible for explaining a substantial portion of the variation in the composition, abundance and height of (sub-) woody plant species in transects. In chapter 2 (section 2.3.5.) we demonstrated that variation in the composition and abundance of (sub-)woody species is best explained by altitude, accessibility (measured as travel time to transects), evidence of firewood harvest, and occurrence of burning activities. In addition, we demonstrated that the relative density of (sub-)woody plants significantly increases with travel time from the village center (section 2.3.6). In the present chapter, it was demonstrated that the variation in the mean height of (sub-)woody plants in transects can, in addition to altitude, partly be explained by travel time, plantation of exotic species in sites, and occurrence of burning activities. Firewood harvesting did not appear as a determinant in ordination analysis. However, as explained in chapter 2, this might be due to the fact that our observations of firewood harvest were snapshots. Most likely, firewood is harvested in all the sample sites.

Similar observations as ours, whereby lower mean densities and heights of woody species in sites are correlated with the intensity of anthropogenic pressure on those sites, have been made all over the world (Kumar and Shahabuddin, 2005; Mahamane and Mahamane, 2005; Veach *et al.*, 2003; Williams-Linera, 2002; Nakul *et al.*, 2002). Distance to human settlements (as a measure of accessibility) has in this respect often been identified in the literature as being positively correlated with woody plant densities and species richness (e.g. Codron *et al.*, s.d.; Beck *et al.*, 2001; Williams-Linera, 2002; Veach *et al.*, 2003; Mahamane and Mahamane, 2005).

The negative effect of fire on the diversity of woody plants is also also well-documented (Veach *et al.*, 2003). As stated before (chapter 2, section 2.3.7.), Kessler and Driesch (1993) have argued that frequent burning of the vegetation is responsible for reducing forest cover in the high Andes. The main objective of burning is to improve fodder quality (cf. figure 2.18) but in the past burning was probably also a part of hunting practices. Although mature *Polylepis* trees often survive fire, this is not the case for seedlings and young trees (Kessler and Driesch, 1993).

The negative impact of fire is intensified by grazing, which is practiced in most parts of the Andes with livestock densities well above the ecosystem's carrying capacity (García and Beck, 2006; Kessler, 2006). Overgrazing is particularly detrimental for the reproduction of native tree species, but people can not afford to reduce grazing so that the vegetation can recover (cf. Bentley and Valencia, 2003). To assess the impact of grazing in Apillapampa exclosure experiments should be conducted at various sites in the landscape. Hereby, natural vegetation patches are enclosed to prevent livestock from entering after which the impact on vegetation is monitored.

Evaluation of the impact of planted exotic species on the mean height of wild (sub-)woody plants is less straightforward. In Andean Ecuador (3,000-4,000 m), Hofstede *et al.* (2002) observed regeneration of Andean woody species in some pine plantations, while understorey vegetation was completely lacking in others. This made these authors conclude that the impact of pine plantations cannot be generalized but should be evaluated on a case by case basis. However, the negative allelopathic impacts of *Eucalyptus globulus* and *Pinus radiata* on understorey vegetation are well known and studied (Molina *et al.*, 1991; Mahboubi *et al.*, 1997; Souto *et al.*, 2001; Ibisch, 2003e). In chapter 2 (section 2.3.6.) we have observed that the allelopatic effects of these exotic species seem to reduce the diversity of native species in transects. The observations made in this chapter suggest that these allelopathic effects might also control the mean growth height of (sub-)woody plants to some extent.

5.5. Conclusions

People in Apillapampa rely heavily on wild firewood species for fulfilling their fuel needs. We made an appraisal of the impact of harvest on the populations of wild firewood species by taking into account local people's assessments of (1) decreasing plant abundance, (2) coppicing or resprouting capacity of plants, (3) practice of root harvesting and (4) quality of firewood. The results suggest that wild populations of several (sub-)woody plant species are negatively affected by firewood harvesting. Some people practice sustainable harvesting of firewood species, but as farmers are entitled to do as they like on their land, no general agreed social system exists to promote sustainable plant use.

In addition to altitude, mainly anthropogenic variables explain the variation in height of firewood species available at different sites throughout the landscape. These include the accessibility of sites, burning of natural vegetation and planting exotic species. Anthropogenic pressure on wild firewood species in Apillapampa also seems to parallel the abundance and accessibility of these species throughout the landscape. The negative impact of harvest is particularly high on more abundant and accessible firewood species.

Long-term measurements of the evolution in the biomass of firewood species under existing harvest regimes in Apillapampa are necessary to irrefutable proof the relation between firewood harvesting and vegetation degradation. However, an approach that takes into account local people's assessments could provide a valuable alternative. Based on our findings, we strongly recommend that urgent measures ought to be taken for lowering the pressure on populations of wild firewood species. This could be achieved through fostering a mentality change among people and stimulating them to rely more on already cultivated timber species as sources of firewood. In addition, priority should be given to development plans that integrate cultivation of locally valued and vigorously coppicing firewood species into the existing agroforesty system.

6.

Floristic Composition and Diversity of Tropical Forest Vegetation in Southern TIPNIS

6.1. Introduction

In spite of increased research efforts over the past few decades, the tropical flora remains understudied (Prance *et al*., 2000; Wilson, 2003). Particularly the flora of Bolivia is among the least studied, although it is the 10th or 11th country in the world with highest plant species richness (Rejmánek and Brewer, 2001; Ibisch, 2003c). Probably more than half of the Bolivian territory has never been explored for collection of plant specimens (Ibisch and Beck, 2003). *Territorio Indigena Parque Nacional Isiboro-Sécure* (Indigenous Territory National Park Isiboro-Secure; TIPNIS), is one of many examples. Covering an area of about 12,000 km², its floristic composition has hardly been inventoried up to present. Due to its position on the verge between Andes and Amazon, high levels of diversity are to be expected in the park (Ibisch, 2003c). Some initial ecological sampling has recently been carried out by Macía and Fuertes (s.d.) in the "Serrania de los Mosetenes", the mountain chain that delineates the western border of TIPNIS. Altamirano and Fernandez (2003) studied the epiphytic vegetation of TIPNIS' *terra firme* forests, whereas Fernandez and Altamirano (2004) sampled the general forest vegetation in the southern part of the park. Also Vandebroek *et al.* (2004a and 2004b) and Thomas and Vandebroek (2006) made significant contributions to the knowledge of its medicinal flora. A few months prior to the start of the present study several forest inventories were made by the forestry company CETEFOR (CEntro TÉcnico FORestal) but these were based on vernacular names and did not include voucher collections (www. cetefor.org).

However, given the ever-increasing threats to local biodiversity, the urge to study TIPNIS vegetation has never been greater. Apart from global threats such as climate change (Miles *et al.*, 2004), forest destruction by timber companies and Andean settlers in search of virgin lands suitable for agriculture has reached alarming levels in the Bolivian lowlands, including TIPNIS (Townshend *et al.*, 1995; Steininger *et al.*, 2001; Millington *et al.*, 2003; Rico Pareja *et al.*, 2005). Cultivation of coca (*Erythroxylum coca*) is a major driving force for forest destruction by Andean settlers (Lilienfeld and Pauquet, 2005). It is estimated that more than one fifth of the coca production in the Cochabamba Department originates from TIPNIS (United Nations, 2004). Between 1993 and 2001, the old growth forest cover in the area colonized by highland farmers decreased from 60 to 41% (Beetstra, 2005b). Also the petroleum industry is likely to become a future motor of forest destruction in TIPNIS (Calvo, 2003a; Lilienfeld and Pauquet, 2005). Yet, according to Lilienfeld and Pauquet (2005) the greatest threat of all is the plan to construct a road which connects the cities of Villa Tunari (Cochabamba department) with San Ignacio de Moxos (Beni department) and would cut TIPNIS in half. This will open the territory to a new, unrestricted invasion of settlers.

The present study wants to provide an initial, but significant step towards filling the gap in the floristic knowledge of TIPNIS. The objectives of this chapter are to: (1) present an overview of the taxonomic composition and variation in life form of all plants inventoried during the present study; (2) study the diversity, structure and floristic composition of woody plants in three different forest types of the southern and central part of TIPNIS; and (3) discuss our results in a broader Bolivian and Amazonian context.

6.2. Research Area

The overall goal of the present ethnobotanical study was to inventory all useful plant species known by Trinitario and Yuracaré communities in the southern part of TIPNIS. Therefore, five different communities that had agreed to participate during an initial formal meeting of CONISUR[1] in March 2004, were selected. Four communities are situated near the geographical center of TIPNIS, in the upstream area of Rio Ichoa and Rio Moleto (figure 6.1). In the following, we will call this area the first study site. Two of the participating communities from the first study site are inhabited by Trinitarios (El Carmen de la Nueva Esperanza and San Jose de la Angosta), one by Yuracarés (San Antonio de Moleto) and one by members of both ethnic groups (Tres de Mayo). The second study site was located near the southeastern margin of TIPNIS at the Yuracaré village of Sanandita, on the banks of Rio Isiboro. This second research area was chosen to balance the number of Yuracaré and Trinitario communities.

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[1] *CONsejo Indígena del SUR del TIPNIS*, the indigenous council providing political representation for the Yuracaré and Trinitario communities from the southern part of TIPNIS

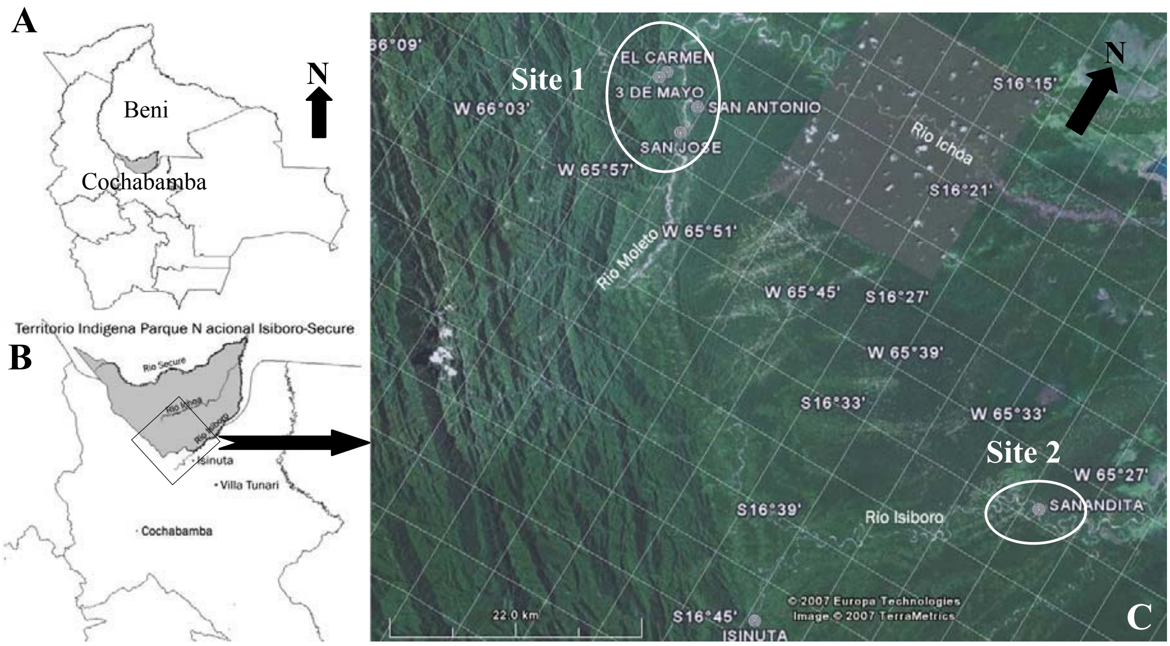

Figure 6.1 A: location of TIPNIS in Bolivia; B: Location of TIPNIS and its main rivers on the border between the Beni and Cochabamba departments. Villa Tunari and Isinuta are the successive main access villages to the southern part of TIPNIS; C: Satellite image of the research area (highlighted in figure 6.1B) with participating villages (study site 1: El Carmen, Tres de Mayo, San Antonio and San Jose; study site 2: Sanandita), main rivers and location of Isinuta at the extreme bottom of the map (Source: Google Earth, 12/3/2007)

Climate

Owing to its geographic position, Bolivia is characterized by a tropical climate (Navarro, 2002). The research area is situated at the margin of the wettest region of Bolivia. In the closest city of Villa Tunari, mean annual precipitation is as high as 5,573 mm (Rico Pareja *et al*., 2005), up to 5,990 mm (Navarro, 2002). No exact precipitation data are available for our study sites. Therefore, estimates are based on the isohyetal map provided by Rico Pareja *et al.* (2005) (figure 6.2). For the area surrounding the estuaries of rio Moleto and rio Ichoa (i.e. study site 1), precipitation probably amounts to some 3,500 mm per year, while in Sanandita (i.e. study site 2) values of up to 4,000 mm per year can be expected. There is a marked dry season from May till September, but only up two months per year are actually arid (i.e. ≤100 mm precipitation) (Rafiqpoor *et al*., 2003; Ibisch *et al*., 2003). Hence, according to the classification of Rivas-Martinez *et al.* (1999) and adapted by Navarro, (2002), the area has a humid pluvial bioclimate (Navarro, pers. comm.). Mean annual temperature fluctuates between 24 and 26°C with extremes of 40°C and 8°C (Rico Pareja *et al*., 2005). Based on these data, the bioclimatic level would be classified as inferiorly thermotropical (Navarro, pers. comm.).

Soils

According to the classification system of FAO (1975 and 1995b), the *terra firme* soils of the research area are ferrasols (Gerold, 2003), whereas Navarro (2002) identified them as ferric-humic acrisols. *Varzea* soils are classified as fluvisols (Gerold, 2003). In general, all these soils are characterized by an elevated to extremely high acidity, high levels of aluminum and iron toxicity and low nutrient concentrations (Rico Pareja *et al*., 2005).

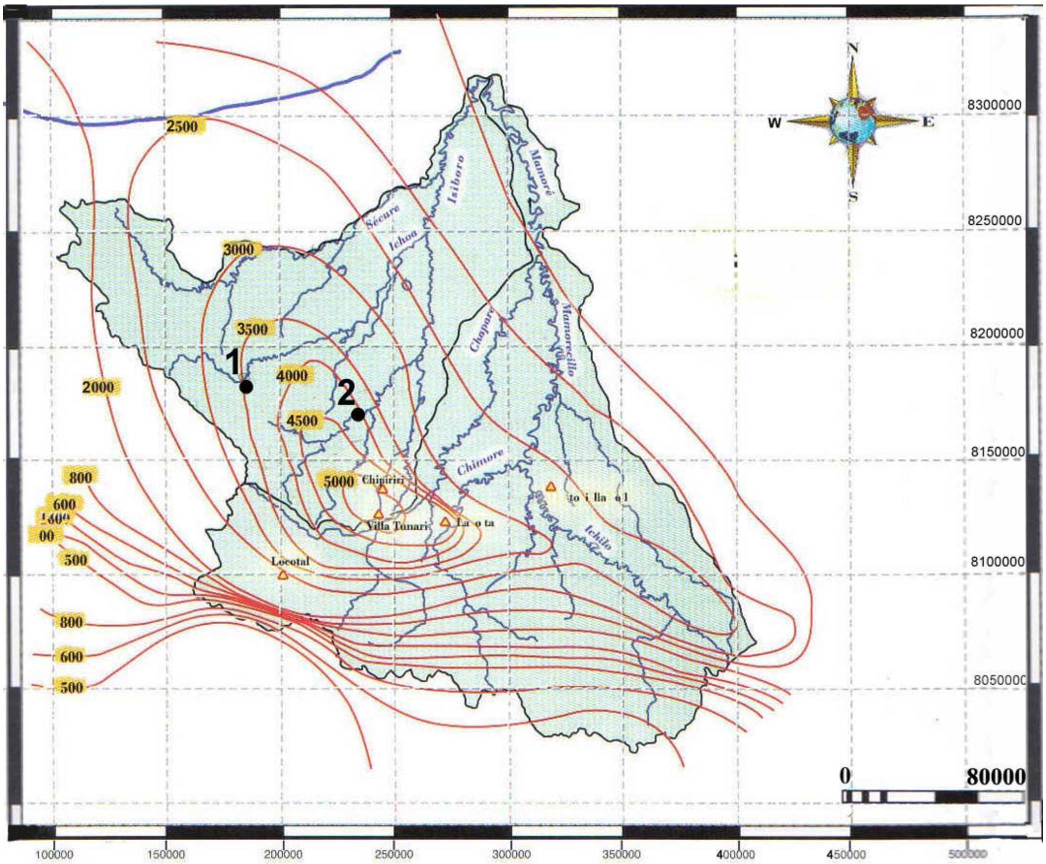

Figure 6.2: Isohyetal map of the research area with annual precipitation levels in mm; 1= first study site, representing San Jose, San Antonio, El Carmen and Tres de Mayo; 2= second study site, representing Sanandita

Vegetation

Following a classification of different vegetation types in Bolivia based on ecoregions, the research area (comprising both study sites) belongs to the preandean Amazonian forests (see Ibisch *et al*., 2003 for a detailed definition). Recently, on behalf of NatureServe, Josse *et al*. (2007) developed a much more detailed map of the Bolivian vegetation according to international standards and based on ecological systems. The latter authors define terrestrial ecological systems as: "groups of vegetation communities that tend to co-occur in the landscape because of their relation with common and determinant factors, such as ecological processes, substrates and/or environmental gradients" (Josse *et al*., 2007). This vegetation map basically represents an adjustment of Navarro's (2002) local phytosociological classification of Bolivian vegetation, to an internationally valid classification system. Therefore, in the following we describe the main ecological systems where plants were collected during the present study, based on the works of both Navarro (2002) and Josse *et al*. (2007):

(1) *southwestern Amazon subandean evergreen forests* (CES408.543; ecological system classification code used by Josse *et al*. (2007)), characterized as dense, tall and multi-stratified Amazonian forests with some *Yungas* (i.e. the principal ecoregion on eastern Andean slopes (Ibisch *et al*., 2003)) elements, highly diverse in angiosperms and poorly studied. These *terra firme* forests are distributed along the low subandean ridges of central south Peru to northern Bolivia characterized by pluvial humid to

hyper-humid bioclimates, and situated at altitudes below 1000 m to 1300 m. From a local perspective, these forests correspond to the *Chapare upland Amazonian rainforest* (Navarro, 2002) which constitutes the local potential climax vegetation with a canopy height of 25-30 m covering 75% of the surface with emergent trees of up to 40 m. The understorey consists of two tree layers; one of 15-18 m high, covering 40%, and another of about 10 m high, covering 60%. Beneath these understorey layers, a shrub layer of 2-4 m prevails, covering 75% of the surface area, and a herb layer of 0.5-1 m high, covering 60%. Characteristic species that were also inventoried during the present study include: *Apeiba membranacea*, *Clarisia biflora*, *C. racemosa*, *Eschweilera coriacea, Euterpe precatoria, Guarea kunthiana, G. macrophylla, Inga capitata, Iriartea deltoidea, Quiina florida, Micropholis venulosa, Jessenia bataua, Pouteria guianensis, P. hispida, P. multilora, Pseudolmedia laevis, Sloanea fragrans, S. guianensis, S. obtusifolia, S. terniflora, Sorocea steinbachii, Sterculia apeibophylla* and *Trophis caucana*. During the present study, two 0.1-ha transects were sampled in this ecological system (i.e. at research site 1, in the vicinities of El Carmen and San Antonio; see further).

(2) *southwestern Amazon white-water floodplain forests* (CES408.531) that are seasonally flooded by white-waters carrying important loads of sediments and that develop in the (sub-)recent alluvial plains of the southwestern Amazon. Locally, this ecological system corresponds with the *Chapare Varzea forets* described by Navarro (2002). Characteristic species are *Hura crepitans*, *Calycophyllum spruceanum*, *Dipterix odorata*, *Clarisia racemosa* and *Ceiba pentandra*. During the present research, one 0.1-ha transect was sampled in this ecological system (i.e. at research site 2; in the vicinities of Sanandita).

(3) *southwestern Amazon piedmont forest* (CES408.570) which is an assemblage of several types of forests developed on the alluvial glacis of the eastern piedmont of the Andes, primarily on well-drained top soils but with poor drainage or a high water table in the subsurface zone. The combination of upland (i.e. *terra firme*) species together with species from the white-water floodplains is characteristic for this ecological system, and Navarro (2002) classified it as *Preandean Amazonian Chapare wetland forest*. This forest type is characterized by the coexistence of species from *Chapare upland Amazonian rainforest* and the seasonally flooded *Chapare Varzea forets*, including *Eschweilera coriacea, Ceiba pentandra, Astrocaryum murumuru, Dipterix odorata* and *Guadua chacoensis.* During the present research, one 0.1-ha transect was sampled in this ecological system (i.e. at research site 1; in the vicinities of El Carmen).

(4) *preandean Chapare riverine succesional shrublands and woodlands* (Navarro, 2002), consisting of strips of succession vegetation on sandy-muddy beaches of white-water rivers. Different vegetation types in these ecological systems include riverbank forest, typically with *Ochroma pyramidale* and *Cecropia membranacea*; shrublands and low riverbank forest with *Tessaria integrifolia* and *Salix humboldtiana*; and riverbank reed land with communities of *Gynerium sagittatum* (Navarro, 2002). Plants were collected in all of these vegetation types.

6.3. Methods

6.3.1. Ecological sampling

Two general methods have been applied for sampling the vegetation in the research area of TIPNIS. These are walk-in-the-woods and 0.1-ha transects. Both methods are complementary in the sense that the first ensures collection of plants in all possible habitats such as the *terra firme*, floodplain, *varzea* and secondary forest, the village area, the agroecosystem, ruderal places, river banks, wells, etc., whereas the second technique detects inconspicuous plants in forest habitats that would otherwise be missed (cf. van Andel, 2000).

6.3.1.1. Walk-in-the-woods and Homegarden Sampling

From March 2004 till February 2006, 81 plant collection trips were undertaken in the research area. During walk-in-the-woods, participants are encouraged to actively lead fieldtrips and seek useful plants they use and/or know (Phillips and Gentry 1993a). Upon indication by accompanying participants, all useful plants that were growing along (or near) the transect line (see lower) and not fulfilling protocol requirements of minimum dbh were also inventoried simultaneously with transect sampling (cf. Bernstein *et al*., 1997). This resulted in the inclusion of useful herbs, small epiphytes and vines in the inventory. Finally, a substantial number of plants were gathered in homegardens and swiddens upon indication by their owners. All possible growth forms were sampled and specimens were collected and preserved according to botanical standards.

6.3.1.2. Transects

Location

During several fieldwork periods between October 2004 and June 2005, four 0.1-ha transects were laid out in the southern part of TIPNIS. All transect sites were chosen upon indication by Yuracaré and Trinitario participants to make sure we were sampling different forest types (or ecological systems). This was particularly important since one of the research objectives of the study in TIPNIS was to determine and compare the usefulness of different types of mature forests in the living area of Trinitario and Yuracaré communities (chapter 9).

Three transects were constructed in the first study site, near the estuary of Rio Moleto and Rio Ichoa, at altitudes between 250 and 300 m.a.s.l. Two of these transects were located in *terra firme* forest in the surroundings of El Carmen and San Antonio (transects 1 and 3, see figure 6.3). This *terra firme* forest is classified as "*southwestern Amazon subandean evergreen forests*" (Josse *et al*., 2007), locally called "*Chapare upland Amazonian rainforest*" (Navarro, 2002). A third transect was laid out in a forest on floodplain near El Carmen (transect 2, see figure 6.3) which belongs to the "*southwestern Amazon piedmont forest*" (Josse *et al*., 2007), or in local terms "*Preandean Amazonian Chapare wetland forest*" (Navarro, 2002).

In the second study site, only one transect was constructed; more precisely in *varzea* forest on the seasonally flooded bank of river Isiboro, in the vicinity of Sanandita (transect 4, see figure 6.4) located at about 200 m.a.s.l. This *varzea* forest is classified as "*southwestern Amazon white-water floodplain forest*" (Josse *et al.*, 2007), or locally "*Chapare Varzea forets*" (Navarro, 2002).

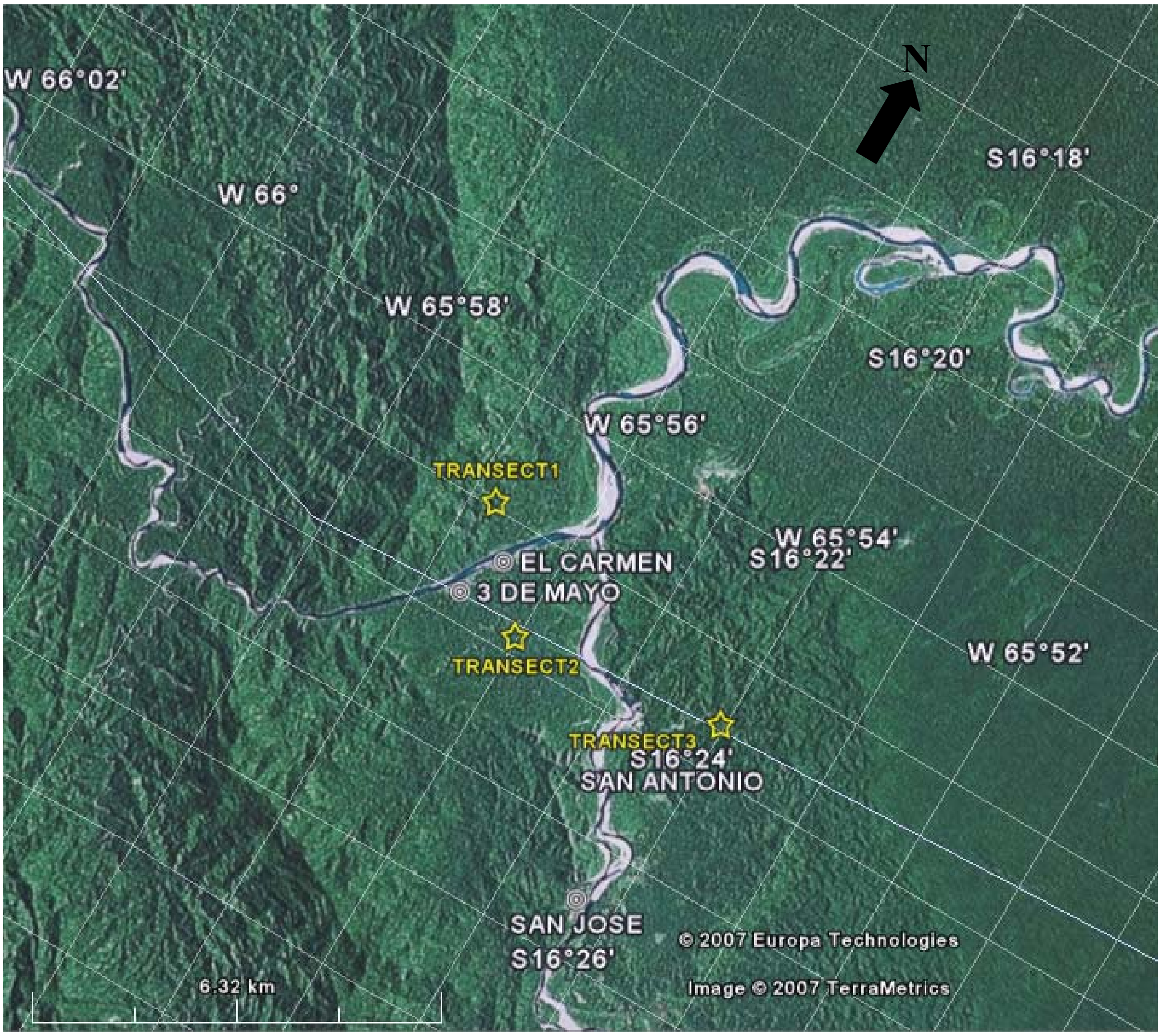

Figure 6.3: Satellite image of the first study site with participating villages (El Carmen, San Antonio and San Jose) and location of three 0.1-ha forest transects. Transects 1 and 3 represent the *terra firme* transects in *southwestern Amazon subandean evergreen forest* near El Carmen and San Antonio, respectively. Transect 2 was sampled in the *southwestern Amazon piedmont* (floodplain) *forest* near El Carmen (source: Google Earth, 12/03/2007).

The reason why two transects were sampled in *terra firme* forest and only one transect in the other vegetation types (i.e. floodplain and *varzea*) is related to the actual surface they occupy in the landscape. The majority of land used by Yuracarés and Trinitarios is covered by *terra firme* forests (particularly in the first study site); whereas floodplain and *varzea* forests represent far smaller surface areas. In line with most relevant scientific literature (related to the western Amazon), no distinction will be made between floodplain and *varzea* forest in the scope of our discussion. Both belong to the same group of "inundated forests" and are further addressed as floodplain forests, as opposed to *terra firme* forests.

Layout and Sampling

Each of the four 0.1-ha transects was made in the most homogenous and physiognomically mature part of the selected forest types using the techniques described by Gentry (1982a) and summarized by Phillips and Miller (2002). Each 0.1-ha transect consisted of ten 2 x 50 m^2 transects laid out in directions haphazardly arranged in an irregular geometric pattern (but avoiding trails, rivers and clearings to the extent possible) (cf. Gentry and Dodson, 1987a).

Slope corrections were made in accordance with the methodology provided in chapter 2 (section 2.2.1.2.). All plants with a stem diameter at breast height (dbh; breast height corresponds with 1.3 m) of 2.5 cm or more and rooted within the transect area were included in the sample. The samples included trees, larger shrubs, lianas and hemi-epiphytes. For lianas rooted within the plot, their greatest stem diameter was recorded if this was ≥ 2.5 cm at any given point (even if this point of maximum diameter frequently fell below breast height). Any hemi-epiphyte with descending roots of at least 2.5 cm at or below breast height was included. For a more detailed description of sampling strategy, the reader is referred to Phillips and Miller (2002). Each measured plant was identified or recorded as a unique 'morphospecies'. A voucher specimen was collected when the taxon was encountered for the first time or in case its identity was uncertain (adopted from Phillips *et al.* 2003). For liana individuals, stem cuttings were collected to facilitate identification and to establish a reference collection. In the rare cases no leaf material could be collected from liana species, cuttings served as vouchers.

Figure 6.4: Satellite image of the second study site in the research area showing the participating village (Sanandita), main river (Rio Isiboro) and location of the 0.1-ha forest transect. A closer inspection of this map reveals the (periodically flooded) forest that represents the *southwestern Amazon white-water floodplain forest*, in the belt covering the meandering Isiboro river (source: Google Earth, 12/03/2007).

All plants were identified by the author with the help of several international taxonomic specialists (see Acknowledgements) and deposited in the national Bolivian herbaria of BOLV and LPB. Cronquist's (1988) classification of plant families was followed, and Fabaceae-Caesalpinioideae, Fabaceae-Mimosoideae, and Fabaceae-Papilionoideae were pooled together into Fabaceae.

6.3.2. Data Analysis

We used both species richness and Fisher's α to quantify and compare diversity in transects. Shannon-Wiener H' values are also reported. It has been argued that Fisher's α and Shannon-Wiener H' capture diversity in small stem samples (i.e. <1000 stems; which is nearly always the case for 0.1-ha transects (Phillips and Miller, 2002)) more efficiently than counting the number of species (species richness) (Condit *et al.*, 1996; Ter Steege *et al.*, 2000). However, nearly all 0.1-ha transect studies employ species richness for analyzing and comparing diversities between sites (e.g. Gentry, 1988b; Foster and Gentry, 1991; Romero-Saltos *et al.*, 2001; Phillips and Miller, 2002; Phillips *et al.*, 2003, Macia and Fuertes, s.d.; Macia and Svenning, 2005; Quisbert and Macía, 2005; Araujo-Murakami *et al.*, 2005). To allow comparison with these studies species richness will also be used in every analysis.

Diversity indices were statistically compared using PAST programme (Hammer *et al.*, 2001). Fisher's α is calculated as:

$$S=\alpha*\ln(1+n/\alpha)$$

where S is the number of taxa, n the number of individuals and α is Fisher's α. Shannon diversity (H) is computed as:

$$H = -\sum p_i*\log(p_i)$$

where p_i is the proportional abundance of species *i*. Also Jaccard and Bray-Curtis ecological distances were calculated in PAST. Bray-Curtis distance between two transects j and k is calculated as:

$$Bray-Curtis_{jk} = \frac{\sum_{i=1}^{s} \left| x_{ij} - x_{ik} \right|}{\sum_{i=1}^{s} (x_{ij} + x_{ik})}$$

where s is the total number of taxa and x represents the abundance of a species in a transect. The Jaccard similarity index is simply calculated as M/(M+N), whereby M is the number of taxa shared by two sites, and N the total number of non-overlapping taxa found in both sites.

To verify whether a transect size of 0.1 hectare was able to cover the majority of species present in any particular forest type, species-area curves were made for all stems ≥ 2.5 cm dbh in each transect. Data for the species-area curves were calculated in the statistical program Biodiversity Pro (McAleece, 1997) and exported to MS Excel for elaboration of graphs.

Ordination analysis (see chapter 2 for explanatory notes on this statistical technique) was performed in PC-Ord 4.0 (McCune and Mefford, 1999). Main matrices consisted of rows with transect data and columns with species data. Cells contained the number of individuals for each species in transects. The length of gradients was determined by detrended correspondence analysis (DCA). Following the advice of Jongman *et al.* (1996), correspondence analysis (CA) was carried out in case these gradients were larger than two standard deviations (2 s.d.).

The importance value index (IV) of Curtis and McIntosh (1951) and the family importance value index (FIV) of Mori *et al.* (1983) were calculated to describe the ecological importance of species and families in transects, respectively. The IV of a species was calculated as the sum of its relative density, its relative frequency and its relative dominance. The FIV of a family was likewise calculated as the sum of its relative diversity, its relative density and its relative dominance. All other statistical analyses such as Mann-Whitney and Kruskal-Wallis non-parametric tests were conducted in SPSS 12.0.

6.4. Results

6.4.1. Complete Inventory

A total of 1586 voucher specimens were made in TIPNIS. Together with plant species with known identity, these specimens accounted for 906 different botanical species and morphospecies (Appendix 2). Up to present, 39 species remain unidentified to genus level. For seventeen of these species it was not possible to identify plant family. These latter specimens were sterile and all but one were collected during transect sampling (see lower). In the course of research in TIPNIS, at least four plant species new to science have been discovered, as confirmed by taxonomical specialists. A new *Bauhinia* sp. (Fabaceae) (ET1786) is about to be published by R. Fortunato while a new *Calyptranthes* sp. (Myrtaceae) (ET610, ET657, ET759, ET861 and ET1241B) will be described in the near future by B. Holst. According to T. Pennington and G. Prance (pers. comm.) also a new *Inga* sp. (Fabaceae) (ET2120 and ET2143) and a new *Licania* sp. (Chrysobalanaceae) (ET1876) were inventoried, but of the former species only fruits were collected, while the latter species is represented by a vegetative specimen. The unsatisfactory quality of the plant material hampers scientific description of these species.

All species are distributed over 116 different families and 446 genera. Best-represented families are Fabaceae (80 species), Rubiaceae (44), Lauraceae (29), Moraceae (26), Melastomataceae (25), Sapotaceae (25), Solanaceae (25), Euphorbiaceae (24), Bignoniaceae (21) and Annonaceae (19) (table 6.1). The ten most species rich genera are *Inga* (24 species), *Pouteria* (18), *Neea* (14), *Miconia* (12), *Sloanea* (12), *Ficus* (10), *Paullinia* (10), *Solanum* (10), *Piper* (9) and *Trichilia* (9).

The majority of inventoried plant species (59%) has a tree or shrub habit (412 (45%) and 119 (13%) species, respectively), followed by lianas and climbers (23%; 177 and 35 species, respectively), herbs (10%), (hemi-)epiphytes (4%) and graminoids (1%; including Poaceae and Cyperaceae) (figure 6.1). Also, nine hemi-epiphytic strangler species were collected, 5 hemi-parasites and 4 fungi. A detailed account of the management status and origin of inventoried species is given in chapter 10.

6.4.2. Transects

6.4.2.1. Overall Forest Composition

A total of 465 species and morphospecies was found in the four 0.1 ha transects, including 38 unidentified species. Nearly all unidentified species were liana species (32) of which only stem cuttings could be harvested. Identification of plant family based on stem cuttings was possible for 21 species. Also, for six canopy trees it was not possible to collect leaf material. Fifty-five species could only be identified to genus level. A summary of the findings is given in table 6.2. Best-represented families in the transect data set are Fabaceae (40 species), Moraceae (20), Sapotaceae (20), Lauraceae (20), Bignoniaceae (16) and Annonaceae (15). Most species-rich genera are *Inga* (17 species), *Pouteria* (15 species), *Trichilia* (9 species), *Sloanea* (9 species) and *Neea* (8 species). Liana diversity was rather high with Bignoniaceae (15 species), Hippocrataceae (14), Dilleniaceae (10) and Fabaceae (9) being most speciose.

Table 6.1: Family distribution in number of species and percentages

Family	species	%	Family	species or families	%
Fabaceae	80	9.3	Poaceae	10	1.2
Rubiaceae	44	5.1	Monimiaceae	10	1.2
Lauraceae	29	3.4	Menispermaceae	10	1.2
Moraceae	26	3.0	Flacourtiaceae	10	1.2
Solanaceae	25	2.9	Cucurbitaceae	10	1.2
Sapotaceae	25	2.9	Polygonaceae	9	1.0
Melastomataceae	25	2.9	Convolvulaceae	9	1.0
Euphorbiaceae	24	2.8	Sterculiaceae	8	0.9
Bignoniaceae	21	2.4	Passifloraceae	8	0.9
Annonaceae	19	2.2	Orchidaceae	8	0.9
Sapindaceae	17	2.0	Malpighiaceae	8	0.9
Myrtaceae	17	2.0	Gesneriaceae	8	0.9
Meliaceae	17	2.0	Dilleniaceae	8	0.9
Nyctaginaceae	16	1.9	Violaceae	7	0.8
Acanthaceae	16	1.9	Anacardiaceae	7	0.8
Piperaceae	15	1.7	Myrsinaceae	6	0.7
Hippocrataceae	15	1.7	Myristicaceae	6	0.7
Chrysobalanaceae	15	1.7	Malvaceae	6	0.7
Arecaceae	14	1.6	Bombacaceae	6	0.7
Elaeocarpaceae	13	1.5	Vitaceae	5	0.6
Asteraceae	13	1.5	Urticaceae	5	0.6
Araceae	13	1.5	Lecythidaceae	5	0.6
Apocynaceae	12	1.4	Dichapetalaceae	5	0.6
Clusiaceae	11	1.3	families with 4 spp.	11	5.1
Cecropiaceae	11	1.3	families with 3 spp.	13	4.5
Verbenaceae	10	1.2	families with 2 spp.	12	2.8
Rutaceae	10	1.2	families with 1 sp.	30	3.5

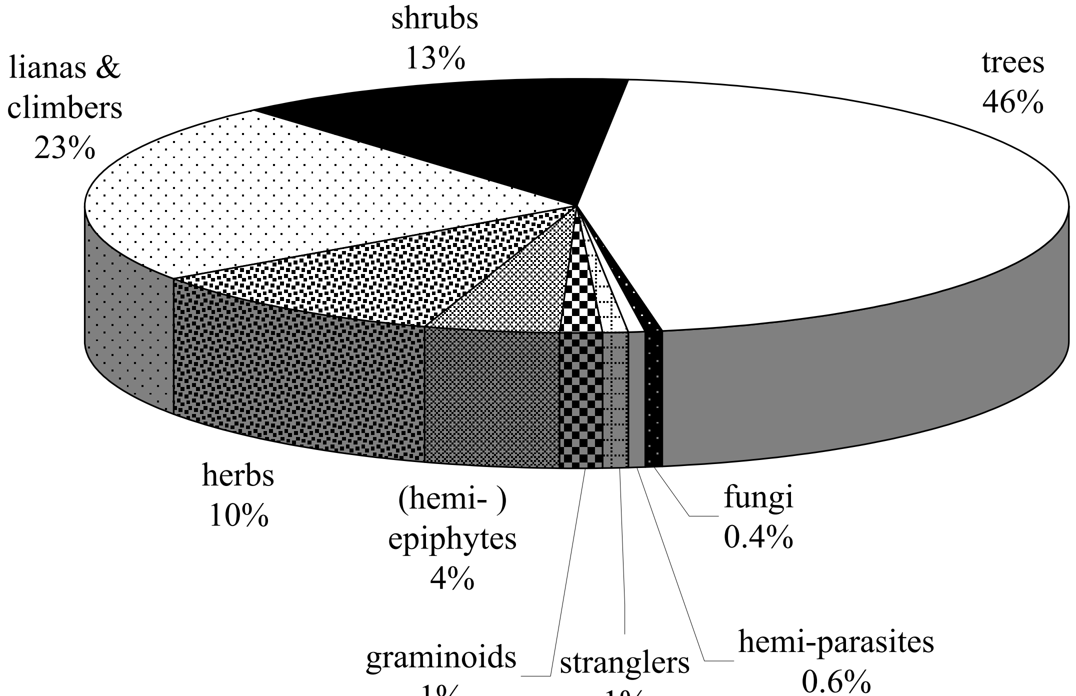

Figure 6.1: Distribution of all inventoried plant and fungi species in TIPNIS according to growth form

Table 6.2 Summary of the floristic composition of four 0.1 ha transects in *terra firme*, floodplain and *varzea* forest. The number of unidentified species (i.e. genus and/or family unknown) represents species that were previously unrecorded during the present study. Significantly equal mean diameters are underlined.

	Carmen (*terra firme*)	**San Antonio (*terra firme*)**	**Carmen (floodplain)**	**Sanandita (*varzea*)**
number of stems in 0.1 ha	395	414	351	404
number of species in 0.1 ha	183	186	148	170
number of families in 0.1 ha	60-64	50-53	52-58	57-61
number of tree species in 0.1 ha	140	135	99	109
number of liana species in 0.1 ha	28	39	34	45
number of shrub species in 0.1 ha	9	7	10	11
number of (hemi)epiphyte species in 0.1 ha	4	2	3	4
number of strangler species in 0.1 ha	2	3	2	1
mean diameter stems ≥2.5 cm dbh [cm]	10	10.3	11.6	8.3
unidentified species	11	8	8	11
number of species exclusively found in transect	84	96	66	83
Shannon-Wiener	4.74	4.77	4.58	4.72
Fisher's α	132.38	128.37	96.42	109.20

Transects in *terra firme* forest contained the highest number of species. Lowest species richness was recorded for the floodplain transect. Fisher's α was also significantly higher for the *terra firme* transects than for the floodplain transect (bootstrap test; $p=0.003$ and $p=0.01$ for San Antonio and Carmen (*terra firme*), respectively). For the *varzea* transect, no significant differences were found with other transects based on Fisher's α . Shannon-Wiener diversities were equal (at the 5% level) for all four transects. Transects in *terra firme* forest contained proportionally more tree species (77 and 73%, respectively) than transects in the floodplain (67%) and *varzea* forest (64%). In the *varzea* forest transect, the highest number (45) and proportion (26%) of liana species was recorded. *Terra firme* forest in Carmen scored lowest with only 15% of species being lianas.

Mean stem diameter was significantly different between transects (Kruskal-Wallis; $p \leq 0.001$). The lowest value was recorded for *varzea* forest. The majority of stems in all four transects had a dbh between 2.5 and 10 cm. Proportions of stems with 2.5 cm ≤ dbh < 10 cm on the total stem number ranged from 65% and 71% for *terra firme* forest in San Antonio and El Carmen, respectively, over 77% for *varzea* forest in Sanandita, to 85% for floodplain forest in El Carmen. Frequency diagrams (not shown) according to dbh of stems in each of the four transects follow inverted "J" distributions, characterized by an exponentially decreasing number of individuals with increasing dbh. As demonstrated in figure 6.5, most of the species sampled were represented by one or two individuals in a single transect (55 and 75% of species, respectively).

The number of species overlapping between transects was rather low and varied between 45 and 63 with corresponding Jaccard indices between 0.16 and 0.21 and Bray-Curtis indices between 0.22 and 0.35. This is confirmed by the CA ordination diagram represented in figure 6.6. The use of CA is justified since the lengths of gradients (calculated as 2.9 s.d.) are higher than the threshold value of 2 s.d. Species (represented by scores (+) in figure 6.6) that are located in between the transect scores are most likely to be shared by various transects. Only 24 species occur in all four transects. Examples of the most abundant ones are *Iriartea* *deltoidea*, *Cyathea pungens, Leonia crassa, Pseudolmedia laevis, Iryanthera juruensis, Pouteria torta* and *Siparuna decipiens*.

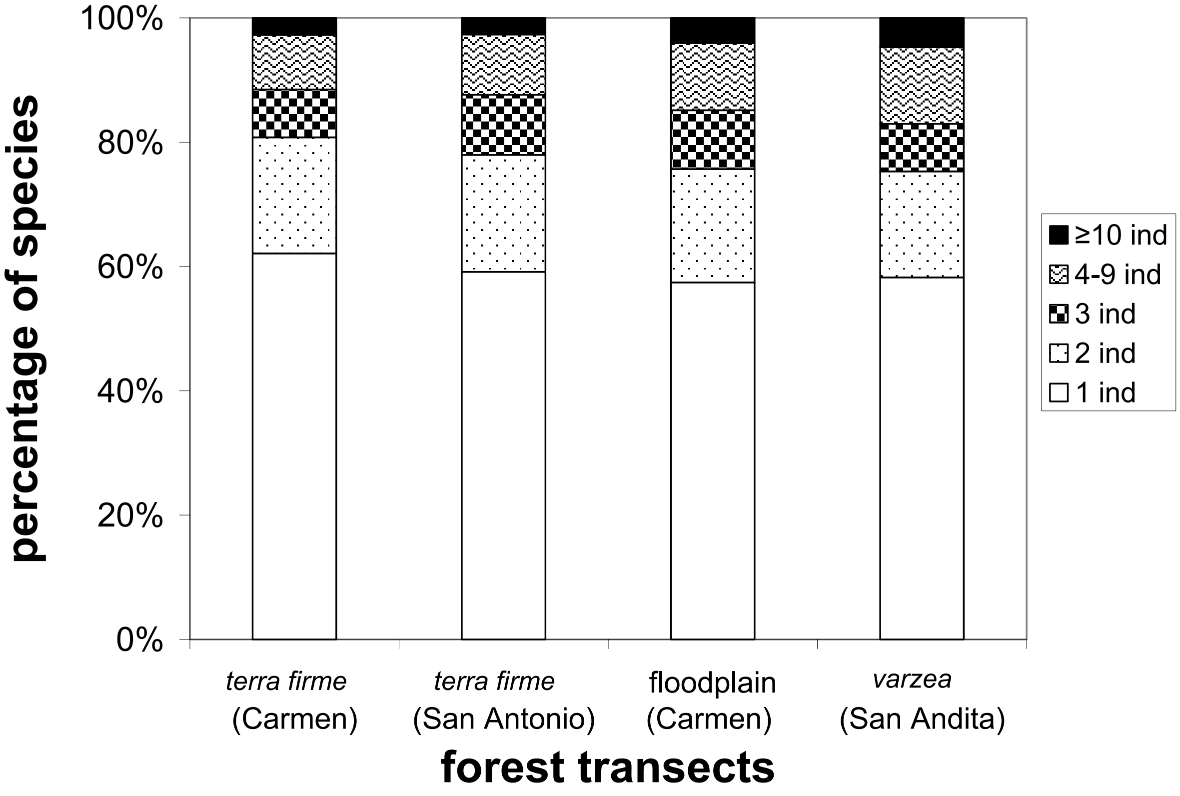

Figure 6.5: Percentage of species with different numbers of individuals in the four transects in two *terra firme*, one floodplain and one *varzea* forest

The majority of species (329 species, 71%) was sampled in only one transect (cf. table 6.2). This is also evident from the listing of species at the four extremes of the ordination axes in figure 6.6. In fact, the scores of the species listed at each of the four sides of the ordination axes have identical locations, indicated by the four encircled crosses (⊕). Sixteen percent of species was found in two transects and eight percent in three.

When all 40 component 0.01-ha transects of the four 0.1-ha transects are compared separately by means of mean Bray-Curtis ecological distance, it is clear that component transects sampled at one site (i.e. within site comparison) are more alike than component transects sampled at different sites (i.e. between site comparison) (table 6.3). The ten 0.01-ha transects sampled on the floodplain site show the highest mean within site similarity. Mean Bray-Curtis indices for within site comparisons of component transects are equal for each of the other three 0.1-ha transects. Although sampled on a different substrate and in a different topological environment, both transects in the Carmen region occupy the fifth place in the ranking of pairs of 0.1-ha transects according to Mean Bray-Curtis index (table 6.3). The two *terra firme* transects yield the second lowest mean Bray-Curtis value (table 6.3).

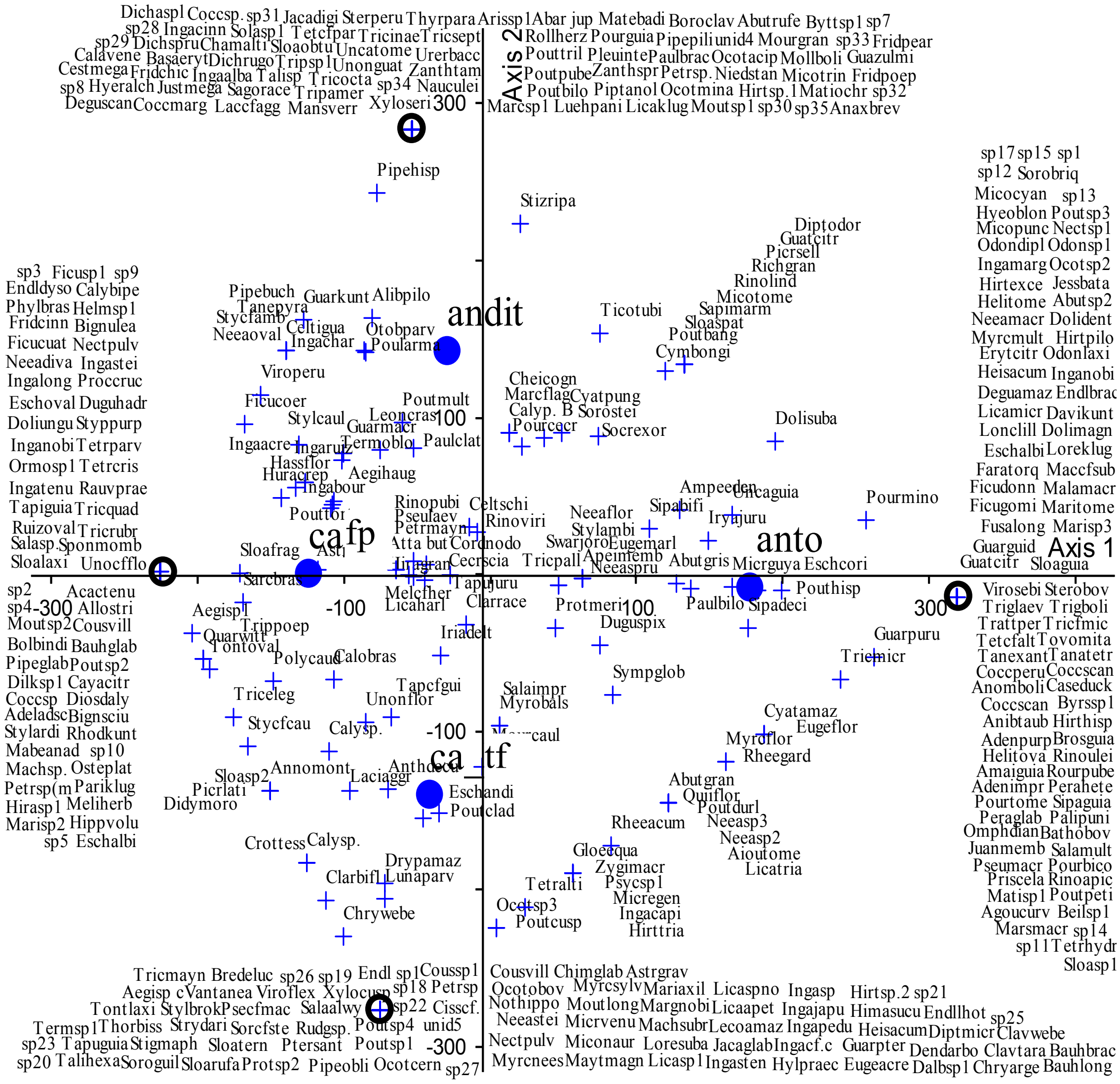

Figure 6.6: Ordination diagram of a CA for the four sampled 0.1-ha transects. The eigenvalues of the first two axes are 0.55 and 0.51, representing 37 and 34% of the variation in species abundance data. Crosses (+; i.e. species scores) mark the points where the abundance of each species is highest, with (imaginary) concentric circles away from the species position indicating lower abundances. Transects (represented by solid circles: ●) with a high value for a species tend to be close to the point of that species. Crosses are accompanied by abbreviated scientific names, whereby the first four letters correspond to the genus and the last four letters to the species. The scores (+) of numerous species have identical locations. Therefore various abbreviated plant names may be associated with one cross or species score. Species listed at the four extremes of the ordination axes are represented by the four respective encircled crosses (⊕) (andit: Sanandita (*varzea* forest); anto: San Antonio (*terra firme* forest); ca_fp: Carmen (floodplain forest); and ca_tf: Carmen (*terra firme* forest).

Figure 6.7 was constructed to test whether the trend of higher similarity between transects sampled at the same site is also visualized when considering all 0.01-ha component transects of the four 0.1-ha transects. The length of the ordination axes is higher than 2 s.d. (3.9 according to DCA), justifying CA. Despite their relatively high eigenvalues (0.66 and 0.59), the first two axes explain only 9% of total variance in data. Figure 6.7 shows that, based on species composition, transects sampled in the vicinities of San Antonio and Sanandita group together fairly well. Component 0.01-ha transects, sampled in *terra firme* and floodplain forests in the vicinities of Carmen, are much more alike than other combinations of 0.1-ha transects. Although component transects of the floodplain transect tend to accumulate on the right side of the second axis and those of the *terra firme* transect on the left side, they can not be separated unequivocally. This suggests that in our research area, vicinity or geographical distance is a more decisive factor for species composition (but not for diversity) than forest type. Clustering of component 0.01 ha transects also indicates that transects were sampled in relatively homogenous vegetations. Only the fifth component 0.01-ha transect in San Antonio and the second component 0.01-ha transect in Sanandita have a markedly different species composition (figure 6.7).

Table 6.3: Ranking according to mean Bray-Curtis distance for all pairs of 0.1-ha transects whereby the 10 component 0.01-ha transects of all possible 0.1-ha transect pair were compared with each other. Equal values are indicated by vertical lines in the right side margin (p<0.01; Mann Whitney tests) (Ca=Carmen; sAnt= San Antonio; sAnd= Sanandita).

Pairs of 0.1-ha transects	Mean Bray Curtis
floodplain (Ca) vs. floodplain (Ca)	0.23
terra firme (Ca) vs. *terra firme* (Ca)	0.19
terra firme (sAnt) vs. *terra firme* (sAnt)	0.18
varzea (sAnd) vs. *varzea* (sAnd)	0.16
terra firme (Ca) vs. floodplain (Ca)	0.15
floodplain (Ca) vs. *varzea* (sAnd)	0.14
terra firme (sAnt) vs. *varzea* (sAnd)	0.12
terra firme (Ca) vs. *varzea* (sAnd)	0.11
terra firme (Ca) vs. *terra firme* (sAnt)	0.11
floodplain (Ca) vs. *terra firme* (sAnt)	0.09

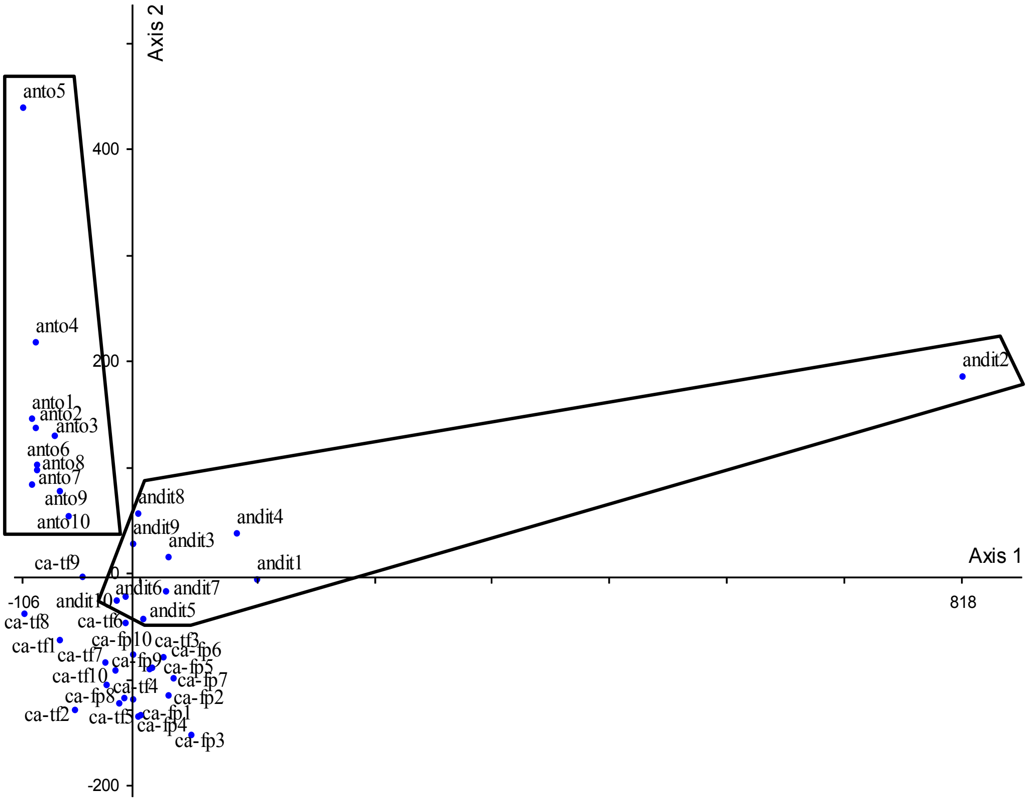

Figure 6.7: Ordination diagram of a CA for the forty sampled 0.01-ha component transects. Two relatively clear groups of component transects can be distinguished: one for transects sampled in the vicinities of San Antonio (anto1-10) and one for Sanandita (andit1-10). Component transects of the two transects sampled in the vicinities of Carmen are all clustered together (ca-tf: *terra firme* forest and ca-fp: forest on floodplain).

Figure 6.8 shows that the species-area curve for all four transects is still steeply rising after 0.1 hectare. This shows that that transects of only 0.1 hectare in size are insufficient for calculating the true diversity of the forests we sampled.

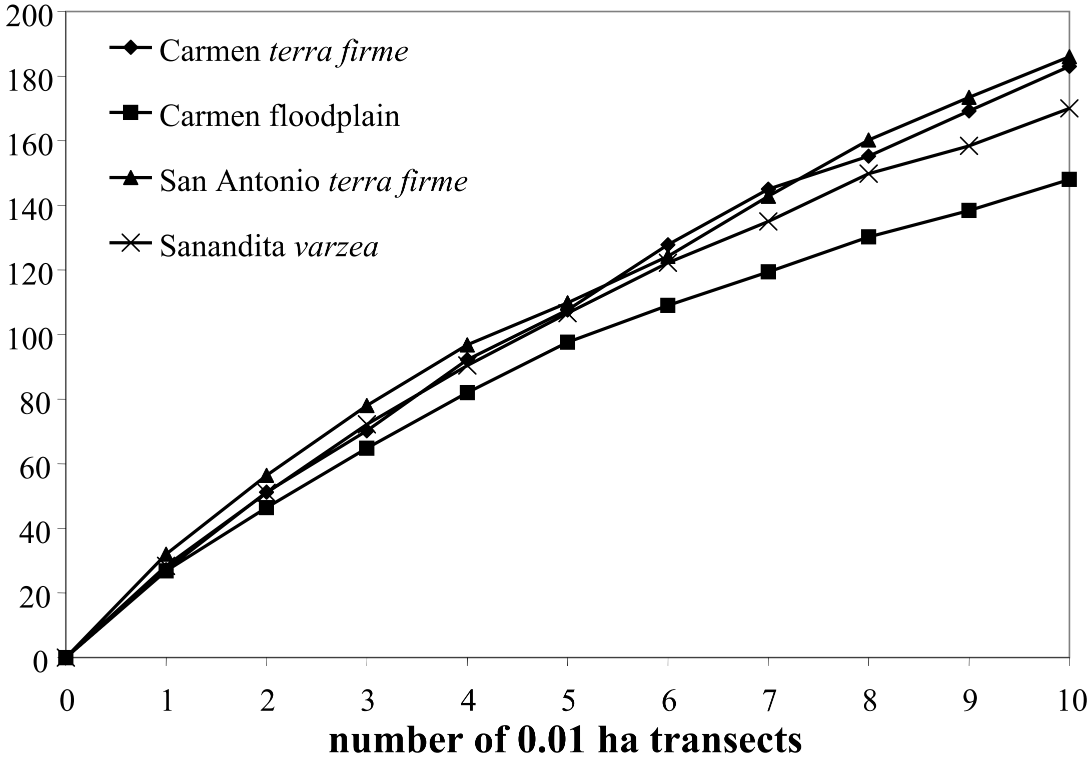

Figure 6.8: Species-area curves of the four sampled transects in TIPNIS

Table 6.3 shows that Fabaceae, Sapotaceae, Moraceae and Arecaceae figure in the top ten ranking according to family importance values of all four 0.1-ha transects. Moreover, the first three families are among the five most important in *terra firme* transects. They are completed by Euphorbiaceae and Arecaceae for the Carmen transect and Lauraceae and Cecropiaceae for the San Antonio transect. The exceptionally high FIV of Euphorbiaceae in the floodplain transect can basically be ascribed to one giant *Hura crepitans* tree with a dbh of 2.4 m. Although only one large Ebenaceae individual (dbh= 1.29 m) was sampled during the entire field work period, this family occupied the fifth place in FIV values for the floodplain transect. Differently from the other three transects, Violaceae and Elaeocarpaceae are in the top five of FIVs for the *varzea* forest transect.

6.4.2.2. El Carmen *Terra Firme* Forest Transect

The *terra firme* forest transect in the vicinity of El Carmen had a closed canopy, except for an occasional gap caused by a fallen tree. Some places crossed by the transect line were characterized by rocky outcrops. The soil layer was rather thin and consisted principally of sand mixed with rocks. Transect slopes ranged from 0 to 25°.

Families with most species were Fabaceae (18 species), Sapotaceae (12), Moraceae (10), Myrtaceae (8) and Lauraceae (8). Families with highest abundances were Flacourtiaceae (32 individuals), Arecaceae (26), Sapotaceae (26), Moraceae (25) and Violaceae (24). The forest was characterized by relatively high abundances of *Lunania parviflora* and *Iriartea deltoidea* (table 6.4). *Hura crepitans* obtained a high IV due to the large dimensions (dbh = 123 cm) of the sole individual by which it was represented. The latter species had the largest recorded diameter in the transect. Other species with a high IV were *Eschweilera andina* and *Clarisia racemosa.* Genera with the highest species count were *Inga* (9 species) and *Pouteria* (7 species). In this transect, the smallest number of lianas was found (15% of all species and 8% of all stems), whereas the highest diameters were recorded for *Moutabea* cf. *longifolia* (22 cm), *Hiraea grandifolia* (12 cm) and *Bredemeyera* cf. *lucida* (10 cm). Most abundant shrub species were *Styloceras brokawii*, *Calyptranthes* sp. nov. and *Cordia nodosa*. Of the four (hemi-)epiphytes sampled, the climbing fern *Polybotrya caudata* was most abundant. Although very abundant in the transect, *Thoracocarpus bissectus* reached a minimum diameter of 2.5 cm in only one specimen. *Coussapoa villosa* was the best-represented strangler species.

Table 6.3: Thirty families with highest family importance values (FIV) for each of the four 0.1-ha transects. Families with five highest FIV values are marked in bold for each transect site.

	Carmen (*terra firme*)	**San Antonio (*terra firme*)**	**Carmen (floodplain)**	**Sanandita (*varzea*)**
Fabaceae	**22.7**	**17.6**	**21.4**	**16.0**
Euphorbiaceae	**22.6**	10.1	**47.7**	**25.6**
Moraceae	**20.3**	**17.6**	**26.0**	14.1
Arecaceae	**18.2**	12.4	9.9	**14.2**
Sapotaceae	**16.4**	**18.6**	**12.7**	12.2
Violaceae	10.0	13.3	5.2	**14.7**
Flacourtiaceae	12.7	2.5	8.2	2.4
Myrtaceae	10.8	7.1	6.0	2.9
Anacardiaceae	10.0	-	7.0	5.9
Lauraceae	9.5	**16.9**	3.6	3.5
Clusiaceae	8.6	9.1	3.6	0.9
Chrysobalanaceae	8.6	8.2	2.3	3.4
Lecythidaceae	7.6	11.1	3.4	10.9
Myristicaceae	7.5	13.0	6.4	9.4
Burseraceae	6.6	6.0	1.0	1.1
Hippocrataceae	6.2	6.8	8.1	3.8
Meliaceae	6.2	8.7	8.7	5.3
Annonaceae	5.9	6.1	8.3	11.5
Bombacaceae	4.8	2.0	5.6	1.5
Nyctaginaceae	4.6	6.1	2.3	3.0
Elaeocarpaceae	4.3	6.1	8.0	**14.6**
Monimiaceae	4.2	14.6	2.6	3.9
Rubiaceae	3.9	9.8	1.9	6.7
Myrsinaceae	2.9	0.8	5.5	3.4
Cyatheaceae	2.5	4.6	2.3	4.4
Ulmaceae	1.9	2.8	2.3	12.0
Boraginaceae	1.7	3.0	5.7	2.0
Piperaceae	1.1	-	3.2	4.6
Cecropiaceae	0.8	**15.9**	3.0	4.9
Bignoniaceae	0.8	4.4	6.4	9.3
Verbenaceae	0.0	1.6	6.6	2.6
Rutaceae	-	2.3	1.0	5.1
Ebenaceae	-	-	**10.0**	-
Sterculiaceae	-	-	-	8.1

Table 6.4: Density, basal area and importance value (IV) of the 20 most common species ≥ 2.5 cm dbh in 0.01-ha of *terra firme* forest, El Carmen; species are ranked in order of decreasing IVs

Taxon name	Absolute density [# ind/0.1ha]	Basal area [m^2/0.1ha]	Rel. density [%]	Rel. dominance [%]	Rel. frequency [%]	IV [%]
Iriartea deltoidea	23	0.61	5.82	7.87	3.31	17.01
Hura crepitans	1	1.19	0.25	15.36	0.33	15.94
Lunania parviflora	29	0.18	7.34	2.31	2.65	12.30
Eschweilera andina	8	0.33	2.03	4.22	1.66	7.90
Anacardiaceae sp.	1	0.55	0.25	7.16	0.33	7.75
Clarisia racemosa	3	0.39	0.76	5.03	0.66	6.46
Styloceras brokawii	11	0.06	2.78	0.73	2.32	5.83
Bauhinia aff. *longifolia/ungula*	1	0.38	0.25	4.97	0.33	5.56
Gloeospermum cf. *equatoriense*	10	0.08	2.53	1.03	1.99	5.55
Quararibea wittii	3	0.27	0.76	3.54	0.99	5.29
Drypetes amazonica	6	0.19	1.52	2.43	1.32	5.27
Calyptranthes sp. nov.	11	0.01	2.78	0.11	1.99	4.88
Tetragastris altissima	3	0.21	0.76	2.74	0.99	4.49
Otoba parvifolia	2	0.25	0.51	3.29	0.66	4.46
Siparuna decipiens	8	0.06	2.03	0.78	1.32	4.13
Pouteria cladantha	6	0.09	1.52	1.17	1.32	4.01
Pseudolmedia laevis	6	0.08	1.52	1.02	1.32	3.87
Rinorea viridifolia	8	0.03	2.03	0.33	1.32	3.68
Poulsenia armata	3	0.12	0.76	1.54	0.99	3.29
Iryanthera juruensis	6	0.02	1.52	0.25	1.32	3.10
Total of other species (163)	246	34.12	2.64	62.27	72.85	169.24
Total	395	100	7.74	100	100	300

6.4.2.3. San Antonio *Terra Firme* Forest Transect

The geomorphological and physiognomical characteristics of the *terra firme* forest sampled in the surroundings of San Antonio were similar to those presented for El Carmen. Even the most speciose families were quite similar, including Moraceae (11 species), Fabaceae (11), Sapotaceae (10), Lauraceae (10) and Rubiaceae (8) (table 6.5). However, the most abundant families showed less overlap: Monimiaceae (34 individuals), Violaceae (30), Myristicaceae (24), Moraceae (23) and Fabaceae (17).

Floristic composition at the species level was quite different form the Carmen *terra firme* transect. *Siparuna decipiens* and *Iryanthera juruensis* were present in nearly every 0.01-ha transect and were the most abundant species. Also, *Iriartea deltoidea* and *Eschweilera coriacea* received high IVs, whereas the tree fern *Cyathea pungens* figured among the 20 species with highest IVs, together with four *Pourouma* species.

The genus *Pouteria* was the best-represented genus in the San Antonio transect with eight different species, followed by *Neea* with five species. Lianas were common (21% of all species and 15% of all stems); the largest diameters were recorded for *Salacia multiflora*

(20 cm), *Omphalea diandra* (11.5 cm) and *Uncaria guianensis* (10 cm). Shrub species were not abundant and only *Cordia nodosa* was represented by more than one individual. Stranglers (*Ficus gomilleira* and *F.* cf. *donnell-smithii*) and other (hemi-)epiphytic species (*Juanulloa membranacea* and *Marcgravia flagellaris*) were rare as evidenced by the presence of only one individual of each species.

Table 6.5: Density, basal area and importance value (IV) of the 20 most common species ≥ 2.5 cm dbh in 0.01-ha of *terra firme* forest, San Antonio; species are ranked in order of decreasing IVs

Taxon name	**Absolute density** [# ind/0.1ha]	**Basal area** [m²/0.1ha]	**Rel. density** [%]	**Rel. dominance** [%]	**Rel. frequency** [%]	**IV** [%]
Siparuna decipiens	29	0.29	7.04	4.56	2.27	13.86
Iriartea deltoidea	11	0.38	2.67	6.03	1.94	10.64
Eschweilera coriacea	8	0.42	1.94	6.66	1.94	10.54
Iryanthera juruensis	22	0.15	5.34	2.37	2.59	10.30
Pouteria hispida	3	0.27	0.73	4.24	0.97	5.94
Rinorea lindeniana	13	0.03	3.16	0.55	1.94	5.65
Pourouma cecropiifolia	3	0.23	0.73	3.59	0.65	4.97
Pourouma tomentosa	3	0.19	0.73	3.09	0.97	4.79
Guarea purusana	6	0.10	1.46	1.59	1.62	4.66
Dipterix odorata	1	0.26	0.24	4.06	0.32	4.62
Cordia nodosa	9	0.02	2.18	0.33	1.94	4.45
Richeria grandis	4	0.14	0.97	2.18	1.29	4.45
*Salacia multiflora**	6	0.09	1.46	1.47	1.29	4.22
Cyathea pungens°	10	0.03	2.43	0.46	1.29	4.18
Pseudolmedia laevis	6	0.06	1.46	0.98	1.29	3.74
Sloanea sp.1	6	0.04	1.46	0.56	1.62	3.64
Pourouma minor	5	0.05	1.21	0.75	1.62	3.58
Pourouma bicolor	2	0.15	0.49	2.37	0.65	3.50
Aniba taubertiana	4	0.10	0.97	1.52	0.97	3.46
Machaerium cf. *subrhombiforme**	6	0.02	1.46	0.33	1.62	3.41
Total of other species (166)	257	3.29	61.89	52.31	71.20	185.40
Total	414	6.29	100.00	100.00	100.00	300.00

*= liana °= tree fern

6.4.2.4. El Carmen Floodplain Forest Transect

The forest sampled on the floodplain in the vicinity of El Carmen was located on a flat terrain with a clayish soil without rocks. Respondents declared that the forest is occasionally flooded a few days each year after heavy rainfall. They stated that if this terrain was to be turned into swidden, it would be suitable for rice (*Oryza sativa*), but not for *yuca* (*Manihot esculenta*) because the latter does not tolerate inundation (http://ecocrop.fao.org/). The forest had a closed canopy with emergent trees of *Dipterix micrantha* of which only juveniles were encountered in the transect. Fabaceae was the family richest in species (15 species), followed by Moraceae (9), Meliaceae (6), Hippocrataceae (6) and Annonaceae (6) (table 6.6). In terms of abundance, Moraceae and Sapotaceae scored highest (24 individuals each) followed by Fabaceae (20) and Arecaceae (18). *Inga* was the most diverse genus with eight different species. Although diversity was significantly lower as compared to *terra firme* forest, tree species attained greater diameters in the floodplain in El Carmen. The dominant species in terms of importance values was *Hura crepitans* due to the large dimensions of the three individuals by which it was represented: dbhs of 70, 123 and 240 cm, respectively. Other species with high IV (following relatively high dominance values (table 6.6)) were *Ficus coerulescens* and *Diospyros dalyom*. Among the most abundant canopy trees were *Iriartea deltoidea, Pseudolmedia laevis, Pouteria torta* and *Quararibea wittii*. Lianas were abundant (23% of species and 15% of stems) with *Acacia* cf. *tenuifolia* (20.4 cm) and *Aegiphila* sp.1 (10.3 cm) attaining the largest diameters. Similar to the Carmen *terra firme* transect, *Cordia nodosa* and *Calyptranthes* sp. nov. were the best represented shrub species. *Coussapoa* cf. *villosa* and *Ficus cuatrecasana* were the only two strangler species, whereas amongst the (hemi-)epiphytes the climbing ferns *Polybotrya caudata* and *Bolbitis lindigii* were most abundant.

Table 6.6: Density, basal area and importance value (IV) of the 20 most common species ≥ 2.5 cm dbh in 0.01-ha of floodplain forest, El Carmen; species are ranked in order of decreasing IVs

Taxon name	**Absolute Density** [# ind/0.1ha]	**Basal area** [m²/0.1ha]	**Rel. density** [%]	**Rel. dominance** [%]	**Rel. frequency** [%]	**IV** [%]
Hura crepitans	3	6.10	0.85	42.13	1.08	44.06
Ficus coerulescens	2	1.31	0.57	9.02	0.72	10.31
Diospyros dalyom	1	1.31	0.28	9.01	0.36	9.66
Iriartea deltoidea	14	0.34	3.99	2.33	3.23	9.54
Pseudolmedia laevis	12	0.41	3.42	2.81	2.51	8.74
Pouteria torta	12	0.30	3.42	2.09	2.51	8.01
Cordia nodosa	17	0.03	4.84	0.18	2.87	7.89
Quararibea wittii	12	0.21	3.42	1.46	2.51	7.39
Sloanea fragans	9	0.24	2.56	1.63	2.51	6.70
Leonia crassa	10	0.10	2.85	0.70	2.51	6.06
Sarcaulus brasiliensis	9	0.04	2.56	0.26	2.51	5.33
Calyptranthes sp. nov.	8	0.01	2.28	0.09	2.87	5.24
Terminalia oblonga	1	0.58	0.28	4.01	0.36	4.65
Lunania parviflora	7	0.04	1.99	0.30	1.79	4.08
Hasseltia floribunda	7	0.13	1.99	0.88	1.08	3.95
Spondias mombin	1	0.47	0.28	3.27	0.36	3.92
Aegiphila sp.1*	6	0.02	1.71	0.14	1.79	3.64
Tontelea ovalifolia	7	0.03	1.99	0.18	1.43	3.61
Inga aff. *longipes*	1	0.38	0.28	2.66	0.36	3.30
Otoba parvifolia	6	0.02	1.71	0.15	1.43	3.29
Total of other species (128)	206	2.42	58.69	16.71	65.23	140.63
Total	351	14.48	100	100	100	300

*= liana

6.4.2.5. Sanandita *Varzea* Forest Transect

The *varzea* forest in Sanandita had an irregular, open canopy. It was characterized by a high incidence of natural disturbance, mainly due to wind disturbance. Hence, natural tree gaps were frequent. According to participants, this forest may remain flooded for periods of up to (several) weeks throughout the rainy season. The soil in depressions consisted of heavy brown, sticky clay, whereas soils at higher elevations were slightly sandier and thus lighter. Fabaceae (10 species), Sapotaceae (9), Bignoniaceae (8), Annonaceae (7) and Moraceae (6) consisted of the highest number of species, while high abundances were recorded for Violaceae (38 individuals), Moraceae (29), Myristicaceae (25), Fabaceae (19) and Arecaceae

(18) (table 6.7). Similar to previously described transects, the *Inga* and *Pouteria* genera were the most diverse (6 and 7 species, respectively). Largest dbhs were recorded for the species that yielded highest IVs: *Hura crepitans* (110 cm diameter), *Sloanea* cf. *obtusifolia* (100 cm), *Eschweilera coriacea* (80 cm) and *Celtis schippii* (72 cm). Highest densities were observed for *Leonia crassa, Rinorea lindeniana, Otoba parvifolia* and the tree fern *Cyathea pungens*.

Table 6.7: Density, basal area and importance value (IV) of the 20 most common species ≥ 2.5 cm dbh in 0.01-ha of periodically flooded forest in Sanandita; species are ranked in order of decreasing IVs

Taxon name	**Absolute Density** [# ind/0.1ha]	**Basal area** [m^2/0.1ha]	**Rel. density** [%]	**Rel. dominance** [%]	**Rel. frequency** [%]	**IV** [%]
Hura crepitans	2	0.96	0.50	15.83	0.70	17.02
Sloanea cf. *obtusifolia*	1	0.79	0.25	12.90	0.35	13.50
Celtis schippii	3	0.53	0.74	8.66	1.05	10.45
Iriartea deltoidea	12	0.28	2.98	4.64	2.79	10.40
Eschweilera coriacea	1	0.50	0.25	8.26	0.35	8.85
Leonia crassa	14	0.02	3.47	0.39	3.14	7.00
Rinorea lindeniana	13	0.05	3.23	0.81	2.44	6.48
Otoba parvifolia	13	0.05	3.23	0.82	2.09	6.14
Guazuma ulmifolia	3	0.30	0.74	4.89	0.35	5.98
Rinorea viridifolia	10	0.10	2.48	1.70	1.74	5.92
Cyathea pungens°	13	0.03	3.23	0.54	1.74	5.51
Pseudolmedia laevis	7	0.11	1.74	1.75	1.74	5.23
Poulsenia armata	12	0.04	2.98	0.66	1.39	5.03
Iryanthera juruensis	10	0.02	2.48	0.39	1.74	4.61
Sagotia racemosa	7	0.10	1.74	1.58	1.05	4.36
Jacaratia digitata	2	0.19	0.50	3.11	0.70	4.30
Pouteria torta	8	0.05	1.99	0.87	1.39	4.25
Thyrsodium paraense	1	0.20	0.25	3.23	0.35	3.82
Ticorea tubiflora	9	0.03	2.23	0.44	1.05	3.72
Anaxagorea brevipes	7	0.02	1.74	0.28	1.39	3.41
Total of other species (150)	256	1.72	63.28	28.28	72.47	164.03
Total	404	6.09	100.00	100.00	100.00	300.00

° tree fern

Of all sampled transects, this was the richest one in terms of lianas (26% of species and 16% of stems). The largest diameters were attained by *Trichostigma* cf. *octandrum* (18 cm), *Arrabidaea chica* (18 cm) and *Uncaria tomentosa* (12 cm). Due to openings in the canopy, various disturbance shrub species were recorded, including *Urera baccifera* and *Piper* spp. Nevertheless, these shrub species were not represented by a high number of individuals. Hemi-epiphytes and stranglers were only found occasionally and only *Marcgraviastrum* sp.1 was represented by more than one individual.

6.5. Discussion

6.5.1. Families and Genera

Most Species-Rich Families

Floristic composition at the family level is highly consistent among lowland tropical moist and wet neotropical forests (Gentry, 1988b; Ter Steege *et al.*, 2000; Ter Steege *et al.*, 2006).

Although a total of 292 plant families are known to grow in the Neotropics (Maas and Westra 1993), relatively few families account for the majority of Amazonian plant species (Gentry, 1988b). Fabaceae are almost always the most species-rich family in neotropical lowland forests (Gentry, 1988b; Duivenvoorden, 1995; Vasquez and Phillips, 2000), including in Bolivia (Quisbert and Macía, 2005 and Araujo-Murakami *et al*., 2005). Our findings clearly support this trend, but in one of the four transects we sampled Fabaceae were equaled by Moraceae. Where Gentry (1986; 1988b) found Moraceae to become very diverse and as species-rich as Fabaceae in his 0.1-ha transect samples, he related this to the extremely high fertility of the soils of these sample sites. However, high Moraceae species richness might in our case also partly be a consequence of continental-scale patterns, whereby Moraceae are more species-rich in western Amazonia than in any other area of Amazonia (Ter Steege *et al*., 2000).

Apart from Fabaceae and Moraceae, nine other families typically contribute most to species richness of different plant communities in any neotropical lowland moist or wet forest 0.1-ha sample, including Lauraceae, Annonaceae, Rubiaceae, Myristicaceae, Sapotaceae, Meliaceae, Arecaceae, Euphorbiaceae and Bignoniaceae (Gentry, 1988b). The five most species-rich families of the entire inventory and in each of our transects are included in this list, except for Myrtaceae and Hippocrataceae. However, it has been demonstrated elsewhere that Myrtaceae can also become dominant under certain conditions, such as in altitudinal bands on neotropical hills (e.g. Mori *et al*., 1983). In the studies of Araujo-Murakami *et al*. (2005) and Quisbert and Macía (2005) in the Bolivian Madidi forest region, Myrtaceae ranked fifth and fourth, respectively. A similar diversity of Hippocrataceae that was found in our transects (particularly in the floodplain forest with 6 species) has also been reported from Madidi by Quisbert and Macía (2005).

As predicted by Gentry (1988b) for the Neotropics and in accordance with studies from Madidi, Bignoniaceae was the most diverse liana family in our inventory (Gentry, 1991; Quisbert and Macía, 2005). Both absolute and relative numbers of liana species in our transects (28-45 species that account for 15-26% of the total species number) fall within the range of values reported by Gentry (an average of 41 species, corresponding to 23%) for other neotropical forests, whereby nearly as many species of climbers ≥ 2.5 cm dbh as of trees ≥ 10 cm dbh were found (Gentry, 1982a; Gentry and Dodson, 1987a).

Recently, Enquist *et al.* (2002) used the Gentry dataset to examine the relationship between species richness in 0.1-ha transects and the corresponding number of genera and families. They concluded that these relations are described by simple power functions whereby $F_{\text{(number of families)}} = 1.625 * S_{\text{(number of species)}}^{0.683}$. This function represents our data also fairly well, with the predicted number of families differing about five units from the recorded number of families (detail not given).

Abundance

The sixteen most common Amazonian tree families in order of abundance are Fabaceae, Sapotaceae, Lecythidaceae, Moraceae, Burseraceae, Chrysobalanaceae, Euphorbiaceae, Lauraceae, Annonaceae, Arecaceae, Bombacaceae, Meliaceae, Rubiaceae, Sterculiaceae, Violaceae and Myristicaceae (Terborgh and Andresen, 1998; Ter Steege *et al*., 2000). These families alone make up close to 80% of all tree individuals at ≥ 10 cm dbh (Ter Steege *et al.*, 2000). Apart form Flacourtiaceae and Monimiaceae, the five most abundant families in all of our transects are included in this list. These high scores for Flacourtiaceae and Monimiaceae in our data are probably related to our sampling strategy. The Flacourtiaceae and Monimiaceae species sampled are mostly relatively thin, understorey trees or shrubs and may not be adequately represented in samples of dbh ≥ 10 cm as compared to samples of dbh ≥ 2.5 cm. Alternatively, the high abundance of these families might reflect a regional phenomenon as they also appeared among the ten most abundant families in recent 0.1-ha based studies in the Bolivian Madidi region (Araujo-Murakami *et al.*, 2005; Macia and Svenning, 2005).

Fabaceae dominate neotropical forests, not only in terms of species richness, but also in the proportional abundance of individuals. This observation has recently been related to the remarkably high seed mass they produce (Ter Steege *et al.*, 2006). However, in our transects Fabaceae only occupied a third to seventh place in terms of abundance. Only Moraceae consistently appears in the top five of most abundant families of all four transects, and is represented in all cases by more individuals than Fabaceae. The high abundance of Moraceae in our transects would seem to correspond to certain patterns in distribution of families as revealed by Ter Steege and co-workers (2007) and based on 1-ha plot data from the entire Amazon area. They have shown that the Amazonian abundance of Moraceae varies along a northeast-southwest gradient whereby the highest values are found in Pando, the most northern Bolivian department (see also Ter Steege *et al.*, 2000). Based on available 1-ha plot data, the authors suspect that even higher values are to be found southwards of Pando and thus closer towards our research area, but sufficient data are still lacking to substantiate this claim (Ter Steege, pers. comm.).

Arecaceae, the palm family, is also among the most abundant families in all four transects. This is in agreement with its reported high abundance in western Amazonia (the region which most resembles our study area) (Ter Steege *et al.*, 2000). A rather unexpected result is obtained for Sapotaceae. While this family is most abundant in Central Amazonia (Ter Steege *et al.*, 2000), it is also among the families with the highest number of individuals in all our transects.

Family Importance Values

Various authors have shown that in Amazonian *terra firme* forests high FIVs are obtained for Lecythidaceae, Chrysobalanaceae, Fabaceae, Moraceae, Sapotaceae and Lauraceae (e.g. Duivenvoorden, 1995; Milliken, 1998; Haugaasen and Peres, 2006). According to Haugaasen and Peres (2006), and Wittmann *et al.* (2006), Euphorbiaceae and Fabaceae are among the more important families in white-water floodplain forests (including *varzea*). These patterns are confirmed by our findings. On a more regional scale, rankings of plant families according to descending FIVs in the present study are in agreement with literature data from the Bolivian Madidi region (De Walt *et al.*, 1999; Araujo-Murakami *et al.*, 2005; Quisbert and Macía, 2005)

Genera

The extraordinarily high levels of sympatry that were documented for the genera *Inga* and *Pouteria* during our study (6-9 and 7-8 species per transect, respectively) seems to follow Gentry's data from ultradiverse tropical sites (Phillips and Miller, 2002). In a Peruvian transect of tropical moist *terra firme* forest at Yanamono, up to eleven different species of *Inga* were found by Gentry. Phillips and Miller (2002) listed other genera (e.g. *Acacia*, *Ficus*, *Guarea*, *Protium*…) that showed high levels of sympatry in 0.1-ha dataset but *Pouteria* was not included. Therefore, the species richness of this genus might represent a local trend.

6.5.2. Diversity

Species Richness

A diversity analysis in the sampled transects based on the number of species is justified because the large majority of species has been identified to the level of clearly distinguished species and morphospecies. Only 8% remains unidentified, whereas for studies applying similar diameter limits, proportions of unidentidentied species ranging between one fourth to more than one third of the total plant inventory plants has been reported (e.g. 31% by Duque *et al*., 2002; 35% by Grandez *et al*., 2001 and 26% by Romero-Saltos *et al*., 2001).

Obviously, a vegetation sample of four 0.1-ha transects is far too small to adequately represent the flora of the research area which encompasses several thousands of hectares. For the ecoregion that includes our study area (i.e. preandean Amazonian forests; figure 1.1), the number of estimated tree species alone is above 800 (Ibisch *et al*., 2003). Therefore, it is not a surprise that species-area curves for all four transects are still far away from reaching asymptote, as usually is the case in (neo)tropical forest studies (Gotelli and Colwell, 2001). Despite their relatively small size, 0.1-ha transects have nevertheless been shown to provide a good assessment of the diversity of particular forests (Gentry, 1988b; Phillips and Miller, 2002; Phillips *et al*., 2003) since results obtained for replicates in the 0.1-ha data set are fairly consistent (Phillips and Miller, 2002). At sites where Gentry collected replicate transects, these yielded remarkably similar results in terms of species richness (Phillips and Miller, 2002). The two *terra firme* forest transects in San Antonio and Carmen can also be considered replicates. Although their species composition differs significantly, a highly similar total number of species (183 and 186) were recorded for both transects.

Continental Scale

Diversity patterns can be predicted remarkably well from environmental gradients such as latitude, precipitation, altitude and soil (Gentry, 1988b; Clinebell *et al*., 1995; Ter Steege *et al*., 2003). Gentry (1988b) showed that species richness increases linearly with precipitation in western Amazonia. Givnish (1999) suggested that by favouring natural enemies of plants (fungi and insects), higher rainfall would promote more density-dependent plant mortality and hence higher diversity. The regression line equation which predicts species diversity from rainfall figures for 0.1-ha transect sites with <5,000 mm annual precipitation proposed by Gentry (1988b) is calculated as follows: the number of species in 0.1-ha transect = 0.0488*(annual precipitation, expressed in mm) + 10.2. Hence, for an annual precipitation between 3,500 and 4,000 mm (prevailing in our research area), one would expect to find between 181 and 205 different species. These estimates approach our findings fairly well, taking into account that no exact precipitation data are available yet for the research area (Navarro, pers. comm.).

Moreover, the fact that in Amazonia tree species richness appears to be greatest in aseasonal high rainfall areas, made Gentry (1988b) suggest that species richness decreases as dry season becomes more pronounced. This trend has recently been reconfirmed on a continental scale (Ter Steege *et al.* 2003 and 2006). Our research area is characterized by a clearly marked dry and wet season. Hence, one would expect to find lower species richness than for an area with an aseasonal climate. However, monthly precipitation does not drop below 100 mm for more than two months in the research area (Ibisch *et al.*, 2003) and therefore the effects of the dry season might be less marked as compared to similar latitudes elsewhere.

Recently, Phillips and Miller (2002) published a compendium of Gentry's complete 0.1-ha transect data set, amounting to 226 transects, including the 87 discussed in the paper of 1988 (Gentry, 1988b). The authors calculated the mean species richness in transects that were classified following Holdrige's life zones (Phillips and Miller, 2002), which resulted in an average of 111 species (range 42-210) for subtropical wet forest (2,000-4,000 mm average rainfall per year). Hence, our data clearly are in the upper range class of species richness in this life zone.

Regional Scale

The Bolivian subtropical wet forest sites sampled by Gentry that correspond best with ours in terms of altitude and precipitation are those from the Madidi national park, close to the border with Peru. Here, Gentry sampled his richest transects in Bolivia with 205, 197 and 174 different species, respectively (Foster and Gentry, 1991; Phillips and Miller, 2002). Although we obtained significantly different floristic compositions, other floristic parameters such as the number of families and the proportion of growth forms correspond fairly well. The sole difference is that total basal areas in the transects we sampled were considerably higher than those encountered in all Bolivian transects in Gentry's 0.1-ha data set (Phillips and Miller 2002). Nevertheless, they are not exceptional in Gentry's complete 0.1-ha transect data set. Moreover, the mean dbhs recorded for our transects correspond well with those reported for the Bolivian Madidi region. Araujo-Murakami *et al.* (2005) found that the stems in twelve 0.1-ha transects in Madidi had a mean dbh of 9.6 cm, while Quisbert and Macía (2005) mentioned values between 8.3 and 9.6 cm.

Species richness reported in recently published 0.1-ha studies in the Madidi area is much lower, ranging from 47 to 105 species (Quisbert and Macía, 2005; Araujo-Murakami *et al.*, 2005). The higher species richness in our transects as compared to those from the Madidi area can partly be ascribed to different methodologies: we sampled transects of 500 x 2 m^2 whereas Quisbert and Macía (2005) used plots of 50 x 20 m^2 and Araujo-Murakami *et al.* (2005) plots of 10 x 100 m^2. Hence, the perimeter of the traditional Gentry transects, used in our study, is much longer and increases the possibility of erroneously including "borderline plants" that actually grow outside the transect (Peters, 1996; Condit *et al.*, 1996; Araujo-Murakami *et al.*, 2005). In view of the significantly higher length of our transects, also the continuity of sub-samples was different in our study and we probably bisected a greater number of different habitats and species patches, providing more representative descriptions of our study area and thus higher species numbers (cf. Peters, 1996). Our transects were also located at slightly lower altitudes (200-300 m.a.s.l.) than those in Madidi (300-420 m.a.s.l.), but it is expected that altitude is not a significant factor as Gentry (1988b) argued that altitudinal effects do not play in Amazonian forest below 500 m.a.s.l. As mentioned before, the effect of less precipitation at the sites sampled by Quisbert and Macía, 2005 and Araujo-Murakami *et al*. (2005) (2,550 and 2,000-2,500 mm a year, respectively) might be more significant.

Impact of substrate

It has been suggested that diversity is lower in forests with poor drainage, since fewer species are able to survive longer periods of soil anaerobiosis (Phillips *et al*., 2003; Wittmann *et al*., 2006). Therefore, *terra firme* plots would have a significantly higher diversity than floodplain plots, as is confirmed by our findings. Swamp plots appear to have the lowest diversity (Ter Steege *et al*., 2000; Haugaasen and Peres, 2006; Wittmann *et al*., 2006). The high diversity of *terra firme* forests has partly been related to the high occurrence of rare species (i.e. represented by < 1 individual per hectare) in well-drained upland forests as compared to floodplain or *varzea* forests (Duque *et al*., 2002).

On a larger scale, Ter Steege *et al*. (2000) linked the positive relationship between the level of drainage and species richness to the particular area occupied by floodplain and *varzea* forests in Amazonia. These authors hypothesize that larger areas such as *terra firme* forest should have more species for four reasons. Two of these reasons are related to speciation (i.e. the evolutionary process by which new species arise) rates and two to extinction rates. “Speciation rates are higher in larger areas because (1) larger areas are more likely to contain geographical barriers, important for allopatric speciation (i.e. speciation as a consequence of geographical separation of a population) and (2) species with larger ranges show more genetic variation and seem to evolve faster. Extinction rates in large areas/populations are lower because (3) larger ranges lead to larger populations that are less likely to become extinct due to random population fluctuations; and (4) larger ranges encompass richer niche refugia, where populations may survive when large changes (e.g. climatic) occur” (Ter Steege *et al*., 2000). In other words, according to the latter authors, the lower species richness of floodplain forests and swamps could, at least in part, be explained by the much smaller and more fragmented areas they occupy. The fact that floodplains are more species-rich at places where they cover larger areas in western Amazonia backs up this hypothesis (Rosales-Godoy *et al*. 1999).

Individuals

Temperate sites are significantly less stem-dense than tropical equivalents (Phillips and Miller, 2002). The stem densities we measured (351-414) are in line with data from similar sites. Almost 60% of transects in the “Gentry data set” had between 300 and 500 individuals per 0.1-hectare. Most of the species we inventoried were represented by one or two individuals on a single transect, as is usually the case in species-rich tropical forests (Gentry, 1988b; Pitman *et al*. 1999). One could argue that there is a possibility that the sampled transects or plots happened to fall in areas were such species are poorly represented (Pitman *et al*., 1999). However, the large (continental) scale of these trends indicates that such low densities of individual species can partly be ascribed to strong ecological pressures (Gentry, 1988b).

Our finding that a large majority of stems sampled in our transects (65-85%) are smaller than 10 cm dbh has also been reported by Gentry and Dodson (1987a). The latter authors argued that roughly three times as many small trees and shrubs (<10 cm dbh) as trees ≥ 10 cm dbh are found in 0.1-ha samples. Macía and Fuertes (n.d.) found a proportion of 80% of small trees and shrubs in their 0.1-ha transects in the "Serrania de los Mosetenes" of TIPNIS, at altitudes of > 1200 m.a.s.l.; Macia and Svenning (2005) reported 72 % for the Bolivian Madidi area, between 200-610 m.a.s.l.; whereas Romero-Saltos *et al.* (2001) obtained 75% for the Ecuadorian Yasuni national park. Therefore the 0.1-ha method seems better suited than the 1-ha method (which measures stems with dbh ≥ 10 cm) for characterizing the understorey, where a large part of a forest's diversity is stored (Gentry and Dodson, 1987b; van Andel, 2001; Quisbert and Macía, 2005; Araujo-Murakami *et al.*, 2005).

Fisher's alpha

As opposed to species richness, Fisher's alpha is relatively insensitive to sample size (Ter Steege *et al.*, 2000). For Fisher's alpha, the positive correlation between precipitation and species diversity is only significant for western Amazonia. Moreover, Ter Steege *et al.* (2000) nuanced this correlation by suggesting that rainfall may be a good estimator of the maximum species diversity of sites, rather than of average species diversity. According to data presented by the latter authors, Fisher's alpha in western Amazonia varies between 75 and 225 for annual precipitation levels of 3,500 mm. Our data fall nicely within this range. The same authors calculated that in western Amazonia (8°S-8°N, annual rainfall ≥ 2000 mm) mean Fisher's alphas for *terra firme* and floodplain forests were 124.5 and 78.7, respectively. In spite of the higher latitude of our research sites, the match of the Fisher's alphas we recorded with the above-cited mean values is remarkable.

At first sight, our data correspond relatively well with continental-scale correlations based on precipitation described in Ter Steege *et al.* (2000). However, a different picture is visualized on the map with estimates of average Amazon *terra firme* tree α-diversity published by Ter Steege *et al.* in 2003 (figure 6.9). Indeed, the extremely low predicted Fisher's alpha values for our research area in figure 6.9 are rather eye-catching. According to the calculations of Ter Steege *et al.* (2003) values between 3 and 25 are expected. We found values that are more than five times as high. Nevertheless, our findings are not exceptional, since also Gentry reported Fisher's alpha values of up to 148 for a *terra firme* site in the Bolivian Madidi area (Phillips and Miller, 2002). A similar observation is made for our floodplain forest sample. Wittmann *et al.* (2006) found that Fisher's alphas for floodplain forests (*varzea*) vary between 1.3 and 83.0 throughout Amazonia, following a trend of increasing diversity from east to west. The values we found are significantly higher than those proposed by Wittmann *et al.* (2006).

At first, one would be tempted to relate these differences between measured and predicted or averaged alpha diversity to the different sampling strategy since Ter Steege *et al.* (2003) and Wittmann *et al.* (2006) based their findings on stems of ≥ 10 cm dbh, measured in 1 hectare plots. However, quite the contrary seems to be true: according to data presented by Phillips *et* *al*. (2003), 0.1-ha transects would underestimate rather than overestimate the Fisher's alpha measured in 1 ha plots located at the same sites. Also Ter Steege confirms that Fisher's alphas found for 0.1-ha transects and 1-ha plots correspond fairly well (H. Ter Steege, pers. comm.). Hence, other forces must be at play. In the case of *terra firme* forest, one possibility is that Ter Steege *et al*. (2003) overestimated the strength of the dry season at our research area: according to a map they published in the same article, TIPNIS would be characterized by 5-6 months with < 100 mm of rain, whereas in reality this occurs maximally two months a year (Ibisch *et al*., 2003). However, whereas seasonality is significantly linked to species richness (Gentry, 1988b), according to Ter Steege *et al*. (2003), it is only of limited influence on Fisher's alpha diversity of trees in Bolivia.

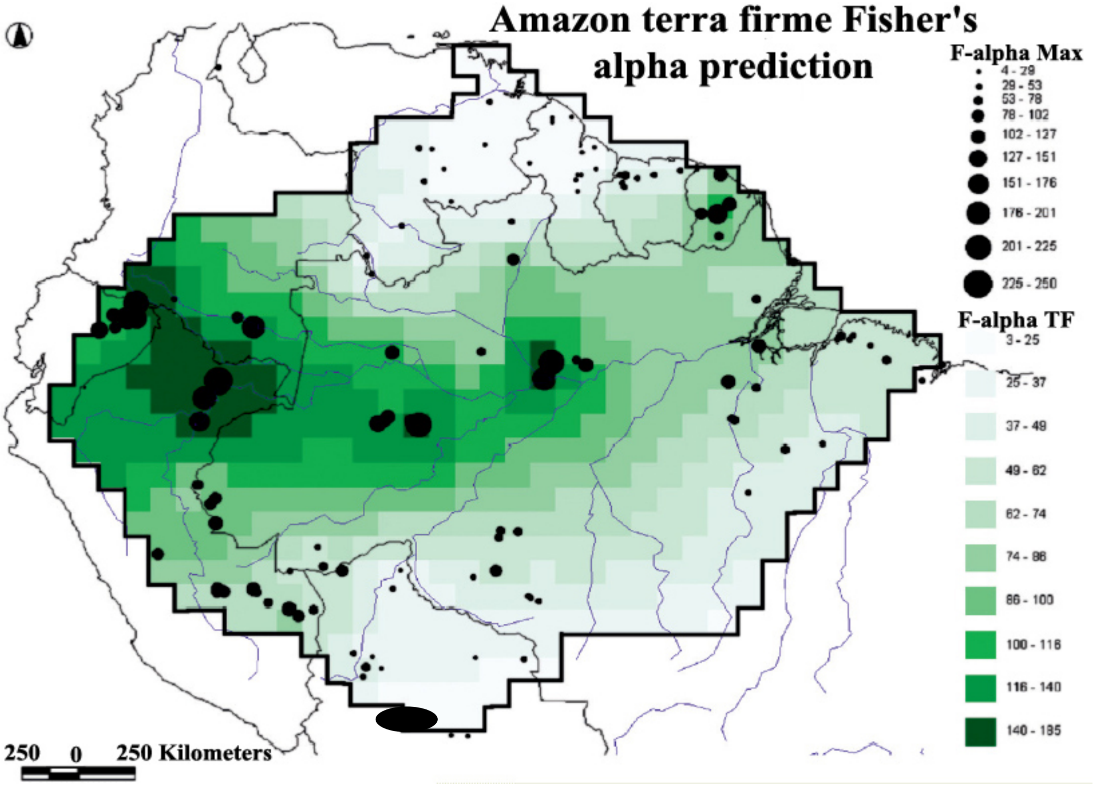

Figure 6.9: Map of average tree α-diversity (Fisher's α) based on 275 plots in *terra firme* forests in the Amazon and Guayana Shield rain forest area mapped on a 18 grid cell scale. The extent of tropical wet/moist and semi-deciduous forest area is based on NOAA-AVHRR NDVI satellite data (http://terra.whrc.org/). Diversity is highest in a narrow band from western Amazonia towards central Amazonia with peaks around Iquitos and Manaus. Dots indicate the maximum Fisher's α found at one location (*n*=275). Because many plots may be in close proximity (and overlapping), much less than 275 dots are visible. Location of TIPNIS is indicated by a solid ellipse at the bottom of the map (map reprinted from Ter Steege *et al*., 2003).

Another possibility that could explain why we recorded higher Fisher' alphas than expected is that the soils of our study sites would be significantly more fertile than those of other Bolivian tropical forest locations. Gentry (1988b) hypothesized that species richness increases with soil fertility, even though to a lesser extent than with precipitation (Clinebell *et al*., 1995). In this respect, the relatively high abundance and diversity of Moraceae we recorded could be an indication of high soil fertility of the research sites, since Gentry (1986; 1988b) related high Moraceae diversity to extreme soil richness. However, in our case Moraceae species richness might be a consequence of continental-scale patterns rather than being soil fertility-driven. As mentioned earlier, higher Moraceae diversities and abundances are found in western and southwestern (i.e. Bolivia) Amazonia, respectively (Ter Steege *et al.*, 2000). The soil fertility hypothesis is further contradicted by the observation of Rico Parejas *et al.* (2005) that the soils of the research area are poor to extremely poor. In addition, the Sapotaceae came out second and third in terms of species richness in three of our transects, and according to Gentry (1988b) Sapotaceae are expected to become prevalent on poorer soils. Hence, soil fertility does not seem to be particularly relevant for explaining the high Fisher's α in our transects.

A possibly more powerful explanation for the high Fisher's alpha we found might be related to disturbance. Both the intermediate disturbance hypothesis and the dynamic equilibrium theory predict higher species richness with intermediate disturbances that delay or prevent competitive exclusion (Huston, 1994). Although it is complicated to quantify the disturbance regimes in the research area, there are some indications of disturbance both from personal observations and literature. During our repeated forest trips we have witnessed many times the impressively devastating local effects of wind, especially during austral summer. On a few occasions, we erroneously thought to have reached freshly cleared swiddens of half a hectare or more, when closer inspection revealed that literally dozens of trees had been blown over by wind. For this reason, wind has a negative connotation among local people. People will tend to get out of the woods as soon as possible from the moment heavy wind starts blowing to prevent being caught by falling tree trunks. Therefore, people undertake less forest trips during the rainy season when winds are frequent as compared to the calmer dry season.

In addition, the austral winter (dry season) is characterized by a regular influx of cold polar fronts along the Andean base, locally known as *surazo*s, that provoke temperature drops of more than 20°C in a few hours (down to 4.5°C) and often strong winds and thunderstorms. *Surazos* can last for up to ten days and represent the main source of precipitation in the dry season (Ronchail, 1989; Plotkin, 1999; Townsend, 2000; Kessler, 2000; Navarro, 2002; Rafiqpoor *et al.*, 2003; Quisbert and Macía, 2005). However, it is not clear whether the effect of (sudden) weather change on local plant diversity is positive or negative. Positive effects have been suggested for the Bolivian Madidi region (Araujo-Murakami *et al.*, 2005) while *surazo* related temperature drops have also been reported to damage Amazonian fauna and flora (Rafiqpoor *et al.*, 2003) and determine the southern distribution limit of many Amazonian organisms (Navarro, 2002).

Other indications of disturbance in the research area are backed up by literature. According to the intermediate-disturbance theory, a high dominance of species indicates a low rate of disturbance (Hart, 1990, cited in van Andel, 2000; Huston, 1994). In line with this argument, the fact that none of our transects is dominated by one or even a few species in terms of density could be a consequence of locally active disturbance regimes. Moreover, also high abundance of Moraceae in our transects could be partly related to disturbance. Ter Steege *et al.* (2000) suggested that the higher disturbance regimes in western Amazonia may partly be responsible for higher abundance and species-richness of Moraceae. Indeed, higher dynamics may allow members of families with pioneer-like characteristics such as light wood, small seeds and short generation times (many Moraceae) to dominate over the slower growing species from the densely wooded and large-seeded families (Ter Steege *et al.*, 2000). In this respect, the importance of another pioneer family, i.e. the Cecropiaceae, in our San Antonio *terra firme* transect might not be a coincidence either.

Also, the relatively high abundance and diversity of lianas, particularly in the *varzea* transect, might be a consequence of continuous natural disturbance regimes. The positive correlation between the abundance of lianas and increasing levels of forest disturbance has been shown by several studies (e.g. Schnitzer *et al.*, 2000; Pérez-Salicrup *et al.*, 2001; Laurance *et al.*, 2001).

Apart from natural disturbance, the effect of historical anthropogenic impacts on the vegetation might not be negligible either (cf. Balée, 1994). The research area is one of the historical homelands of the Yuracarés who have a long-standing small-scale horticultural tradition (Querejazu, 2005a). The sporadic finding of stone axes in the topsoil has been mentioned by various indigenous participants, and would point towards an early presence of humans. Intriguingly, rather than linking these artifacts to ancient human activities, people believe they originate from lightening. In fact, lightening itself is understood as stones cleaving the air at enormous speeds. When these stones hit the ground, they are believed to have the shape of axes. Balée (1994) has made similar assertions for the Ka'apor of Brasil.

6.5.3. Species Assemblages

The fact that many (if not most) Amazonian tree species are not distributed randomly (Pitman *et al.*, 1999; Macía and Svenning, 2005) is locally reflected by many Yuracaré toponyms that are still in use today. *Chimore* is the place where *almendrillos* (*Dipterix* spp.) are abundant; *Ichoa* stands for 'place of *chontas*' (*Astrocaryum murumuru*) and the place called *yañiyouta* is known for its high abundance of *chuchíos* (*Gynerium sagittatum*) (Paz *et al.*, 1995). Recently, many studies that have focused on understanding patterns in Amazonian species distribution have confirmed the substantial effects of substrate (e.g. drainage, structure and nutrient concentrations) and topography on floristic composition of both understorey vegetation and canopy trees (e.g. Gentry, 1988b; Tuomisto *et al.*, 1995; Duivenvoorden, 1995; Pitman *et al.*, 1999; Vormisto *et al.*, 2000; Phillips and Miller, 2002; Duque *et al.*, 2002, Tuomisto *et al.*, 2003; Valencia *et al.*, 2004; Dalberg Poulsen *et al.*, 2006; Balvanera and Aguirre, 2006; Ter Steege *et al.*, 2006; Macía 2008). Much of upper Amazonia appears to constitute a conspicuous habitat mosaic with very different sets of plant species occurring in adjacent communities on different substrates and topographical units (Gentry, 1988b; Valencia *et al.*, 2004). This has clearly been demonstrated by our data as well: although no more than five kilometers apart in distance, the *terra firme* transects near Carmen and near San Antonio differed significantly in species composition.

In agreement with the general Amazonian trend described in literature (Gentry, 1988b; Cerón and Montalvo, 1998; Valencia *et al.*, 2004; Macía and Svenning, 2005), only a small portion of species in the forests we sampled seems to be omnipresent and relatively common, while the large majority grows at discrete locations in very low densities. A meager 5% of all species inventoried (24 species) was shared by all four transects, while 71% was found in only one transect. Fifteen of the 24 overlapping species in all four transects also figure in the top twenty ranking of importance values (IV) in at least one transect. The high ecological importance of a number of these overlapping species (e.g. *Celtis schippii*, *Clarisia racemosa*, *Eschweilera coriacea*, *Iriartea deltoidea*, *Iryanthera juruensis*, *Otoba parvifolia*, *Pseudolmedia laevis, Guarea macrophylla, Leonia crassa*, and *Siparuna decipiens*) has been confirmed by various comparable studies throughout western Amazonia (e.g. Gentry, 1988b; De Walt *et al*., 1999; Vormisto *et al*., 2004; Quisbert and Macía, 2005; Macía and Svenning 2005). Other examples of such dominant species that were found in at least three transects in the present study are *Hasseltia floribunda*, *Rinorea viridifolia*, *R. lindeniana*, *Lunania parviflora*, *Socratea exorrhiza* and *Meliosma herbertii* (Macía and Svenning, 2005).

Such generalist species seem to be broadly tolerant to a range of nutrients and moisture levels. Their large geographical range and lack of habitat specialization suggest broad ecological niches, rather than finely partitioned ones (Pitman *et al*., 1999). Most other overlapping species in our transects (*Cordia nodosa*, *Cyathea pungens, Duguetia spixiana*, *Licania harlingii, Pouteria torta, Pourouma cecropiifolia, Paullinia clathrata*, *Petrea maynensis, Siparuna bifida*, *Sorocea steinbachii* and *Tapura juruana*) also grow in other Amazonian regions, but possibly not as frequently and abundantly as in our research area. For some overlapping species, the research area could even encompass (one of) the region(s) where these species are particularly abundant and/or frequent. Most notably is *Calyptranthes* sp. nov. (leaves with a lemongrass-like odour), which might be a local endemic as it has not yet been recorded anywhere else (B. Holst, pers. comm.).

6.5.4. Importance of the Present Study

Figure 6.10 shows part of a map that represents ecological systems of the Amazon Basin in Peru and Bolivia. This map has been elaborated by Navarro and Ferreira (2007a) on behalf of NatureServe (Josse *et al*., 2007). According to this map, transects 1-3 and transect 4 were sampled in forests that are classified as *Southwestern Amazon subandean evergreen seasonal forest* (CES408.545; number 18 in figure 6.10) and *Beni white-water riparian forests and vegetation complex* (Co05 Beni; number 65 in figure 6.10). Nevertheless, the first author of this map (G. Navarro, pers. comm.) confirmed that, based on our floristic data, transects 1 and 3 were sampled in *Southwestern Amazon subandean evergreen forests* (number 17 in figure 6.10); transect 2 was sampled in *Southwestern Amazon piedmont forest* (number 19 in figure 6.10) and transect 4 in *Southwestern Amazon white-water floodplain forest* (number 61 in figure 6.10). Hence, none of the ecological systems predicted by this map corresponds with the ones we actually sampled. According to Navarro (pers. comm.), these cartographic errors are due to the lack of floristic inventories in the zone.

6.6. Conclusions

In this chapter, we presented the results of one of the first ecological studies conducted in the southern part of TIPNIS. Our inventory of 906 different species is substantial but likely not completely representative for the entire study area, and therefore probably hundreds of species are still to be inventoried during future studies. The outcomes of our transect sampling in three local forest types correspond fairly well with Bolivian and other neotropical studies in terms of species distribution patterns, physiognomy, family distribution, growth forms, and species and family richness. However, our study has clearly shown that there exists a great need for updating the existing phytosociological vegetation map of the southern part of TIPNIS (Navarro and Ferreira, 2007a), since this map is based on limited information. Further plot and/or transect-based ecological studies will definitely be necessary to fully characterize and map locally prevailing ecological systems.

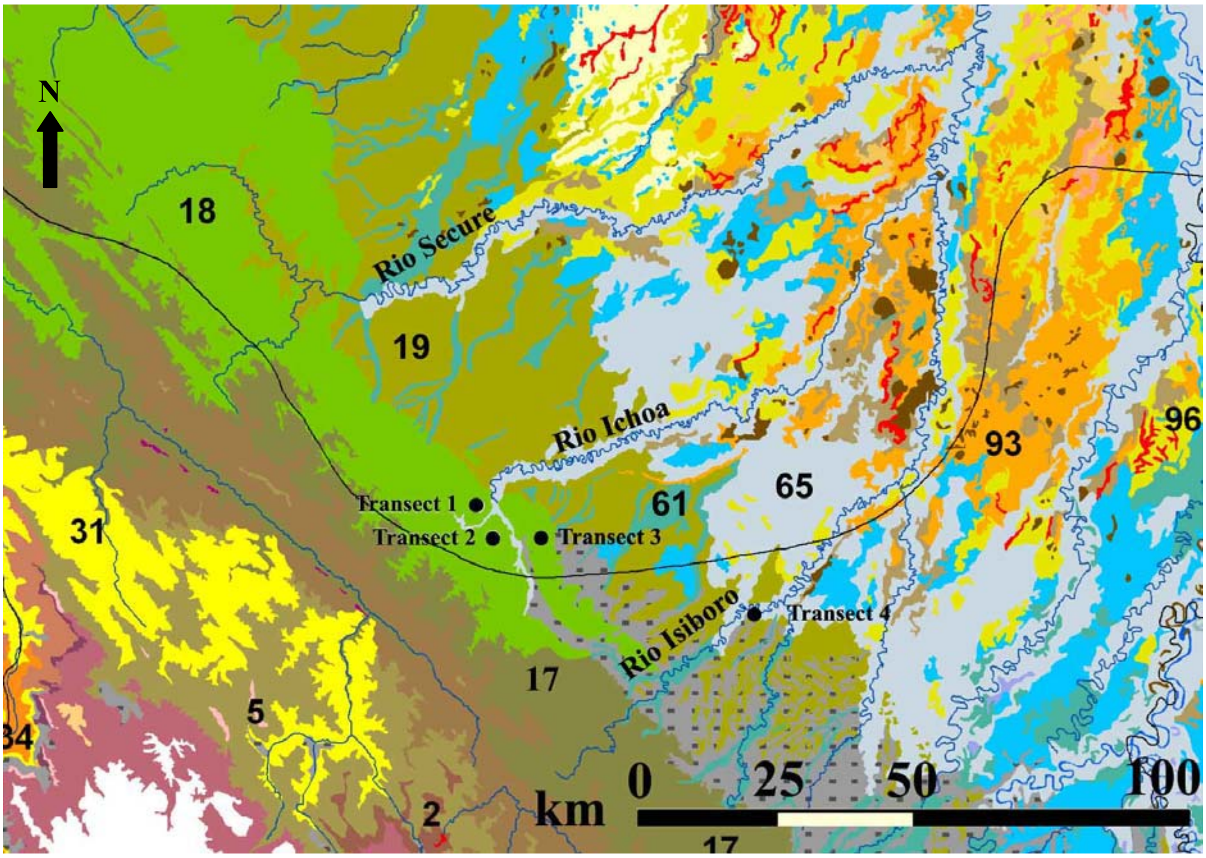

Figure 6.10: Map that represents the ecological systems of the research area (scale: 1:1,500,000). The line that crosses through the middle of the map is the ill-defined border between the departments of Cochabamba (S) and Beni (N). According to the latest developments, this line would be located northwards to the location of transect 1. (17= ***Southwestern Amazon subandean evergreen forests*****; 18=** ***Southwestern Amazon subandean evergreen seasonal forest*****; 19=** ***Southwestern Amazon piedmont forest*****; 61=** ***Southwestern Amazon white-water floodplain forest*****; and 65=** ***Beni white-water riparian forests and vegetation complex;*** **adapted from Navarro and Ferreira, 2007a)**

0.1-hectare transects provide a fair estimate of local plant diversity, but enlarging the sample area would substantially increase the total number of species. Species-richness and Fisher's alphas calculated from our transect data are in line with patterns in precipitation and substrate described in literature. By contrast, Fisher's alphas are up to five fold higher than expected from a map published by Ter Steege and colleagues in 2003 which represents estimates of average Amazonian *terra firme* tree α-diversity. We have put forward several possible explanations for this anomaly. Possibly, Ter Steege *et al.* (2003) overestimated the strength of the dry season in our research area and/or did not fully take into account the exceptionally high precipitation levels. We also hypothesize that local natural and (historical) anthropogenic disturbance regimes are factors that might be responsible for the high levels of plant diversity found in southern TIPNIS.

In summary, our results suggest that TIPNIS represents a strongly underestimated center of plant diversity and we strongly recommend further in-depth studies of its flora. These studies are urgently needed before modernization of the study area will make it impossible to do so.

7.

What Works in the Field? A Comparison of Different Interviewing Methods in Ethnobotany with Special Reference to the Use of Photographs[1]

7.1. Introduction

One of the principal tools used by ethnobotanists for obtaining ethnobotanical information is the interview. Apart from the questions themselves, a great deal of variation in interviews can be attributed to the plant prop that is used to stimulate answers from respondents. During interviews *in situ*, living plants are used as a reference, and questions are asked at the location where plants are growing, including cultural as well as natural landscapes (e.g. Boom, 1987; De Walt *et al*., 1999; Phillips *et al*., 1994). By contrast, *ex situ* interviews make use of harvested and/or artificial plant references and are conducted physically away from the plant's growing place *sensu stricto*, such as in the home of a participant. Several scholars use fresh

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[1] This chapter was published in a slightly different form in *Economic Botany*, 61(4) under the same title (Thomas *et al*., 2007)

material for *ex situ* interviews (e.g. Davis and Yost, 1983b; Plotkin, 1994; Bennett *et al.*, 2002), while others resort to voucher specimens (e.g. Vandebroek *et al.*, 2003 and our study in Apillapampa; see chapter 3). Fewer reports exist on the use of plant artefacts or handicrafts (Boom, 1987), photographs (Alexiades, 1996a; Martin, 1995; Nguyen, 2003) or line drawings (Atran, 2002; Ellen, pers. comm.) as stimuli for interviews.

Drawing upon our own research experience, in the present paper we discuss the pros and cons of *in situ* interviews during transect, *walk-in-the-woods* and homegarden sampling and *ex situ* interviews using fresh plant material, voucher specimens and photographs. A major concern for using photographs lies within the ability of participants to link abstract images to reality. To the best of our knowledge, there exists no literature in ethnobotanical research evaluating plant recognition accuracy based on photographs and voucher specimens, as compared to *in situ* identification. Nguyen (2003) reports on people's ability to identify photographed fruits, but no reference is made to their identification skills of fresh fruits of these species. The null hypothesis from which we depart is that a similar proportion of plant species is recognized by participants from photographs and voucher specimens.

7.2. Methods

Ethnobotanical data were gathered in the five Yuracaré and Trinitario communities from TIPNIS mentioned in chapter 1: Sanandita, San Antonio, San José de la Angosta, El Carmen de la Nueva Esperanza and Tres de Mayo. The participating communities are characterized by low accessibility (Vandebroek *et al.*, 2004a). Following a 3-5 hours drive in a cargo truck, the nearest community is reached on foot after a 0.5-4 hour walk, the furthermost after a 5-8 hour walk, depending on the location of the last truck stop and weather conditions. For ecological quantification of the local flora, the main methods described in chapter 6 were used, i.e. Gentry transects, walk-in-the-woods and homegarden sampling.

During transect sampling and *walk-in-the-woods*, accompanying participants were always men, whereas mainly women escorted during homegarden collections. This is a logical approach, since most men spend more time in forests than women who are frequently more knowledgeable about non-forest or homegarden plants (Bernstein *et al.*, 1997; Kainer and Duryea, 1992). Ethnobotanical interviews *in situ* were conducted using all three sampling techniques with one or two accompanying participants.

Plant samples were temporarily conserved in alcohol on the same day of collection. Upon arrival in the herbarium several weeks later, plants were transferred immediately to a drier. As such, good quality voucher specimens were obtained. Part of the voucher collection was afterwards brought back to the participating communities to be used as a prop during interviews.

In the village environment (*ex situ*), we interviewed 22 participants (7 women and 15 men; 11 Yuracarés and 11 Trinitarios) who were selected through peer recommendations (see Davis and Wagner, 2003). Participants were presented with fresh plant material, voucher specimens and photographs at distinct moments in time. Individual semi-structured interviews to obtain detailed information on plant names and uses were conducted in Spanish.

To evaluate plant recognition accuracy, five key participants were encouraged to identify fifty useful plant species each, from both photographs and voucher specimens. All participants (three Trinitarios and two Yuracarés) were male and lived in different communities. Female participants were not included since less than fifty plants were collected with each of them. Only species with unique and clearly distinguished vernacular names that had been pointed out by each participant during prior *walk-in-the-woods* were included. Different botanical species were collected with each participant and therefore the nature of photographs and voucher specimens differed between participants. Nonetheless, we made sure that each group of fifty specific plant species was known to each participant, at least *in situ*, as *they* had pointed out the plants to *us*.

Accuracy of recognition of plants from photographs or voucher specimens was evaluated based on how often each participant mentioned the same vernacular name on both occasions. Interviews were conducted at least two months after the *walk-in-the-woods* collection trips. Moreover, interview events using either photographs or dried specimens were separated by at least one month. These measures were taken to prevent participants from remembering collection trips or previous interviews on the same species, and hence avoid possible bias. SPSS 12.0 was used to compare mean percentages of plant recognition from photographs and voucher specimens.

7.3. Results and Discussion

7.3.1. *In Situ* Interviews during Transects, Walk-in-the-Woods and Homegarden Sampling

After participant observation, the most direct and reliable method to obtain ethnobotanical information is to interview participants *in situ* ("on the spot during plant collection") (Alexiades, 1996a). Even in case plants are in vegetative conditions, this method allows participants to make use of a maximum of decisive variables for plant recognition, such as anatomical, physiological, morphological, architectural or ecological characteristics. Many of these features are often lacking in plant artefacts used during *ex situ* interviewing.

Transects

Despite the benefits of working *in situ,* some disadvantages of transect interviewing are worth mentioning. As discussed by Alexiades (1996a), relatively few participants can be involved in transect sampling when time is an issue, potentially hampering quantification of collected ethnobotanical data. Traditionally, scholars have performed *in situ* transect interviews with few, locally recognized plant experts. Although in some cases the plant knowledge of experts can be extrapolated to the entire community, this is not universally valid. It has been shown that the distribution of local knowledge is not random but patterned according to age, gender or social status (Bernstein *et al*., 1997; D'Andrade, 1987; Kainer and Duryea, 1992). Accordingly, Phillips and Gentry (1993a and b) have argued that large and representative samples of participants from different knowledge strata are more desirable if conclusions about the breadth, range or distribution of ethnobotanical knowledge in the local population as a whole are to be drawn. For a more detailed account on the importance of sampling subjects, the reader is referred to Alexiades (1996a) and Martin (1995).

Transect interviewing is a poor technique to determine the general level of ethnobotanical knowledge (expert versus non-expert/lay knowledge), particularly because it limits participation of people with limited mobility due to physical disabilities, social stigma, social role, bad vision, or old age. For example, due to household responsibilities or social stigma, women often can not afford spending entire days in the woods with (male) foreign researchers. Therefore, transect interviewing necessarily has to be complemented with *ex situ* interviews.

Another handicap of transect sampling in forests is that at any given time the majority of sampled plant individuals are in vegetative conditions. According to Phillips *et al.* (2003) the probability of an Amazonian tree being fertile at any one point is less than 4%. Although local people are often able to identify the majority of vegetative plant species, we have been able to observe that mistakes are more frequent than for fertile material.

The exact position of a transect can have a significant effect on ethnobotanical results. For instance, transects in disturbance habitats generally contain higher proportions of herbaceous and pioneer species, transects in abandoned camps and early and old-growth fallows are often rich in exotic and/or managed plant species (see review in Bennett, 1992 and Voeks, 2004; chapter 10), whereas in mature forest transects old-growth forest trees, lianas and bushes are mostly predominant. Therefore, it is important to carefully consider the placement of transects prior to research and to stimulate participants to systematically indicate *every* useful species they observe during transect sampling, thus also those not fulfilling transect sampling protocol requirements.

Walk-In-The-Woods

Contrary to transect sampling, where the investigators present species to participants, during *walk-in-the-woods* ethnobotanical information is collected about those plants that are specifically indicated as being useful by accompanying participants. Consequently, quality and reliability of collected information are probably better than in the case of transect interviewing. Collection priority is usually directed to fertile specimens, but vegetative plants should also be collected, as it might be difficult to find them elsewhere later on.

The main disadvantage of the *walk-in-the-woods* method is the lower ecological and ethnobotanical sampling yield as compared to the transect method. During day-filling *walk-in-the-woods* collection trips, we collected 10-20 specimens and interviewed accompanying participants about their uses. In an identical time span we sampled two 50 m x 2 m transects, hereby collecting ecological and ethnobotanical information on 30-40 specimens. Hence, in equal periods of time, more quantitative data were obtained from transect sampling than from the *walk-in-the-woods* technique.

During transect sampling, *all* plant individuals fulfilling minimum dbh requirements are systematically shown to and discussed with participants, while plants encountered during *walk-in-the-woods* are dependent on the route followed, the memory and perceptivity of the accompanying participant, phenology, and coincidence. Therefore, transect sampling favours detection of (inconspicuous) useful plant species that are often overlooked during *walk-in-the-*

woods (also see van Andel, 2000). On the other hand, *walk-in-the-woods* sampling is not bound to protocol requirements (such as minimum dbh) and includes virtually all possible plant habits.

There are two additional limitations of the *walk-in-the-woods* method, which are similar to the transect method. These are the relatively low number of local people who can participate over a given time span and the need to work with participants who are not limited in their mobility.

Homegardens

Advantages and disadvantages of interviews in homegardens are basically similar to those of *walk-in-the-woods*. The main difference is that homegardens, as cultural landscapes, are usually situated at short distances from the home environment. This favours local people's participation in research by alternating interview sessions with household tasks. Due to shorter distances and lower time investment, homegarden sampling is better suited to include representatives from all knowledge strata of a population, allowing less mobile people to participate and facilitating individually based *in situ* interviews with multiple participants.

Specific plant species are easier to find in homegardens as compared to natural vegetation, since in the former they are cultivated, protected or tolerated (Bennett, 1992). Although some homegardens may represent a significant proportion of the local flora (Albuquerque *et al.*, 2005), they often contain higher ratios of herbaceous and exotic plants (Voeks, 2004; also see chapter 10). Therefore, homegarden sampling necessarily needs to be supplemented with sampling of the natural landscape to complement ethnobotanical data.

7.3.2. *Ex situ* Interviews with Fresh Plant Material, Voucher Specimens or Photographs

The primary advantage of *ex situ* interviewing ("away from the collection site of plants") is that, in a given period of time, more participants can be involved as compared to *in situ* methods. Because interviews are usually held within the village or home environment, it is easy to include less mobile people. Moreover, when showing artefact plant material to participants at a central place in the village, interest is often drawn from passers-by and children. Such groupings of people frequently reveal additional ethnobotanical information (Alexiades, 1996a; Plotkin, 1994).

Ex situ interviews are less time-consuming and favour short interview sessions, varying from minutes to hours, as opposed to transect and *walk-in-the-woods* sampling that usually take at least several hours to an entire day. This allows for a dynamic and efficient use of participants' time.

However, ex situ interviewing also holds limitations. Recognition of plant species is more problematic than *in situ*, since many botanical and ecological details are missing in artefact plant material. These data should be provided verbally by the interviewer. The collector of the plant material is the most qualified person to do so, as (s)he knows best under which conditions the plant was growing. Other interviewers have to rely entirely on field notes from the collector, which might introduce some degree of bias in data collection.

One of the most important factors for the success of *ex situ* interviewing concerns the selection of appropriate artefact plant material. In the following paragraphs, the strengths and weaknesses of using fresh plant material, voucher specimens and photographs as reference tools will be discussed.

Fresh Material

Logically, the best reference tool to promote positive plant identification during *ex situ* interviews is freshly collected plant material. This would be the best choice to involve people with limited mobility and participants with limited eye sight, since they are able to touch, smell and see plant samples from all angles. However, as pointed out by Alexiades (1996a), it may not be evident for participants to recognize small sections of large shrubs or trees and therefore even fresh material is likely to be recognized less easily *ex situ* as compared to *in situ*.

A problem with fresh material is that it wilts rapidly, which is certainly the case in hot and humid climates. Therefore, plants should be pressed and dried, or soaked in alcohol, as soon as possible after collection, consequently limiting time available for interviewing. In this respect it is wise to collect extra duplicates, including various specimens for immediate conservation, and one or two specimens designated for interviewing.

Since good artificial light sources are frequently nonexistent in remote tropical settings, daylight is a prerequisite for plant interviews. Therefore, day-filling activities such as transect sampling are often difficult to combine afterwards with interviews based on fresh material. The *walk-in-the-woods* method offers more flexibility when kept short and conducted in the morning. The afternoon can then be used to interview people about collected plant material that is still fresh for a few hours.

The use of fresh plants seems less appropriate when one strives to gather extensive quantitative ethnobotanical data. With fresh material, the number of participants living in distant communities can only be increased through repeated collections of the same species. This requires a higher sampling investment, which may not always be possible due to constraining factors such as plant phenology, abundance, and accessibility.

Voucher Specimens and Colour Photographs

The pros and cons of voucher specimens and photographs for use as ethnobotanical reference tools are best understood when discussed in comparison. To allow a transparent evaluation of both methods, we first describe some key aspects regarding the production of photographs as plant artefacts.

- *Taking, developing and preserving pictures*

With the digital era in full expansion, taking pictures has never been easier. Storage possibilities of pictures have become unlimited, photo quality can be checked immediately and relatively cheap digital cameras are available that provide astonishing possibilities.

Moreover, when the camera is protected with a waterproof case, one does not have to worry about humidity and rain.

Pictures should always be taken of fresh material and preferably *in situ*. It is important to include as much details about important plant characteristics as possible, such as details of flowers, fruits (including cross sections), bark aspect, stem cuttings (including exudates), associated fauna (e.g. symbiotic ants) and/or flora (e.g. hosts of (hemi)parasites), etc. Branches of large trees, obtained through tree climbing or by means of telescopic secateurs, are best photographed on the ground.

To preserve photographs for long-term use during interviewing, it is worthwhile to plasticize them. The number of photographs per (A4/office) sheet can range from 1-9 on each side, depending on desired clarity (Figure 7.1). According to our experience, good qualitative and durable results are obtained with high resolution deskjet colour prints on normal paper that are plasticized afterwards. This approach results in a significant reduction of costs as compared to commercial development of photographs. Nevertheless, preparing photographic sheets can represent a higher time investment and cost as compared to preparing voucher specimens.

However, in spite of the many advantages of digital technology, it should be pointed out that the quality of pictures can only be as good as the photographer's experience with this medium. Therefore, training in and experience with (macro-)photography prior to engaging in ethnobotanical field work are recommended.

- *Use of colour photographs versus voucher specimens as ethnobotanical props*

Photographs are much lighter and more compact than voucher specimens. This is particularly important when working with large numbers of plant specimens, as was the case in our own research (>1500 specimens). When large distances have to be travelled in uncomfortable public transport and on foot, heavy and oversized luggage is to be avoided. Moreover, photographs are relatively robust when properly plasticized. Voucher specimens by contrast, are fragile and have to be protected against rot, insect attack, and from getting wet during rains or when crossing rivers (cf. Martin, 1995).

Ethnobotanists who have worked with dried specimens are familiar with the unintentional breaking of specimens by participants during interview sessions, often creating the necessity to replace specimens by new collections. Photographic sheets are much easier to handle and one can look through the sheets for certain pictures with relative ease. Even children can take them at hand without causing any damage, which creates an opportunity to collect additional information.

Photographs provide good representation possibilities of plant species. Oversized plant parts (e.g. palm leafs, large fruits) are generally easily captured as images while they necessarily have to be cut into pieces when working with dried specimens. Also typical fresh characteristics like plant exudates can be represented on photographs, but are generally not present in dried specimens.

Figure 7.1: Example of a full-colour photo sheet used for ethnobotanical interviews (actual size 21cm x 29.7cm); plasticized together with another photo sheet on the reverse side. (1 *Geophila macropoda* (Ruiz & Pavon) DC.; 2 *Pycnoporus sanguineus* (L. ex Fr.) Murril; 3 *Jacaratia digitata* (Poepp. & Endl.) Solms; 4 *Mouriri cauliflora* Mart. ex DC.)

Photographs facilitate simultaneous presentation of different phenological phases that are encountered throughout the fieldwork period. For dried specimens this is usually only possible by showing various specimens. Furthermore, photographs provide natural – albeit two-dimensional – representations of three-dimensional plants. Through pressing and drying, plants become flattened, “two-dimensionalized” specimens that unavoidably lose much of their natural aspect (Alexiades, 1996a; Martin, 1995).

A characteristic of photographs that can be seen either as positive or negative is the ability to magnify or reduce reality. Magnifying details that are crucial for identification by indigenous people can promote recognition considerably. On the other hand, a representation scale that is different from 1:1 can also complicate identification, particularly for participants who are unfamiliar with media such as photography or television. This issue can be countered by including a scaling reference, such as a person standing next to an entire plant in photographs, or a hand holding a depicted plant part.

A disadvantage of photographs is that recognition of plants is strictly visual, whereas in dried species at least some natural characteristics like roughness, hairs, and odors are still present. Also, details that are often not represented in photographs should in theory be visible on dried specimens, as far as they did not vanish during the conservation process. To avoid misidentifications, photographs or voucher specimens of vegetative plant species can generally not be used for interviews.

Picture angle and focus largely depend on decisions made by the photographer and therefore plant characteristics that are actually portrayed can differ substantially from those that people use for identification. After all, *visual data are not 'what the camera can record but…what the eye can see'* (Emmison and Smith 2000). Therefore, it is advisable to ask people which specific characteristics they use for plant identification prior to taking pictures. Another option is to let local people take the picture, or at least show the researcher how they would do so (Reyes-García, pers. comm.).

- *Plant recognition: Colour photographs or voucher specimens?*

A major concern for using photographs for ethnobotanical interviewing is the ability of participants to recognize plant species from pictures. Results from the recognition test presented in table 7.1 show that our participants recognized 92-96% of photographs of plants that they had indicated and named during prior *walk-in-the-woods* collection trips. For voucher specimens, the recognition rate was significantly lower and ranged between 68-86% (Mann-Whitney test; p<0.01). These results confirm the usefulness of photographs in ethnobotanical interviews, as has been recently pointed out by Nguyen (2003). This does not imply that we claim these results to be universally valid. For example, Reyes-Garcia *et al.* (2003a) have argued that Bolivian Tsimane' people had difficulties identifying objects through pictures. Therefore, further research on people's ability to recognize plants from photographs will be necessary to substantiate our claim on a larger scale.

Table 7.1: Number (#) and percentage (%) of 50 plant species recognized by five participants based on photographs and voucher specimens

Participant		**1**	**2**	**3**	**4**	**5**	**Mean ± S.D.**
Recognition photographs	#	46	48	48	47	45	47±1
	%	92	96	96	94	90	94±3
Recognition voucher specimens	#	36	43	41	39	34	39±4
	%	72	86	82	78	68	77±7

7.4. Conclusions

If time is not an issue, the most appropriate way to carry out a(n) (quantitative) ethnobotanical study would be to conduct *in situ* interviews during transect, *walk-in-the-woods* or homegarden sampling, which can partly be combined with *ex situ* interviews using fresh plant material. As such, participants are presented only with those plant props that they are used to seeing in real life. However, when time, financial and/or human resources are limited, researchers often have to turn to using artificial representations of plant species such as voucher specimens, and/or plant photographs for optimizing return on time investment and quantification of ethnobotanical data.

Our findings demonstrate the usefulness of photographs in ethnobotanical interviews. Furthermore, we suggest that in some cases using photographs as props for interviews can be a better alternative than voucher specimens, particularly when research is conducted in remote and isolated study sites. However, in order to generalize this conclusion, people's ability to recognize plant species from photographs should be evaluated on a larger scale with different ethnic groups and communities, and with representatives from all knowledge strata.

8.

Plant use in TIPNIS[1]

8.1. Introduction

About 30 of the 37 different ethnic groups known to Bolivia (Plaza and Carvajal, 1985) reside in the lowlands (Calvo, 2003c; Pacheco, 2003). Many of these groups have been described in early missionary writings (e.g. Castillo, 1676; Caballero, 1706; Eder, 1772) and travel diaries and scientific publications of the numerous ethnographers and explorers who traversed Bolivia (e.g. Nordenskiöld, d'Orbigny, Riester, Métraux, etc.). However, relatively few ethnic societies have been the subject of ethnobotanical research that included collection of voucher specimens (Bourdy *et al*., 2000). In recent years, a renewed interest in people-plant interactions has resulted in a number of relevant ethnobotanical publications.

Some notable examples of Bolivian lowland ethnic groups that have benefited from this attention include: the Mosetenes (Hinojosa, 1991; Quintana and Vargas, 1995; Muñoz *et al*., 2000b); Tacana (Ponz *et al*., 2005; Baelmans *et al*., 2000; Bourdy, 1998 and 1999; Bourdy *et al*., 2000; De Walt *et al*., 1999); Chacobo (Boom, 1987 and 1989; Muñoz *et al*., 2000a);

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[1] The medicinal uses and ethnopharmacological properties of nearly all medicinal plants collected in the southern part of TIPNIS are described in the book "*Guía de Plantas Medicinales de los Yuracarés y Trinitarios del Territorio Indígena Parque Nacional Isiboro-Sécure, Bolivia*" (Thomas and Vandebroek, 2006)

Tsimane (Nate *et al*., 2001; Reyes-Garcia *et al*., 2003a and b and 2006); Yuracarés (Moretti *et al*., 1990; Uberhuaga, 1998; Hinojosa *et al*., 2001; Vandebroek *et al*., 2004a and b); Trinitarios (Vandebroek *et al*., 2004a and b) Isoceño-Guarani (Bourdy *et al*., 2002 and 2004); Chiquitanos (Birk, 1995; Toledo, 1995), Gwarayo (Toledo and Salick, 2006); Machinari (Ponz *et al*., 2005); and Esse-Ejja (Alexiades, 1999). Also the ethnobotany of Andean settler communities in the Bolivian lowlands is beginning to receive attention (Paniagua, 2001 and 2005; Carretero, 2005). In addition to the previous publications, useful ethnobotanical gray literature that address the knowledge of representatives of various ethnic groups have become available as well (e.g. Praedac, s.d.; Killeen *et al*., 1993; Mostacedo and Uslar, 1999; De Lucca, 2004; Vargas and Jordan, 2003; Vasquez and Coimbra, 2002).

In line with other studies throughout Amazonia (e.g.; Prance *et al*., 1987; Milliken *et al*., 1992; van Andel, 2000; Balée, 1994; Phillips *et al*. 1994), ethnobotanical investigations in Bolivia have repeatedly shown the impressive number of plant species used by Amazonian people for every aspect of their physical, cultural and spiritual life (Milliken *et al*., 1992). In this chapter, we will provide a detailed account of plants used by Yuracarés and Trinitarios from the southern part of TIPNIS. Different plant uses are discussed within a context of several major use categories: medicine, food, materials, construction, fuel, social uses and poison. To the best of our knowledge, this is the first general in-depth ethnobotanical study among Trinitarios, except of course the ethnomedical research conducted by Vandebroek *et al*. (2004a and b). The Yuracarés are somewhat better represented in ethnobotanical literature (*e.g.* Moretti *et al*., 1990; Hinojosa *et al*., 2001; Vandebroek *et al*., 2004a and b) but our data add new findings to these existing studies.

8.2. Methodology

Ethnobotanical information about sampled plant species in TIPNIS was gathered between March 2004 and February 2006 according to the techniques described in chapter 7, i.e. *in situ* interviewing during transect, *walk-in-the-woods* and homegarden sampling, and *ex situ* interviewing with fresh plant specimens, dried specimens, and photographs, respectively (Thomas *et al*., 2007). As indicated in table 8.1, a total of twenty-six participants provided ethnobotanical information.

Table 8.1: Numbers of participants involved in the present study, according to sex and ethnic affiliation

	Yuracarés	Trinitarios
♂	9	10
♀	3	4

Participants were selected through peer recommendations as described by Davis and Wagner (2003). The majority were laypeople, but also five female herbalists and midwives, one male traditional healer and one Trinitario shaman were included.

Plant uses were grouped into use categories according to Cook's (1995) Economic Botany Data Collection Standard. However, in analogy with other ethnobotanical studies in tropical forest environments (Prance *et al*., 1987; Boom, 1987; Phillips and Gentry, 1993a; Phillips *et* *al*. 1994; De Walt *et al*., 1999; Galeano, 2000; van Andel, 2000) and for reasons of comparison, construction materials were classified separately from *materials*. The latter are categorized in most other studies as "handicrafts". The 8 resulting use categories are:

- *medicines,* including human and veterinarian medicines;
- *food,* including beverages;
- *construction,* i.e. all materials used in house construction, timber and species used during the manufacturing of canoes
- *materials,* including handicrafts, hunting gears, dyes, hygienic substances, instruments, toys;
- *fuel;*
- *social uses,* including ritual and magical uses, smoking materials/drugs and other unspecified social uses;
- *environmental uses*, i.e. exclusively ornamentals in the present study; and
- *poison*, including fish poison.

We further adapted Cook's classification (1995) by re-organizing plants used as *food additives* under *food,* and plants used for female sterility under *medicine*. For other methodological considerations, we refer the reader to chapter 3 about the Andean study site (Apillapampa).

8.3. Results and Discussion

8.3.1. The Cultural Realm of Usefulness

What is considered useful varies from culture to culture (Prance *et al*., 1987; Phillips *et al*., 1994; Balée, 1994). This notion is clearly supported by our research results as well. A good example concerns the use of the epiphytic orchid *Gongora scaphephorus*. Its medicinal use against swellings and furuncles is confirmed by various Trinitario participants (Thomas and Vandebroek, 2006), but Yuracaré avoid any contact with this plant as they believe sorcerers use it for black magic. Another example is the following. Trinitario children are often seen playing with the inflorescences of *Costus scaber*. By contrast, Yuracaré parents forbid their offspring to pick the plant's flowers because they believe this will cause children's anus to pop out. Intriguingly, Yuracarés use the flower of *Costus scaber* for treating protruding anuses (Thomas and Vandebroek, 2006) in analogy with the line of thinking in Western homeopathy that "*similia similibus curantur*" or "like cures like".

As shown in chapter 10, Yuracarés know significantly more edible wild plants than Trinitarios, which likely is a consequence of their different provenance. During the present study, it was frequently observed that Trinitarios are not really interested in learning about the use of wild food plants. They even look down upon the higher knowledge of Yuracarés regarding wild food species in that this would testify of the less civilized status of the latter. In spite of their higher knowledge, Yuracarés are reluctant to eat some plants that are consumed by Trinitario or Quechua people with whom they share their habitat. For example, *Passiflora tricuspis* which has been identified as a promising "new" fruit species (Vasquez and Coimbra, 2002; Delanoy *et al*., 2006a), is eaten by Trinitarios, while Yuracarés avoid its use. Yuracarés believe that by eating the fruits of this plant, they will increase the risk of being bitten by a snake. Likewise, Trinitario and Yuracaré participants claim that the fruits of *Solanum barbeyanum* are poisonous, whereas Andean settlers from TIPNIS process them into the hot *llajwa* sauce in a similar way as tomatoes. Differences in the use of edible plants also occur between members of the same ethnic group. For example, in the Yuracaré community of Sanandita, we observed that participants consume the fruits of *Ouratea macrobotrys*, a use that has also been described for the Bolivian Chacobo (Boom, 1989). Intriguingly, none of the Yuracaré participants from the community of San Antonio regarded this species as edible.

8.3.2. Participants and Efficacy of Interviewing

A total of 894 species from the plant inventory was shown to a variable number of participants (range: 1 to 19) with an average of approximately five (4.9±3.8 (s.d.)) participants (figure 8.1). The mean overall use value of these 894 species is 1.1 (±0.9 (s.d.)). One hundred and fifty nine (159) species had no use at all. Hence, a total of 735 useful species was recorded (i.e. 82% of all inventoried species). The number of participants interviewed per plant species correlates positively with the species' use value (Kendall's $\tau_b = 0.24$; $p<0.001$). This introduces a type of bias in the use value data since a variable number of participants was interviewed for different plant species.

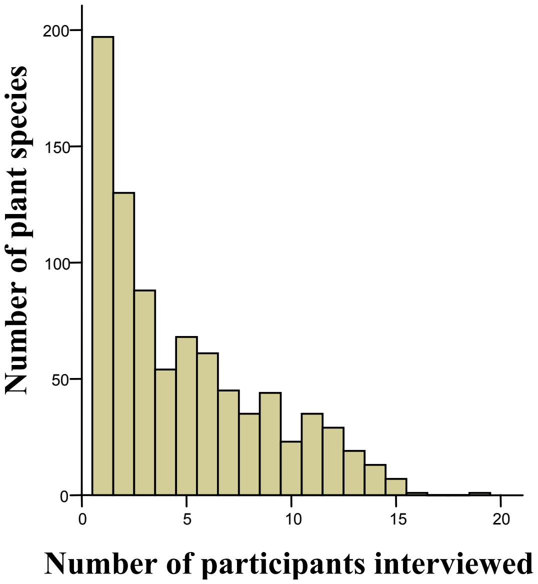

Figure 8.1: Frequency table of the number of Yuracaré and Trinitario participants providing use data on plant species

More specifically, use (and non-use) data were obtained for a total of 704 and 752 plant species from Trinitario and Yuracaré participants, respectively. The number of participants who were interviewed about a species varied between 1 and 10 and between 1 and 9 for Trinitario and Yuracaré participants, respectively. On average, significantly more Trinitarios (3.2±2.0 (s.d.) than Yuracarés (2.8±2.0 (s.d.)) were interviewed per plant species ($p<0.001$; t-test). Respectively 141 and 155 of the species shown to Trinitarios and Yuracarés had no use at all. In total, 463 plant species are used by members of both ethnic groups (i.e. 54% of the pooled total number of species). The number of Trinitario and Yuracaré participants interviewed per plant species correlates positively with the species' use value (Kendall's τ_b = 0.30 for Trinitarios and 0.14 for Yuracarés; $p<0.001$ in both cases). Therefore, comparing use values between Trinitarios and Yuracarés might be subject to bias. If we would have interviewed an equal number of Yuracaré and Trinitario participants use values obtained for Yuracarés could have been higher.

Of the 735 species, slightly more species were reported as useful by Yuracarés (597 species) than by Trinitarios (554 species). A similar number of useful species (625) was reported for the Huarani from Ecuador (Cerón and Montalvo, 1998), whereas van Andel (2000) documented 587 species used by Caribs and Arawaks from northwest Guyana. Balée (1994) found that the Brazilian Ka'apor use 90% (i.e. 693 species) of 768 species, and the Guajá 76% (i.e. 418 species) of the 547 species they know. Other studies might be "less complete" because they were not aimed at documenting the entire ethnobotanical inventory of ethnic groups. These studies include: 292 useful species for the Cofanes from Ecuador (Ceron, 1995); more than 300 useful species for the Brazilian Waimiri Atroari (Milliken *et al*., 1992); 305 useful species for the Bolivian Chacobo (Boom, 1989); and 298 useful species for the Izoceño-Guarani from the Bolivian Chaco (Bourdy *et al*., 2004).

8.3.3. Overall Usefulness of All Collected Plant Species

A total of 5315 responses (or citations) and 2789 different plant uses were recorded. In analogy to chapter 3, a *response* or *citation* is defined as an answer from a participant with regard to a use of a particular plant species. On average, 7.3 (±8.0 (s.d.)) responses per useful plant species were recorded. A *plant use* is defined as a well-defined use of a particular plant species for one particular goal by one or more participants. On average, there were 3.8 (±3.3 (s.d.)) uses per plant species.

Figures 8.2A and 8.2B show the wide range in the number of uses and use values for the 735 useful species, illustrating the point that only a few species are outstandingly useful (cf. Phillips *et al*., 1994). The number of uses reported per species varies between 1 (186 different species) and 22 for *Uncaria guianensis*. The mean use value of all useful species is 1.31 (±0.87 (s.d.)). The most useful species, *Attalea phalerata* is nearly 60 times more useful than *Oxalis juruensis* (use values 6.13 and 0.11, respectively).

The most important families in terms of average overall use values are Arecaceae (FUV=3.54), Myristicaceae (2.17), Burseraceae (2.17), Sapotaceae (2.07), Poaceae (2.01), Anacardiaceae (1.89) and Annonaceae (1.86). From this list, Arecaceae, Myristicaceae, Burseraceae, Sapotaceae and Annonaceae have been identified as the highest scoring families by Phillips and Gentry (1993a), Stagegaard *et al.* (2002) and Lawrence *et al.* (2005) in their studies among *Mestizo* and indigenous people from the Peruvian rainforest. High family use values for these families were also confirmed by Galeano (2000) in a study among Afro-Americans from the pacific coastal forest in Colombia.

In table 8.2, the fifty most useful species are ranked according to decreasing use values (UV_S). The latter table shows that quality use values (QUV_S) are rather similar to UV_S This indicates that, at least for the fifty most useful species, the majority of plant uses are of good quality. Therefore, a ranking based on QUV_S values is almost identical to one based on UV_S values. This is confirmed by the high correlation coefficient between $QUV_{S\,\text{and}}$ UV_S values (0.96; table 8.3). The number of uses per species correlates positively with its use value and quality use value (table 8.2). However, correlation coefficients (0.42 for both correlations) are relatively small (table 8.3). This indicates that most of the variance in the (quality) use values is due to the process of averaging (quality) uses obtained from various participants. As shown by table 8.2, rankings of plant species based on use diversity ($UD_{s)}$ or use equitability (UE_s) values are largely different from rankings based on UV_s or QUV_s. This lack of correspondence implies that species with high (quality) use values are not necessarily used within the majority of use categories. It also means that the different uses do not necessarily contribute evenly to the total (quality) use value of a species. Nevertheless, a species' UD_s value is positively correlated with its UV_s and QUV_s values (table 8.2). Hence, if a species is used in several use categories and its uses are more evenly distributed over these categories then it will have higher UV_s and QUV_s values.

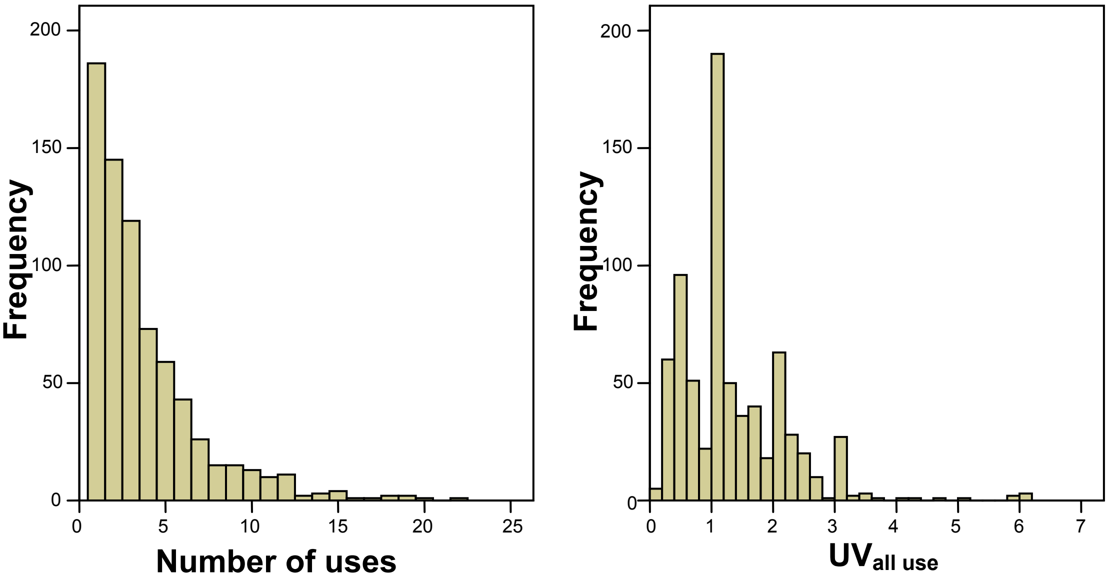

Figure 8.2 Frequency diagrams (number of species) for number of uses (A) and overall use values per species (B)

As far as UE_S is concerned, quite a different picture emerges. UE_S is negatively correlated with all other other "usefulness" parameters (although correlation coefficients are rather low). This indicates that for species with a high number of uses and/or higher UV_s and QUV_s values, different use categories contribute less evenly to their total (quality) use value as compared to species with few uses and/or low UV_S and QUV_S values.

8.3.4. Categorical Plant Uses and Mean Use Values

Of the 735 useful species that were recorded for TIPNIS in the present study, nearly half are used in traditional medicine (345 spp.; 47%) or as fuel (333 spp.; 45%) (figure 8.3). Two hundred and ninety five species (40%) are used as food and one third is used as a source of material or for construction purposes (256 and 259 species, respectively; both account for 35% of species). Useful plants possess similar mean medicinal, food, fuel and construction use values (figure 8.4). The mean material use value of all collected useful species is significantly lower than the former values but still much higher than mean social and environmental use values ($p<0.01$; Mann Whitney tests).

Table 8.2: Top fifty most useful species based on use values. For each species, the number of participants to whom it was shown, the number of different types of uses, as well as the number of use categories are listed. The ten highest values of each 'usefulness' index are underlined. Only species that were shown to at least three participants are included.

Species	Family	# participants	# uses	# categories	UD$_s$	UE$_s$	UV$_{\text{all uses}}$	QUV$_{\text{all uses}}$
Attalea phalerata	Arecaceae	8	18	5	1.33	0.83	6.13	6.13
Bactris gasipaes	Arecaceae	8	10	3	0.78	0.71	5.88	5.88
Attalea butyracea	Arecaceae	8	13	4	1.10	0.79	5.83	5.83
Jessenia bataua	Arecaceae	8	11	4	1.31	0.94	4.63	4.63
Guarea macrophylla	Meliaceae	13	18	5	1.31	0.81	4.23	4.04
Gynerium sagittatum	Poaceae	9	9	2	0.68	0.98	4.22	4.22
Swietenia macrophylla	Meliaceae	4	11	3	1.04	0.95	4.00	4.00
Myroxylon balsamum	Fabaceae	5	11	4	1.37	0.99	3.80	3.80
Socratea exorrhiza	Arecaceae	14	16	5	1.07	0.67	3.43	3.36
Genipa americana	Rubiaceae	8	8	4	1.22	0.88	3.38	3.38
Hura crepitans	Euphorbiaceae	12	19	5	1.24	0.77	3.33	3.33
Persea americana	Lauraceae	5	10	3	0.86	0.79	3.20	3.00
Iriartea deltoidea	Arecaceae	11	15	5	1.05	0.65	3.18	3.18
Clarisia racemosa	Moraceae	12	14	4	1.14	0.82	3.17	3.13
Theobroma cacao	Sterculiaceae	6	10	3	0.84	0.76	3.17	3.17
Calophyllum brasiliense	Clusiaceae	10	14	5	1.11	0.69	3.10	3.10
Aspidosperma rigidum	Apocynaceae	11	15	4	0.98	0.71	3.09	3.04
Guarea guidonia	Meliaceae	13	17	4	1.11	0.80	3.00	2.79
Cissus gongylodes	Vitaceae	3	5	1	0.00	0.00	3.00	3.00
Pouteria cf. *multiflora*	Sapotaceae	3	5	4	1.27	0.92	3.00	3.00
Guadua cf. *weberbaueri*	Poaceae	10	12	4	1.06	0.76	2.90	2.90
Licania harlingii	Chrysobalanaceae	5	5	3	0.99	0.90	2.80	2.80
Triplaris americana	Polygonaceae	9	12	4	0.82	0.59	2.78	2.78
Iryanthera juruensis	Myristicaceae	8	8	4	1.19	0.86	2.75	2.63
Pouteria torta	Sapotaceae	12	11	4	1.37	0.98	2.75	2.56
Calyptranthes nov sp	Myrtaceae	15	14	5	1.04	0.65	2.73	2.73
Sida rhombifolia	Malvaceae	7	10	2	0.58	0.83	2.71	2.71
Guatteria citriodora	Annonaceae	4	2	3	0.90	0.82	2.67	2.67
Astrocaryum murumuru	Arecaceae	12	12	3	1.09	0.99	2.67	2.58
Ochroma pyramidale	Bombacaceae	11	10	3	0.70	0.63	2.64	2.64
Erythroxylum coca	Erythroxylaceae	5	7	3	1.09	0.99	2.60	2.60
Nicotiana tabacum	Solanaceae	7	9	2	0.59	0.85	2.57	2.57
Momordica charantia	Cucurbitaceae	7	8	3	1.07	0.97	2.57	2.57
Pouteria durlandii	Sapotaceae	9	6	4	1.34	0.97	2.56	2.08
Protium cf. *meridionale*	Burseraceae	11	15	5	1.48	0.92	2.54	2.50

Table 8.2 continued

Species	Family	# participants	# uses	# categories	UD_s	UE_s	$UV_{all\ uses}$	$QUV_{all\ uses}$
Salix humboldtiana	Salicaceae	10	11	4	1.09	0.78	2.50	2.50
Euterpe precatoria	Arecaceae	4	9	4	1.37	0.99	2.50	2.50
Ormosia nobilis	Fabaceae	6	6	4	1.27	0.92	2.50	2.29
Parinari klugii	Chrysobalanaceae	4	4	3	1.04	0.83	2.50	2.50
Zingiber officinale	Zingiberaceae	7	7	3	0.81	0.74	2.43	2.43
Hymenaea courbaril	Fabaceae	5	6	4	1.33	0.96	2.40	2.25
Bixa orellana	Bixaceae	5	8	2	0.68	0.98	2.40	2.30
Dipterix odorata	Fabaceae	8	6	5	1.16	0.72	2.38	2.38
Dipterix micrantha	Fabaceae	8	3	5	1.16	0.72	2.38	2.38
Cecropia concolor	Cecropiaceae	6	6	4	1.09	0.79	2.33	2.25
Gallesia integrifolia	Phytolaccaceae	9	12	3	0.59	0.54	2.33	2.28
Sapindus saponaria	Sapindaceae	6	5	3	0.76	0.69	2.33	2.33
Chenopodium ambrosioides	Chenopodiaceae	6	10	1	0.00	0.00	2.33	2.33
Virola peruviana	Myristicaceae	3	4	3	1.08	0.98	2.33	1.92
Bactris major var. *infestans*	Arecaceae	6	5	2	0.69	1.00	2.33	1.71

Table 8.3: Kendall's τ_b correlation coefficients and significance levels for combinations of different plant use indexes (N=735)

	Number of uses	UD_s	UE_s	$UV_{all\ uses}$
UD_s	0.523***			
UE_s	-0.313***	0.217***		
$UV_{all\ uses}$	0.424***	0.358***	-0.090***	
$QUV_{all\ uses}$	0.416**	0.350***	-0.093***	0.961**

*** = $p<0.001$; ** = $p<0.01$; UD_s= use diversity; UE_s= use equitability; UV_s= use value; QUV_s= quality use value

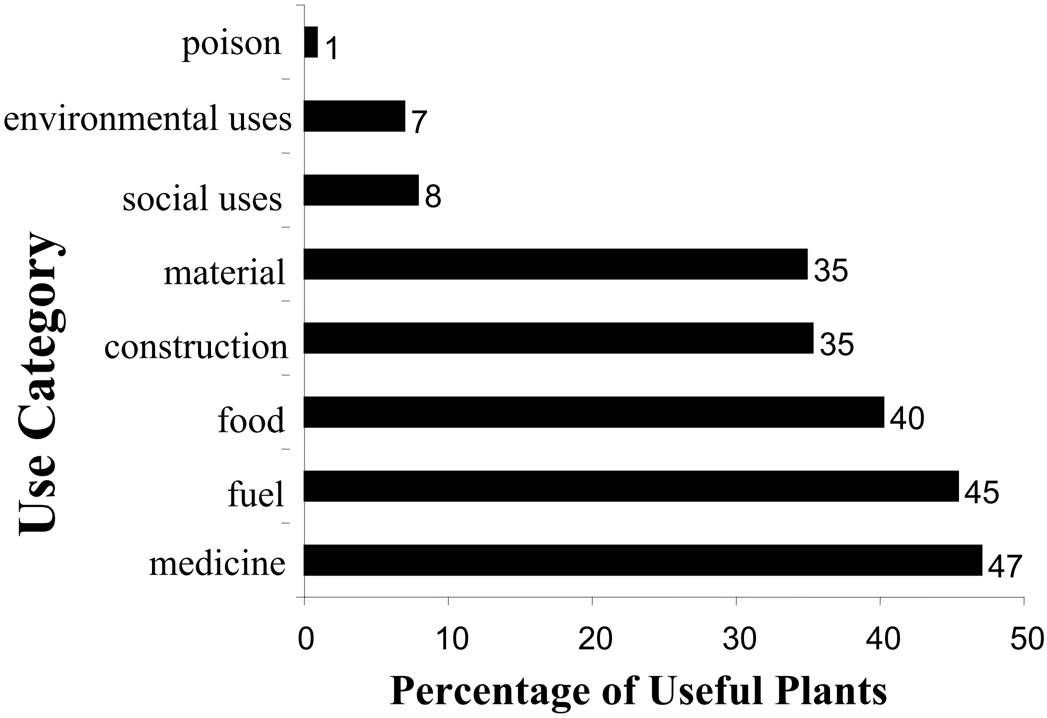

Figure 8.3: Proportional distribution of plants species shown to Yuracaré and Trinitario participants over different use categories

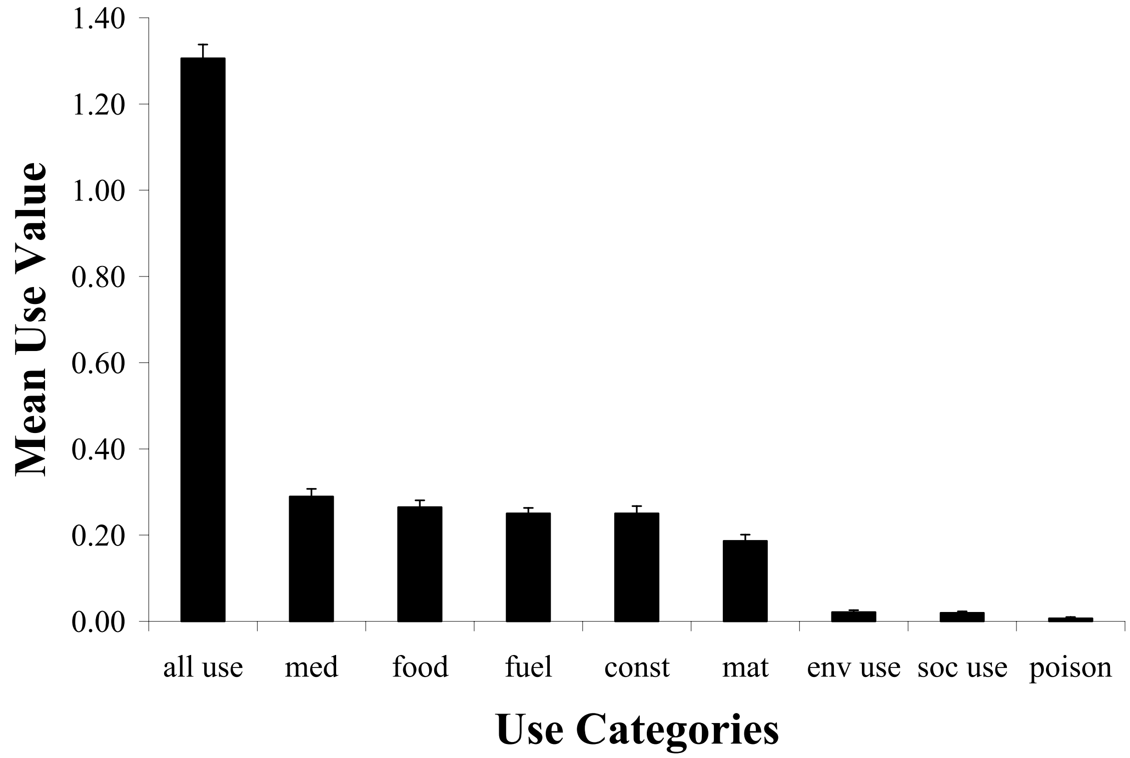

Figure 8.4: Mean categorical use values of all plant species that were shown to Yuracaré and Trinitario participants. Error bars represent standard error of the mean (med = medicine; const = construction; mat = material; env use= environmental uses; soc use = social uses).

8.3.5. Variation in Plant Use Knowledge in Relation to Demographic Characteristics of Participants

Relative use values (RUV_i) were calculated for our participant sample (cf. section 3.2.2.1). Only participants that had provided use data on at least twenty different species were included. As such, 22 participants were retained for this analysis (table 8.4).

Table 8.4: Numbers of participants for which RUVs were calculated, according to sex and ethnic affiliation

	Yuracarés	Trinitarios
♀	3	4
♂	8	7

Kruskal-Wallis tests show that mean UV_{is}/UV_s ratios differ between participants for each use category ($p<0.01$). The highly significant nature of these comparisons is an indication of how knowledge varies considerably between participants. Therefore, these results support the generally accepted notion that there exists an extreme heterogeneity in plant knowledge among tropical forest people (Milliken *et al.*, 1992; Phillips and Gentry, 1993b).

Next, it was verified whether a participant's mean RUV_i was gender related. RUV_i values of the seven female participants were compared with those of the fifteen male participants by means of independent sample t-tests (all categorical RUV_i values are normally distributed and homoscedast between both sexes). Test results show that only differences in construction and environmental plant use knowledge can be ascribed to gender ($p=0.05$ and $p=0.04$, respectively); all other categorical RUV_i values are equal. It may not be a surprise that men have a higher knowledge of construction uses than women, as they are basically responsible for most construction tasks. This is in line with the results from Lawrence *et al.* (2005) from the Peruvian Amazon. In TIPNIS, women have significantly higher environmental RUV_i values because this category exclusively comprises ornamental uses and apparently, mostly women appreciate the aesthetic aspects of plants.

Seven participants are recognized in the communities for their ability as a traditional healer and/or a midwife. Therefore, we tested whether plant use knowledge was higher for healers as compared to non-plant specialists. As could be expected, statistical tests showed that only medicinal and social RUV_i values are significantly higher for healers and midwives ($p= 0.005$ (Mann-Whitney) and $p=0.002$ (t-test), respectively); all other categorical RUV_i values are equal between both groups. Social uses mainly involve magical or ritual plant uses (see lower) which generally belong to the domain of plant specialists such as healers and particularly shamans.

RUV_i values can also be used to test the influence of ethnic affiliation on plant knowledge. This comparison shows that the mean overall and medicinal RUV_i values calculated for Trinitario participants are significantly higher than for Yuracarés ($p=0.03$ (t-test) and $p=0.05$ (Mann-Whitney test), respectively). By contrast, the mean food RUV_i values obtained for Yuracaré participants is significantly higher than for Trinitarios ($p=0.007$, t-test). All other categorical RUV_i values are independent of ethnic affiliation. Lawrence *et al.* (2005) found that indigenous people from the Peruvian Amazon value food species more than Andean settlers. In a certain way these finding correspond with ours in that Trinitarios are also ‘settlers’ in TIPNIS, which is one of the original habitats of Yuracarés.

In chapter 3, we have shown that in Apillapampa, the age of a participant partly explains the variation in RUV_i for most use categories. Age in TIPNIS ranged from 22 to 68 years at the time of the present study. However, no significant correlation between participant age and categorical RUV_i values was found. The same result was obtained when Yuracaré and Trinitario participants were considered separately. There might be various explanations for this result. A first possibility is that such relations are simply not universally valid among traditional societies residing in different environments. Second, our sample size might be too small to detect these trends, or else the age spectrum of participants was not sampled wide and/or evenly enough. It could also be related to the fact that different sets of plant species were shown to each participant. Finally, our inability to detect significant correlations between plant use knowledge and participant age may be related to the fact that we evaluated the knowledge of specialists (healers) and non-specialists (laypeople) simultaneously. Indeed, based on the results from an ethnomedical study in TIPNIS, Vandebroek *et al.* (2004b) have shown that large part of the variation in medicinal plant knowledge between Yuracaré and Trinitario healers could be attributed to age, or better age of initiation in traditional healing.

In sum, our findings from TIPNIS show that local knowledge is not evenly distributed among traditional societies and that this distribution is not random but patterned (D’Andrade, 1987). However, where age was identified as the only significant factor determining plant use knowledge of participants in Apillapampa (cf. section 3.3.3.), in TIPNIS plant knowledge was not age-related. Here, gender and social status were the only significant variables explaining patterns in plant knowledge. This is well documented in literature (Ellen, 1979; Berlin, 1992; Bernstein *et al.*, 1997; Begossi *et al.*, 2002; Ladio and Lozada, 2004; Kainer and Duryea, 1992; Milliken and Albert, 1997; Stagegaard *et al.*, 2002; Howard, 2003; Deda and Rubian, 2004; Lawrence *et al.*, 2005). The uneven distribution of knowledge is certainly valid for traditional medicine, where usually a distinction can be made between laypersons and specialists (i.e. healers) who possess more in-depth knowledge (Ryan, 1998; Vandebroek *et al.*, 2004b).

8.3.6. Medicinal Plant Use

8.3.6.1. An Overview of the Trinitario Ethnomedical System

It is impossible to discuss Trinitario ethnomedicine and their plant pharmacopoeia, without mentioning the role of *sobanderos*, the Trinitario equivalent of shamans.

One of the principal aspects that distinguished the Mojeño culture from most other Amazonian societies was their hierarchic priesthood system (Denevan, 1980; Lehm, 1999). The highest social status was occupied by the *mapono* (identified as *comocois* by d’Orbigny, 1845 and *komokoy* by Castillo, 1676, cited by Santamaria, 1994), a sort of magical priest who was believed to obtain his power from killing a jaguar (Caballero, 1706). The main role of the *mapono* was to consult the gods, which were addressed with the general term of *Tinimaacas*, about climatological events such as droughts or inundations, or where to find abundant game animals (Caballero, 1706). One step down the ladder stood the *tiharauqui* whose sole duty it was to cure the sick. The *tiharauqui*, literally meaning “he with the clear sight” (see also Parejas, 1976; d’Orbigny, 1845; Serrano y Sanz, 1933; Ballivian, 1906; Orellana, 1704, cited in Lehm, 1999; Castillo, 1676 cited in Santamaria, 1994) were initiated into their profession through a magical initiation rite whereby the *mapono* or *comocois* dropped bitter sap of a liana species in his followers’ eyes to ‘clear them’ (Wegner, 1931). Among the Trinitario people who participated in the present study, the present-day equivalent of *tiharauqui* is termed *sobandero* (Spanish) or *tkonñahi* (Trinitario). This term has also been reported by Villavicencio (1992), but with a different spelling: *conña’i.*

As further specified in chapter 11, according to the Trinitario worldview (*Weltanschauung*), all animal species and most landscape and climatological elements (rocks, rivers, mountains, rainbows, rain…) have their spiritual owners or masters. These masters need to be treated with respect at all times. Through offences (e.g. overhunting) or for unknown reasons, these masters are believed to cause diseases in people such as *susto* (discussed in chapter 11) or rainbow curses (see section 8.3.11). Apart from illnesses caused by spiritual masters, among Trinitarios many diseases are believed to be caused by evil bodies that are introduced into the patient’s body through witchcraft by rival sorcerers. According to Trinitario participants, evil bodies that can cause sickness range from insects, hair, (fish) bones to pieces of electric wire (personal observation). These evil bodies are believed to slowly weaken the patient, and often lead to depression. If they are not removed on time, this can even cause death. Especially insects are dangerous, as they are believed to breed inside the body and slowly digest it. A similar concept is described for the Isoceño-Guarani (Bourdy *et al*., 2004) but instead of insects, they mention worms. According to a well-respected *sobandero* who we interviewed, evil bodies in a patient’s body can be observed on X-ray images as blackish spots.

The belief of evil bodies causing illness in people is widespread among South American lowland societies (e.g. Chaumeil, 2000; Bourdy, 2000 and 2004). Krickeberg (1922) discussed how South American tribes from tropical forest areas were not used to accredit any disease or death to natural causes and generally believed that many illnesses originated from substances introduced into the patient’s body by powerful sorcerers from rival tribes. In line with our observations, Villavicencio (1992) described how Trinitarios believe that witches (*yopéru*) deliver their spells by wind. Up to date, belief in witches is very common in the participating Trinitario communities. Also among the Yuracarés, many disorders were attributed to evil sorcerers and bad spirits that are transported by wind (Métraux, 1942).

The main and most important duty of *sobanderos* is to identify disease aetiology. Health conditions of natural origin (e.g. leishmaniasis, cough, haemorrhages…) can obviously be treated by herbalists, whereas illnesses of supernatural origin can only be successfully dealt with if their very cause(s) is (are) uncovered. Hence, treatment of disorders in Trinitario ethnomedicine is influenced by both aetiology and symptoms. In this respect, it seems very similar to that of the Isoceño-Guaranis from the Bolivian Chaco (Bourdy *et al*., 2004). In general, *sobanderos* use spiritual powers for healing. The importance of medicinal plants in their healing ceremonies is almost nil, except for tobacco and plants with garlic-like scents such as *Petiveria alliacea*. These observations are in accordance with the well-established fact that in many indigenous societies there exists a clear distinction between shamans, who heal spiritual and psychosomatic disorders, and herbalists, who use empirical medicine, including medicinal plants (Santamaria, 1994; Chaumeil, 2000; Cocks and Dold, 2000; Bourdy *et al.*, 2000 and 2004).

In the Trinitario communities who participated in the present research, all known *sobanderos* are men. However, among the Mojeños, early reports of men and women who acted as traditional healers without hierarchical distinction have been reported since the 17th century (Castillo, 1676 cited by Santamaria, 1994). Likewise, Chaumeil (2000) argued that among the Peruvian Yagua there exists no distinction between sexes on who can become a shaman. The four female Trinitario healers who collaborated in the present study practiced ethnomedicine of herbalists and midwives.

The practice of *sobandero* clearly has a very long tradition in the healing tradition of Mojeños. Already in 1706, Caballero mentioned how the *tiharauqui* treated illnesses believed to be caused by bewitchments or punishments by divinities, by sucking the afflicted body from which they simulated to remove dead objects or living creatures. Caballero (1706) further described how also the *mapono* used to engage in this practice, but much more sporadically. Instead of removing evil bodies, the *mapono* used to suck immense quantities of blood from a patient's skin without piercing it.

Present-day *sobanderos* are still experts in removing evil bodies from a patient's body. In this respect, during the present study Trinitario participants distinguished three types of *sobanderos*: those who (1) use their hands to heal; (2) cure with their mouth by sucking; and (3) cure without physical contact with the patient. The first type of healers massage the part of the body where the "illness", or in fact the "evil body", is presumably situated and rub it with alcohol and garlic while simultaneously blowing tobacco smoke over the affected area. Through spiritual dominance and experienced hand manipulation, they are believed to be able to force the "evil body" out of the patient's body. Other *sobanderos* place their mouth against the afflicted body part and, as described by Caballero (1706), bring the evil bodies out by sucking. The last, and most respected type of *sobanderos* just sit at the patient's side and smoke tobacco in order to cure him/her. They destroy the evil principle inside the patient's body by means of mere spiritual power: no touching is required and as a consequence no evil bodies are physically removed.

These procedures for removing evil bodies have been described exhaustively in literature. Early publications such as those by Eder (1775) and Krickeberg (1922) document how traditional healers in Amazonia used legerdemain, simulating to pull objects like little stones, thorns, feathers, tobacco leaves, small worms or fangs out of the patient's body by means of kneading, sucking, blowing, breathing and/or spitting on the affected body while blowing tobacco smoke over it. Among the Bolivian Baure, local healers (*motire*) first rubbed and pressed the skin to fix the foreign object and isolate it in a fold of the skin, and consequently sucked and/or bit in the skin (Eder, 1772). After secretly having put the 'foreign' object that had to be removed in their mouth, they suddenly made it appear to the spectators' eyes. Removal of evil bodies (worms, wires…) through sucking a patient's skin while intensely smoking tobacco has also been reported for the Yugua from the Peruvian Amazon (Chaumeil,

2000) and the Izoceño-Guarani from the Bolivian Chaco (Bourdy *et al.*, 2004). Tobacco is clearly omnipresent in all of these shamanistic practices.

As reported for other societies (Chaumeil, 2000; Bourdy *et al.*, 2004), the line between (benevolent) *sobanderos* and (malevolent) witches in the Trinitario culture is very thin. According to participants, it happens frequently that after numerous years of practice, *sobanderos* may be tempted to indulge in black magic and eventually become (malevolent) witches. Particularly *sobanderos* who remove evil bodies through sucking the skin are believed to incline more frequently towards witchcraft, because they would be able to taste their patients' blood during the mouth treatments. In his discussion of shamanism among the Amazonian Yagua, Chaumeil (2000) also argued that the "good shaman" and the "witch" are two facets that compose the shaman's personality.

In the following, we will present two examples that illustrate the role of *sobanderos* in identifying disease aetiology and treatment. We were able to personally witness the first story. It shows how two important concepts in Trinitario ethnomedicine (i.e. *susto* and evil bodies) are intertwined in one illness case. As discussed in chapter 11, *susto* is a folk illness that evidences itself through a series of symptoms that are believed to originate from the loss of one or several souls a person possesses.

> The 15 year old son of a respected female herbalist of San Jose de la Angosta had been diagnosed to suffer from *susto*. The boy had gone fishing the night before and had unexpectedly fallen in the water. The community *sobandero* was called in to examine the sick boy who was lying restlessly in bed and suffered from fever and abdominal pains. His mother explained that he also suffered from diarrhoea, vomiting, and excessive thirst. She had already administered him a decoction of *palta* (*Persea americana*) leaves to alleviate his thirst. The *sobandero* started his treatment by rubbing the boy's lower abdomen with alcohol, followed by massaging and repeatedly blowing tobacco smoke over the affected area. After some ten minutes, the *sobandero* seemingly forced a small piece of electric copper wire out of the boy's abdomen, believed to have been put in there by witchcraft. The *sobandero* explained, however, that it was not the wire that had caused the boy to suffer the symptoms, but *susto*. More precisely, he claimed that the owner of the river patch in which the boy had fallen had stolen his shadow. This type of curse is called *hechizo del agua* (water curse). The patient's mother was instructed to return to the place of the accident with the boy's clothes and call for his soul to return. The boy recovered fast and two days later resumed his daily activities. Although the piece of electric copper wire was not directly responsible for the patient's symptoms, it would have become harmful in the long run. The *sobandero* declared that evil bodies can remain in one's body for years without his or her knowing, slowly digesting the victim's life force.

Intriguingly, Chaumeil (2000) described a similar healing session among the Peruvian Yagua whereby a shaman removed several pieces of wire from a sick child's body. When the boy did not recover and was returned to him a few days later, the shaman found out that the real reason for his illness was caused by a rival sorcerer stealing the boy's souls. He was able to make the spirits return to the boy’s body, but his work still resulted to be in vain, because a few days later the boy died.

The second story was told to us by one of the Yuracaré members of CONISUR (*CONsejo Indígena del SUR del TIPNIS*), the indigenous council providing political representation for the Yuracaré and Trinitario communities from the southern part of TIPNIS. The Trinitario *sobandero* from the previous story and the Yuracaré narrator are friends of each other and at the time when the following events took place, the Trinitario *sobandero* was staying at the latter’s house.

> The Yuracaré’s cousin was a passionate hunter. He always left for hunting during the night and was reluctant to return without a prey. One morning he came back from the forest as a complete madman. His relatives managed to get him into bed, but he destroyed his mosquito net, bit people, was unable to talk rationally, and suffered from visions and nightmares. At first, the *sobandero* thought it were the masters of the animals that had taken revenge on the young man because of his excessive hunting habit. The *sobandero* calmed his patient down while saying: “I can help you, but only if you trust me, you will only have a chance to get better”. After prolonged easing while holding hands, the man finally calmed down and the *sobandero* made his diagnosis: he had been cursed. The *sobandero* blew tobacco smoke over his patient’s body and rubbed it in with alcohol and garlic. While kneading the skin of his forehead, in front of a number of spectators, the *sobandero* suddenly pulled out a living, black two-horned insect (probably a beetle) simultaneously saying: “evil go out of this person”. He explained that the patient had already been infected for fourteen years and that the creature he had just removed had bred inside the man’s body. He repeated the same procedure to take out two more insects…. Spectators were allowed to touch them to convince themselves of their authenticity. Next, the *sobandero* poured alcohol over the animals and burned them. The remaining ashes were buried. From that moment onwards, the patient started recovering. He became rational again and emotionally claimed he regretted his actions. Since then, the man never hunted again during nighttime.

8.3.6.2. Plant Pharmacopoeia and Most Important Medicinal Families

A total of 340 medicinal plant species was recorded during the present study, covering 38% of all plants shown to participants. In a previous study that focused on the medicinal plants known by eight traditional healers from six Yuracaré and Trinitario communities of TIPNIS (of which three overlap with the present investigation), the medicinal use of some 124 different plants species was reported (see Vandebroek *et al.* 2004a and 2004b). Thirty-six of these species were not inventoried during the present investigation. For eleven overlapping species that were recorded as medicinal by Vandebroek *et al.* (2004a and 2004b), ethnobotanical interviews during the present study did not yield any ethnomedicinal data (table 8.5). The combined results of both studies have recently been published in Thomas and Vandebroek (2006). To ensure a representative image of overall medicinal plant use in TIPNIS, the results presented here apply to the total of 387 (= 340+36+11) reported medicinal plants, except when indicated differently.

Four traditional healers participated in both investigations, whereas three participants were involved in the study of Vandebroek *et al.* (2004a and 2004b) exclusively. As such, information on the medicinal use of plants was provided by a total of twenty-nine participants (*i.e.* 26 from the present research plus 3 from the study of Vandebroek *et al.*, 2004a and 2004b). The number of participants interviewed per medicinal plant varied between 1 and 20, with an average of eight (8.1 ±4.0 s.d.). During the present investigation, a total of 1513 different medicinal responses were recorded. Vandebroek *et al.* (2004a and 2004b)) listed 724 responses. Of those 724 responses, 207 correspond with 88 species for which ethnomedical information was collected during both investigations. Sixty-eight (68) overlapping medicinal responses were counted between both studies. Hence, nearly one-third (32%) of the responses that were documented during the study of Vandebroek *et al.* (2004a and 2004b) and related to the 88 overlapping species were actually repeated during the present research. At an individual level, the four participants who engaged in both studies repeated between 27 and 36 percent of their responses from the study of Vandebroek *et al.* (2004a and 2004b). These percentages are similar to those obtained for participants in Apillapampa (see section 3.3.4.).

Table 8.5: Number of medicinal species and responses recorded during the present study in comparison to the study of Vandebroek *et al.* (2004a and 2004b)

	Present study	**Vandebroek *et al.* (2004a and 2004b)**	**Overlapping species and responses**
medicinal species	340	124	88
medicinal responses	1513	724	68

In the present study, the medicinal use of 282 and 186 medicinal species was documented for Trinitarios and Yuracarés, respectively, with 115 overlapping species. When the medicinal plants that were exclusively recorded during the study of Vandebroek *et al.* (2004a and 2004b) are included, these numbers rise to 329 and 195, respectively, with 124 overlapping species. Hence, 21% and 34% of all inventoried plants are used medicinally by Yuracarés and Trinitarios, respectively. These values are within the range of the world mean which was calculated by Farnsworth and Soejarto (1991) to vary between 14 and 28% for angiosperms (see also chapter 3, section 3.3.4.7.). A similar plant range in other pharmacopoeias has been reported in literature for other Amazonian groups (Cavalcante and Frikel, 1973; Boom, 1987; Kohn, 1992; Bennett, 1992; Balée, 1994; Quintana and Vargas, 1995; Milliken and Albert, 1996 and 1997; Cerón and Montalvo, 1998; van Andel, 2000; Bourdy *et al.*, 2000; Shepard, 2004; Grenand *et al.*, 2004). However, the number of medicinal plants used by Trinitario people is among the highest recorded for any Amazonian society to date, especially when bearing in mind their relatively recent settlement in TIPNIS. Most likely, many medicinal plants that used to be known by Trinitarios in their homelands, i.e. the savannahs of the Beni department, do not occur in TIPNIS. In chapter 10 (sections 10.4.2. and 10.4.4.), we propose various possible explanations for the superior medicinal plant use knowledge of Trinitarios as compared to Yuracarés.

All 387 medicinal plants are distributed over 98 botanical families and 257 genera. Eight percent of all medicinal species are Fabaceae (33 species; 8%), followed in importance by Rubiaceae (27 species; 7%), Solanaceae (22 species; 6%), Asteraceae (16 species; 4%) and Piperaceae (16 species; 4%). The genera with the highest number of medicinal taxa are

Solanum (10 species), *Piper* (9), *Ficus* (7), *Psychotria* (6), *Guarea* (5), *Miconia* (5), *Passiflora* (5), *Peperomia* (5), *Philodendron* (5) and *Siparuna* (5).

As we have demonstrated for Apillapampa, it is no coincidence that the botanically most diverse families in TIPNIS (i.e. Fabaceae, Rubiaceae and Solanaceae) also provide the highest number of medicinal species. Regression analysis shows that the number of medicinal plant species in a family (NMS) can be predicted from the total number of species inventoried for that family (NSF) in TIPNIS by the following equation:

$$\text{NMS} = 0.412 \times \text{NSF} + 0.191 \ (r^2=0.75 \text{ and } p<0.001)$$

Following the technique proposed by Moerman (1991) (see chapter 3, section 3.2.2.5.), regression residuals were calculated for all inventoried families. Figure 8.5 graphically shows the significance of the departure of each NMS from its predicted value. This figure demonstrates that Trinitario and Yuracaré participants statistically under- and overuse six and four families, respectively. As for Apillapampa, we compared the results obtained from TIPNIS with other studies around the world. However, family size in our calculations is based on our inventories and not on complete checklists from the study area (which do not exist at present). Therefore, comparing with studies reported in literature might be more problematic for TIPNIS than for Apillapampa. Even with more than 900 collected plant species during the present study and 36 additional ones from the study of Vandebroek *et al.* (2004a and 2004b), our inventory of the available plants in TIPNIS is probably far from complete. For example, epiphytes (mainly Orchidaceae, Araceae, Bromeliaceae and *Peperomia* spp.) which are known to be very numerous in our area (Altamirano and Fernandez, 2003; Ibisch *et al*., 2003) are strongly underrepresented in our collection. Also, the species area curves from our 0.1-ha transects (figure 6.8) suggest that enlarging the sampling area would probably yield many more species than currently inventoried.

In spite of these shortcomings, a comparison of the over- and underused species from TIPNIS with similar studies reported in literature (table 8.4) shows some considerable overlap, particularly for the overused families. Solanaceae appeared among the overused families in Apillapampa, as well as in the Mexican Chiapas study described in Moerman *et al.* (1999). Piperaceae and Rubiaceae have been identified as overused families by Treyvaud Amiguet *et al*. (2006) in their study among Q'eqchi' Maya from a semi-evergreen rainforest in Belize. As pointed out by Moerman *et al*. (1999), the medicinal use of Rubiaceae is unusual, since some ethnic groups use them frequently, whereas others have virtually no medicinal applications for this family (Leonti *et al*. 2001). Araceae, the fourth most overused family in the present study also proved to be most overused in the Ecuadorian study discussed in Moerman *et al.* (1999).

The fact that there exists far less overlap between the most underused families identified in the present study and studies reported in literature is probably due to our underestimations of family sizes (which are based on collections rather than on a checklist for the entire area). Nevertheless, Lauraceae, the second most underused family with only 5 medicinal species out of 29 collected species, was also statistically underused in the Ecuadorian study of Moerman *et al*. (1999).

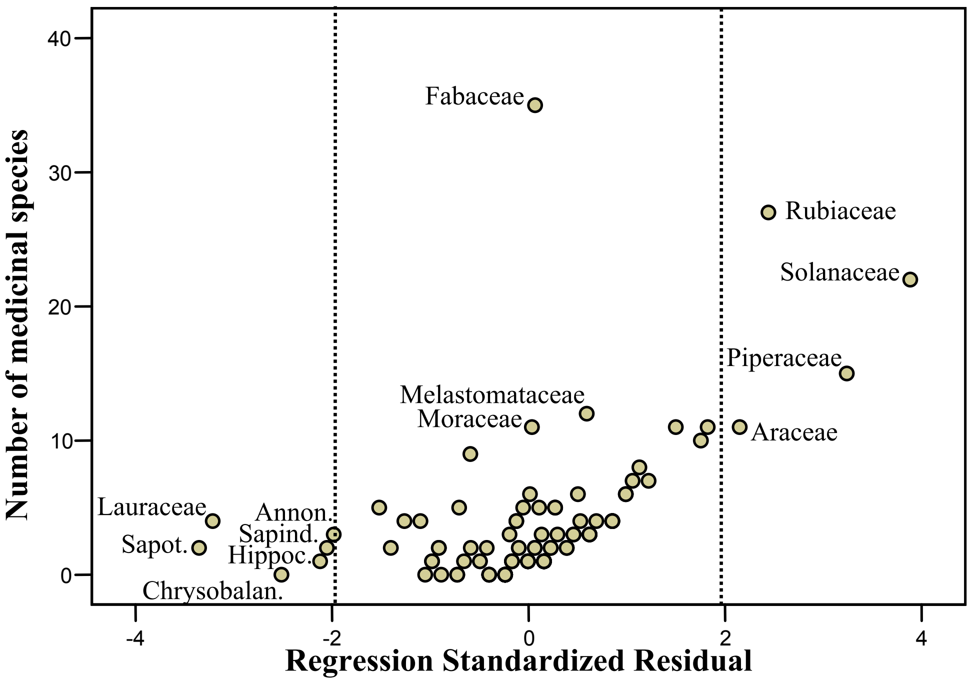

Figure 8.5: Number of medicinal species (NMS) vs. standardized residuals of the regression of NMS on family size (NSF). Families with standardized residuals >1.96 or <-1.96 (p=0.05) have significantly higher, respectively lower NMS than expected from their size (Annon.= Annonaceae; Sapot.= Sapotaceae; Sapind.= Sapindaceae; Hippoc.= Hippocrataceae; Chrysobalan.= Chrysobalanaceae).

Table 8.4: The top three ranking of overused and underused families of medicinal plants in Apillapampa (chapter 3) and seven other locations based on standardized residuals (adopted from Treyvaud Amiguet *et al.*, 2006)

	Most overused families			Most underused families		
	1	2	3	1	2	3
TIPNIS	Solanaceae	Piperaceae	Rubiaceae	Sapotaceae	Lauraceae	Chrysobalanaceae
Apillapampa	Solanaceae	Lamiaceae	Scrophulariaceae*	Poaceae	Bromeliaceae*	Polygalaceae*
Toledo[1] (Belize)	Piperaceae	Rubiaceae	Asteraceae	Orchidaceae	Poaceae	Cyperaceae
Veracruz[2] (Mexico)	Asteraceae	Piperaceae	Fabaceae	Orchidaceae	Poaceae	Rubiaceae
Chiapas[3] (Mexico)	Asteraceae	Lamiaceae	Solanaceae	Poaceae	Orchidaceae	Cyperaceae
Kashmir[3]	Asteraceae	Euphorbiaceae	Ranunculaceae	Poaceae	Urticaceae	Anacardiaceae
North America[3]	Asteraceae	Apiaceae	Ericaceae	Poaceae	Cyperaceae	Fabaceae
Ecuador[3]	Araceae	Fabaceae	Bignoniaceae	Orchidaceae	Moraceae	Lauraceae
Korea[3]	Asteraceae	Lamiaceae	Ranunculaceae	Cyperaceae	Poaceae	Orchidaceae

[1] Treyvaud Amiguet *et al.*, 2006; [2] Leonti *et al.*, 2003b; [3] Moerman *et al.*, 1999
*: only significant at the 10% level

The most important families (with at least 3 collected species) in terms of medicinal family use values are Cyatheaceae (FUV_{med}= 1.29), Cactaceae (1.17), Loranthaceae (0.99), Phytolaccaceae (0.95), Costaceae (0.92), Vitaceae (0.82), Poaceae (0.80), Rutaceae (0.77) and Malvaceae (0.71). The fact that precisely these families yield the highest scores is because of the relatively small numbers of species inventoried in these families and because most of these species are used medicinally.

8.3.6.3. Life Form, Habitat and Origin

Figure 8.6 indicates that the majority of medicinal plant species are trees (111 species; 29%), followed by herbs (93 species; 24%) and shrubs (75 species; 19%). A far lower number of lianas (31 species; 8%), epiphytes (28 species; 7%), non-woody climbers (25 species; 6%) and graminoids (11 species; 3%) are used as medicinals. These proportions are more or less in accordance with the representation of different growth forms in the entire inventoried flora. However, regression standard residual analysis shows that based on the number of plant species inventoried per growth form (NSGF), herbs are overrepresented as medicinal species (regression equation: NMS = 0.254* NSGF +14.859; r^2=0.67 and p=0.004). As discussed further in detail in chapter 10 (section 10.4.3.), this is not a real surprise because it has been argued before that the popularity of herbaceous plants in traditional medicine can be linked to their higher likeliness to contain bioactive phytochemicals as compared to woody growth forms (Stepp and Moerman, 2001; Voeks, 2004).

More than half of the medicinal species listed here typically grows in natural environments, including old growth forest (49%) and riverbanks (7%). More than one-third (35%) prevails in homegardens and swiddens. Other disturbance habitats where medicinal plants are collected include fallows (3% of species), secondary forest (3%) and ruderal places (3%). Hence, almost half of all plants used in traditional medicine in TIPNIS come from disturbance habitats.

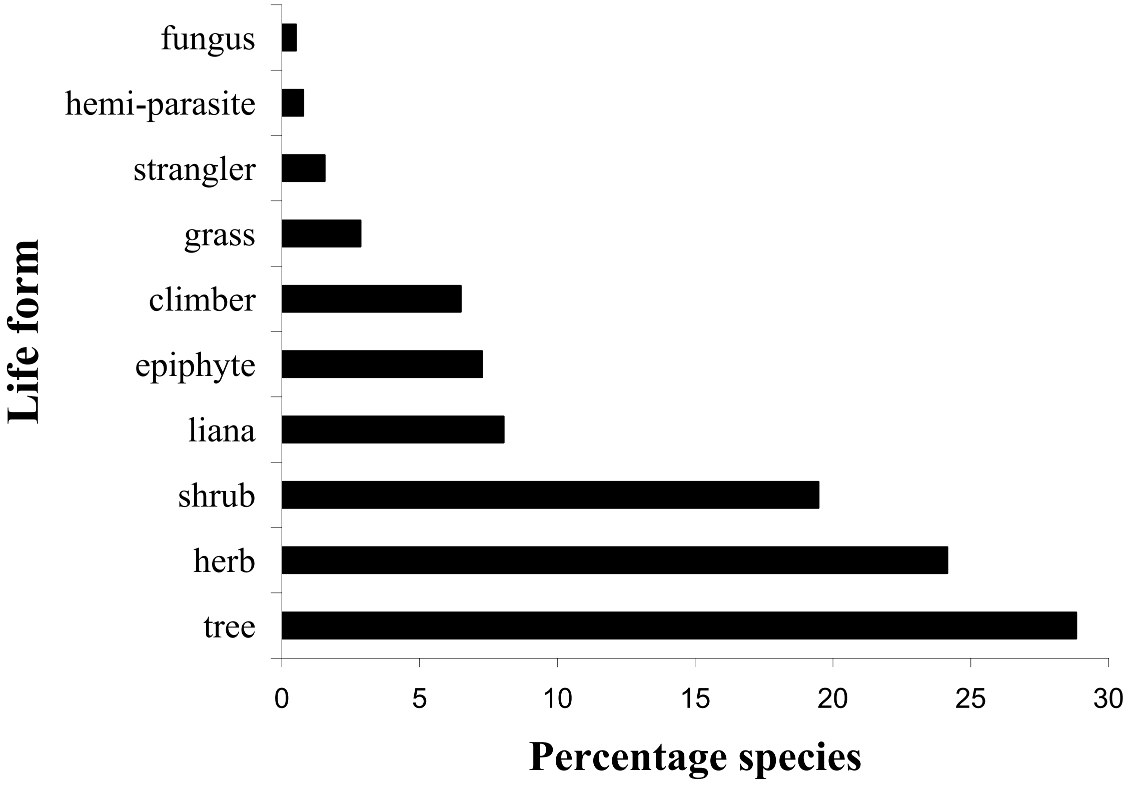

Figure 8.6: Proportional distribution of life forms of medicinal plants and fungi in TIPNIS

These results support the growing consensus regarding the importance of disturbance landscapes in the provision of medicinal remedies (Posey, 1984; Balée, 1994; Voeks, 1996; Ankli *et al.*, 1999a; Frei *et al.*, 2000; Stepp and Moerman, 2001; Thomas, 2001; Etkin, 2002;

Begossi *et al.*, 2002; Di Stasi *et al.*, 2002; Hernández Canoa and Volpato, 2004; Voeks, 2004). The usefulness of moderately humanized landscapes as sources of healing principles is often explained through the existence of a causal link between the frequency and/or intensity of contact with certain species and their utility (Voeks, 1996 and 2004). In other words: the better a species is known from its prevalence, the higher the probability that people will ascribe medicinal uses to it. In chapters 9 and 10, we provide a more profound discussion on these topics and test their validity on our own data. Twenty-seven medicinal species (7%) used in TIPNIS were initially introduced from the Old World. These are also listed and discussed in chapter 10 (tables 10.2 and 10.3).

8.3.6.4. Ailment Categories

To obtain a general overview of medicinal plant use in TIPNIS, recorded medicinal uses of inventoried plants (N=387) were classified according to general ailment categories defined by Cook (1995) and whereto we added the category of 'Culture-Bound Syndromes'. Figure 8.7 shows the broad range of ailment categories Trinitario and Yuracaré participants cure with medicinal plants. Most medicinal plant use and knowledge in TIPNIS seems to be situated in the ailment categories *Infections/Infestations*, *Digestive Disorders*, *Pain* and *Injuries*. For these categories, more than 200 medicinal responses and 100 medicinal species responses were documented.

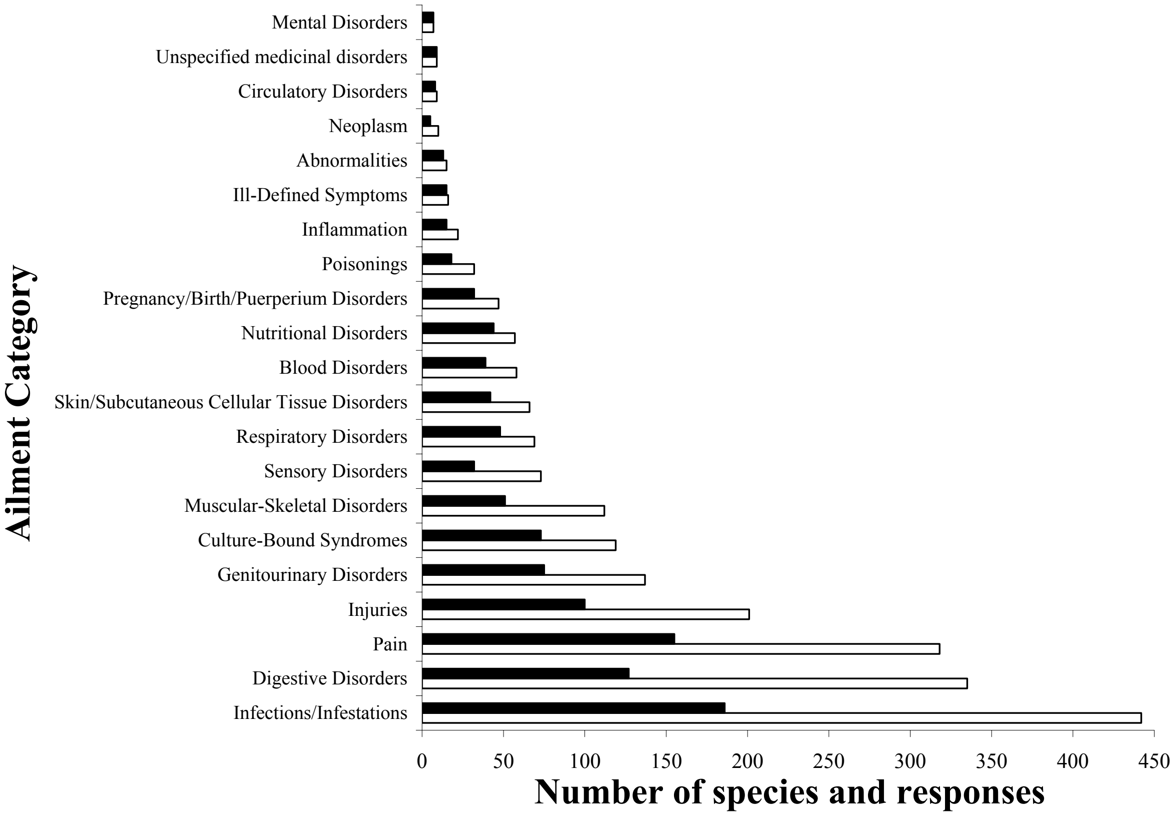

Figure 8.7: Distribution of medicinal species and medicinal responses over ailment categories defined by Cook (1995). Many plant species have multiple medicinal uses and are therefore classified under various ailment categories (white bars: number of responses; black bars: number of species).

A comparison of ailment categories based on Factors of Informant Consensus (F_{ic}) (Trotter and Logan, 1986; Heinrich *et al*., 1998b; Leonti *et al*., 2001), shows that highest level of agreement between participants is obtained for *Digestive Disorders* (0.62), *Infections/Infestations* (0.58), *Sensory Disorders* (0.57) and *Muscular-Skeletal Disorders* (0.55). These results are in agreement with other studies among societies living in tropical forest environments where gastrointestinal ailments, rheumatic complaints, skin afflictions (including injuries of the skin) or infectious disorders seem to yield the highest number of plant remedies and/or the highest consensus among indigenous participants (e.g. Milliken and Albert, 1997; Bourdy *et al*., 2000; van Andel, 2000).

8.3.6.5. Informant Consensus: Unanimity in Treating Health Conditions

A total of 107 different health conditions (including 3 veterinary disorders) were reported during ethnobotanical interviews. Eight of these are related to pain in different body parts (e.g. toothache, backache, headache, abdomen pain, etc.). The most diverse medicinal plant use was recorded for pain as a general symptom (155 species), followed by fever (94 species), stomach-ache (62 species), diarrhoea (54 species), *susto* (50 species) and bruises (49 species). For a description and symptoms of bad wind and *susto* the reader is referred to chapters 3 (section 3.3.4.4.) and 11, respectively.

Table 8.5 lists health conditions with IAR values higher than 0. Highest consensus was documented for worm infection, fractures and sprains, otitis, diarrhoea, wounds, and pain as a general symptom. There was no consensus at all regarding the use of medicinal plants for the treatment of 50 additional health conditions. These conditions are therefore not listed in table 8.5.

8.3.6.6. Quality of Medicine[2]

In TIPNIS, the emic perception of the efficacy of plant remedies for treating different health conditions is subject to a considerable amount of variation. Some plants clearly provide better remedies than others for treating similar health conditions. To quantify the proportion of less potent herbal remedies in ethnomedicine in TIPNIS, Trinitario and Yuracaré participants were encouraged to systematically assess the quality of each remedy on an ordinal scale, choosing between (1) good to excellent; (2) fair; or (3) bad. Quality of remedies was reported for a total of 1477 responses and "good to excellent" scored highest with 89%, followed by "fair" (10%). Only twelve responses (1%) referred to the rather bad quality of herbal remedies. Analogously to Apillapampa, participants often declared that remedies classified as 'fair', may be case and patient specific: sometimes and in some persons they are effective in alleviating particular symptoms but in other cases or persons they are not helpful at all.

Health conditions with the highest percentage of remedies reported as "fair" and/or "bad" in quality are headache (6 responses; corresponding with 30% of the responses for this health condition), hernia (11; 27%), fever (27; 26%), uterus ailments (2; 20%), scabies (8; 20%), body pains (9; 20%), otitis (4; 18%), cough (5; 18%), kidney ailments (4; 17%) and rheumatism (4; 17%) (only health conditions with at least 10 responses are given).

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[2] Results described in this section apply only on the present study and not on Vandebroek *et al*. (2004 a and b)

Table 8.5: IAR values for health conditions in TIPNIS. Only those health conditions for which the number of responses was higher than 3 and IAR>0 are listed. Animal medicine is not included.

disorder	# spp	# resp	IAR	disorder	# spp	# resp	IAR
worm infection	20	72	0.73	insect infestations (skin)	7	10	0.33
fractures/sprains	20	63	0.69	swelling	15	22	0.33
otitis	9	26	0.68	*susto*	50	72	0.31
diarrhoea	54	127	0.58	headache	33	47	0.30
wounds	47	99	0.53	candidiasis	8	11	0.30
pain (general)	155	318	0.51	bad wind	32	45	0.30
female sterility	3	5	0.50	bruises	49	69	0.29
insect stings	13	25	0.50	labour pain	6	8	0.29
lactation stimulant	2	3	0.50	post-partum	11	15	0.29
dysentery	2	3	0.50	hernia	9	12	0.27
snake bite	2	3	0.50	scabies	36	49	0.27
skin fungus	18	34	0.48	malnutrition	32	43	0.26
ophthalmia	25	47	0.48	rheumatism	31	41	0.25
abdomen pain	66	123	0.47	body pains	62	81	0.24
purgative	8	14	0.46	influenza	11	14	0.23
stomach-ache	62	107	0.42	anal ailments	5	6	0.20
dysuria	17	28	0.41	hair loss	5	6	0.20
haemorrhages	20	33	0.41	pneumonia	13	16	0.20
leishmaniasis	25	41	0.40	kidney ailments	30	37	0.19
fever	94	155	0.40	menorrhagia	14	17	0.19
anuria	12	19	0.39	uterus ailments	11	13	0.17
abscesses/furuncles	35	56	0.38	vomiting	16	19	0.17
cough	28	43	0.36	cardiovascular ailments	7	8	0.14
toothache	36	54	0.34	oedema	13	15	0.14
anaemia	39	58	0.33	gastroenteritis	9	10	0.11
anti-abortive	5	7	0.33	dysmenorrhoea	12	13	0.08
fungal infection	9	13	0.33				

spp= number of species used; # resp= number of responses; IAR= informant agreement ratio

8.3.6.7. Culturally Most Relevant Medicinal Remedies and Species

Medicinal Plant Remedies

A total of 1380 different plant remedies (or medicinal plant uses) have been documented in TIPNIS. A plant remedy is defined as the use of one particular plant for one particular health condition, irrespective of the preparation or plant part used. In figure 8.8, the number of plant remedies is plotted against the number of participants who confirmed these remedies. On average, remedies were confirmed by 1.6 (±1.5) participants. Nearly one fourth of all reported remedies (i.e. 24% or 337 remedies) was confirmed by at least two participants. The inverted J-shaped curve obtained for TIPNIS (figure 8.8) is very similar to that obtained for Apillapampa (figure 3.8, chapter 3). Hence, it corroborates our argument from chapter 3 that there exists a widespread pattern whereby few remedies are known by almost everyone while most plant knowledge is idiosyncratic (also see Friedman *et al.*, 1986; Barrett, 1995; Alexiades, 1999; Casagrande, 2002).

Highest consensus was recorded for the remedies listed in table 8.6. The large majority of interviewed participants agreed on these uses and therefore the likelihood that these plants are bioactive is probably higher than for other species. Most remedies with a high participant consensus are prepared with native species, but the therapeutic potential of some introduced medicinal species such as *Ocimum micranthum*, *Zingiber officinale* and *Cymbopogon citratus* (Bennett and Prance, 2000) is also widely recognized in TIPNIS (see Thomas and Vandebroek, 2006).

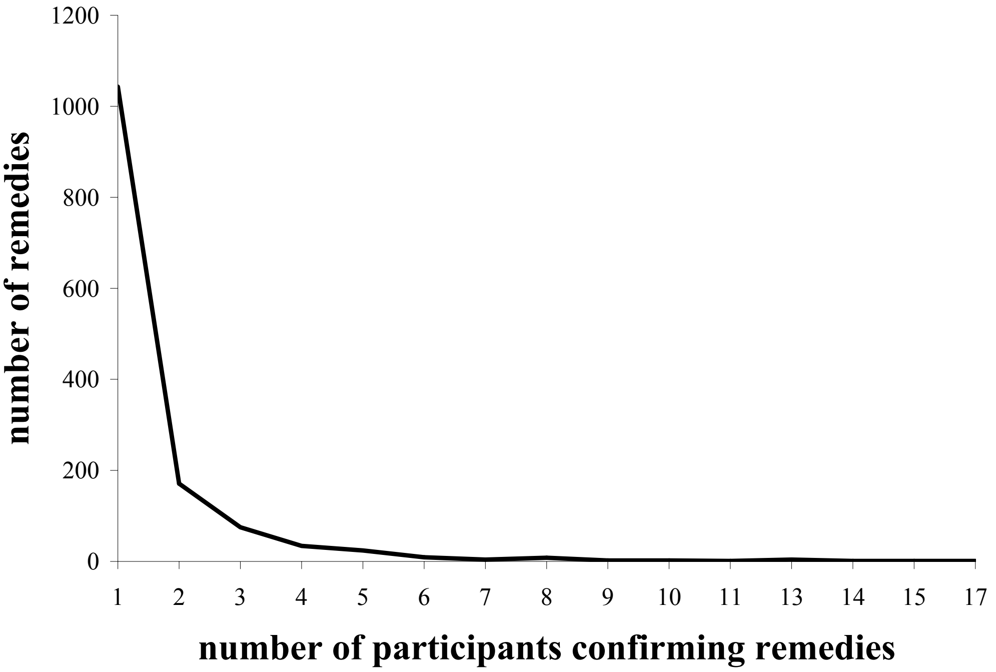

Figure 8.8: Number of remedies versus the number of participants who confirm these remedies in TIPNIS

Table 8.6: Medicinal plant remedies ranked according to participant consensus (only species with a consensus higher than 7 are shown)

Scientific name	Health condition	Number of confirming participants
Cyathea pungens	wounds	17
Ficus insipida	worm infection	15
Salmea scandens	abdomen pain	14
Jatropha curcas	worm infection	13
*Ocimum micranthum**	ophthalmia	13
Triplaris americana	diarrhoea	13
*Zingiber officinale**	abdomen pain	13
Ficus paraensis	fractures/sprains	11
Geophila macropoda	skin fungus	10
Salix humboldtiana	diarrhoea	10
Ficus insipida	anaemia	9
Sida rhombifolia	fever	9
Aspidosperma rigidum	diarrhoea	8
Aspidosperma rigidum	abdomen pain	8
*Cymbopogon citratus**	abdomen pain	8
Guarea guidonia	worm infection	8
Peperomia rotundifolia	ophthalmia	8
Psidium guajava	diarrhoea	8
Struthanthus acuminatus	fractures/sprains	8
Uncaria guianensis	diarrhoea	8

*= exotic

Medicinal Plant Species

On average, ethnomedicinal data was provided by 3.4 (±3.5) participants per medicinal plant species. The medicinal use of 74 (19% of the total number of medicinal plants) and 155 species (41%) was confirmed by only one and two participants, respectively. Medicinal plant species that have the most diverse ethnomedical applications are listed in table 8.7. Many of these species also score high for medicinal (quality) use values (table 8.8), partly due to the fact that both medicinal UV_s and QUV_s values of plants are related to the number of medicinal applications per species (Kendall's τ_b=0.59 and 0.46, respectively; $p<0.001$ for both cases).

Table 8.7: Medicinal plant species with the highest number of different medicinal applications

Scientific name	# part	# med uses	Scientific name	# part	# med. uses
Chenopodium ambrosioides	12	21	*Hura crepitans*	16	13
Petiveria alliacea	20	20	*Erythroxylum coca*	9	13
Urera baccifera	16	18	*Sida rhombifolia*	11	13
Polygonum punctatum	14	17	*Ricinis communis**	14	13
Peperomia rotundifolia	17	16	*Ocimum micranthum**	16	12
Nicotiana tabacum	11	15	*Bixa orellana*	9	12
Uncaria guianensis	19	15	*Zingiber officinale**	11	12
Jatropha curcas	19	14	*Pothomorphe peltata*	18	12
Uncaria tomentosa	15	14	*Aspidosperma rigidum*	15	12
Salmea scandens	19	14	*Urera laciniata*	7	12

part= participants; med uses= medicinal uses
*= exotic

In analogy with data from Apillapampa (see chapter 3), table 8.8 shows that the medicinal quality use values of plant species are generally lower than their corresponding medicinal use values. This illustrates that even for the most highly valued medicinal plants not every reported ethnomedical application is perceived to be of "good" quality. Regressing medicinal quality use values of species on their medicinal use value results in a R^2 value of 77, indicating that assigning qualities to medicinal uses explains nearly one fourth (23%) of variance in QUV_s values, hereby confirming the relevance of the latter index. As for Apillapampa, QUV_s values calculated for TIPNIS tend to incorporate informant consensus better than UV_s values. Table 8.8 shows that the ranking obtained for QUV_s selects a combination of those species that have the highest consensus for particular remedies (table 8.6) *and* those species with the highest number of medicinal applications (table 8.7).

Correlation analysis shows that both a species' IAR_s and QUV_s values correlate strongly with the number of good quality responses reported for that species (Kendall's τb= 0.63; $p<0.001$ for both cases). This indicates that QUV_s's take into account consensus because a higher degree of consensus about remedies parallels a higher incidence of "good quality" responses.

In chapter 3, we proposed using quality use agreement ratios ($QUAR_s = QUV_s * IAR_s$) as a way to estimate the importance of medicinal plant species for a particular ethnic group. We argued that the strength of this index is that it incorporates both quality use values (QUV) and informant agreement ratios calculated for individual species (IAR_s). Both indices focus on different aspects of ethnobotanical data. Here we verify, whether this argument, which was based on data from Apillapampa also holds true for our study in TIPNIS.

Table 8.8: Medicinal plant species with highest medicinal use value (UV) and quality use value (QUV). Top fifteen species according to UV and QUV values are underlined in the corresponding columns. Species in the top ten of IAR$_s$ values are marked in bold. Only species that were shown to at least 3 participants are included

Scientific name	**# medicinal uses**	**# participants**		**UV$^1_{medicine}$**	**QUV$^2_{medicine}$**	**IAR$_s$**
		Combined^1	Present^2			
Cissus gongylodes	5	3	3	3.00	3.00	0.50
Chenopodium ambrosioides	21	12	6	3.00	2.50	0.43
Nicotiana tabacum	15	11	7	2.73	1.86	0.52
Sida rhombifolia	13	11	7	2.55	2.00	0.56
Polygonum punctatum	17	14	10	2.36	1.23	0.50
*Zingiber officinale**	12	11	7	2.27	1.57	0.54
Erythroxylum coca	13	9	5	2.22	1.00	0.37
Petiveria alliacea	20	20	16	2.10	1.59	0.54
Carica papaya	10	11	5	2.09	1.78	**0.59**
*Kalanchoe pinnata**	10	12	8	2.08	1.81	**0.63**
Eleutherine citriodora	3	3	3	2.00	2.00	**0.60**
Triplaris americana	11	13	9	2.00	2.00	**0.60**
*Cymbopogon citratus**	9	10	6	2.00	1.08	0.58
Pereskia sacharosa	5	7	7	2.00	2.00	**0.64**
Bixa orellana	12	9	5	2.00	1.30	0.35
Vernonia patens	6	4	7	2.00	-	0.29
Urera laciniata	12	7	3	2.00	0.33	0.15
Jatropha curcas	14	19	15	1.95	1.72	**0.64**
Salix humboldtiana	11	14	10	1.93	1.50	**0.62**
Gallesia integrifolia	8	9	9	1.89	1.89	0.56
Aspidosperma rigidum	12	15	11	1.87	1.50	**0.59**
Ficus insipida	8	19	15	1.84	1.67	**0.79**
*Ocimum micranthum**	12	16	12	1.81	1.42	**0.61**
Hura crepitans	13	16	12	1.81	1.58	0.57
Salmea scandens	14	19	15	1.79	1.67	**0.61**

^{1}: based upon combined results from the present study and Vandebroek *et al.* (2004a and 2004b)
^{2}: based upon results from the present study only
***=introduced species**

Medicinal species with highest IAR$_S$ values are given in table 8.9. Although both medicinal UV$_S$ and QUV$_S$ correlate positively with IAR$_S$ (Kendall's τ_b= 0.23 and 0.45, respectively; p>0.001 for both cases), ranking of species based on IAR$_S$ (table 8.9) is significantly different from rankings according to UV$_S$ and QUV$_S$ values (table 8.8). The only species that is listed in both tables is *Ficus insipida*. This outcome is, at least in part, related to the fact that rankings based on UV$_S$ and QUV$_S$ values favour plant species with multiple medicinal applications, whereas IAR$_S$ is much less sensitive to this characteristic. Instead, a ranking based on IAR$_S$ values favours species with high participant consensus. This is also evidenced by the fact that the number of different medicinal uses per species is significantly higher (p<0.001; Mann-Whitney) for species with the highest medicinal UV$_S$ and QUV$_S$ values (table 8.8) than for species with the highest IAR$_S$ values (table 8.9).

Nonetheless, the IAR$_S$ of a medicinal plant species correlates positively with its number of medicinal uses (Kendall's τ_b=0.37; p<0.001), similar to UV$_S$ and QUV$_S$. However, regression analysis shows that the number of medicinal uses per species explains only 8% of the variation in IAR_s values ($R^2=0.08$; $p=0.002$), against 17% of the variation in UV_s values ($R^2=0.17$; $p<0.001$) and 36% of the variation in QUV_s ($R^2=0.36$; $p<0.001$). Hence, IAR_s seems to be less sensitive for the number of different medicinal uses reported per species than UV_s and QUV_s.

Table 8.9: IAR_s values for medicinal species in TIPNIS; only those species for which the number of responses is higher than 3 are listed

Scientific name	# participants interviewed	# responses	# medicinal uses	IAR_s
Rauvolfia praecox	3	3	1	1.00
Coussapoa villosa	5	5	1	1.00
Geophila macropoda	14	10	1	1.00
Alsophila cuspidata	9	4	1	1.00
Lycianthes asarifolia	7	3	1	1.00
Psidium guajava	12	9	2	0.88
Ficus paraensis	14	14	3	0.85
Ficus insipida	19	35	8	0.79
*Portulaca grandiflora**	12	10	3	0.78
Struthanthus acuminatus	11	13	4	0.75
Tabernaemontana vanheurckii	6	5	2	0.75
Ormosia nobilis	6	5	2	0.75
Jessenia bataua	8	5	2	0.75
Genipa americana	8	5	2	0.75
Cyathea pungens	17	30	10	0.69
Ficus guianensis	6	7	3	0.67
*Momordica charantia**	7	7	3	0.67
Mucuna rostrata	9	7	3	0.67
Cyperus luzulae	7	4	2	0.67
Maxillaria funicaulis	10	4	2	0.67

*=introduced species

Medicinal QUV_s and IAR_s values of plants correlate significantly with the number of participants interviewed (Kendall's $\tau_b=0.92$ and 0.53 respectively; $p<0.001$ for both cases). These correlations indicate that probably higher QUV_s and IAR_s values would have been obtained if the number of interviewed participants per species had been higher and equal for all species. A plants' medicinal UV_s does not correlate with the number of participants interviewed.

In sum, rankings based on QUV_s values favour species with multiple ethnomedical uses, whereas IAR_s favours plants with high informant consensus. Hence, our reasoning behind the calculation of $QUAV_s$ in chapter 3 holds true for data obtained from TIPNIS. In table 8.10, the top 20 ranking of medicinal plant species according to $QUAV_s$ values shows that several species from the top twenty based on IARs and QUVs are represented in the former ranking as well, although in an uneven way (5 and 15 species, respectively).

8.3.6.8. Explaining High Numbers of Medicinal Plants per Health Condition

A certain number of health conditions in TIPNIS is treated with many medicinal plants. These include fever, stomach-ache, and diarrhoea (see table 8.5). Based on a high degree of informant consensus (table 8.6) and available experimental biomedical evidence (Thomas and

Vandebroek, 2006) some of these health conditions probably can be treated effectively by only a few species. For example, latex from *Ficus insipida* is such a highly potent antihelmintic (Thomas and Vandebroek, 2006) that it was used some years ago in official deparasitation campaigns organised by state health services in the Bolivian lowlands (C. Moretti, pers. comm.). Nevertheless, even though *F. insipida* is present and used in TIPNIS, a total of twenty different plant species was documented for expelling intestinal parasites. Likewise, we have personally witnessed the impressive wound-healing properties of *Cyathea pungens*. Yet, no less than 47 different plant species were mentioned for wound healing. Hence, the question arises as to what might be the reason why people use so many different plant species to cure specific ailments, while they have highly effective ones at their disposal.

Table 8.10: Ranking of medicinal species according to decreasing quality use agreement values (QUAV$_s$)

Scientific name	# disorders	# participants interviewed	UV$_{med}$	QUV$_{med}$	IAR$_s$	QUAV$_s$
Cissus gongylodes	5	3	3.00	**3.00**	0.50	1.50
Ficus insipida	8	19	1.84	**1.67**	**0.79**	1.32
Pereskia sacharosa	5	7	2.00	**2.00**	0.64	1.27
Cyathea pungens	10	17	1.76	**1.76**	**0.69**	1.21
Eleutherine citriodora	3	3	2.00	**2.00**	0.60	1.20
Triplaris americana	11	13	2.00	**2.00**	0.60	1.20
Kalanchoe pinnata	10	12	2.08	**1.81**	0.63	1.13
Sida rhombifolia	13	11	2.55	**2.00**	0.56	1.11
Jatropha curcas	14	19	1.95	**1.72**	0.64	1.10
Chenopodium ambrosioides	21	12	3.00	**2.50**	0.43	1.07
Struthanthus acuminatus	4	11	1.18	1.43	**0.75**	1.07
Gallesia integrifolia	8	9	1.89	**1.89**	0.56	1.06
Carica papaya	4	11	2.09	**1.78**	0.59	1.05
Salmea scandens	14	19	1.79	1.67	0.61	1.01
Rauvolfia praecox	1	3	1.00	1.00	**1.00**	1.00
Guarea macrophylla	8	13	1.46	**1.62**	0.61	0.99
Nicotiana tabacum	15	11	2.73	**1.86**	0.52	0.96
Salix humboldtiana	11	14	1.93	1.50	0.62	0.92
Hura crepitans	13	16	1.81	**1.58**	0.57	0.90
Ficus paraensis	3	14	1.00	1.05	**0.85**	0.89

Obviously, a high number of plant species used for treating similar health conditions in TIPNIS is partly related to the fact that the results presented here represent the combined knowledge of two ethnic groups (Yuracarés and Trinitarios). However, we hypothesize that some of the factors proposed in chapter 3 that explain high levels of medicinal plant use in Apillapampa might by valid here as well. These include: (1) availability and accessibility of medicinal plants; (2) characteristics related to specific health conditions; and (3) sensory perception of plant species. In addition, in chapter 10, the number of medicinal plants used by Yuracarés and Trinitarios is viewed in light of the respective contact history and traditional lifestyle of both ethnic groups.

Spatial Availability

In the southern part of TIPNIS, availability and accessibility of plant species are mainly determined by spatial parameters like physical accessibility and seasonal availability, although the latter to a lesser extent. Seasonality seems particularly relevant for specific plant parts because reproductive organs of many if not most plants are only available during short periods of the year. However, spatial availability is a far more important factor in explaining the variability in plant use. The results from our transect sampling in TIPNIS (chapter 6) suggested an extreme level of floristic heterogeneity between different forest types people have at their disposition. This adds to evidence that most of upper Amazonia constitutes a conspicuous habitat mosaic with very different sets of plant species occurring in adjacent communities on different substrates and topographical units (Gentry, 1988b; Valencia *et al.*, 2004). In addition, our results also support another general Amazonian trend described in literature (e.g. Gentry, 1988b; Cerón and Montalvo, 1998; Valencia *et al.*, 2004; Macía and Svenning, 2005), i.e. only a small portion of species in forests seems to be omnipresent and relatively common to most areas, while the large majority occurs at extremely low densities. Such a highly uneven distribution of forest species is expected to complicate people's ability to consistently track down and collect particular (medicinal) species when needed (at a short notice). As argued in chapter 3 (section 3.3.4.7.), accessibility or availability of plants have been reported among the primary considerations for indigenous people when selecting a treatment option, at least during the early stages of an illness episode (Alexiades, 1999; Casagrande, 2002). Therefore, knowledge about several alternative plant species for treating similar health conditions is an advantage when one wants to respond quickly to a health condition.

The influence of plant availability and accessibility on medicinal plant use might be particularly relevant in view of the migratory history of Yuracarés and Trinitarios. Until recently (up until the arrival of Andean settlers in the early 1970s), Yuracarés engaged in a semi-nomadic lifestyle, changing settlements every 3-8 years (Paz, 1991; Nordenskiöld, 2003; Querejazu, 2005a). By contrast, Trinitarios originally had a sedentary society. However, as discussed profoundly in chapter 10, land pressure problems in their homelands, i.e. the plains of Moxos, forced many Trinitarios to flee and search for new havens (Riester 1976; Lehm 1999). The Trinitario communities who participated in the present research were founded from the 1970s onwards (Vandebroek *et al.*, 2004a) as a result of this migration. However, establishment of these communities was not the result of relocation from one place (the plains of Moxos) to another (TIPNIS). It has been the outcome of years of peregrinations throughout Bolivian lowlands. Whether it is within the same habitat (as is the case for Yuracarés), or between different habitats (as is the case for Trinitarios), the act of moving around and/or human dispersion confronts people with various sets of plants. This, in turn, probably favours an extensive plant pharmacopoeia (Milliken and Albert, 1997). For a more profound discussion on this topic, the reader is referred to chapter 10.

Characteristics of Health Conditions

Data from TIPNIS support the notion that the number of medicinal plants used to treat particular health conditions correlates positively with prevalence of these conditions (e.g. van Andel, 2000; Vandebroek *et al.*, 2008). From the literature, it is known that gastrointestinal complaints (such as (infant) diarrhoea), parasites, respiratory ailments, fever, leishmaniasis and conjunctivitis tend to be more frequent in Neotropical lowland areas as compared to the Andean area (Gimenez Turba, 1996; Oths, 1998). A small household survey was conducted to identify the most prevalent disorders in the participating communities. The male or female household head, or both (according to presence at the time of interviewing) were asked to spontaneously mention those disorders or illnesses they considered most important and/or serious through free listing (Alexiades 1996a; Quinlan 2005). In total, 24 Yuracaré and Trinitario households were interviewed.

A total of 21 different health conditions was recorded during these free listing sessions (table 8.11). Most frequently reported health conditions were fever (75% of households), followed by diarrhoea (58%), cough (54%), *susto* (33%), flu (33%), pain as a general symptom (25%) and intestinal parasites (21%) (table 8.11). Interestingly, eight of ten health conditions for which the highest number of medicinal species are used, were mentioned during the household survey. It is possible that people failed to mention bruises and wounds because these conditions are too trivial to be mentioned. Nevertheless, in analogy with our observation for Apillapampa, people cut and bruise themselves frequently because most activities and work are done with traditional tools (machetes) and human muscle. Of the twenty health conditions treated with the highest number of medicinal species, fifteen were mentioned during the household survey. These results suggest the existence of a correlation between the incidence of health conditions and the number of plant species used for treatment. However, this conclusion should be considered with diligence, taking into account the limited number of families that participated in the household survey.

Table 8.11: Results of household survey with percentages of interviewed households (N= 24) mentioning health conditions

Health condition	% households	Health condition	% households
fever*	75	vomiting	13
diarrhoea*	58	curse	13
cough°	54	stomachache*	13
*susto**	33	scabies*	13
flu	33	anemia*	8
pain general symptom*	25	bad wind°	8
intestinal parasites°	21	dysuria	8
headache°	21	rheumatism°	4
ophtalmia°	17	leishmaniasis°	4
toothache*	17	bad memory	4
cold	13		

* among 10 health conditions treated with highest number of medicinal species
° among 20 health conditions treated with highest number of medicinal species

Table 8.5 also highlights the trend whereby more medicinal plants are used to treat health conditions (disorders or symptoms) that can be provoked by a wide array of potential causal agents (i.e. MCAD, e.g. fever or diarrhoea) as compared to those that are caused by one (or a restricted number of) causal factor(s) (i.e. SCAD, e.g. fractures/sprains or candidiasis). For a more detailed discussion on this topic, the reader is referred to chapter 3 (section 3.3.4.7.).

Sensory Perception

The importance of sensory cues in the selection of medicinal plants may be highly relevant for Yuracarés and Trinitarios in TIPNIS. When participants were asked if bark preparations of specific tree species provided good medicines, they frequently answered: "of course … it is extremely bitter". As elsewhere, Yuracarés and Trinitarios mostly use bitter plants to cure diarrhoea or expel intestinal parasites (Heinrich *et al*., 1992; Van Damme *et al*., 1992; Milliken and Albert, 1997; Ankli *et al*., 1999a; van Andel, 2000; Shepard, 2004). In chapter 11, it is shown that aromatic to pungent plants are frequently used to treat *susto*. This is based on the belief that the repulsive odours will force symptoms to flee from the body. A similar line of thought has been described for the Waorani from Ecuador (Davis and Yost, 1983a). The concept of odour and taste seems to work both ways. On occasions when plants with bitter or pungent properties were encountered that were presently not used in traditional medicine, Yuracaré and Trinitario participants often suggested that they probably would provide good medicines against diarrhoea and *susto*, respectively.

The philosophy of the doctrine of signatures has been described for many Amazonian societies (Milliken *et al*., 1992, Balée, 1994; Plotkin, 1994; Grenand *et al*., 1987 and 2004; Casagrande, 2002; Shepard, 2002 and 2004). Hereby, medicinal properties are attributed to plants through morphological (and physiological) association. This doctrine also exists among Yuracarés and Trinitarios. For example, the white latex of various climbers (basically all in the Apocynaceae family) and herbs is used for wound healing (Thomas and Vandebroek, 2006). Casagrande (2002) interpreted this as an example of the doctrine of signatures in that people might associate the slowly hardening latex of these species after bleeding from cuts with the healing and scarring process in human tissue. The fact that *Carica papaya* is used as a lactation stimulant relates to the resemblance between a female breast and the form of the plant's fruits in combination with the white latex concealed in the fruit skin. According to Grenand *et al*. (2004), papaya is often linked to symbolics of fertility in tropical America; its name in Guarani literally means "fruit resembling a breast full of milk" (Storni, 1944; cited by Grenand *et al*., 2004). Another example is provided by the use of the penis-like adventive roots of *Iriartea deltoidea* for increasing penis length, whereas the bark of *Ceiba pentandra* is believed to help people gain weight, because it is the "fattest" (i.e. largest) tree available in the forest.

8.3.6.9. Modes of Plant Preparation and Plant Parts Used

Most herbal remedies in TIPNIS are applied externally (61%). Herbal baths are the most frequently mentioned preparation of medicinal plant remedies (figure 8.9). They are most often prepared by boiling medicinal plants in water, decanting and cooling the liquid, and then bathing the body or body parts with this decoction. Baths are mainly applied for treating fever (23%), *susto* (19%, see chapter 11), malnutrition (18%), body pain (10%) and anaemia (8%). Herbal teas follow second after herbal baths. Teas are prepared by soaking or boiling specific plant parts in (hot) water. They are drunk to cure diarrhoea (17%), abdominal pain (13%), stomach-ache (11%), kidney ailments (6%), anaemia (5%), cough (4%) and worm infections (4%). A preparation rather similar to teas is to macerate (pulverized or chopped) plant parts in ambient temperature water and drink the liquid. Plant extracts obtained in this manner are mostly used for treating abdominal pain (21%), diarrhoea (19%), worm infection (8%) and stomach-ache (5%). Occasionally, alcohol is added to herbal teas or macerations prior to consumption.

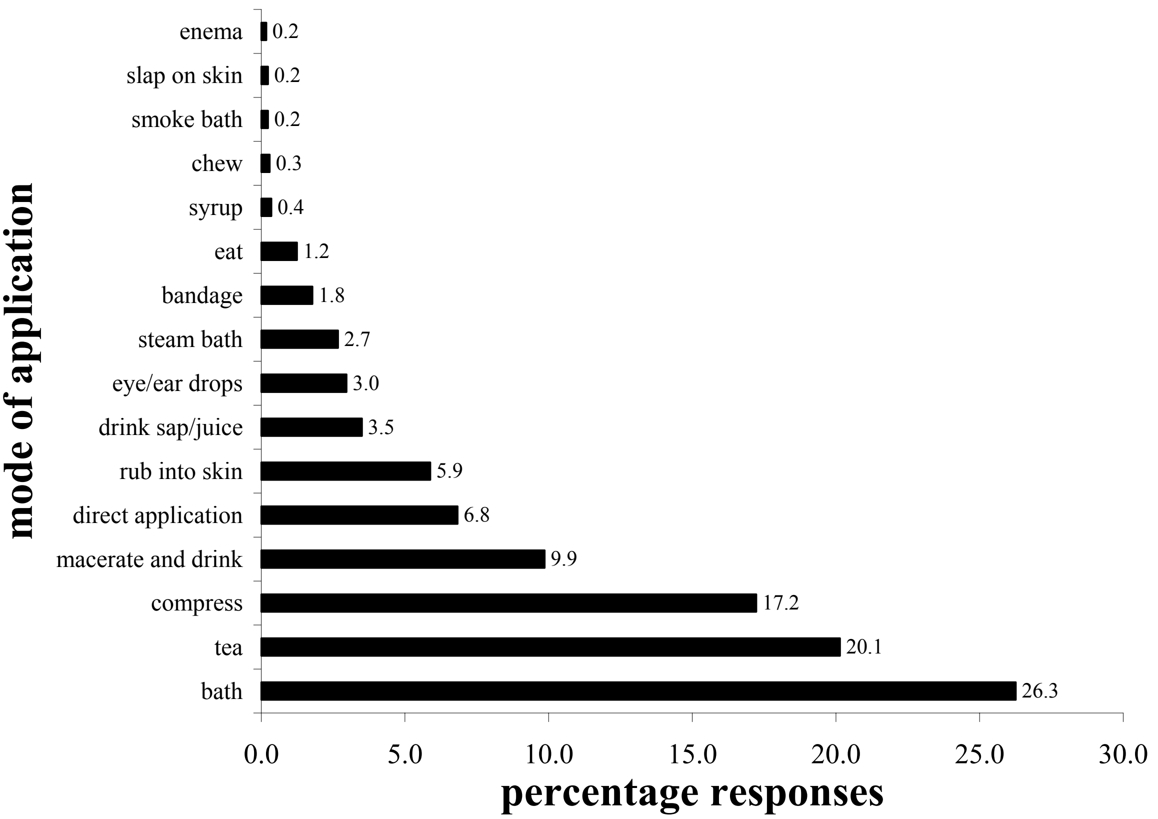

Figure 8.9: Relative frequency of different modes of applications of herbal remedies in TIPNIS as reported during ethnobotanical interviews

Also, the use of compresses is an important mode of application of medicinal plants in TIPNIS. Compresses are prepared by placing fresh, dried or boiled plant parts (grinded and occasionally mixed with salt, oil or raw eggs) on the afflicted part of the body by means of a piece of cloth. Compresses are most often used against bruises (14%), abscesses or furuncles (largely corresponding with the local term *puchichi*; 13%), wounds (12%), leishmaniasis (locally called *espundia*; 7%), scabies (7%) and swellings (7%). By contrast, bandages are exclusively used for treating fractures and sprains. Bandages consist of strips of bark of mainly strangler species (*Ficus* spp. and *Coussapoa villosa*) that are used to wrap fractures and sprains after rubbing the afflicted body part with raw eggs (Thomas and Vandebroek, 2006). Participants declare that once applied, such bandages tighten the wrapped body part and will remain in place until the patient is cured.

A significant portion of medicinal plants is applied directly to the body, without the need for cloths or other tools to keeping the remedy in place. This is the case for plant exudates (latex, sap, resin…) and dried plant parts ground to powder which are applied directly on wounds (32%), leishmaniasis eruptions (11%), fungal skin infections (11%) and sore teeth (10%).

There are various ways to prepare steam baths (representing some 3% of reported modes of application; figure 8.9). Sometimes, a small trench is dug out in the soil wherein smouldering coal is spread out, on top of which medicinal plants are placed. After this, water is poured over the plants to prevent them from burning. Next, the patient is to stand over the trench, covered with a blanket or piece of plastic so that the steam produced underneath has maximal contact with the body. Another way to produce steam is to simply boil plants in water or to add live coal to ambient temperature water containing medicinal plants. The latter approach is mostly used for treating specific body parts (e.g. teeth) instead of the entire body (e.g. rheumatism).

Syrups are prepared by boiling large quantities of plants in water for a long time so as to obtain a highly concentrated liquid which is decanted and mixed with honey to increase preservation time.

Many of these application modes have also been described for the Bolivian lowlands in general (De Lucca, 2004), and for a number of Bolivian lowland societies such as the Chacobo (Boom, 1987 and 1989), the Tacana (Bourdy, 1998 and 1999; De Walt et al., 1999; Bourdy *et al.*, 2000) and the Izoceño-Guaraní (Bourdy, 2002; Bourdy *et al.*, 2004).

Nearly one third of all cited herbal preparations consisted of leaves (29.8%), followed by bark (20.1%), stems (9.3), fruits (8.4%) and roots (6.8%) (figure 8.10). Other studies among Amazonian lowland communities confirm the dominant use of leaves, bark and fruits (e.g. Milliken *et al.*, 1992; Milliken and Albert, 1996; Balée, 1994; Bourdy *et al.*, 2000; van Andel, 2000).

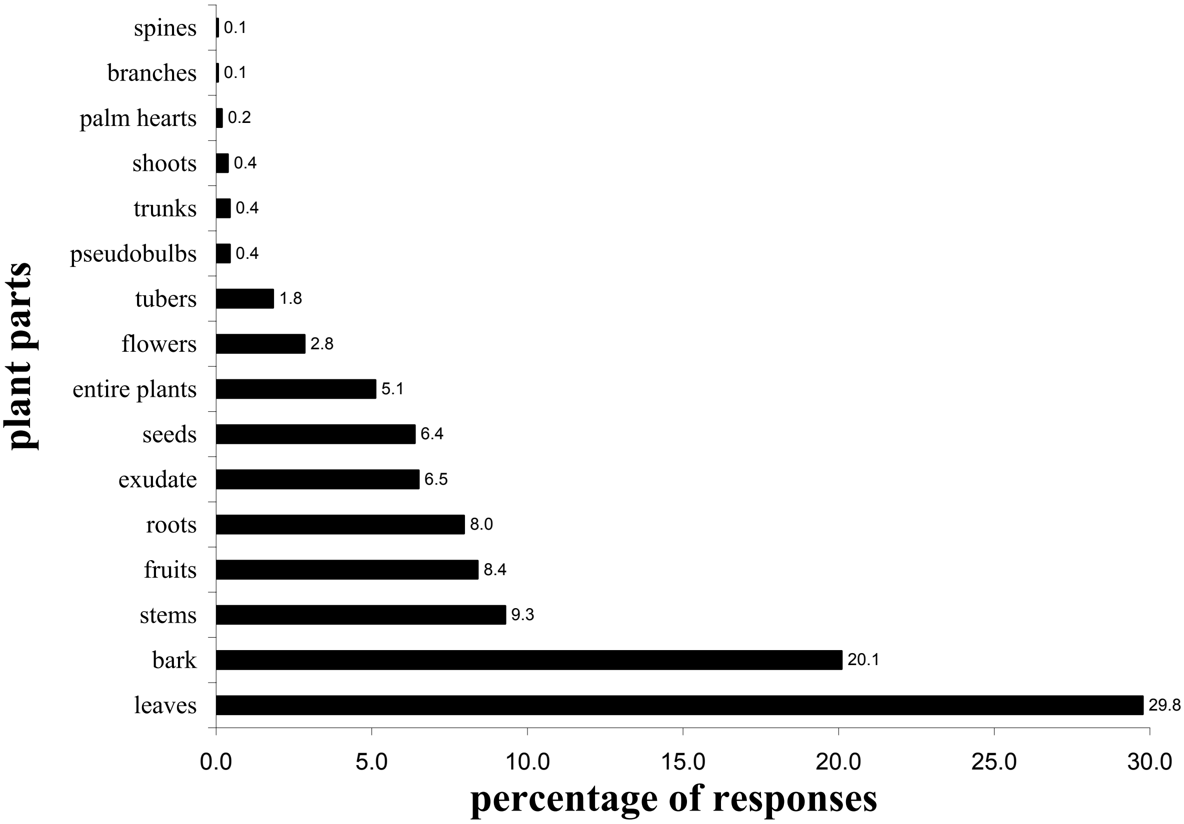

Figure 8.10: Plant parts used for preparing herbal remedies in TIPNIS

8.3.7. Food Plant Use

8.3.7.1. Most Important Edible Families and Genera

One-third (33%) of all plants that were shown to participants during the present study are used as food (i.e. 295 different species). All food species are distributed over a total of 71 different botanical families and 170 genera, whereby Fabaceae (38 species; 13%), Sapotaceae (19; 6%), Rubiaceae (14; 5%), Myrtaceae (14; 5%), Moraceae (13; 4%), Arecaceae (12; 4%), Sapindaceae (10; 3%) and Melastomataceae (10; 3%) are the ones containing most species in the inventory. Genera with the highest number of edible species are *Inga* (24 species), *Pouteria* (12) and *Paullinia* (10).

Regression analysis shows that the number of food species in a family (NFS) can be predicted from the size of the family (the latter is represented here as the total number of inventoried species in a family or NSF) ($NFS = 0.414 \times NSF - 0.480$; $r^2=0.70$ and $p<0.001$). Families with lower NFS than expected from their respective NSF are Lauraceae (with only 2 edible species out of 29 collected species), Euphorbiaceae (2 out of 24) and Nyctaginaceae (0 out of 16). Families with a higher number of edible species than predicted from the regression equation are Sapotaceae, Myrtaceae, Arecaceae, Myrsinaceae, Cecropiaceae, Moraceae and Anacardiaceae. These families are quite different from the over- and underused families for food species mentioned in Moerman's (1996) analysis of the food flora of native North Americans. The only family in common with Moerman's (1996) study is the Euphorbiaceae; in the latter study it ranks fourth among the most underused families for food (Moerman, 1996). Differences between Moerman's study and ours can obviously be attributed to differences in the local floristic composition. Phillips and Gentry (1993a) applied regression residual analysis on their data from Amazonian Peru, but did so by regressing categorical family use values on the number of species in a family instead of using the number of useful species. Nonetheless, the latter authors' findings are much more in correspondence with our results. In their study, Nyctaginaceae, Lauraceae and Euphorbiaceae ranked third, fourth and eighth of the most underused families with edible species, whereas Arecaceae, Fabaceae, Sapotaceae and Moraceae were significantly overused. The most overused families in the present study have also been identified as best-represented fruit tree families in other Amazonian studies (Milliken *et al.*, 1992; Balée, 1994; Stagegaard *et al.*, 2002; Van den Eynden *et al.*, 2003; Van den Eynden, 2004).

Hence, we have reason to believe that the regression residual analysis is a better method for identifying important food families as compared to calculating family use values proposed by Phillips and Gentry (1993a). The latter method seems to favour families with a relatively low number of species in the inventory. In the present study, families with high food family use values are Arecaceae (1.19), Dioscoreaceae (0.67), Anacardiaceae (0.63), Myrsinaceae (0.59), Musaceae (0.54), Theophrastaceae (0.54) and Sapotaceae (0.54). For three of these families, only three species were collected (Musaceae, Dioscoreaceae, Theophrastaceae), whereas for two families (Anacardiaceae and Myrsinaceae) this amounted to less than 7 species.

Seventy eight percent (78%) of food species are exclusively harvested from the wild. For a discussion of managed edible plant species in TIPNIS, the reader is referred to chapter 10.

Nearly all reported food plants are used by Yuracarés (93%; 275 species), whereas Trinitarios "only" use 58% (172 species).

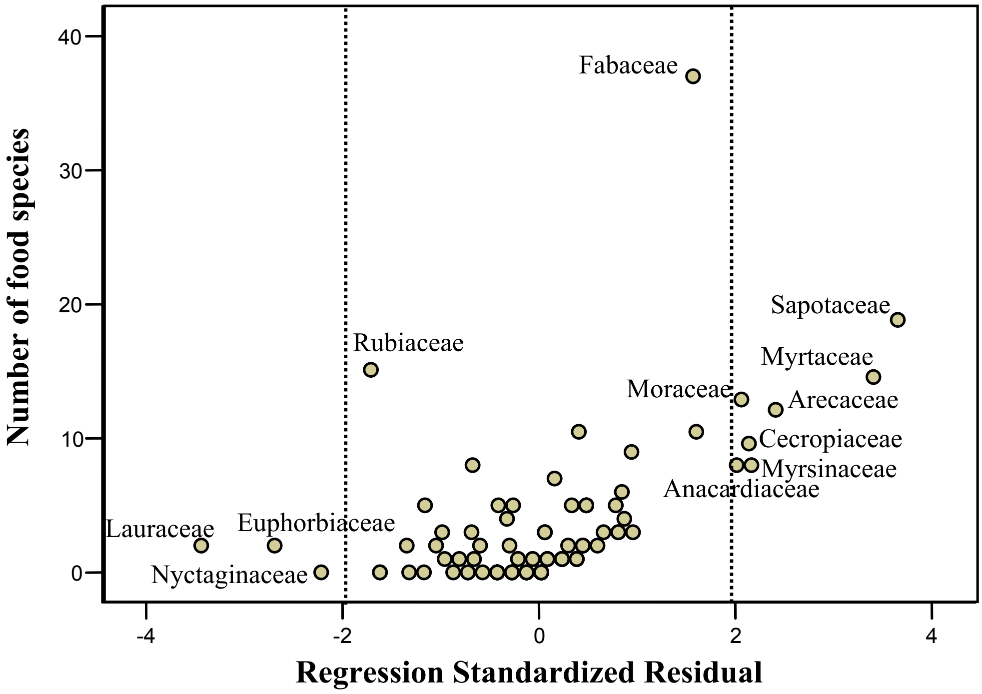

Figure 8.11 Numbers of food species (NFS) vs. standardized residuals of the regression of NFS on family size (NSF). Families with standardized residuals >1.96 or <-1.96 (p=0.05) have significantly higher, respectively lower NFS than expected from their size

Yuracarés have a superior knowledge of the wild edible flora as compared to Trinitarios. Evidence of this is that they know 213 food species, whereas Trinitarios reported 113 species. These numbers rise to 237 and 131, respectively, when including cultivated and tolerated species that also occur in natural environments. In chapter 10 (sections 10.4.2. and 10.4.4.), we discuss possible causes for the difference in knowledge about food plants between Trinitarios and Yuracarés. The number of wild plants regarded as edible by Yuracarés is undoubtedly among the highest ever reported for an Amazonian group. However, in spite of this extraordinarily high number, there are still other edible species that are regard as inedible by Yuracares such as the fruits of *Passiflora tricuspis* mentioned earlier (see section 8.3.1). Likewise, Yuracarés do not eat the edible tree tomato fruits either (*Solanum* sp. 3 (ET1455) and *Solanum exiguum*). This is in accordance with Balée (1994) who claims that "any estimation of the number of edible nondomesticates to a given Amazonian society […] is likely to be much lower than the potential of such food plants in the region, were the criteria of edibility based on actual parameters of biological toxicity rather than on highly variable cultural criteria." In this respect, Trinitarios and Yuracarés, regard certain plant species as inedible that are edible according to criteria of other cultures. For example, neither ethnic group considers any parts of the following species as edible (all occurring in TIPNIS): *Osteophloem platyspermum*, *Ceiba pentandra*, *Hibiscus rosa-sinensis* or *Bunchosia armeniaca*. However, according to Cavalcante (1976), Kunkel (1984) and Milliken *et al.* (1992), one or more parts of these species are consumed by at least one or more ethnic groups around the globe.

Occasionally, ritual practices are performed when harvesting particular food plants. The Yuracarés believe that vanilla plants (*Vanilla* spp.) have evil spiritual owners that will put a spell on whoever harvests their fruits. Therefore, vanilla fruits are "bathed" in tobacco smoke prior to harvest. As discussed in chapter 11, the spiritual connotation of tobacco and its ability to ward off evil spiritual divinities is widespread in Amazonia (Zerries, 1951).

The numbers of edible plants used by other Amazonian societies are substantially lower than in our study. According to Boom (1987), the Bolivian Chacobo use(d) a total of at least 102 edible species of which 75 are wild. Davis and Yost (1983b) initially documented only 44 wild species that were regarded as edible by the Ecuadorian Huaorani, but in a later study by Cerón and Montalvo (1998) this number was raised to 150. In his pioneering ethnobotanical study, Grenand (1980) found that the Wayãpi from French Guiana proscribed 129 nondomesticates as edible. Balée (1994) found that the Brazilian Ka'apor used 179 nondomesticated plants for food.

8.3.7.2. Subsistence Food Plants

In spite of the high number of wild edible plants, energy requirements among Yuracarés and Trinitarios are largely satisfied by formal horticulture. Nowadays, forest foods clearly provide a limited contribution to their diets (cf. Balée, 1994). Main staple food sources are *yuca* or cassava (*Manihot esculenta*), rice (*Oryza sativa*), bananas (*Musa sapientum*), plantain (*Musa paradisiaca*), including varieties and cultivars. One Trinitario participant distinguished between at least 7 *M. sapientum* and 4 *M. paradisiaca* varieties. Paz (1991) described five varieties of *yuca* that are cultivated by Yuracarés. Maize (*Zea mays*) is also cultivated. However, based on our observations, maize is only of minor importance for food consumption in the participating communities.

These starch foods are consumed in a variety of ways. Rice, *yuca,* plantains and maize are generally eaten cooked, while (sweet) bananas are eaten raw. It is also common practice to toast plantains and/or bananas in the fire to accompany almost any meal. Occasionally, rice and *yuca* are processed into bread, a practice that seems more common among Trinitarios than among Yuracarés. Alcoholic beverage (*chicha*) is prepared by fermenting decoctions of rice, *yuca* or maize in water, whereas beverages prepared from bananas or plantains are usually consumed as refreshing drinks.

Trinitarios also prepare cassava flour (*pito de yuca*) by peeling the fresh tubers and chopping them into small pieces that are dried during three days, out of reach from direct sunlight. The dried pulp is then ground by means of large mortars and pestles, sieved (see section 8.3.10 for plant species used) and dried in the sun. Once well dried, the flour is toasted in the fire. Participants claim that manioc flour processed in this way can be stored for several weeks. Due to its light weight and high caloric load it is often taken along on long journeys. *Pito de yuca* can be eaten dry, but is usually mixed with water and some sugar or honey, if and when the latter are available. The preparation of *pito de yuca* among Mojeños has also been mentioned by Eder (1772) and Denevan (1980).

The majority of food plants are trees (169 species; 57%) and shrubs (45 species; 15%), followed by lianas (34 species; 12%), herbs (19 species; 6%) and climbers (15 species; 5%). Five (hemi-)epiphytes, four grasses, two fungi and two strangler species are also provide edible plant parts. In chapter 10, the role of growth form in edibility of plants is discussed more in detail.

8.3.7.3. Plant Parts Used

A total of 378 different food uses were reported for the 295 species reported as edible. The majority of food uses are based on fruits (74% of uses), followed by edible seeds (8%) (figure 8.12). A number of edible fruits and seeds recorded in the present study have also been identified by some recent publications (Mostacedo and Uslar, 1999; Vasquez and Coimbra, 2002). However, for many other species the present study might be the first to report on their edibility. Eleven liana species and one bamboo supply potable water (5%). Participants claimed to eat the tubers of 5 cultivated and 6 wild species (3%), whereas also the palm hearts (i.e. young leaves, rolled in the crownshaft that have not yet been exposed to sunlight (van Andel, 2000)) of seven palm taxa were reported as consumed in different ways (3%).

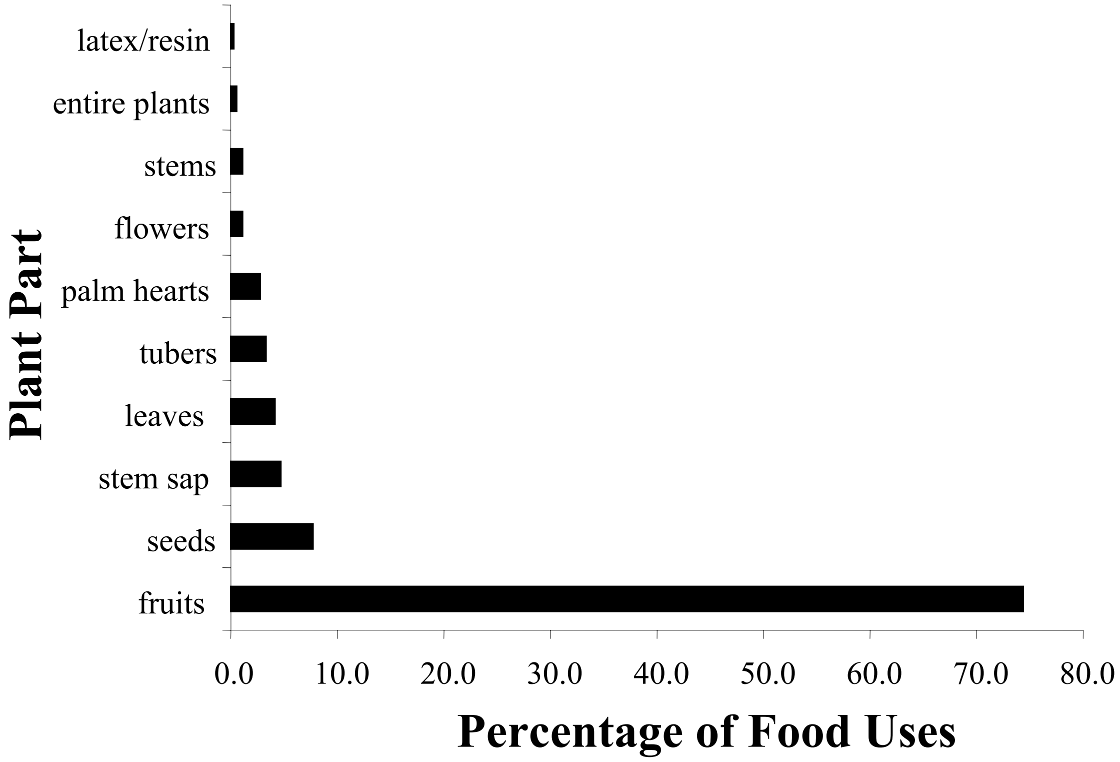

Figure 8.12: Proportional distribution of edible plant parts in TIPNIS

8.3.7.4. Modes of Consumption

Nearly two thirds of uses in the food context (64%) entail direct consumption of mostly raw fruits (figure 8.13), even though some palm fruits such as those of *Bactris gasipaes* are eaten boiled. Edible fruits vary strongly in size: the smallest wild edible fruits are those from *Urera baccifera* and are only a few millimetres in size, whereas *Annona montana* fruits can grow up to 15 cm diameter and weigh up to 3 kg (Vasquez and Coimbra, 2002). The largest cultivated fruits are papaya (*Carica papaya*) and pineapple (*Ananas comosus*). Among the most popular fruits are those of *Bactris gasipaes* (*tembe*) (figure 8.14C). As specified in chapter 1, this species originally played a particularly important role in the Yuracaré society that partially based their annual calendar on its fructification cycle. In past days, the ripening of *tembe* fruits (from March untill May) initiated the relocation of human settlements, as well as a period of festivities during which most ritual ceremonies took place (Richter, 1930a; Haenke, 1974; Paz, 1991; Querejazu, 2005a). Other popular fruits are those produced by 24 *Inga* species. The sweet edible aril around the seeds of these species is particularly liked by children (figure 8.14A). A number of sweet fruits (including many *Inga* species) are occasionally processed into refreshing drinks (6%), by squeezing out their juice or mixing their pulp with water that is sieved afterwards. However, the locally most popular refreshing drink is without any doubt prepared from *majo* fruits (*Jessenia bataua*) (see also chapter 10). The ripe fruits are heated in water for about an hour on a low fire to prevent it from boiling. Next, the softened fruits are squeezed. Subsequently, the creamy juice is decanted. Prior to consumption, water and sugar may be added to this juice (Vasquez and Coimbra, 2002).

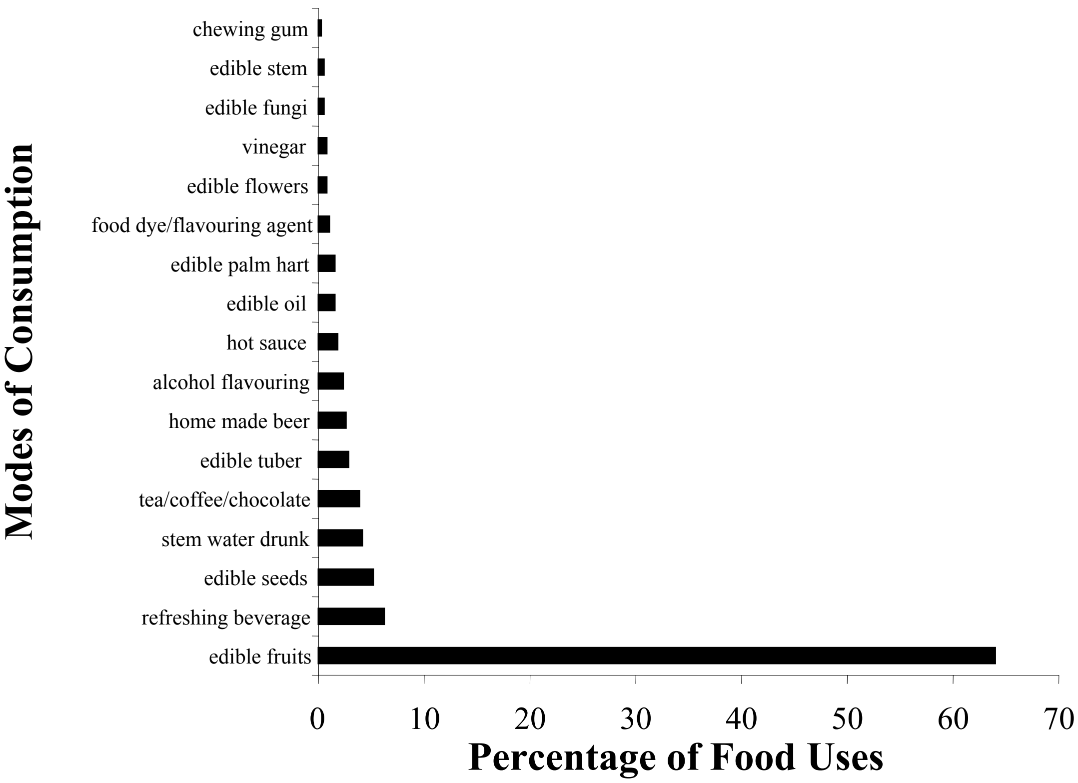

Figure 8.13: Proportional modes of consumption of edible plants and fungi in TIPNIS

Apart from cultivated rice and maize, seventeen species provide edible seeds (figure 8.13), the smallest being those of *Celosia argentea*, especially favoured by small children. Most seeds need to be toasted prior to eating (*Anacardium occidentale*, *Omphalea diandra, Dipterix odorata, D. micrantha, Sloanea fragans, Sloanea* sp.1 (ET1556)*, Naucleopsis ulei* and *Sterculia apeibophylla*). Four palm species also provide edible seeds (*Attalea butyracea* and *A. phalerata*, *Bactris major* var. *infestans* and *Astrocaryum murumuru*).

Figure 8.14A: Small Trinitario boy protecting his *Inga stenoptera* pods. B: The popular fruits of *Rheedia acuminata*; C: *Bactris gasipaes* fruits; D: Yuracaré man harvesting mushrooms (*Polyporus tenuiculus*); E: Edible mushrooms (*Marasmiellus* cf. *semiustus*); F: Trinitario girl collecting cacao (*Theobroma cacao*) fruits

In the forest, potable water can be obtained from the stems of some specific liana species (cf. Milliken *et al.*, 1992; Balée, 1994; van Andel, 2000). This involves a procedure whereby a piece of stem of some two meters or longer is cut and held up so that the water gushing from the lower end is directly collected in the mouth. Most popular species are the medicinal cat's claws *Uncaria guianensis* and *U. tomentosa* (Thomas and Vandebroek, 2006), but several Bignoniaceae species have also been mentioned on various occasions. Likewise, water accumulated in the stems of *Guadua* cf. *weberbaueri* is occasionally drunk when no other sources are available.

Thirteen plant species are drunk in infusions or teas (typically at breakfast) after soaking or boiling the entire plant or some of its parts in (hot) water (figure 8.13). Some teas have a lemongrass-like odour, i.e. when prepared with the cultivated *Cymbopogon citratus*, or with the leaves of *Calyptranthes* nov. sp. Tea is also prepared from the bark of *Aniba canelilla* which has more of a cinnamon-like taste. Other (aromatic) teas are prepared from the flowers of *Muntingia calabura* and *Alpinia zerumbet* and the leaves of *Erythroxylum coca*, *Persea americana* and virtually all *Citrus* spp. Coffee is prepared from seeds of the cultivated *Coffea arabica* and a hot chocolate drink from the seeds of *Theobroma cacao* (figure 8.14F).

Cultivated sweet potatoes, yams and cultivated tuber crops other than *Manihot esculenta,* including *Ipomoea batatas*, *Dioscorea trifida*, *Colocasia esculenta,* are generally eaten boiled. If available, the giant tubers of *Pachyrhizus tuberosus* are eaten raw with sugar, (cf. Cardenas, 1989). Wild edible equivalents all need cooking. The latter include *Cissampelos tropaeolifolia*, *Dioscorea dodecaneura*, *D. spectabilis*, *Homalomena crinipes* and *Ipomoea opulifolia*.

Alcohol is consumed very frequently in TIPNIS. Homemade beer (*chicha*) is prepared almost continuously, mostly from cultivated *yuca* and rice, and to a lesser extent from maize seeds, *Cucurbita maxima* fruits or the tubers of *Dioscorea trifida*, *Ipomoea batatas* or *I. opulifolia*. Depending upon the period of the year, *chicha* is also prepared from the fruits of *Bactris gasipaes, Jessenia bataua*, *Pseudolmedia laevis* or other wild fruit species when those are available in sufficient quantities. *Bactris gasipaes* is used most frequently for chicha. Finally, *chicha* can also be prepared from the palm hearts of *Bactris gasipaes, Astrocaryum murumuru* or *Attalea phalerata.* During the present research, people (particularly the adult male population) frequently bought imported pure (97%) alcohol with money earned from the sale of coca leaves or timber. A number of plant species are macerated in this commercial alcohol in order to prevent or reduce hangovers. Most important are the roots of *Zingiber officinale, Salmea scandens* or *Petiveria alliacea*. Ripe fruits of all three collected *Vanilla* species are macerated to flavour alcohol. In addition, aromatic teas obtained from boiling the bark of *Aniba canelilla* or the leaves of *Cymbopogon citratus*, *Calyptranthes* nov. sp. or *Persea americana* are often used to dilute pure alcohol prior to consumption.

Yuracarés reported that in earlier times when they engaged in a semi-nomadic lifestyle and people did not rely as much on crops, cooked stems of the tree fern *Alsophila cuspidata* were frequently eaten as a substitute for *yuca* (*Manihot esculenta*). Aso, boiled palm hearts of *Astrocaryum murumuru* and *Iriartea deltoidea* (cf. Moraes, 2004) were consumed more often in those days. Nowadays, preference is given to the tastier palm harts obtained from *Bactris gasipaes, Attalea phalerata, A. butyracea* and *Euterpe precatoria* (Moraes, 2004).

Edible oil is extracted from the fruits and/or seeds of *Bactris gasipaes, Attalea phalerata, A. butyracea* and *Jessenia bataua*. Therefore, the fruits or seeds are ground and boiled in water so that the oil accumulates on the surface. The latter is decanted and heated once more to remove residue water.

People in TIPNIS occasionally eat a hot sauce (*llajwa*) to accompany their meal. Various cultivated *Capsicum* species (*C. pubescens*, *C. chinense*, *C. chacoense, C. frutescens*) can be used in its preparation (cf. Ulloa, 2006), whereas one extremely hot wild species *C. coccineum* is also harvested sporadically for this purpose. Among Trinitarios, *llajwa* can be prepared by grinding *Capsicum* fruits, together with tree tomato fruits (*Solanum exiguum* and *Solanum* sp. 3 (ET1455)). Otherwise they are simply mixed with water and salt. The aromatic leaves of *Porophyllum ruderale* are added occasionally, but we suspect that this represents a cultural loan from the colonizing Quechua highland farmers with whom Yuracarés and Trinitarios share their habitat nowadays.

The seeds of the cultivated *Bixa orellana* are used for dying food, whereas fruits of various *Vanilla* spp. (which are difficult to find) are used as flavouring agents. Interestingly, these species contain active principles against food contaminating microorganisms and may play a role in food conservation (Thomas and Vandebroek, 2006). Trinitarios prepare a kind of vinegar by boiling the juice of *Citrus aurantiifolia*, *Theobroma cacao* or *Musa sapientum* and fermenting it during several weeks.

Although there appear to be many species of potentially edible fungi in the Amazonian forests, few ethnic groups have been documented to exploit fungi to a significant extent (Fidalgo, 1965, cited in Milliken *et al*., 1992). The Yanomamo (Yanomami) people of northern Brazil are among the notable exceptions: they use at least 21 different species of edible fungi (Prance, 1984). During the present study, fungi were reportedly used only by Yuracarés who claimed to eat three different species, two of which were collected: *Polyporus tenuiculus* and *Marasmiellus* cf. *semiustus* (figure 8.14D & E).

Trinitarios mentioned using *Clarisia racemosa* latex as a source of chewing gum. In this context, its latex is extracted from cut tree bark, dried and mixed with some sugar. The use of chewing gum has been recorded from various South-American societies (e.g. Pestalozzi, 1998). According to Johns (1999), chewing of plant gums, resins, and latexes is a global practice.

In table 8.12, wild food species collected in TIPNIS are listed according to their food use value. The most important managed food species are listed and discussed in chapter 10. Since food uses of these species were always assessed as having a ‘good quality’, equal QUV and UV values were obtained. In spite of the fact that some species in table 8.12 have up to three different food uses, their use values do not exceed 1.6. This means that not all edible species are known, appreciated or actually consumed by all participants. As shown in chapter 10, this can partly be ascribed to ethnic differences in knowledge and use of food plants between

Trinitarios and Yuracarés. No less than twelve *Inga* species are listed in table 8.12. This confirms their popularity as wild foods. As a consequence, Fabaceae is the family in this list with the highest number of wild food species.

Table 8.12: Highest scoring wild food species in TIPNIS based on use values; only species that where shown to at least three participants are included

Scientific name	family	# resp	# uses	QUV_{food}=UV_{food}
Calyptranthes sp. nov.	Myrtaceae	15	4	1.60
Pseudolmedia macrophylla	Moraceae	3	3	1.50
Pseudolmedia laevis	Moraceae	14	3	1.43
Inga steinbachii	Fabaceae	7	2	1.25
Inga tomentosa	Fabaceae	11	2	1.18
Inga marginata	Fabaceae	11	2	1.18
Alibertia pilosa	Rubiaceae	6	2	1.17
Bactris major var. *infestans*	Arecaceae	6	2	1.17
Inga acreana	Fabaceae	8	2	1.13
Inga chartacea	Fabaceae	11	2	1.10
Abuta grandifolia	Menispermaceae	14	2	1.07
Inga tenuistipula	Fabaceae	11	2	1.00
Omphalea diandra	Euphorbiaceae	5	2	1.00
Paullinia clathrata	Sapindaceae	5	2	1.00
Inga punctata	Fabaceae	10	1	1.00
Inga heterophylla	Fabaceae	9	1	1.00
Pourouma cecropiifolia	Cecropiaceae	9	1	1.00
Pourouma guianensis	Cecropiaceae	9	1	1.00
Dipterix micrantha	Fabaceae	8	1	1.00
Dipterix odorata	Fabaceae	8	1	1.00
Inga ruiziana	Fabaceae	7	1	1.00
Inga nobilis subsp. quaternata	Fabaceae	6	1	1.00
Paullinia tarapotensis	Sapindaceae	5	1	1.00
Chrysophyllum venezuelanense	Sapotaceae	4	1	1.00
Inga bourgonii	Fabaceae	4	1	1.00
Helicostylis tomentosa	Moraceae	3	1	1.00
Inga sp. nov.	Fabaceae	3	1	1.00

resp= number of responses

8.3.8. Fuel Plant Use

During the present study, a total of 333 species was reportedly used as fuel, representing 54 families and 157 genera. Families with the highest number of fuel species are Fabaceae (14%), Lauraceae (7%), Sapotaceae (7%), Annonaceae (5%), Melastomataceae (5%), Rubiaceae (4%), Meliaceae (4%) and Euphorbiaceae (4%). Most firewood species were recorded in the genera *Inga* (22 species), *Pouteria* (16) and *Sloanea* (12). Based on all inventoried plant species, families with highest fuel use values are Chrysobalanaceae ($FUV_{fuel} = 0.77$), Burseraceae (0.71), Elaeocarpaceae (0.69), Myristicaceae (0.67), Lecythidaceae (0.63) and Sapotaceae (0.57). Van Andel (2000) also identified species from the Chrysobalanaceae family as highly valued firewood species, because their wood can easily be sliced into small sticks and quickly lit, even in wet conditions.

The majority of firewood species are trees (88%), followed by shrubs (8%) and lianas (3%). Of all inventoried trees, 'only' 72% is used as fuel. This proportion drops to 25% and 6% for shrubs and lianas, respectively. This finding conflicts with the *ad hoc* assumption of Prance *et al*. (1987) that any tree can be burned as fuel when dry enough. The same remark has also been made by various other ethnobotanists who explicitly asked about the fuel value of woody plants (e.g. Boom, 1989; Milliken *et al*., 1992; Balée, 1986, 1987 and 1994; van Andel, 2000). Some species are simply not used as firewood, because they emit an unpleasant odour when burned or because the wood is too hard and does not produce a good flame. Other species do not produce much heat and/or smoke too much.

Fire and firewood are essential for preparation of food for Yuracarés and Trinitarios. Today, all people have matches and lighters at their disposal, but most participants still have knowledge on how to use fire drills. A *Gynerium saggitatum* shaft is used as a drill, whereas dry *Guadua* cf. *weberbaueri* or *Cecropia* spp. slats are used as hearths. The technique for making fire is by rotary friction (see Balée, 1994 or Querejazu, 2005a). The use of fire drills among Yuracarés has also been documented by Mather (1922) and Nordenskiöld (1924). It is worth mentioning that in earlier times, Yuracarés employed their arrow shafts and arrowheads designed to kill large animals (which are manufactured from *G. saggitatum* and *G.* cf. *weberbaueri,* respectively; cf. figure 8.21F) for making fire. Such a practice is not known from other lowland societies. Therefore, it could represent an ancient cultural element of the Yuracarés (Nordenskiöld, s.d.; cited in Querejazu, 2005a). Trinitario participants claimed that, apart from using fire drills, their people used to make fire by hitting a piece of iron on a white stone from the river; the sparks produced would light a piece of cotton. Similarly, Querejazu (2005a) describes how Yuracarés used to make fire by hitting a piece of pyrite on a 'fire stone' and catching the sparks produced on inflammable vegetal debris.

For stirring up the fire, Yuracarés use fans manufactured from the back feathers of a large bird called *mutún* (razor-billed curassow, *Mitu tuberosa* (O. Beck pers. comm.); figure 8.25E) that are cemented in a chunk of black beeswax. This custom was also described by Mather (1922), Nordenskiöld (1924) and Querejazu (2005a). Trinitarios use fire-fans manufactured from the leaves of *Attalea phalerata* or *A. butyracea* for this purpose (figure 8.25B).

Most firewood is harvested from swiddens and fallows, particularly from tree trunks that are felled during swidden clearance. This has also been reported for other Amazonian groups (Milliken *et al*., 1992; Balée, 1994; van Andel, 2000). Among Yuracarés it appears to be the responsibility of women to gather firewood (figure 8.23G), whereas among Trinitarios both sexes are responsibile for this task.

Oil extracted from the fruits and/or seeds of *Ricinis communis*, *Jatropha curcas*, *Attalea phalerata*, *A. butyracea*, *Bactris gasipaes* and *Socratea exorrhiza* is occasionally used to fuel oil lamps. Entire seeds of *Ricinis communis* are also burned as a light source. Finally, Trinitario participants reported the use of *Clarisia racemosa* latex as a fuel source for producing light. Therefore, pure latex of this species is extracted and boiled on the fire to concentrate it. The residue thus obtained is then processed into small balls that are dried. It was a common practice to add dyes of different colours (see *infra*) to the latex residue, as this was believed to bring prosperity. It was said that good quality light is produced when burning these balls.

8.3.9. Construction Plant Use

The construction use category contains all plants species that are used (1) in house construction, (2) as timber and (3) for manufacturing canoes. Two hundred and fifty nine (259) species, belonging to 55 families and 155 genera were reported for house construction, accounting for 444 different uses (figure 8.15). Most species-rich families are Fabaceae (26 species; 10%), Lauraceae (23 species; 9%), Sapotaceae (20 species; 8%), Annonaceae (15 species; 6%), Meliaceae (12 species; 5%), Moraceae (11 species; 4%), Arecaceae (11 species; 4%), Myrtaceae (10 species; 4%) and Euphorbiaceae (8 species; 3%). Popular genera are *Pouteria* (15 species), *Guarea* (6), *Ocotea* (6), *Eschweilera* (5), *Sloanea* (5) and *Trichilia* (4).

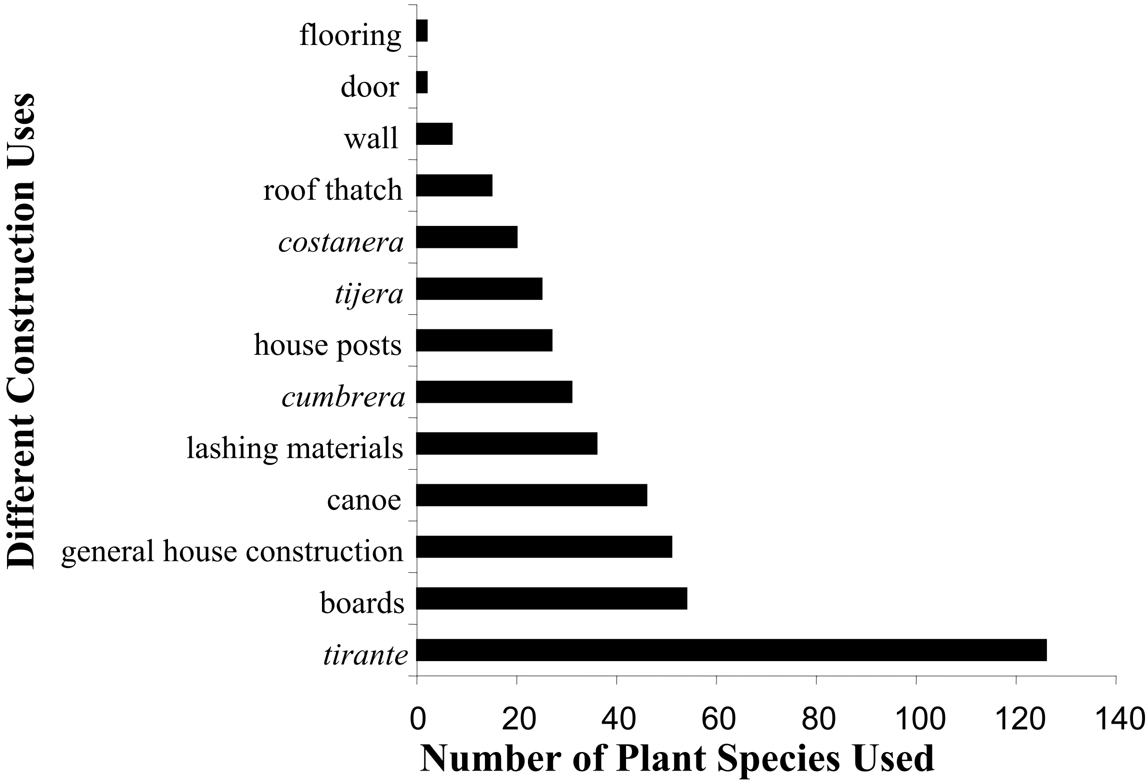

Figure 8.15: Different types of construction uses and number of species used in TIPNIS. For an interpretation of the Spanish terms, the reader is referred to figure 8.17

Regression analysis shows that the number of construction species in a family (NCS) can be predicted from family size (i.e. the number of collected species in a family or NSF), whereby NCS = 0.351x NSF - 0.314 (r^2=0.60 and $p<0.001$). Families with higher NCS than expected from the regression equation are Sapotaceae, Lauraceae, Annonaceae, Meliaceae and Arecaceae. Significantly underused families in construction are Rubiaceae and Solanaceae (figure 8.16). The highest family use values in the construction category were recorded for Annonaceae (0.92), Myristicaceae (0.91), Anacardiaceae (0.90), Arecaceae (0.85), Burseraceae (0.77), Lecythidaceae (0.76), Lauraceae (0.74), Tiliaceae (0.70) and Chrysobalanaceae (0.65). Similarly, in Phillips and Gentry's (1993a) study, the most important plant families in terms of construction uses were Lauraceae, Annonaceae, Myristicaceae, Arecaceae and Chrysobalanaceae.

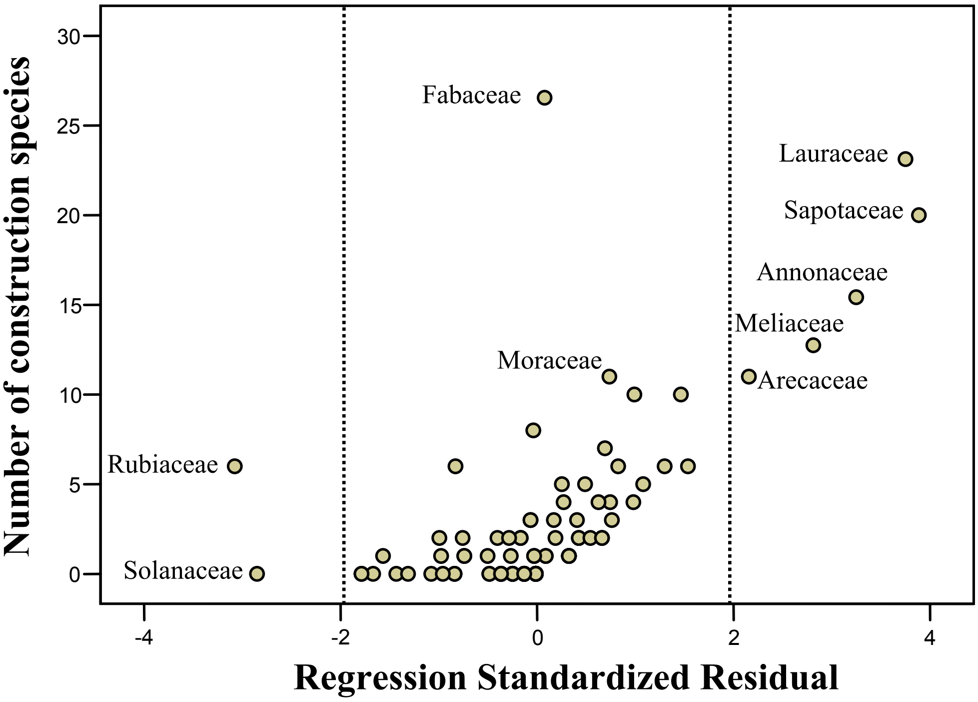

Figure 8.16 Number of food species (NCS) vs. standardized residuals of the regression of NCS on family size (NSF). Families with standardized residuals >1.96 or <-1.96 (p=0.05) have significantly higher, respectively lower, NFS than expected from their size

House construction

Roundwood Frame

The most important component of a house are house posts which are inserted into deep holes along the house's contour lines. Generally, one large post is placed in the middle of one of the widths of the rectangular-shaped houses to support the roof (figure 8.17). At the opposite side, the roof is supported by a type of construction called "*tijera*" or scissors, visualized in figure 8.17. Although house posts may be obtained from 27 different tree species, palms are the most frequently used species. In particular, *Iriartea deltoidea* and *Astrocaryum murumuru* trunks are most popular, but *Socratea exorrhiza*, *Euterpe precatoria* and *Jessenia bataua* may also be used. Trunks of this last species are very heavy and are only used when no alternatives are available. In addition to palms, Fabaceae are well represented among the species used as posts with 8 different species. They include *Dipterix odorata*, *D. micrantha*, *Lecointera amazonica* and *Myroxylon balsamum*. However, most of these hardwood species are mainly used when a chain saw is available. Interestingly, the softwood species *Erythrina dominguezii* and *Salix humboldtiana* may also be used, because once put into the ground they soon resprout and act as living posts.

One hundred and forty nine (149) species are used as cross beams in house construction, including *tirantes* (accounting for 28% of construction uses), *cumbreras* (7%), *tijeras* (5%) and *costaneras* (4%). The reader is referred to figure 8.17 for interpretation of these terms for which no clear-cut translations exist. Most species used as beams belong to Sapotaceae (18 species; 12%), followed by Annonaceae (16; 11), Myrtaceae (9; 6), Fabaceae (8; 5), Lauraceae (7; 5), Euphorbiaceae (7; 5) and Chrysobalanaceae (7; 5).

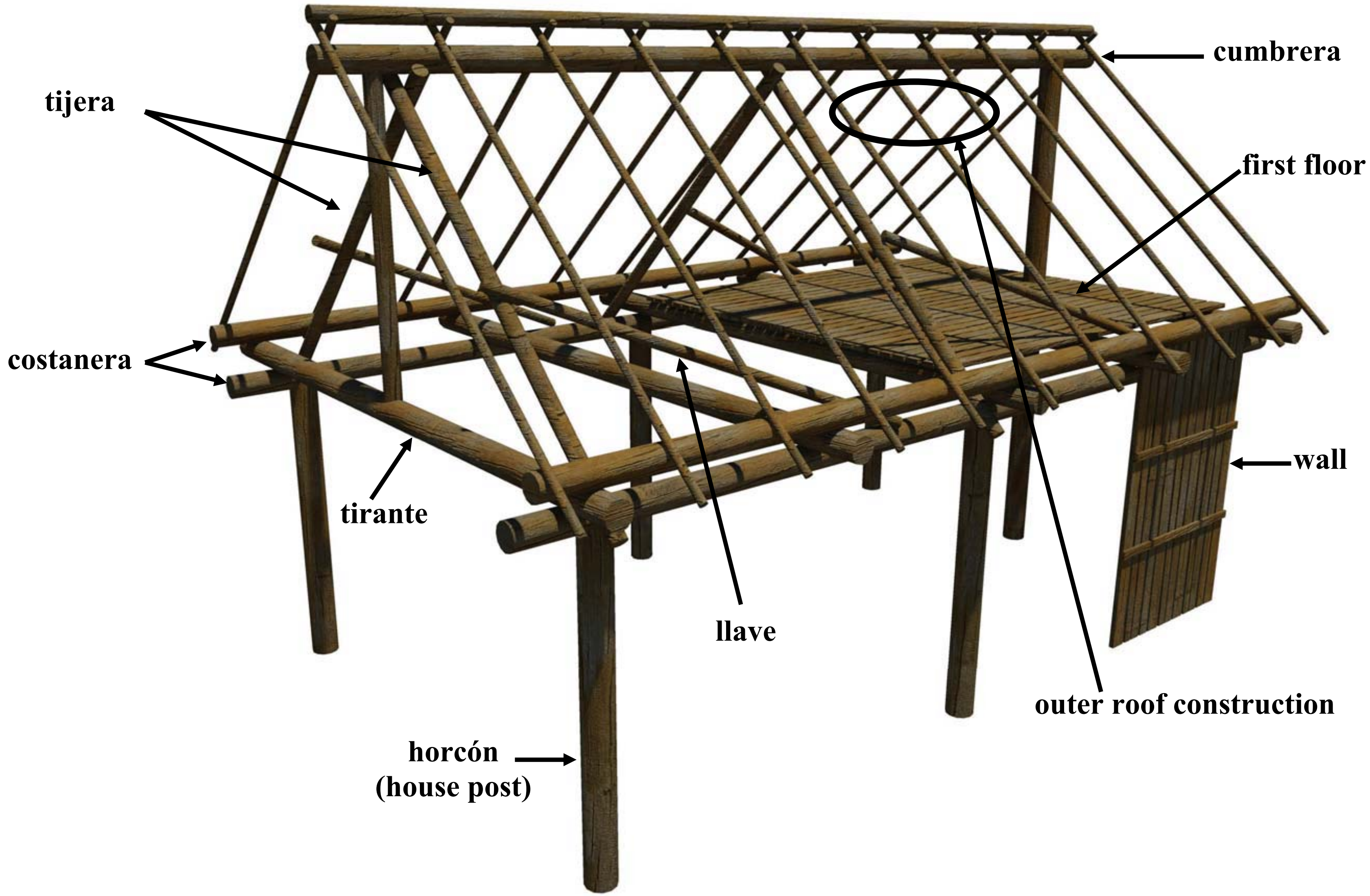

Figure 8.17: Schematic representation of the roundwood frame of a Yuracaré-Trinitario house. On top of the roof structure entire leaves of various palm species or panels composed of *Geonoma* spp. are put in an imbricate manner (drawing by Tiemen Schotsaert).

As mentioned for other ethnobotanical studies throughout Amazonia (e.g. Milliken *et al*., 1992; Balée, 1994; van Andel, 2000; Stagegaard *et al*., 2002), *Pouteria* spp., *Guatteria* spp. *Licania* spp. and *Eschweilera* spp. are widely used. The popularity of the wood of *Licania* spp. and *Eschweilera* spp. in house building has been linked to their resistance against rot due to the abundance of silica found in the rays of their wood, which seems to discourage termites (Ter Welle, 1976; Prance *et al*., 1987; Balée, 1994).

It is interesting to note here that according to Castillo (1676, cited by Nordenskiöld, 1924) and Denevan (1980) the Mojeños used to live in round houses instead of rectangular ones, whereas they used square huts for cooking. The walls were manufactured from reed and mud; the roof was cone-shaped; and the low doors were made of animal skins (Denevan, 1980). The Yuracarés apparently have always lived in rectangular houses, but in origin these houses did not have walls and consisted of a saddle roof frame that came down to the ground (Nordenskiöld, 1924; Querejazu, 2005a).

Lashing Material

Lashing material for tying the roundwood frame of a house and roof thatch is obtained from 35 species: 18 tree species, 14 lianas, 2 epiphytes and one hemi-epiphyte. In case of tree species, bark is used. The majority of species belongs to Annonaceae (12 species), whereas others belong to Bombacaceae (2), Cecropiaceae (2), Euphorbiaceae (1) and Tiliaceae (1). Tree bark used by the Bolivian Chacobo as lashing material is obtained from Annonaceae, Cecropiaceae and Tiliaceae (Boom, 1987)

Most liana species used as lashing material are Bignoniaceae (6 species). However, also some Fabaceae and Dilleniaceae are used. Additionally, the fibres of two epiphytic Araceae were mentioned. The most valued “cord” material is undoubtedly obtained from the hemi-epiphyte *Thoracocarpus bissectus* (Cyclanthaceae). Its very long flexible aerial roots are used undividedly, or else they may be cut once or twice longitudinally, which allows to obtain two to four lashes per aerial root, respectively. The Guyanan Caribs and Arawaks also rely heavily on *T. bissectus* and various Bignoniaceae species for tying the roundwood frames of permanent and temporary dwellings (van Andel, 2000).

Roof Thatch

Yuracarés and Trinitarios almost exclusively use palm leaves for roof thatch. The entire leaves of *Attalea butyracea* are folded or cut longitudinally along the central rachis (figure 8.18E & F). The leaves (entire and folded or leaf-halves) are placed imbricately on the spaced out culms of *Gynerium sagittarum,* or on the split trunks of *Iriartea deltoidea* or *Socratea exorrhiza* that constitute the outer roof construction (shown in figure 8.17). Roofs manufactured from *A. butyracea* are said to last up to 10-15 years or longer (cf. Moraes, 2004), particularly when leaves are folded instead of being cut along their rachis. *A. phalerata, Iriartea deltoidea* and *Jessenia batua* leaves are used in an identical fashion but according to participants, they do not last so long. Leaves of *Socratea exorrhiza* may also be used, but these are said to last only for about one year. The popularity of *Euterpe precatoria* leaves for roof thatching has been reported for various Amazonian peoples (Boom, 1989; De Walt *et al*., 1999; van Andel, 2000). In the participating communities, its use is very limited due to the low local abundance of this palm species.

Figure 8.18 A: Trinitario boy standing in front of a typical house; B: Trinitario man producing thatching panels from the leaves of *Geonoma deversa*; C: Yuracarés assembling a roof with *G. deversa* panels; D: Lower view of a *G. deversa* roof; E: Lower view of a *Attalea butyracea* roof; F: Trinitario family assembling a roof with *A butyracea* leaves that are split along the central rachis; G: Yuracaré male assembling a roof from the leaves of *Gynerium sagittatum* var. *glabrum*; H: lower view of a G. *sagittatum* var. *glabrum* roof

By far the most valued species by Yuracarés and Trinitarios for roof thatching is the caespitose short *jatata* palm (*Geonoma deversa*) (figure 8.18A, C & D). *Geonoma macrostachys* var. *macrostachys* seems to be even more preferred, but barely used because of its extremely low local abundance. Roofs thatched with the leaves of this plant are said to last for 15-20 years (as confirmed by Moraes, 2004). Participants claim that there is no vegetal alternative with a more durable quality.

The petioles of individual *Geonoma* leaves are twisted and locked between two battens made from the stems of *Gynerium sagittarum*, thus producing thatching elements (panels) that are more or less 3 m long (figure 8.18B). These panels are placed imbricately on the roof in a similar way as described for *A. butyracea*. As a consequence of recently decreased local populations of *Geonoma* species (see chapter 10, section 10.3.1.), Trinitarios are nowadays inclined to use the morphologically similar, but far less durable leaves of *Hyospathe elegans*. Tying panels or individual leaves of large palm species to the roof frame is virtually always performed with aerial roots of *Thoracocarpus bissectus.* The roof ridge is frequently covered with a number of large leaves of *A. butyracea* or *A. phalerata*, but folded entire *Diplasia karataefolia* plants have also been reported.

An alternative to palm leaves for thatching roofs is provided by *Gynerium sagittarum* var. *glabrum* (figure 8.18G & H). Its leaves are simply folded over the longitudinally split culms of the same species that are in turn attached to the outer roof construction (figure 8.17). Through the influence of Andean settlers, plastic has been introduced as roofing material as well. In order to prevent the plastic from disintegrating under the burning tropical sun, it is often covered with vegetal debris or some soil material. Especially Trinitarios grow the medicinal *Portulaca grandiflora* (Thomas and Vandebroek, 2006) in the soil on top of their plastic roofs, because they claim it improves durability of the plastic.

Most houses include walls (figures 8.17 and 8.18A) and floors made from slats of *Iriartea deltoidea* or *Socratea exorrhiza*. These species are frequently used for this purpose in Amazonian rustic architecture (Milliken *et al*., 1992; De Walt *et al*., 1999; Stagegaard *et al*., 2002). The undivided culms of *G. sagittarum* var. *glabrum* or *G.* cf. *weberbaueri* are also used for wall construction. Doors in TIPNIS are typically manufactured from the softwood of *Heliocarpus americanus* and *Ochroma pyramidale,* but culms of *G. sagittarum* var. *glabrum* or *G.* cf. *weberbaueri* are used too (e.g. figure 8.18A).

Canoes

Canoes are the principal means of transportation and fishing in TIPNIS (figure 8.19A). Practically every household disposes of at least one and usually more canoes. According to Nordenskiöld (cited in Querejazu, 2005a), the canoe was "imported" into Bolivia by Arawaks who he believed to represent a later culture in Bolivia than Yuracarés. Presumably, the Yuracare have learned the art of canoe building from the Mojeños (Nordenskiöld, 1924). Even though the canoe might thus be borrowed from the Mojeños, the Yuracarés achieved the fame of being the most skilled canoe builders of northeastern Bolivia during the colonial period (Nordenskiöld, 1924; Métraux, 1942; Querejazu, 2005a), whereas the Mojeños were particularly renowned as experienced oarsmen (Denevan, 1980; Balzan, 1894 in Ribera, 1997). According to Querejazu (2005a), the first contacts between Mojeños and Yuracarés must date back to pre-Hispanic times.

Figure 8.19A: Trinitario family crossing Ichoa river; B: Trinitario boy on his self-assembled raft from balsa wood (*Ochroma pyramidale*); C & D: Trinitario men making canoes from the fallen trunks of *Hura crepitans*; E: A canoe is pulled to the river from its place of manufacture in the forest by a chain of male adults

For canoe construction, large trees are felled with iron axes, or preferably with a chain saw, if the latter is available. However, it is also common practice to use tree trunks that have been felled naturally by wind. Although most canoes are manufactured from a limited number of tree species, forty-six species were reported eligible, the majority being Lauraceae (14 species), followed by Meliaceae (8), Fabaceae (6) and Myristicaceae (3). Particularly *Swietenia macrophylla*, *Hura crepitans* (figure 8.19C & D), *Guarea macrophylla*, *G. guidonia* and *Calophyllum brasiliense* are preferred because they last longer. The most durable canoes are undoubtedly made from *Swietenia macrophylla*. When they are properly looked after, they can last for five years or more. Nonetheless, most canoes only last for two to three years and in the case of most Lauraceae the life span is limited to one year only. However, improperly roped canoes are frequently “lost” much sooner when rivers turn into rapids after a heavy rainfall, sweeping them along with the current. A short-lived canoe can be made occasionally from the trunks of *Iriartea deltoidea* that are sometimes belly shaped in their higher half (Moraes, 2004). Also, short-lived rafts are sporadically made from the lightwood of *Ochroma pyramidale* (figure 8.19B). This practice is confirmed by Querejazu (2005a).

Boards

When a chain saw is available, timber can be processed into boards for local use or for selling. Participants reported 54 species that can be used for this purpose (i.e. 12% of all construction uses). Families with the highest number of species are Lauraceae (22%), Meliaceae (13%), Fabaceae (11%) and Burseraceae (7%). Although it is illegal for Trinitarios and Yuracarés to sell timber from the protected area they live in, “hidden” small-scale exploitation including (side) selling does occur (Lilienfeld and Pauquet, 2005). Highly valued trees are selectively felled and processed into boards *in situ*. Boards are then manually brought to collection points from where trucks managed by Andean settlers pick them up. However, during the course of the present study, boards were confiscated on various occasions by officials of the Bolivian National Parks Service (SERNAP) in order to discourage people from continuing with this illegal practice. Nonetheless, local forests are slowly being depleted from the few remaining *Swietenia macrophylla* individuals that are in high local demand (see chapter 10). Soon enough people will be forced to turn to ‘less valuable’ species for obtaining timber.

Most Valued Construction Plants

Table 8.13 lists the most important species in terms of construction use values. The fact that the number of construction uses of species in this list ranges between 2 and 7, whereas construction (quality) use values are not higher than 2.5, suggests that not all construction materials are known or actually used by all participants. Only for some species, quality use values are slightly lower than their corresponding use values. This indicates that nearly all construction uses of these species are appraised to be of good quality by most participants.

8.3.10. Material Plant Use

During the present study, a total of 250 different species were recorded from which Yuracaré and Trinitario participants extract a variety of materials. These species belong to 61 families and 160 genera. Families that contain most species in this category are Fabaceae (8%), Sapotaceae (5%), Arecaceae (5%), Rubiaceae (5%), Nyctaginaceae (4%), Annonaceae (4%) and Moraceae (4%). Genera with most material species are *Pouteria* (10 species), *Neea* (9), *Piper* (7), *Cecropia* (5) and *Ficus* (5).

The number of material species in a family (NMaS) can be predicted from the total number of species collected for these families (NSF). The regression is highly significant and explains 72% of variation in data (NMaS = 0.324 x NSF - 0.153; $r^2=0.72$ and $p<0.001$). Analysis of standardized residuals of individual families shows that Solanaceae, Acanthaceae and Sapindaceae are significantly underutilized. Families that contain significantly higher NMaSs than expected from the regression equation are Arecaceae, Meliaceae, Bignoniaceae, Apocynaceae, Sapotaceae and Nyctaginaceae. Highest family use values in the material category were recorded for Arecaceae (1.24), Marantaceae (1.05), Cyclanthaceae (0.72), Poaceae (0.71), Heliconiaceae (0.67), Myristicaceae (0.53), Orchidaceae (0.44), Costaceae (0.42) and Bombacaceae (0.39).

Table 8.13: Highest scoring construction species based on use values; only species are included that where shown to at least three participants

Scientific name	family	# participants	# uses	UV_{const}	QUV_{const}
Socratea exorrhiza	Arecaceae	14	5	2.50	2.43
Iriartea deltoidea	Arecaceae	11	7	2.27	2.27
Calophyllum brasiliense	Clusiaceae	10	7	2.10	2.10
Swietenia macrophylla	Meliaceae	4	3	2.00	2.00
Otoba parvifolia	Myristicaceae	9	3	2.00	1.72
Guarea macrophylla	Meliaceae	13	4	1.92	1.81
Gynerium sagittatum var. *glabrum*	Poaceae	9	4	1.89	1.89
Guatteria citriodora	Annonaceae	3	2	1.67	1.67
Iryanthera juruensis	Myristicaceae	8	3	1.50	1.50
Tapirira guianensis	Anacardiaceae	6	4	1.50	1.42
Parinari klugii	Chrysobalanaceae	4	5	1.50	1.50
Terminalia oblonga	Combretaceae	7	5	1.43	1.43
Cedrela cf. *fissilis*	Meliaceae	7	2	1.43	1.25
Licania harlingii	Chrysobalanaceae	5	3	1.40	1.40
Lacistema aggregatum	Lacistemataceae	3	3	1.33	1.33
Pouteria cf. *multiflora*	Sapotaceae	3	2	1.33	1.33
Mouriri cauliflora	Melastomataceae	15	5	1.20	1.20
Rhodostemonodaphne kunthiana	Lauraceae	5	3	1.20	1.20
Guarea guidonia	Meliaceae	12	4	1.17	1.13
Lecointea amazonica	Fabaceae	7	3	1.14	1.14

Most materials are obtained from trees (59%), followed by shrubs (11%), herbs (10%), lianas (9%) and climbers (4%). Also eight epiphytes, five grasses and two strangler species have a material use value.

For the 256 inventoried material species, a total of 384 different uses was recorded (figure 8.20). The majority of species (71%) has only one material use. Species with most diverse uses are *Ochroma pyramidale* and *Guadua* cf. *weberbaueri*.

Hunting and Fishing

The principal hunting tools are .22 rifles, bow and arrow, and machetes (figure 8.22D). Trinitario and Yuracaré men carve their bows principally from the hardwood of *Bactris gasipaes*, and more sporadically from *Bactris major* var. *infestans*. Yuracaré bows are about 1.5 m in length (figure 8.21I), while those of Trinitarios tend to be slightly longer, up to 1.8 m, i.e. in line with observations made by Nordenskiöld (1924) and Denevan (1980), respectively. The bowstring, which is knotted to the narrow, whittled ends of the bow (figure 8.21J), is mostly made from rope fibre extracted from the bark of *Cecropia concolor* (cf. Hinojosa *et al.*, 2001), but *C. engleriana* has also been reported. Although Trinitarios seem to rely less on bow and arrow than Yuracarés, according to our observations members of both ethnic groups manufacture bows and arrows in a similar way. However, the bows and arrows described here basically follow the Yuracaré-type.

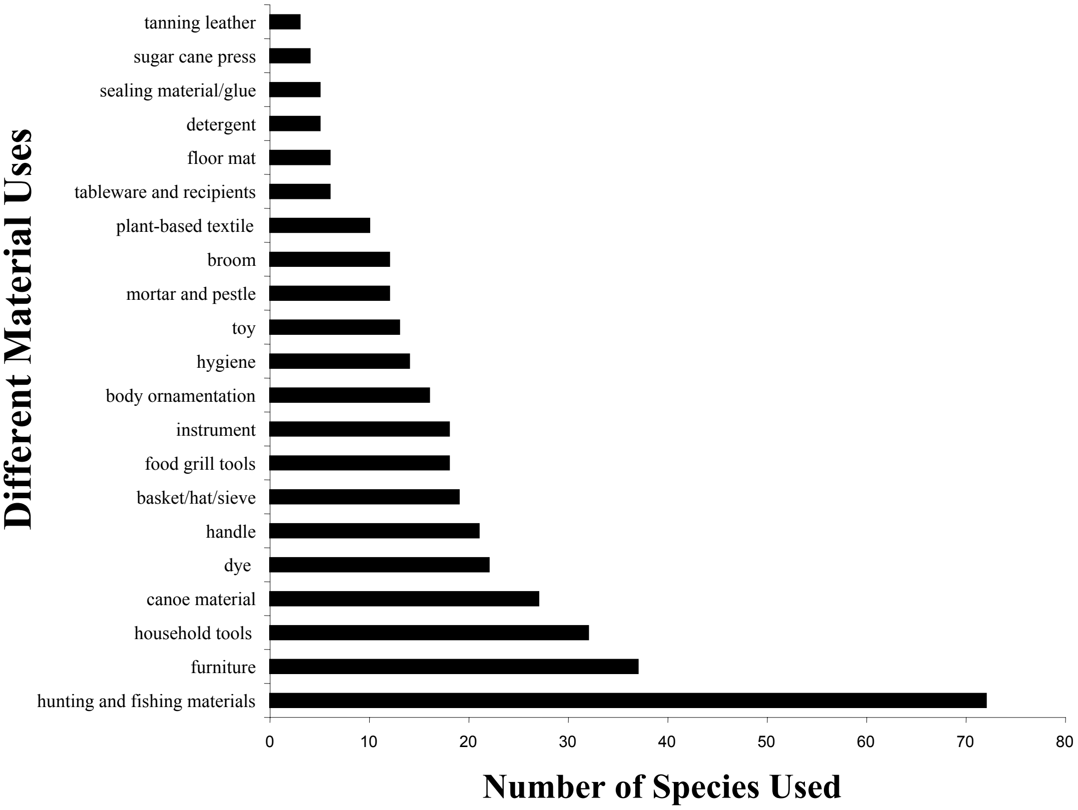

Figure 8.20: Different material uses with number of species used in TIPNIS

As elsewhere in Amazonia, most arrow shafts are made of the flowering culms of *Gynerium sagittatum* (e.g. Boom, 1989; Milliken *et al*., 1992; Balée, 1994; De Walt *et al*., 1999) but the long petioles of leaves of *Didymopanax morototoni* were also mentioned in our study and in the study of Balée (1994). Three varieties of *G. sagittatum* prevail in the research area: *G. sagittatum* var. *glabrum* which is a wild variety typically occurring naturally on high river banks, and two cultivated varieties, i.e. *G. sagittatum* var. *subandinum* and *G. sagittatum* var. *sagittatum*. Arrow shafts for hunting are obtained from the flowering culms of the *glabrum* and *sagittatum* varieties. Flowering culms of the *subandinum* variety are only used for shafts of children's toy arrows.

Prior to assemblance, shafts are straightened by heating them over a low fire, followed by a gentle flexing. *Gynerium* arrow shafts are about 90 cm in length. At the proximal end, a small wooden plug (any kind of hardwood) with a nock to hold the bowstring is introduced into the pith and wrapped with vegetal fibre to prevent the shaft from breaking. At the distal end, an arrowhead is inserted, by twisting its long tapering point into the shaft. Arrowheads are basically made from *Bactris gasipaes* or *Bactris major* var. *infestans* wood. They vary in length according to the use purpose: (1) arrowheads of about 45 cm with a fluke near the end for hunting large fowl and monkeys (figure 8.21D); (2) bearded arrowheads of about 45 cm for fishing (these arrows do not have feathers) (figure 8.21E); and (3) blunt pointed arrowheads of 25-30 cm long for stunning smaller birds whose feathers are used in feather art (figure 8.21L). For large game, a lanceolate arrowhead of about 25 cm long, made of *Guadua* cf. *weberbaueri* stems is attached to axes of *B. gasipaes* or *B. major* var. *infestans* (about 35 cm in length) (figure 8.21F). *Olyra latifolia* or *Ischnosiphon puberulus*, species that are considered of inferior quality, are used in toy arrows in a similar fashion.

Figure 8.21 **A: Detail of Yuracaré arrow feather; adhesive material is *Clarisia biflora* latex coloured with *Bixa orellana* pigment; B: Junction between arrowhead (right) and shaft (left) wrapped with bark strips from *Bauhinia longicuspis*; notice the traces of dried adhesive latex; C & H: Arrow and head for stunning birds according to Nordenskiöld (2003); not observed during present study; D-F & L: Arrowheads designed for hunting different preys (see text for more details); G: Arrowhead historically used during arrow duel; I & J: Yuracaré bow (approximately 1.5 m long); K: Block of adhesive *Clarisia biflora* latex coloured with *Bixa orellana* pigment; M: *Attalea butyracea* fruit with larvae of *Rhynchophorus palmarum, used a a bait for fishing***

The junction between arrowhead and shaft is secured with thin bark strips of *Bauhinia longicuspis* (figure 8.21B) and the fibres mentioned in the following paragraph for attaching feathers to the arrow shaft. These fibres are looped around the joint and pulled tight to compress the shaft around the insertion. Arrowheads and shafts are sometimes glued together with adhesive latex obtained from *Clarisia biflora*, *C. racemosa* or *Symphonia globulifera*. Yuracarés prefer *Clarisia biflora* latex as 'glue' for binding, while Trinitarios seem to be less selective and also use the latex of *C. racemosa*. Latex is boiled so that it can concentrate and is usually mixed with a red dye obtained from *Bixa orellana* seeds. The reddish dried latex residue is fashioned into cylindrical blocks of about 5 cm long and 10 cm in diameter. Nearly every adult male stores a block or two of this resin in his house (figure 8.21K). The yellow latex of *Symphonia globulifera,* which becomes black upon oxidizing, is processed in a similar way, although no dyes are added. Use of the latter species as an adhesive is also reported by Milliken *et al*. (1992), Balée (1994) and van Andel (2000).

Arrow feathers are sewn and cemented to the shafts at about 30-35 cm from their proximal ends (figure 8.21C). In order to proceed to this, the rachis of a feather is cut longitudinally, after which both feather sides are placed oppositely on the shaft that was smeared initially with the adhesive latex described hereabove. The feather is additionally fastened to the shaft by twisting a fine thread in between the barbs (figure 8.21A). In line with the traditional custom (Denevan, 1980) Trinitarios basically use fine cotton thread (*Gossypium barbadense*) as threading material, whereas Yuracarés resort to the fibres of various Apocynaceae and Asclepiadaceae liana and vine species. The most valued species in this context is *Marsdenia macrophylla*, which according to some participants is sometimes even cultivated. Alternative species with similar use include *Blepharodon pictum*, *Mandevilla hirsuta*, *Matelea macrocarpa*, *Mesechites trifida* and *Mesechites* sp. (ET975).

Similar descriptions of bows and arrows among the Yuracarés have been made by early ethnographers (e.g. Von Holten, 1877; Miller, 1917; Richter, 1930d; Denevan, 1980; Nordenskiöld, 1924 and 2003). According to Denevan (1980), the Mojeños used arrow poison obtained from *coropi*, an unidentified plant species. No such use is known among the Yuracarés. Today, arrow poisons are no longer used and none of the Trinitario participants in our study could remember such practice. Nowadays, bow and arrows are basically used for fishing, whereas most hunting is done with rifles. Usually, men go out at night to inspect their swiddens and/or fallows for grazing activity of game animals, particularly large rodents locally called *jochis* (*Cuniculus paca* (figure 8.22E) and *Dasyprocta agouti* according to Emmons and Beer, (1999)). Some hunters undertake nocturnal forest walks (alone or in group) to hunt and return to the community only at dawn. Hunters are profoundly knowledgeable about the food habits of game (Prance *et al*., 1987; Milliken *et al*., 1992; Balée, 1994; Phillips *et al*., 1994). It is therefore common practice for Yuracaré and Trinitario hunters to await particular game animals near fruiting tree species favoured by these species. Often, small platforms are constructed on which the hunter quietly waits without startling the animals. A similar practice has been described for the Waimiri Atroari from the Brazilian Amazon (Milliken *et al*., 1992). Other waiting places for hunters are so-called "saltwells" (mineral outcrops) that occur naturally in the forest. According to participants, and as confirmed by Chavez and Moyano (2000), nearly *all* game animals frequent these places for salt uptake.

Figure 8.22 A: Trinitario men showing off their catch; B: Trinitario boys collecting their father's catch; C: Jaguar trap; D: Yuracaré hunter with .22 rifle and machete, carrying a turtle on his back; E: *Jochi pintado* (*Cuniculus paca*), one of the favourite game animals of Yuracarés and Trinitarios; F: Yuracaré woman butchering a turtle

A less time consuming way of hunting consists in tying a rifle to a tree along a trail or path that is frequented by game animals. A young individual of the liana species *Macfadyena unguis-cati* is then tightened across this path and attached to the trigger. When an animal runs into the tightened string, the rifle goes off and the hunter can collect the catch later. During our study, one Yuracaré participant showed an even more ingenious technique of trap building. Near the end of 2004, the village of San Antonio was frightened by nocturnal visits of a jaguar, which was on the prawl for domestic fowl. In response, the Yuracaré built a completely closed rectangular trap of about 0.5 x 0.5 x 2 m^3 with slats of *Socratea exorrhiza*, which he divided in two separate compartments by means of wooden stalks (figure 8.22C). In one compartment, he kept domestic fowl for the night, whereas in the other he installed a mechanism that closes the entrance when the prey animal enters the trap. A week later, the jaguar was caught and killed.

When animals are killed in the forest, they may be packed in large leaves of *Sloanea fragans* or various *Calathea* or *Heliconia* species prior to transport. Entire or butchered carcasses are usually carried home on one's back by means of straps obtained from various strong-barked tree or liana species. Nine of the thirteen species we recorded for this use are Annonaceae. Two reported liana species are the cat's claws species, *Uncaria guianensis* and *U. tomentosa*. Occasionally, an improvised rucksack can be made in the forest with the leaves of *Attalea butyracea* for transporting game meat or any kind of vegetal resource.

Hunting is learned at an early age and children are highly skilled at shooting at "everything that moves". Nowadays, they develop their shooting skills through practising with purchased catapults, using *Socratea exorrhiza* and *Iriartea deltoidea* fruits as ammunition.

As indicated higher, fishing is done with bow and arrow while standing on a canoe or from another dominant position. Nowadays most fishing is carried out with self-assembled nets of purchased synthetic thread or with simple lines and fishing hooks (figure 8.22A & B). The fruits and/or seeds of some 30 species were reported to be used as fish bait. Small fruits can be harvested from *Phytolacca rivinoides*, *Cissus* spp., *Geophila* spp., *Sabicea* spp. or *Miconia* spp. Larger, sweet fruits are also used such as those from *Jacaratia digitata* or *Cecropia* spp. Noteworthy is the use of beetle larvae *tuyutuyu* (*Rhynchophorus palmarum* (after Piñedo-Vasquez *et al*., 1990 and De Walt *et al*., 1999)) that feed on palm seeds (*Attalea phalerata*, *A. butyracea* (figure 8.21M) and *Astrocaryum murumuru*), as bait for large fish species. Finally, fishing is also done by means of ichthyotoxic plant material (see section 8.3.13).

Furniture

Some thirty species were mentioned to be used in house furniture (i.e. tables, benches, chairs, racks, shelves… (figure 8.23A & B)). Most species are Meliaceae (23%), Lauraceae (20%) and Fabaceae (13%). A pendulous shelve (*sarza*) is made from longitudinally cut *Gynerium sagittatum* var. *glabrum* culms. Relatively fragile racks are mostly assembled from various *Piper* spp. stems. Benches, chairs and tables are made from the wood of a series of forest trees, but also from slats of *Socratea exorrhiza* trunks. In one storey high houses, floors are reached by means of ladders. Most commonly, these are made out of single *Ochroma pyramidale* stems of 20-30 cm in diameter with cutout orifices (figure 8.23D). Alternatively, ladders of the western-type are assembled with the culms of *Guadua* cf. *weberbaueri*.

Figure 8.23A: Yuracaré furniture; B: Trinitario kitchen furniture; C: Yuracaré women peeling rice grains in a mortar made of *Clarisia racemosa* wood; D: Traditional ladder made of *Ochroma pyramidale* softwood E: Pendulous shelve (*sarza*) made from longitudinally cut *Gynerium sagittatum* var. *glabrum* culms. F: Trinitario woman holding a pestle made of *Dipterix* sp. wood; G: Yuracaré grandmother carrying firewood

Bed poles and slats of platform beds are made from *Socratea exorrhiza* (see also Boom, 1989) or *Iriartea deltoidea* trunks, or else from *Gynerium sagittatum* var. *glabrum* culms. According to Steward (1948) and Nordenskiöld (1924), platform beds were originally used by tribes living closest to the Andes. This is the case with the Yuracarés. In origin, the Mojeños used to sleep mainly in hammocks (Denevan, 1980). Nowadays, most Yuracarés and Trinitarios from TIPNIS sleep on *hesteras* that are placed on platform beds or on the ground. *Hesteras* are large mats manufactured from the leaves of *Gynerium sagittatum* var. *glabrum* which are held in place at their margins with bark strips of *Heliocarpus americanus* or *Abutilon laxum* (figure 8.25A). *Hesteras* are also claimed to be made from the leaves of *Attalea phalerata* and *A. butyracea* but we have not been able to observe this. A floor mat that requires less work is obtained by stripping the bark of large *Ochroma pyramidale* trees. As it is, bark strips of up to several square meters can be obtained from adult trees. According to participants, the kapok produced by the latter tree species is also used for stuffing mattresses.

Household Tools

Items found in every house are mortars (*takú*) with pestles (*manija*) (figure 8.23C & F) and troughs (*batán*) (figure 8.26 A-C) for the peeling and grinding of grains, and use in other food preparations. Mortars are generally carved out of logs of *Clarisia racemosa*, but alternatively also *Myroxylon balsamum*, *Parinari klugii*, *Pouteria* cf. *durlandii* and even *Celtis schippii* were mentioned. Pestles are made from *Myroxylon balsamum, Mouriri cauliflora, Lecointera amazonica, Dipterix odorata* or *D. micrantha.* The Bolivian Tacana also use *C. racemosa* and *D. odorata* for mortars and troughs (De Walt *et al.*, 1999). According to participants' own statements and as confirmed by Nordenskiöld (2003), mortars and pestles are exclusive cultural goods of Trinitarios and are probably not part of the historical material culture of Yuracarés. Troughs are basically used for grinding grains by rolling large flat stones over the grains (figures 8.26B & C). They are typically carved from the wood of *Swartzia jorori*, but *Clarisia racemosa* and *Calophyllum brasiliense* have also been mentioned.

Yuracarés as well as Trinitarios still manufacture different kinds of baskets, fans and sieves from at least seven different plant species. A variety of baskets is made from the (1) leaves of *A. phalerata, A. butyracea*, *Jessenia bataua*, *Gynerium saggitatum;* (2) the aerial roots of *Thoracocarpus bissectus*; or (3) the culms of *Ischnosiphon puberulus* or *Olyra latifolia* (figure 8.25 F-H & J); Among Trinitario people, fans are fabricated from *A. phalerata, A. butyracea* or *Carludovica palmata* (figure 8.25 B-D). Sieves generally consist of splints of *I. puberulus* arranged in a lattice-style weaving pattern attached to a square frame that can be made of *Piper* spp. stems (figure 8.25 I). In absence of *I. puberulus*, *Guadua* cf. *weberbaueri* or *T. bissectus* are used. By simply uniting the two ends of a large *Ochroma pyramidale* bark strip, a cylindrical recipient (*pirua*) is obtained that is open at both ends and used for storing rice (figure 8.26F). *Piruas* are placed on elevated surfaces in dry places and covered with a piece of cloth or large plant leaves.

Drinking gourds are present in every house and are made of split and hollowed-out fruits of *Crescenta cujete* or *Lagenaria siceraria*. The broad petioles of *Iriartea deltoidea* (figure 8.24 and figure 8.26D) are processed into large rectangular recipients. Large spoons are carved from the wood of *Aspidosperma rigidum* and *Zanthoxylum* spp. Pottery is not practiced anymore. Although the use of bark of Chrysobalanaceae species (particularly *Licania spp.*)

for temper in ceramics is widespread among indigenous and peasant groups in Amazonia (e.g. Prance *et al*., 1987; Boom, 1989; Beck and Prance, 1991; Milliken *et al*., 1992; Balée, 1994; De Walt *et al*., 1999), the latter use was not confirmed by our participants. In the present study, Trinitario participants claimed they used to mix the ashes of burned animal of fish bones with clay for strengthening the pottery (figure 8.26E). Denevan (1980) described how in post-contact times the Mojeños used an herbaceous plant species for this purpose. According to Nordenskiöld (2003), the Yuracaré did not develop much of a ceramics culture due to the lack of access to adequate clay in their habitat. By contrast, the ceramic art was highly developed among the Arawaks in Mojos (Nordenskiöld, 1924; Denevan, 1980).

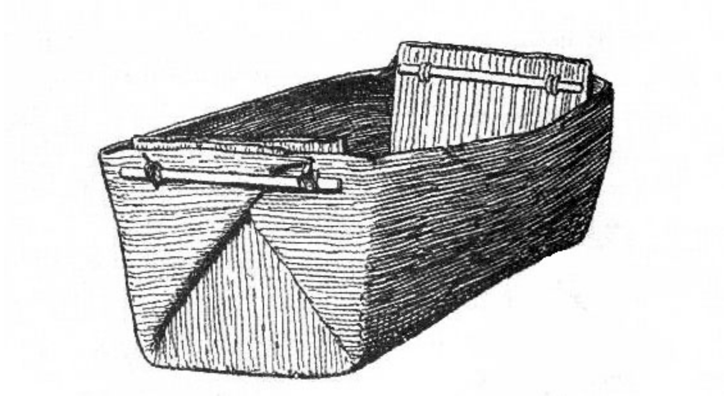

Figure 8.24: Yuracaré recipient made from the petiole of a *Iriartea deltoidea* leaf (source: Nordenskiöld, 2003)

Part of cooking practices among Trinitarios and Yuracarés involves grilling meat or fish on smouldering coal. As a grill, fresh stalks of principally *Piper* spp. are often used because they do not catch fire easily. These stalks are placed horizontally over stones or wood blocks (mostly of *Cecropia* spp.) that are put around the fire. Meat or fish are placed on top of the grill, frequently wrapped in the leaves of several *Musa* spp., *Heliconia* spp. or *Calathea* spp. This method of preparation is locally called *yulula*. Mushrooms are also cooked this way by Yuracarés.

Although at the time of the present study no sugar cane press (*trapiche*) was in use, Trinitario participants still know how to assemble it. The wood of four tree species was reported as used in *trapiches*: *Myroxylon balsamum, Lecointera amazonica*, *Hymenaea courbaril* and *Clarisia racemosa*.

Canoe Materials

Canoes are powered by human muscle through either rowing with wooden oars or poling with long sticks (*singas*). For oars, preference is given to Myristicaceae species, including *Otoba parvifolia*, *Virola peruviana* or *V. flexuosa*. These are relatively lightweight timber species. However, a disadvantage is that these oars have to be looked after carefully since termites are rather fond of the wood. Oars are also carved from the large but relatively thin buttress roots of species such as *Sloanea* spp. and *Aspidosperma rigidum*. This practice is confirmed by Milliken *et al*. (1992) for the Waimiri Atroari from Brasil. Very popular species for *singas* in TIPNIS are *Mouriri cauliflora* and *Gynerium sagittatum* var. *glabrum*, but alternative species include *Drypetes amazonica*, *Guadua* cf. *weberbaueri, Mouriri* spp., *Calyptranthes* spp. and *Osteophloeum platyspermum.*

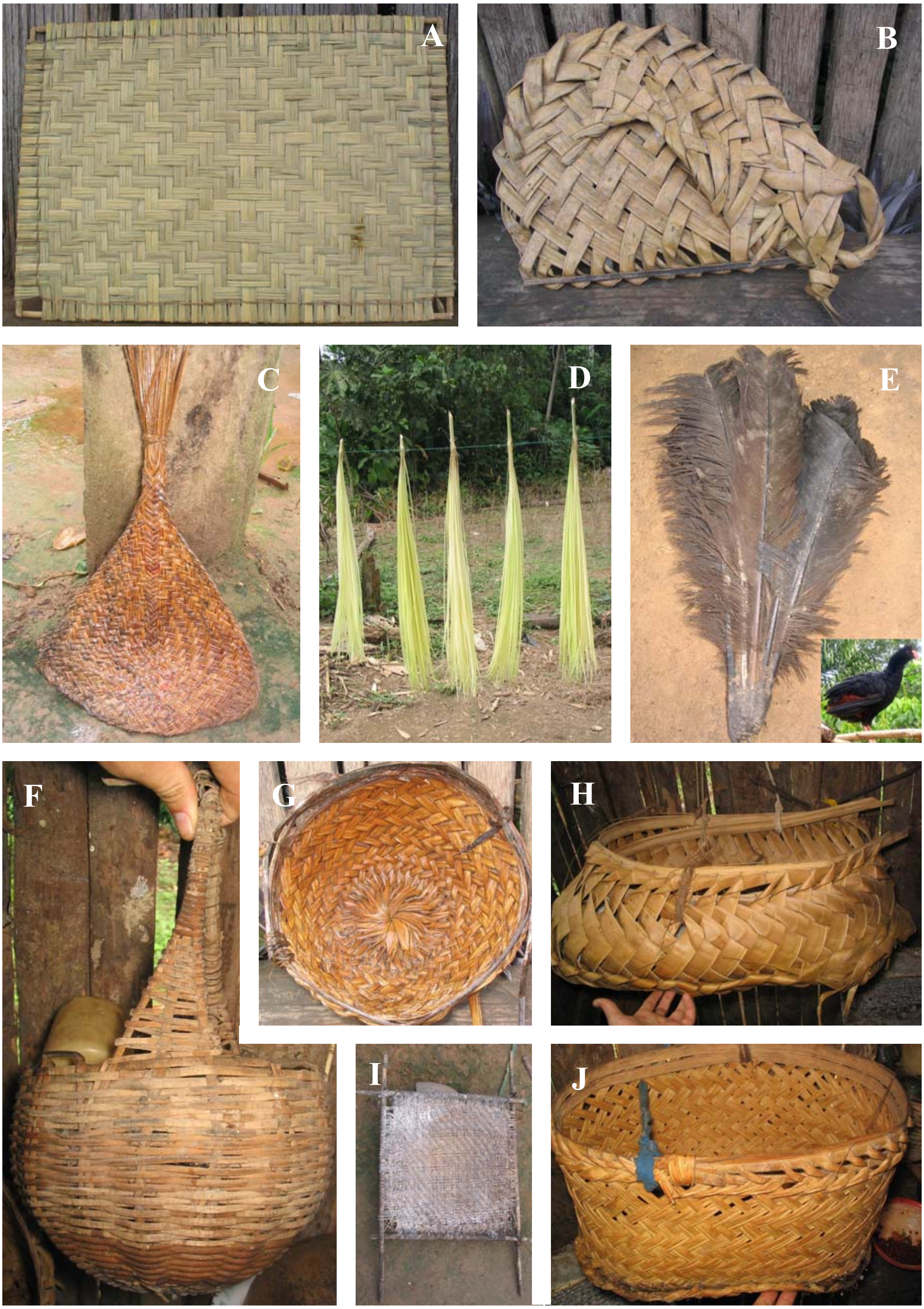

Figure 8.25 A: *Hestera* made from the leaves of *Gynerium sagittatum*; B: Trinitario fan made from a *Attalea butyracea* leaf; C: Yuracaré fan made from *Carludovica palmata;* D: *Drying Carludovica palmata* fibres; E: Yuracaré fan made from the back feathers of *Mitu tuberosa* that are cemented in beeswax; F: Trinitario basket made from *Thoracocarpus bissectus*; G & J: Trinitario baskets made from a *Attalea phalerata* leaf ; H: Trinitario basket made from a *Attalea butyracea* leaf; I: Yuracaré sieve made from *Ischnosiphon puberulus*

Figure 8.26 A: Trinitario women preparing non-alcoholic beverage from *Musa* spp. in large troughs; B & C: Yuracaré girl and Trinitario man grinding grains by means of flat stones from the river; D: Yuracaré recipient made from the petiole of a *Iriartea deltoidea* leaf; E: Trinitario pottery; F: Old *pirua*, made from *Ochroma pyramidale* bark strip and used for storing rice

Canoes are not necessarily manufactured in the vicinity of rivers or streams. When fabricated deeper in the forest, a large liana is attached to the canoe after which it is pulled to the river by a chain of male adults (figure 8.19E). Ten lianas were reported for this specific use, the majority of which are Bignoniaceae (6 species). Interestingly, also the young aerial roots of the strangler *Ficus cuatrecasana* were claimed to be used for this purpose.

Fissures or holes in canoes are often repaired by sealing them up with latex from *Clarisia biflora*, *C. racemosa* or *Symphonia globulifera*. According to participants, the latex of these species has similar properties as tar. The use of *S. globulifera* for boat caulking is widespread in Amazonia (Milliken *et al*., 1992).

Handles

Twenty-one woody species are used to fabricate handles of axes, pickaxes, shovels, etc. Not all wood can be used for this purpose: only wood of species that is light, somewhat flexible and does not break or splinter easily is preferred. Similarly to oars, handles are often carved from the large thin buttress roots of selected species since this does not require cutting down the entire tree. Most species are Sapotaceae (57%), but also *Aspidosperma rigidum*, *Eschweilera andina*, *Clarisia racemosa* and *Iryanthera juruensis* were reported, among others. All woodwork is sanded with the rough leaves of *Pourouma guianensis*. This practice has also been reported from the Brazilian Ka'apor (Balée, 1994).

Indigenous Textile, Leather and Hats

According to literature, Trinitario people basically relied on cultivated cotton fibre (*Gossypium barbadense*) for manufacturing plant-based textile, whereas barkcloth has been documented as one of the cultural traits belonging to Yuracarés (Lloyd, 1854; Von Holten, 1877; Miller, 1917; Mather, 1922; Nordenskiöld, 1924; Richter, 1930c; Denevan, 1980; Querejazu, 2005a). However, according to Armentia (1905) and Denevan (1980), the Mojeños also used barkcloth. Today, barkcloth is no longer worn as clothing, but most participants still know how to harvest and process it. Four Moraceae species are considered sources of barkcloth: apart from the most-favoured *Poulsenia armata* (figure 8.27E), also *Ficus insipida*, *F. maxima* and *F.* cf. *piresana* were reported used as such. For obtaining barkcloth, medium-sized trees (about 30 cm in diameter) are felled. The trunk is then cut according to the desired length of the cloth. The bark is cut longitudinally with a knife, after which the trunk is heated in the fire, to facilitate stripping of the bark. The bark is spread out to smooth the progress of separating the outer bark from the useful inner bark. The latter is scraped for removing coarse white fibres. Finally, the "clean" inner bark is beaten with a specially designed wooden club until it becomes soft and can be stretched to increase its surface area. Barkcloth thus obtained can be sewn together into clothing, blankets or mosquito nets (Steward, 1948). A similar description for preparing bark cloth was presented by Métraux (1942).

Textile technology based on cotton fibre clearly reached a higher level of development among Trinitarios than among Yuracarés, although the use of cotton-based cloth has also been observed among the latter (Nordenskiöld, 1924; Querejazu, 2005a). According to participants, Trinitario garments used to be exclusively made from cotton. Nowadays only purchased clothes are used. However, the manufacturing of hammocks is still actively practiced by most

Trinitario women. Cotton is harvested and spun to thread by means of a spool that is twisted horizontally, supported by the orifice between one's toes on the one end and a hard (wooden) surface on the other end (figure 8.27A & B). The spool's axis is carved from the wood of *Bactris gasipaes* whereas the disk consists of a piece of calabash (*Crescenta cujete*). According to Querejazu (2005a), the Yuracarés applied a similar technique, but instead of using the cavity between one's toes, they used a Y-shaped wooden instrument that was planted in the ground. Once enough thread is produced, it is dyed using the plants described lower (i.e. *Neea* spp., *Guapira* cf. *opposita, Ixora spruceana, Picramnia sellowii, Genipa americana, Hiraea fagifolia)* and weaved into a hammock on a vertically positioned loom (figure 8.27C & D). According to Nordenskiöld (1924) and Métraux (1942), Yuracarés adopted the vertical Arawak way of weaving that is still in use among Trinitarios.

Trinitario participants also claimed that hammocks were occasionally manufactured from the bark of *Duguetia spixiana*, *Cecropia concolor* or *C. engleriana*. The Yuracarés used to manufacture carrying nets from the bark fibres of *C. concolor*. These nets were carried on the forehead by means of a piece of barkcloth (Nordenskiöld, 1924; Querejazu, 2005a).

Yuracarés did not make use of hammocks (Nordenskiöld, 1924 and 2003; Querejazu, 2005a). Nevertheless, Richter (1930c) described how babies were rocked in pieces of barkcloth that were hung up on roof beams. Nowadays, purchased pieces of cotton cloth are used for this purpose. The Yuracarés used to manufacture mosquito nets from barkcloth and were probably already doing so before to the arrival of Caucasians (Nordenskiöld, 1922). This made Nordenskiöld (2003) suggest that mosquito nets would be an Amazonian (or maybe even a Yuracaré) "invention". Today, all mosquito nets are from industrial origin. Mostly, stems of *Hyospathe elegans* are used for hanging the net over the bed.

Participants reported three different plant species for tanning leather (figure 8.27F). The barks of *Swietenia macrophylla* or *Anadenanthera colubrina* are ground and macerated in water for three days together with the animal skin that needs to be treated. Alternatively, ashes obtained from the wood of *Gallesia integrifolia* are applied on the "hairy" side of the fresh skin and left there until the hair comes lose. Next, the skin is stretched tight, the remaining ashes are scraped off and the skin is thoroughly washed. Afterwards, the skin can be dyed and rubbed with animal fat to make it impermeable. The use of bark of a related species, *Anadenanthera macropcarpa*, for tanning leather has also been reported by Vidaurre *et al.* (2006).

Several ethnographic studies fail to mention the use of hats among Yuracarés and therefore they were probably introduced to them by Trinitarios. Nowadays, hats are also occasionally manufactured under guidance of governmental and non-governmental organizations to sell them as souvenirs to tourists and provide people with extra income. Hats are made from (1) the leaves of *Attalea phalerata, Euterpe precatoria* or *Carludovica palmata;* (2) the aerial roots of *Thoracocarpus bissectus*; (3) the culms of *Ischnosiphon puberula*; or (4) bark strips of *Abutilon laxum*.

Figure 8.27 A: Locally produced cotton fibre; B: Trinitario woman spinning cotton thread; C: Trinitario woman weaving a hammock on a vertical loom; D: Tools (manufactured from the wood of *Bactris gasipaes*) used for weaving textile (the smallest item is about 14 cm in length); E: Piece of barkcloth made from *Poulsenia armata*; F: Drying deer skin (*Mazama* sp.) for future use in a drum

Dyes

Seventeen different species were mentioned as natural dyes. The family that contains most of the species used as dyes is Nyctaginaceae. The ripe fruits of nine *Neea* spp. (e.g. *N.* cf. *spruceana*) and *Guapira* cf. *opposita* are crushed and the juice is directly applied to the textile to be dyed. According to participants, it was this purple-mauve dye Yuracarés used to print the famous patterns on their barkcloth garments that were applied by means of wooden stamps (figure 8.28B) (Mather, 1922; Richter, 1930c; Nordenskiöld, 1924 and 2003; Querejazu, 2005a). Similar purples are also obtained by crushing the fruits of *Ixora spruceana* or by grinding the leaves of *Picramnia sellowii*, mixing them with some water and then immersing the textile in this liquid. Unripe fruits and/or leaves of *Genipa americana* are ground and boiled in water together with the textile to provide a blue dye, whereas the ground bark of the liana *Hiraea fagifolia*, mixed with a small quantity of water, was said to produce a yellow colour.

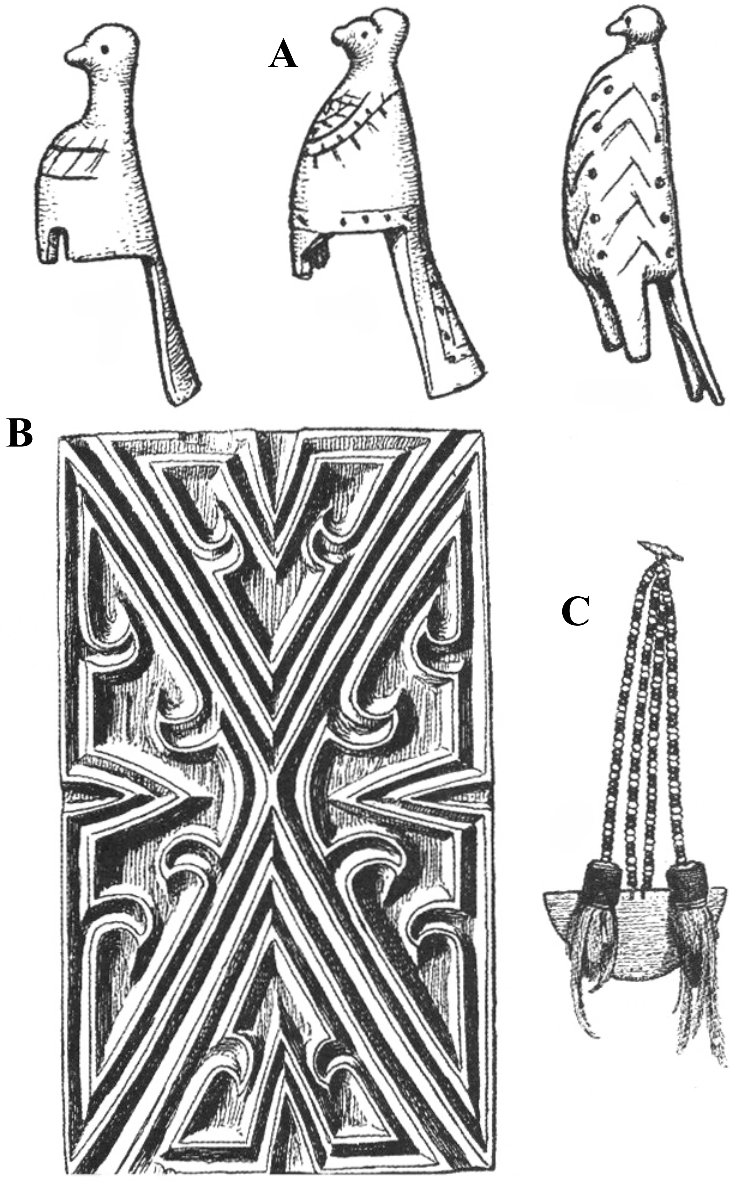

Figure 8.28 A: Small birds carved from crocodile teeth, used in the hair or on garments; B Wooden stamp for applying pigments on barkcloth; C: Yuracaré earring; the blade is made from silver, before it was probably made from shells; the rest is made from beads, feathers, etc. (source: Nordenskiöld, 2003)

Corporal Ornaments

As described by various ethnographers (Church, 1912; Miller, 1917; Richter, 1930c; Haenke, 1974; Nordenskiöld, 2003; Querejazu, 2005a) and confirmed by our participants, Yuracarés used to engage in body painting, particularly facial painting (figure 8.30A-C). Paint was applied as dots and lines by means of wooden pallets (figure 8.30D) or wooden stamps (figure 8.29C-E), similar to those used for painting barkcloth (Richter, 1930c). According to Richter (1930c) and Nordenskiöld (2003), Yuracarés used red, violet, blackish blue and black paint obtained from plants, as well as mineral paint in red and bluish tones. Pigments were kept in recipients made of bamboo (figure 8.30E). During the present study, the only plants that were reported to be used in facial painting are (1) sap of the fruits of *Genipa americana* which oxidises blackish-blue; (2) leaves of *Picramnia sellowii* for a purple pigment; (3) seeds of *Bixa orellana* for a red colour; and (4) fruits of several *Neea* spp. (e.g. *Neea boliviana*) for a mauve-purple colour. The Guyana Caribs also prepared body paint from ripe *Neea* fruits (Fanshawe, 1948). Nowadays, in TIPNIS all pigments mentioned are mainly used during carnival (month of February) by both Trinitarios and Yuracarés (see chapter 10). However, in line with similar practices reported elsewhere (e.g. Chaumeil, 2000), Trinitarios also use the sap of *Genipa americana* fruits to paint crosses on the bodies of newborns in order to ward off evil spirits (see Thomas and Vandebroek, 2006). According to Karsten (1926), the basic motivation for nearly all body painting among Amazonian groups was in fact for warding off evil divinities. This hypothesis is supported by Richter (1930c) for the case of the Yuracarés who, according to this author, additionally believed that painting their bodies during war or hunt would terrify their enemies or prey, respectively.

Richter (1930c) and Nordenskiöld (2003) documented the use of necklaces, waist adornments, rings and earrings (figure 8.28C) among Yuracarés. Only barkcloths of men were decorated with geometric patterns, whereas barkcloths of both sexes were adorned with pompom-like items (figure 8.29B) and small figures carved from wood, crocodile teeth or bones (figure 8.28A) (Richter, 1930c; Métraux, 1942; Nordenskiöld, 2003). As confirmed by Yuracaré participants during the present study, people also used to attach beaks of different kinds of local bird species, as well as beautiful feathers to the shoulders of children's garments, apparently more to act as talismans than as decorative elements (cf. Querejazu, 2005a). Yuracaré men used wristbands woven from cotton thread to reduce the impact of the arrow string during hunting. By means of cotton thread, Yuracaré women strung the seeds or fruits of different plant species for necklaces. During the present study, the fragrant fruits of *Myrcia fallax* in addition to those of *Notopleura leucantha, Besleria longipedunculata Ouratea macrobotrys* and the cultivated *Coix lacryma-jobi* were documented for their use in making necklaces.

The only adornments Nordenskiöld (1924 and 2003) and Eder (1772) described for the Mojeños are the mounted feather crowns that are still in use today during the dance of the *"macheteros",* one of the cultural traits of Trinitarios (figure 8.31E). However, Castillo (1676; cited in Nordenskiöld, 1924) also mentioned pieces of tin and silver as nasal and lip adornments, respectively, among the Mojeños. The seeds of *Ormosia nobilis* and *Sapindus saponaria* are also used by contemporary Trinitarios to manufacture necklaces or rosaries. Rings are made by members of both ethnic groups from the hard seeds of *Astrocaryum* *murumuru*. This use was also documented by Richter (1930c) and Nordenskiöld (1924) for the Yuracarés and by Balée (1994) for the Ka'apor.

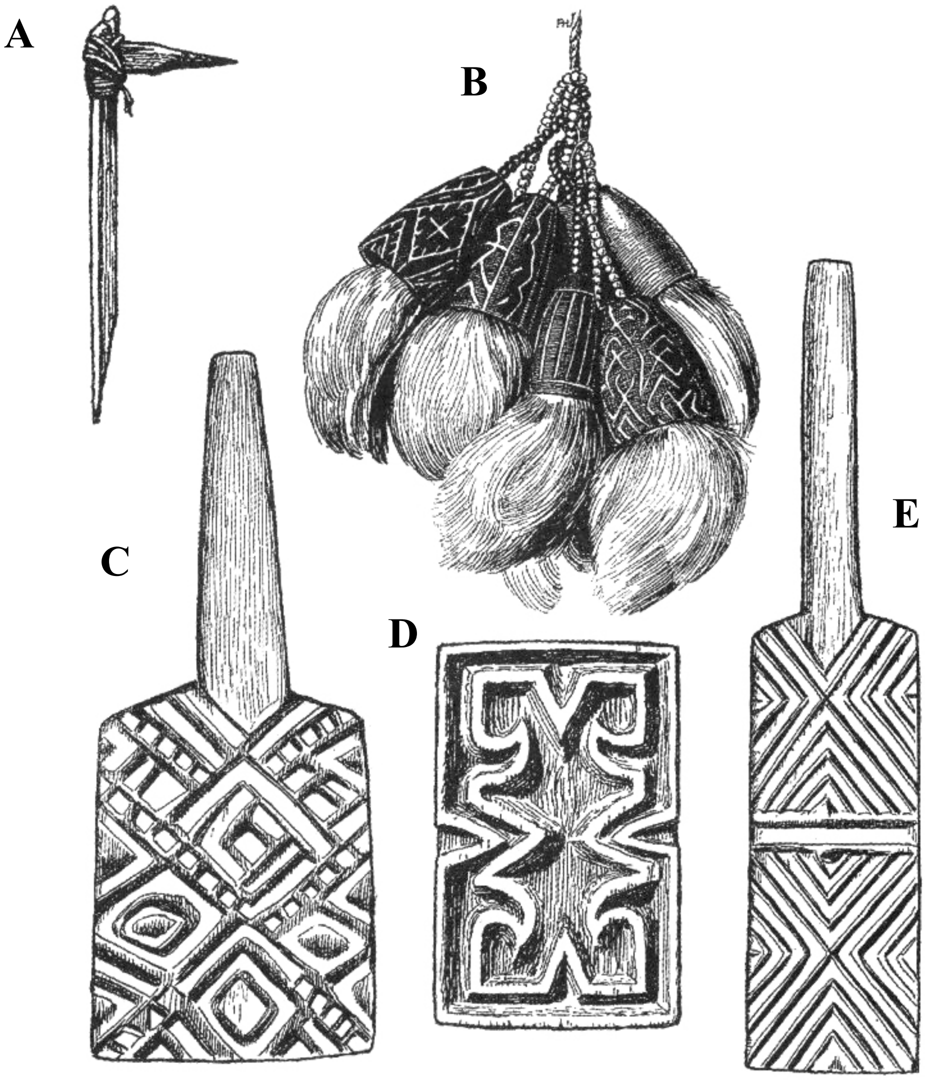

Figure 8.29 A: Yuracaré tool for blood-letting; B: Yuracare ornament made from engraved black fruits (*Cariniana* sp.?) and red Toucan feathers; C-E: Wooden stamps for applying pigments on skin (source: Nordenskiöld, 2003)

Hygiene

Yuracaré and Trinitario women take good care of their hair. They comb and oil it frequently. Nowadays, imported combs are used, but these used to be made from various plant species. The teeth used to be made from the wood of *Bactris gasipaes* or *B. major* var. *infestans* and were held together with slats of *Gynerium saggitatum* or *Guadua* cf. *weberbaueri.* Makeshift combs in the forest are available from the spiny fruits of *Apeiba membranacea*. Conditioner oils are obtained from the fruits or seeds of most palms trees, such as *Attalea phalerata, A. butyracea, Bactris gasipaes, Euterpe precatoria, Jessenia bataua, Socratea exorrhiza* and *Astrocaryum murumuru*. The liquids obtained from macerating the stems of the epiphytic cactus *Epiphyllum phyllanthus*, or the young shoots of the liana *Davilla nitida*, in water were also reported as sources of hair tonics (cf. Thomas and Vandebroek, 2006). Therefore, plant parts are ground, mixed with water, and applied to the hair which is rinsed afterwards.

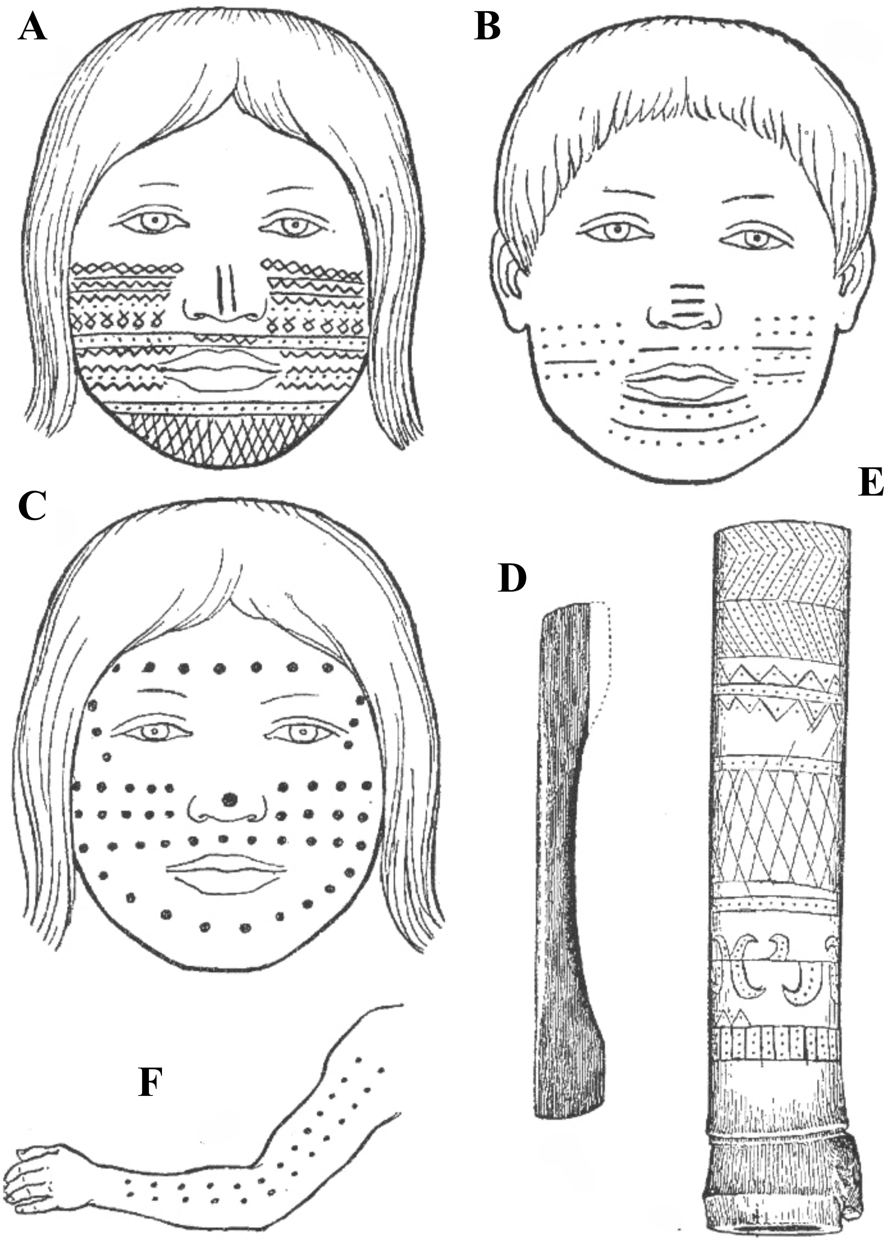

Figure 8.30 A, B & C: Facial painting in a girl, man and woman, respectively; D: Wooden pallet for applying body paint; E: Bamboo container for storing pigments; F: Tattooed arm with scars from a Yuracaré boy (source: Nordenskiöld, 2003)

Trinitario participants mentioned the use of three species for obtaining soap or shampoo: *Attalea phalerata, Gallesia integrifolia* and *Sapindus saponaria*. Ashes obtained from the wood of *G. integrifolia,* or from the bracts of *A. phalerata,* are put in a basket. Water is poured on top and the liquid that drops out beneath is used as "soap" for washing the body. A soap substitute is also obtained by grinding the fruits of *S. saponaria* and mixing them with water.

Women do most of the laundry, which usually takes place while seated in a canoe that is secured on a riverbank. Nowadays, detergent is bought in shops run by Andean settlers, but people still know how to use traditional detergents. At least five plant species are useful detergents. The fruits of *Enterolobium contortisiliquum* are ground and boiled in water until the liquid coagulates. This gelatinous residue is dried and used for washing clothes. The ashes of *G. integrifolia* are used directly as detergent but participants claim one should take care with the dosage, because using too much ashes makes holes in textile. Fruits of *Sapindus saponaria,* or the leaves of *Carica papaya* and *Momordica charantia,* are also ground and used as a soap substitute. The use of papaya leaves is confirmed by Balée (1994) for the Ka'apor. The latter author also mentions that the Ka'apor use the inner bark of an *Enterolobium* sp. as a detergent. Bourdy (2002) reports how both bark and fruit of *E. contortisiliquum* are used for the same purpose by the Izoceño-Guarani from the Bolivian Chaco. The use of *S. saponaria* fruits and leaves of *M. charantia* as soap substitutes is confirmed by Killeen *et al.* (1993) and Bourdy (1999). Ashes obtained from *G. integrifolia* together with papaya leaves are processed into soap by the Bolivian Tacana (Bourdy, 1999).

For clotheslines or fencing, people generally resort to stems of *Erythrina dominguezii, E. poeppigiana*, *Salix humboldtiana* or *Urera caracasana*, basically because they soon take root and resprout when put into the soil, and thus act as living posts or fences.

Trinitarios and Yuracarés use the fragrant fruits of all three *Vanilla* spp. that were inventoried as 'perfumes'. Usually they keep one or more fruits in their wardrobes to prevent clothes from smelling mouldy. Trinitarios burn the resin of *Hymenaea courbaril* as incense during religious ceremonies. According to Boom (1989), the Bolivian Chacobo burn the resin of the latter species as a light source.

Yuracarés and Trinitarios keep houses and yards clean. The patio around houses is constantly freed of vegetation. One of the main tools used during yard cleansing is a flat shovel with a long handle, but brooms are also frequently used for removing waste. Two general types of brooms are used. The first type is made of entire *Scoparia dulcis* or *Sida rhombifolia* plants with a handle fabricated from almost any woody tree or shrub species. The second broom type is smaller and mostly used inside the house. It consists of a bundle of rigid pinna costae of various palm species such as *Astrocaryum murumuru*, *A. phalerata, A. butyracea*, *Jessenia bataua* and *Iriartea deltoidea*. Similar brooms have been described by Bourdy (1999) for the Bolivian Tacana people.

Musical Instruments

During the present study, it became evident that the use of musical instruments was more frequent among Trinitarios than among Yuracarés. Only one Yuracaré elder was still able to play the traditional Yuracaré flute described by Métraux (1948) and Nordenskiöld (2003). The small flute he played was made from the bone of a deer. It had only three small orifices – two on the frontal side and one on the backside – as well as a score at the end of the upper half, where the mouth is to be placed. Besides animal bones, culms of *Guadua* cf. *weberbaueri* are also used for carving these flutes. Another instrument Yuracaré participants claimed to use is the panpipe, which is made from *G.* cf. *weberbaueri*, *Lasiacis ligulata* or *Olyra latifolia*. The Chacobo use the latter two species for the same purpose (Boom, 1989). Trinitarios also use flutes carved from animal bone (figure 8.31F), but they fabricate their panpipes exclusively from the stems of *Guadua* spp. According to Denevan (1980), the panpipes used in the Mojos missions were enormous and could reach up to 1.8 m (figure 8.32).

Figure 8.31 A: Toy version of an oxen-pulled cart, used as a means of transportation of goods in the Trinitario homeland, the plains of Moxos; B & C: Trinitario drums; D: Foot rattles made from cotton thread and dried *Thevetia peruviana* fruits, used during the dance of *Macheteros*; E: Playing the violin during a procession of *Macheteros*; F: Trinitario man playing on a flute made from the bone of a deer

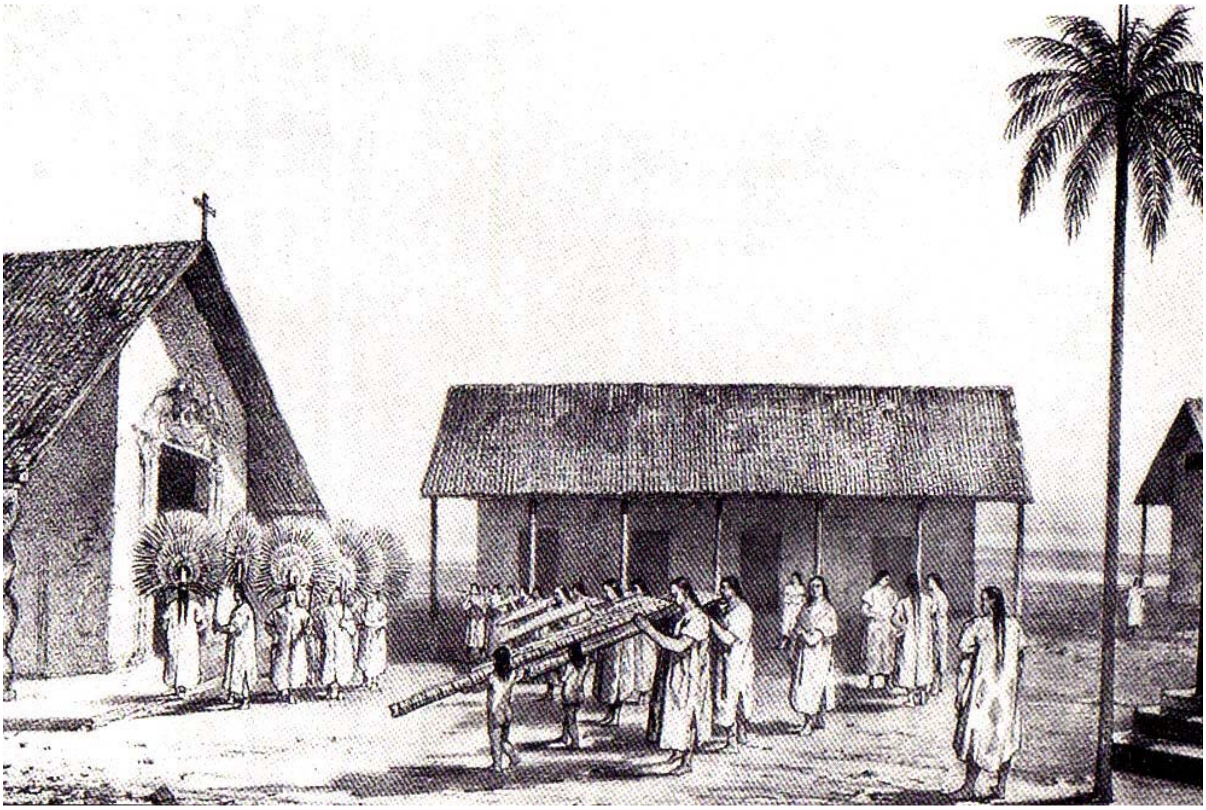

Figure 8.32: Mojeños dancing and playing on large panpipes in front of a church in Trinidad in the first half of the 19th century (drawing by d'Orbigny; source Nordenskiöld, 2003)

Trinitarios also make drums with the skins of the animals that were killed for food (figure 8.27F). Drums are mostly made from the wood of *Genipa americana*, but the liana species *Uncaria guianensis* or *U. tomentosa* are used as well to manufacture the wooden rings (*aros de tambor*) that are placed on either side of the wooden sound box to keep the skins tightly stretched (figure 8.31B & C). A number of Trinitarios know how to play the violin (figure 8.31E), a skill picked up in the catholic missions that are still based today in some remote Trinitario communities. Violins are assembled locally with the wood of *G. americana*. Resin obtained from *Protium* cf. *meridionale* is used as string wax. Finally, for making foot-rattles used during the dance of the "*macheteros*", the dried fruits of *Thevetia peruviana* are employed (figure 8.31D).

Participants also reported that colonizing Quechua highland farmers use the fine wood of *Zanthoxylum tambopatense* and *Z. sprucei*, for fabricating *charangos*, small 8-stringed instruments that are characteristic to the Andean culture (see chapter 3, section 3.3.7.).

Toys

Children use a variety of toys of plant origin. Toy bows and arrows are an integral part of the playthings of every young boy. The woody fruits of *Cariniana* cf. *estrellensis* are used as flutes. Dried fruits of *Crotalaria nitens* serve as rattles, a use that has also been documented for the Shuar from Ecuador (Bennett, 1992). As confirmed by Eder (1772) and Querejazu (2005a), Trinitarios used to make a "football" from the latex of *Sapium glandulosum*. The procedure goes as follows: several cuts are made in the bark and after a day or two the "threads" of hardened latex that have gushed out are harvested. These threads are then wound to form solid "rubber" balls.

The woody pods of several lianas from the Bignoniaceae family are used as toy canoes. Bubbles are blown from the resin of *Jatropha curcas*. Drinking straws are made from *G.* cf. *weberbaueri* or *Lasiacis ligulata* stems. Trinitario fathers make miniature versions of the oxen-pulled carts for their children as a gift (figure 8.31A). These carts are used as a means of transportation of goods in their homelands, the plains of Moxos. The wood comes from *Ormosia* spp. or *Calophyllum brasiliense*.

Highly Valued Material Plants

Table 8.14 lists twenty species with the highest material (quality) use values. Arecaceae are clearly represented best with 5 species. Almost every species in this list is used for at least three different material applications. However, consensus regarding these uses is relatively low, since UV_{mat} and QUV_{mat} values are all lower than three. As mentioned previously, this indicates that not every material species is known or actually used by all participants, which can be ascribed, in part, to the different ethnic affiliation of participants. However, low values may also be evidence for the gradual loss of traditional practices concerning the use of natural materials, as they have become replaced by 'superior' alternatives from industrial origin.

Table 8.14: Ranking of material plants according to quality use values

Scientific name	family	# participants	# uses	$QUV_{mat}=UV_{mat}$
Attalea butyracea	Arecaceae	6	6	2.83
Bactris gasipaes	Arecaceae	8	4	2.63
Attalea phalerata	Arecaceae	8	7	2.38
Gynerium sagittatum	Poaceae	9	6	2.33
Ochroma pyramidale	Bombacaceae	11	7	2.00
Guadua cf. *weberbaueri*	Poaceae	10	7	1.80
Clarisia racemosa	Moraceae	12	7	1.75
Sapindus saponaria	Sapindaceae	6	3	1.67
Genipa americana	Rubiaceae	8	4	1.63
Ischnosiphon puberulus	Maranthaceae	9	6	1.56
Picramnia sellowii	Simaroubaceae	12	3	1.33
Aspidosperma rigidum	Apocynaceae	11	3	1.27
Jessenia bataua	Arecaceae	8	3	1.25
Lasiacis ligulata	Poaceae	4	3	1.25
Myroxylon balsamum	Fabaceae	5	3	1.20
Thoracocarpus bissectus	Cyclanthaceae	12	4	1.17
Cecropia concolor	Cecropiaceae	6	2	1.17
Bactris major var. *infestans*	Arecaceae	6	3	1.17
Marsdenia macrophylla	Apocynaceae	3	1	1.00
Poulsenia armata	Moracae	8	1	1.00

8.3.11. Social Plant Use

Plant applications categorized as social uses include ritual, religious and spiritual uses, as well as smoking materials and drugs. At least 55 different species are used within this category in TIPNIS (figure 8.33). They are distributed over 34 families and 42 genera. Families with many species for this use category are Araceae (7%), Piperaceae (7%), Costaceae (7%), Fabaceae (5%), Orchidaceae (5%), Solanaceae (5%), Theophrastaceae (5%), Rubiaceae (5%) and Urticaceae (5%). Nearly one third of plants with a social use value are shrubs (31%), followed by herbs (20%), trees (17%) and epiphytes (12%).

Curses

Sixteen species are used to treat curses (*hechizos*). The latter can be caused by different phenomena. Some curses are believed to be evoked by evil sorcerers by means of particular plant species. Participants were not keen to reveal the identity of these plant species and the only species that we were able to record was *Gongora scaphephorus* (mentioned in paragraph 8.3.1). Spells from evil sorcerers from distant places are believed to be transported by wind, but jealousy from people within the same or neighbouring villages can also result in curses. According to Yuracarés, the areal parts of the fungus *Phallus indusiatus* represent the heads of the deads and by damaging these, people are said to become cursed.

A particular kind of curse is the rainbow curse (*hechizo de arco iris*), which is also known to Yuracarés (Metraux, 1942). According to Trinitarios, it is transmitted by spiritual entities called "*ohekuna*" that are claimed to have made a pact with the rainbow. *Ohekuna* are said to appear when a rainbow is accompanied by strong winds (therefore, it is somewhat related to the so-called wind disease (see chapter 3, section 3.3.4.4.)). On such occasions, these spiritual beings are believed to shoot dirt (mainly putrefied menstruation blood) at people by means of their arrows, thus creating burning coloured swellings. According to Balée (1994), such a concept of female pollution is widespread in lowland South America. It has also been reported by Eder (1772) in his account of the eighteenth century plains of Moxos. Interestingly, in TIPNIS, treatment of rainbow curses among Trinitarios seems to represent an example of the 'doctrine of signatures'. Indeed, treatment of the "rainbow-coloured" swelling, involves the use of the rainbow vine (*ohejyepre*) *Dioscorea dodecaneura* whose leaves show a pattern of different colours similar to a rainbow. Yuracarés claimed to treat rainbow curses through rubbing affected body parts with the melted fat of land turtles. Intriguingly, the rainbow curse concept is not confined to our study population. Stein (1981) identified rainbow sickness as one of the folk illnesses found in the Andes, and Lenaerts (2006) reported how the Arawakian Ashéninka from the Peruvian Amazon also treat "rainbow burns". Pieroni *et al.* (2002b) even described rainbow illness for ethnic Albanians in Italy.

Other types of curses reported by Trinitario participants are water and rain curses which correspond with swollen abdomens and malnutrition (thin bodies with large bellies), respectively. Hence, most curses seem to manifest themselves as different types of swellings or oedemas. However, when babies are not positioned right at the time of birth, this can also be caused by the fact that a spell is put on the mother. Paralysis in different body parts, or (temporally) contracted limbs, are also possible. For particular plant remedies used for treating curses, the reader is referred to Thomas and Vandebroek (2006).

Fetish for Children to Walk

Fourteen plant species were reported by Yuracaré as well as Trinitario participants for their use to ensure that an infant will walk at the appropriate age and for treating children who have problems with beginning to walk. Families with the highest number of species in this use category are Araceae and Piperaceae with four species each. According to Grenand *et al.* (2004), Araceae differs from other families in that it is used more often in a magical context among most ethnic groups from tropical America. These authors describe a number of species in this family that are used by ethnic groups in Guyana to treat about any (magical) health condition in children. Balée (1994) mentions two species of the latter family used by the

Brazilian Ka'apor as a fetish for children to walk and to stimulate leg growth, respectively. Yuracarés use the leaves of *Monstera dubia*, *Philodendron brandtianum* and *Philodendron* sp. (ET671) species for wrapping up the knees and ankles of an infant, while a more drastic approach is to slap the urticating leaves of *Urera baccifera* on the child's body. Trinitarios prepare herbal baths of all other plants documented for making children walk more rapidly.

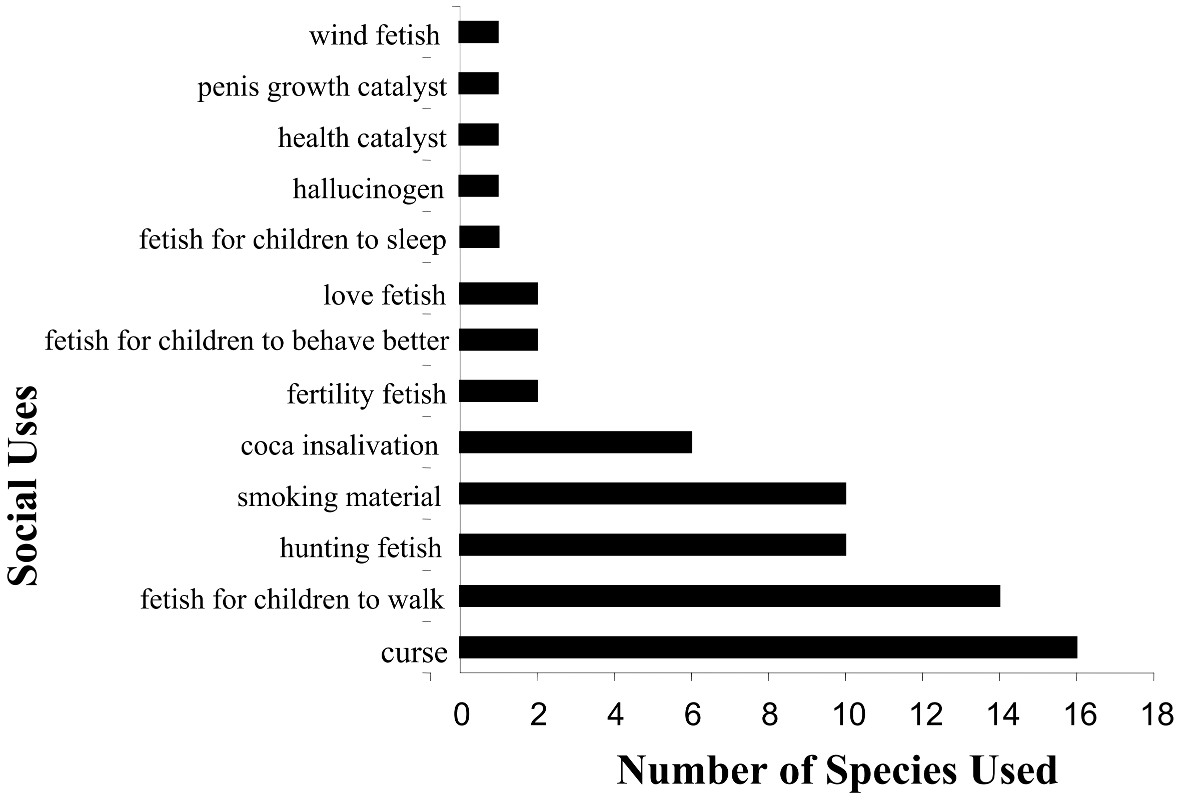

Figure 8.33: Different material uses with numbers of species used in TIPNIS

Hunting fetishes

Dogs are considered valuable animals by Yuracarés and Trinitarios. Most people are concerned for the well-being of their dogs and may even allow them to sleep under their mosquito nets during the night. The value of dogs is that they can increase a hunter's catch considerably by tracking down game species and driving them towards their owner. However, dogs should not get scared in the forest or by the animals they are expected to track down. As reported elsewhere in Latin America (e.g. Milliken *et al.*, 1992; Balée, 1994; Muñoz *et al.*, 2000b; Lans *et al.*, 2001; Lenaerts, 2006), it is therefore common belief among Yuracarés and Trinitarios that dogs need initiation in the art of hunting. Most initiation practices involve some kind of plant preparation. In particular, members of the Theophrastaceae family are perceived as useful. The rhizomes of *Clavija lancifolia*, *C. tarpotana* or *C. weberbaueri* are ground and mixed with the dog's food, or macerated in water which the dog is forced to drink. Yuracarés use the roots of *Neea* cf. *virens* and *N. boliviana,* and Trinitarios use the roots of *Petiveria alliacea* and *Floscopa peruviana* in similar ways. Yuracarés also claim to mix some of the (poisonous!) fruit of *Solanum mammosum* with the dog's food. A Trinitario participant also mentioned that tapping a toucan beak on the dog's nose increases its hunting abilities. In order to protect dogs against jaguar attacks, Yuracarés bathe them in a maceration of

Erythrina poeppigiana bark in water. In analogy, Roucouyennes (Caribs) (used to) rub their dogs with *Hibiscus abelmoschus* with the expectation that the smell of this would prevent jaguars from biting their dogs (Roth, 1915).

A less humane way to force dogs to become braver was mentioned by a Trinitario participant. It consists of tying them up to *Triplaris americana* trees which are inhabited by aggressive ants that soon swamp the dogs with painful bites. In a similar fashion, ants and other insects were made to bite the nostrils of hunting dogs for improving their hunting abilities among Guyanese Amerindians (Im Thurn, 1967 cited by Lans *et al*., 2001). According to Roth (1915), there may be a mental connection (conditioning) between the pain previously inflicted on the dog and his success in the acquisition of game. The latter author hypothesized that the nervous system of the dogs is irritated to such an extent that it becomes responsive to even the slightest external stimulus and renders the animal more likely to be successful in hunting. A practice that is similar to the one described by Roth (1915) is the slapping of urticating *Urera lacinata* branches on dogs as mentioned by Trinitario participants.

Smoking Material

Most households, but particularly those of Trinitarios, cultivate tobacco. According to our observations, Trinitarios tend to smoke more frequently than Yuracarés. Apart from being used as smoking material, tobacco also has important spiritual and medicinal applications in TIPNIS (see chapter 11 and Thomas and Vandebroek, 2006). According to various authors (e.g. Von Holten, 1877; Stahl, 1925; Nordenskiöld, 1924 and 2003), the Yuracarés originally used tobacco only as herbal medicine, particularly for removing botfly larvae (*Dermatobia hominis*) that infest the human skin (Thomas and Vandebroek, 2006).

People like to add flavourings to cigarette tobacco. To this effect, either one of the fragrant fruits of *Erythrina poeppigiana*, *Guazuma ulmifolia* or *Vanilla* spp. are boiled in water. Once the liquid has cooled a bit, semi-dry tobacco leaves are drenched in this decoction and hung up to dry again. Cigarette paper is obtained by peeling the stems of any one of the collected *Costus* and *Dimerocostus* species.

Coca Insalivation

Coca (*Erythroxylum coca*) is cultivated by nearly all families in the participating communities. It is partly grown for its medicinal properties (Thomas and Vandebroek, 2006) and for personal insalivation, but the largest part of production is sold to Andean settlers. According to participants, coca insalivation is not an indigenous custom, but has been acquired from Andean settlers. People tend to chew coca leaves when undertaking hard work such as clearing swiddens or during consumption of alcohol. As is the case in Apillapampa (chapter 3, section 3.3.8.), it is common practice for Yuracarés and Trinitarios to chew the leaves together with *lejía*, which is prepared by mixing the ashes of particular plant species together with water. This mass is subsequently “baked” over a fire. Only five different plant species were mentioned for the preparation of *lejía*: the wood of *Vernonia patens*, *Marcgravia flagellaris*, *Paullinia clathrata* and *Abuta* sp. 2 (ET1614), and the tubers of *Ipomoea batatas*. Alternatively, sometimes commercial sodium carbonate ($NaHCO_3$) is mixed with coca leaves during chewing.

Miscellaneous
Fertility fetish. It is a Trinitario belief that a woman, who bears only daughters, can enhance her chances of giving birth to a boy by carrying the fruits of *Syngonium podophyllum* with her during pregnancy. According to a Yuracaré participant, the scraped bark of *Siparuna thecaphora* is traditionally applied in a cataplasm to the vagina of girls who menstruate for the first time, but no particular purpose was specified for this practice.

Fetish for Children to Behave. When *Yuracaré* children behave badly, they are sometimes gently "whipped" with the branches of *Bouchea fluminensis* or *Laportea aestuans*.

Love fetish. Love charms seem to be used in many Latin American cultures and beyond (e.g. Balée, 1994; van Andel, 2000; Tabuti, 2003; Shepard, 2004: Lenaerts, 2006) to attract members of the opposite sex. In TIPNIS, it was only mentioned by Trinitario participants who claim that by touching females with the liana *Macfadyena unguis-cati* they will fall in love with the male 'actor'. The fruits of *Notopleura leucantha* are said to have the same effect.

Fetish for Children to Sleep. The spiny liana *Piptadenia* cf. *anolidurus* is gently moved over the bodies of infants who have difficulties sleeping. Interestingly, a very similar practice was documented by Balée (1994) for the Ka'apor who hang the morphologically similar spiny liana *Acacia multipinnata* above infants' hammocks to soothe them to sleep.

Hallucinogen and Wind Fetish. As described in chapter 10 (section 10.4.4.), and in Thomas and Vandebroek (2006), Trinitarios drink the maceration of ground flowers and leaves of *Brugmansia graveolens* in water for hallucinogenic purposes, in analogy with other ethnic groups (e.g. Schultes and Hofmann, 1983; Chaumeil, 2000). In general, this drink is ingested by shamans and traditional healers only, but some laypersons also declared to have used it. People say the plant helps to "see" past actions or actions that occur at distant places. According to participants, the plant is most often used for revealing the identity of thieves who stole something from the person who ingests it. Interestingly, one female traditional healer said that apart from ingesting the maceration, some liquid should also be dropped in the eyes. This might represent a reference to the initiation rite of *tiharauqui*, the historical equivalent of present day *tkonñahi* (see section 8.3.6.1.). This initiation rite involved the dropping of the bitter sap of a liana species in the *tiharauqui*'s eyes in order to "clear" them (Wegner, 1931).

Even though *Brugmansia graveolens* does not seem to be used to provoke hallucinations by Yuracarés, they do employ this species in a magical context. Participants claimed that burning the leaves of this plant would force strong incoming winds to change their course.

Health Catalyst. According to Trinitario midwives, mothers can stimulate good health of both mother and child by chewing some fresh seeds of *Arachis hypogaea* and rubbing the masticated seeds on the newborn's body, as well as on the mother's body prior to leaving the childbed.

Penis Growth Catalyst. When one is unhappy about the length of his penis, he can resort to the penis-like adventive roots of *Iriartea deltoidea* for increasing its length. Obviously, this is an example of the ‘doctrine of signatures’. According to participants, the treatment consists in drinking the maceration of ground *I. deltoidea* adventive roots in water. Once the penis has reached its desired length, one should cut the tree from which the remedy was obtained to prevent that the penis keeps on growing.

Most Valued Plants with Social Uses

Most plants only have one or two social uses, but social (quality) use values of all species are considerably lower than 1 (table 8.15). This is partly because typical Yuracaré social plant uses are not known by Trinitario participants and vice versa. In addition, it shows that knowledge about social uses is strongly idiosyncratic and/or that most social uses of plants are no longer practiced or remembered by most participants.

Table 8.15 : Ranking of plants from TIPNIS with social uses according to (quality) use values

scientific name	family	# participants	# uses	$UV_{soc\ uses}$=$QUV_{soc\ uses}$
Clavija weberbaueri	Theophrastaceae	6	1	0.83
Erythroxylum coca	Erythroxylaceae	5	1	0.80
Clavija lancifolia	Theophrastaceae	13	1	0.77
Nicotiana tabacum	Solanaceae	7	2	0.71
Clavija tarapotana	Theophrastaceae	12	1	0.67
Datura suaveolens	Solanaceae	15	2	0.47
Vanilla cf. *planifolia*	Orchidaceae	12	1	0.42
Vanilla sp. 2	Orchidaceae	12	1	0.42
Petiveria alliacea	Phytolaccaceae	16	2	0.38
Neea cf. *virens*	Nyctaginaceae	3	1	0.33
Urera lacinata	Urticaceae	3	1	0.33
Struthanthus acuminatus	Loranthaceae	7	2	0.29
Vernonia patens	Astercaeae	7	1	0.29
Vanilla sp. 1	Orchidaceae	11	1	0.27
Piptadenia cf. *anolidurus*	Fabaceae	4	1	0.25
Syngonium podophyllum	Araceae	9	2	0.22
Cyperus cf. *corymbosus*	Cyperaceae	10	1	0.20
Paullinia clathrata	Sapindaceae	5	1	0.20
Marcgravia flagellaris	Marcgraviaceae	5	1	0.20
Dioscorea dodecaneura	Dioscoreaceae	5	1	0.20

8.3.12. Environmental Plant Use

This use category only represents ornamental uses of plants. Fifty one species were reported, belonging to 33 families. Fabaceae (22%), Heliconiaceae (6%) and Solanaceae (6%) contain most species. Nearly half (47%) of these species is cultivated. However, our list of wild species with an ornamental value is most likely far from complete, as most participants declare to enjoy the beauty of almost all coloured plants in their natural environments.

8.3.13. Poison Plants

An important component of the indigenous way of fishing deals with the use of fish poison (cf. Acevedo-Rodríguez, 1990; Milliken *et al*., 1992; van Andel, 2000; Balée, 1994; Grenand *et al*., 2004). In TIPNIS, this fishing technique is generally practiced in small forest streams that can be dammed. Ichthyotoxic plant parts are dispersed in the water. After a while stupefied or dead fish start floating at the surface where they can be collected by hand. During the present study, participants reported to use the ichthyotoxic properties of four different plant species; two Euphorbiaceae, one Sapindaceae and one Fabaceae.

Latex of *Hura crepitans* is considered most potent. According to participants, its use is currently forbidden by Bolivian law (cf. Lilienfeld and Pauquet, 2005). Those who are caught during the act are said to be sentenced for ten years. The reason is that this latex is extremely poisonous even in small concentrations, and fishing in small creeks may eventually lead to the death of numerous animals downstream, even in larger rivers. To illustrate this point we quote D. Jabín, a French anthropologist who was working among the Bolivian Yuqui at the time of the present research. He described how literally *all* cold-blooded animals (fish, snakes, crocodiles…) had died after a *H. crepitans* tree standing at the border of a pond had been felled and fallen into the water. Use of *H. crepitans* in Bolivia as fish poison has also been mentioned by Steward (1948) and Denevan (1980). A second species used by Yuracarés as fish poison is the forest liana *Serjania tenuifolia*. This species is not included in Acevedo-Rodríguez's (1990) list of the known piscicides and stupefactans in the plant kingdom. *S. tenuifolia* stems are chopped into small pieces that are subsequently transported to the stream, where they are ground and thrown in the water. Intriguingly, some Trinitario participants claimed that Yuracarés use this species for committing suicide. It has been reported that suicide once was common among Yuracarés (d'Orbigny, 1945; Querejazu, 2005a). Also during the present study, one Yuracaré male committed suicide by drinking a commercial pesticide.

Nowadays, leaves of *Tephrosia vogelii* and *Phyllanthus brasiliensis* are used more frequently for killing fish. Yuracarés particularly cultivate the first species, whereas Trinitarios seem to prefer the second.

One of the main chemical components of ichthyotoxic plants is rotenone. This extremely active isoflavonoid is highly toxic to cold-blooded animals but much less to warm-blooded species when ingested (by Acevedo-Rodríguez, 1990). Therefore, rotenone is one of the most potent natural insecticides; it has very low toxicity to warm-blooded animals and has a short residual life (Higbee, 1947 cited by Acevedo-Rodríguez, 1990). Trinitarios take advantage of this active principle in agriculture as well. Leaves of either *T. vogelii* or *P. brasiliensis* are ground and macerated in water. The liquid is then sprinkled on rice or coca fields with purchased manual sprinklers to kill insects. The Palikur from French Guyana also use *P. brasiliensis* macerations to kill ants (Grenand *et al.*, 2004). The medicinal use of rubbing the leaves of *T. vogelii* or *P. brasiliensis* on skin infected with scabies (Thomas and Vandebroek, 2006) can probably be ascribed to the same active principles. Moretti and Grenand (1982) report how fish poisons are used to eradicate lice and scabies in French Guyana.

8.4. Conclusions

In this chapter, a general overview was provided of ethnobotanical uses recorded for 735 plant species collected in TIPNIS. It was shown that Yuracarés and Trinitarios still depend on a large number of plant species to fulfil basic subsistence needs. The most important categories in terms of species and average use values are medicine, food, fuel, construction and materials. These categories have an almost equal importance because they represent the combined knowledge of Yuracarés and Trinitarios. Plant use knowledge of both ethnic groups is complementary in that Yuracarés know and use much more edible plants, whereas Trinitarios dispose of a much broader pharmacopoeia. A comparison with literature data shows that the number of medicinal and food plants used by Trinitarios and Yuracarés, respectively, are among the highest recorded to date for any Amazonian group. In addition to the use of medicinal and edible plants, collection of firewood for cooking is an almost daily practice for Yuracarés and Trinitarios, but also house building and repairing, together with manufacturing canoes are important activities of people throughout the year. Factors that might contribute to the ethnic differences in medicinal and food plant uses between Yuracarés and Trinitarios are discussed in chapter 10.

Our research has demonstrated that most adults who participated in this research are still knowledgeable about most present and past plant uses. We have been able to identify (for the first time) those species that were (and often still are) employed for the same uses that were described by early ethnographers and missionaries who visited the Yuracarés and Trinitarios (Mojeños) at various moments throughout their respective contact histories.

Although participant age did not correlate with plant knowledge in TIPNIS, signs of modernization are clearly present. Modernization is most notable among Yuracarés who have been and sometimes still are looked upon as an inferior culture by Trinitarios and Andean settlers, ever since their arrival to TIPNIS in the 1970s. This has pushed Yuracarés in a position of shame and provoked the rapid abandonment of most of their traditional customs and practices. Most Yuracaré elders who participated in the present study still hold a good knowledge of most of the traditional practices, customs and legends (Appendix 3) of their people. However, transmission of this knowledge to the younger generation seems to be strongly decreasing and nowadays most Yuracaré children only learn Spanish and no longer Yuracaré. Trinitario people appear more resistant to modernization. Nearly all Trinitario children from the participating communities first learn to speak Trinitario before Spanish. Also, the fact that traditional customs such as the dance of the *macheteros* and shamanistic healing techniques are still actively practiced in an almost identical fashion as described by early missionaries and ethnographers, shows that the Trinitario culture has withstood hundreds of years of outside influences relatively well.

Similar to the Quechuas from Apillapampa (chapter 3), Trinitarios have maintained a specialised ethnomedicinal system throughout history. Disorders that are believed to have a supernatural origin are typically treated by shamans or *sobanderos*, whereas disorders with natural causes are treated by self-medication or through the intervention of herbalists. We have been able to show that traditional healers (including shamans, herbalists and midwives) in TIPNIS hold more knowledge about medicinal and social plant uses than laypeople. Social uses mainly involve magical or ritual plant uses and generally belong to the domain of plant specialists, such as healers and particularly shamans. The ethnomedical specialisation of Trinitarios is undoubtedly one of the reasons why the Trinitarios possess a more substantial pharmacopoeia than Yuracarés.

The usefulness of the technique of quality use values (QUV_s) we proposed in chapter 3, was less pronounced for our non-medicinal plant use data from TIPNIS than from Apillapampa. Particularly in the non-medicinal use categories, high qualities (i.e. =1) were ascribed to different plant uses in TIPNIS, such that QUV_s values approximate UV_s values. We hypothesize that this is partly related to different ecological conditions in both study areas. The degraded vegetation in Apillapampa forces people – for want of something better – to use plant species with inferior quality to fulfil certain needs. By contrast, people in TIPNIS have an overwhelming choice of plant species at their disposition. Consequently, they seem to select mainly those plant species that are best suited for certain applications in the categories of materials, construction and fuel. It appears that especially when a resource becomes rare, plants of inferior quality are used. For example, in response to overharvesting, *Geonoma deversa* leaves are more and more being substituted as a primary source of roof thatch by less durable alternatives such as *Hyospathe elegans*. This example is discussed into further detail in chapter 10.

9.

Indigenous Valuation of Different Forest Types and Plant Species in TIPNIS

9.1. Introduction

Historical evidence has suggested that the indigenous Amazonian population was not evenly distributed at the time of contact in 1492 (Balée, 1989; Meggers, 1992; Denevan, 1992, Clement, 1999a). High population densities (as compared to other parts of Amazonia) have been reported for the Amazonian floodplains and *varzeas*. This is basically because the limits of agriculture using indigenous technology were lower in nutrient-poor interfluves (i.e. *terra firme* soils) than in fertile floodplains (Balée, 1994). Floodplains also appear to harbour forests that are more useful to people, as compared to forests on other substrates. For example, Phillips *et al*. (1994) have demonstrated that mature floodplain forests are significantly more useful to *mestizo* people from Amazonian Peru than *terra firme* and swamp forests. In this chapter, we will investigate whether similar differences can be found in the way Yuracarés and Trinitarios value the forest types that were described in chapter 6.

Several scholars have assessed and compared the usefulness of different Amazonian forest types to local people (e.g. Prance *et al*., 1987; Balée, 1994; Chazdon and Coe, 1999; Van Andel, 2000; Toledo and Salick, 2006). However, their comparisons are all based on the percentage of used species and/or individuals in plots, rather than on informant indexing techniques such as those developed by Phillips and Gentry (1993a and b) and applied by Phillips *et al.* (1994). Nonetheless, comparisons based on the percentage of useful plants can be misleading because most species have minor uses and only few species are exceptionally useful. Moreover, this type of comparisons is less suitable for statistical analysis. For example, in the study of Phillips *et al.* (1994) the most useful forest type in terms of useful species and individuals (swamp forest) scored lowest for the informant indexing technique. This might also explain why van Andel (2000) found that species-poor swamp forest yielded the highest proportion of useful species in her study. In the first part of this chapter, we will follow the reasoning made by Phillips *et al.* (1994) and make a comparison of the usefulness of the forest types sampled in this study according to the methodology described by the latter authors.

In the second part of this chapter, we will then, in analogy with our study in Apillapampa (chapter 4), test the significance of various phylogenetic, morphological, ecological, and anthropological variables in influencing the usefulness of individual plant species. Research results are confronted with relevant scientific literature.

9.2. Methods

Ecological Sampling

All ecological and floristic data used in this chapter were obtained following the sampling techniques described in chapter 6. Data on the size, frequency and density of trees, shrubs, lianas and hemi-epiphytes were gathered by measuring the stem diameters of more than 1500 stems ≥ 2.5 cm dbh belonging to 465 species and morphospecies in the four 0.1-ha forest transects described in chapter 6. Other analyses are based on the complete inventory from TIPNIS (i.e. the 465 species collected in transects and 441 species inventoried exclusively during walk-in-the-woods and homegarden sampling.

Ethnobotany

Ethnobotanical information related to plant species sampled (presented and discussed in chapter 8) was gathered according to the techniques described in chapter 7. These include *in situ* interviewing during transect, walk-in-the-woods and homegarden sampling, and *ex situ* interviewing using fresh plant material, dried specimens and photographs of plants. Most ethnobotanical data was gathered from photograph-based interviews. This had particularly implications for the plant use data obtained for plants collected in transects. The majority of plants species encountered during transect sampling was in vegetative condition. For plants sampled in transects, use data was obtained only through (1) interviewing *in situ*; and (2) photograph-based interviews. However, the major limitation of photographs as props during *ex situ* interviews is that they cannot be used for vegetative specimens (Thomas *et al*., 2007).

As we did not work with permanent transects, use data on vegetative plants encountered in transects were therefore obtained from one (or occasionally two) accompanying participant(s) only. Yet, for a limited number of such vegetative plant species, we have been able to increase the number of participants providing use data through repeated collections (vegetative and/or fertile) of the same species during posterior transect or walk-in-the-woods sampling.

The main consequence of this participant bias is that for a significant number of species that were exclusively found in transect, use data was provided by only one Yuracaré or Trinitario participant, respectively.

Measuring the "Usefulness" of Different Forest Types

In the following analysis, it is presumed that 0.1-ha transects are representative samples of the forest types where they were initially laid out. Similarly to the methodology used for sampled transects in Apillapampa (see chapter 4), usefulness of different forest types as perceived by Yuracaré and Trinitario participants, was assessed by calculating (1) the percentage of useful species in transects; and (2) use values, averaged for individual plants in transects and for each use category separately. For a description of different plant uses within use categories (i.e. medicine, food, materials, construction, fuel, social uses, environmental uses and poison), the reader is referred to chapter 8. For the use value-based comparison of the usefulness of forest types, the method developed by Phillips *et al.* (1994) was applied. Therefore, each 0.1-ha transect was approached as a combination of ten 0.01-ha transects. The categorical use values (see chapter 3 for terminology used) of all woody stems were summed and divided by the number of stems in each component 0.01-ha transect. As a consequence, for each component 0.01-ha transect one mean use value was obtained per use category. These values, which we will name *the average categorical use values of a transect*, were then used to compare the estimated usefulness of forest types to Yuracaré and Trinitario people. The use categories *environmental uses* and *poison* are not taken into account here since they contain only a few plant species.

Statistical Analysis

SPSS 12.0 was used for performing all statistical tests, including t-tests, ANOVA, Mann-Whitney tests, Kruskal Wallis tests, Kendall correlation and linear regression.

9.3. Results and Discussion

9.3.1. Comparison of the Usefulness of Different Forest Types

An average number of 4.1 (± 3.8 (s.d.)) participants (range: 1-19) provided information on the use of plant species sampled in the four 0.1-ha transects. The mean number of participants interviewed per species was similar for Yuracarés (2.5 ± 1.8 (s.d.); range: 1-9) and Trinitarios (2.9 ± 2.2 (s.d.); range: 1-10) ($p>>0.1$; Mann-Whitney test). Overall use values ranged from 0.17 (*Justicia megalantha*) to 5.83 (*Attalea butyracea*). On average, 84% of species and 89% of individuals in transects were claimed to be used in at least one way (figure 9.1). More than two thirds (68%) of species and individuals (70%) is used as fuel, whereas more than half is used for construction (56% of species and 61% of individuals). Thirty nine (39) percent of species and 41% of individuals has a food use whereas approximately one third of species (29%) and individuals (36%) is used in traditional medicine. Plants in the material use category represent 32% of species and 37% of individuals on average. About 10% of species and 15% of individuals provide social uses.

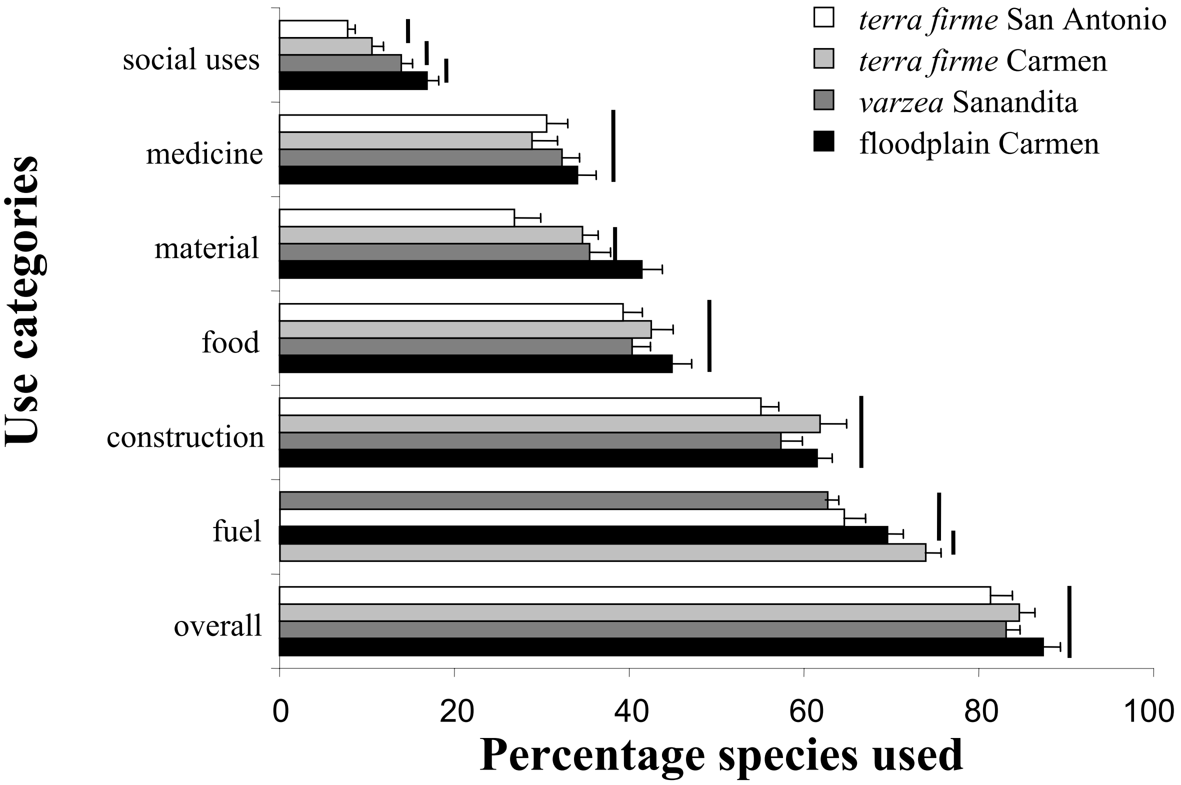

Figure 9.1: Mean percentage of species per use category and forest types. Significant differences between forest types are recorded for *fuel*, *material* and *social uses* (p<0.01 for all three cases; ANOVA). Equal mean categorical use values between different forest types are indicated by vertical lines (Duncan post hoc test). Error bars represent standard errors of the mean.

These use percentages are in accordance with most studies reported in literature. As already mentioned in chapter 4, estimates of plant use in plots of Amazonian societies broadly range between 49-100 percent for overall uses, 17-40% for food uses, 7-35% for medicinal uses and 3-32% for construction uses (Balée, 1986 and 1987; Prance *et al.*, 1987; Milliken *et al.*, 1992, Phillips *et al.*, 1994; Boom, 1987 and 1989, Miller *et al.*, 1989; Piñedo-Vasquez *et al.*, 1990; De Walt *et al.*, 1999; Galeano, 2000; Van Andel, 2000; Macía *et al.*, 2001). However, most of these studies made use of 1-ha plots and measured only plants with dbh ≥ 10 cm. If only stems with dbh ≥ 10 cm are considered in our transects (amounting to 191 different species), plant use percentages are 89% for the overall use category, 73% for fuel, 61% for construction, 44% for food, 30% for material, 22% for medicine and 7% for social uses.

These values suggest that the proportion of forest species considered useful to Yuracarés and Trinitarios are in the upper range of those obtained in other studies conducted in the Neotropics. However, our results are based on combined use data of two ethnic groups, whereas most studies in literature present use proportions of one indigenous group only. Also, results were obtained from 0.1-ha samples and these might not be comparable to those from 1-ha plots.

Studies of 0.1-ha seem less popular for quantifying the local usefulness of vegetation types. La Torre Cuadros and Gerald (2003) studied the usefulness of Mexican forests by means of twenty 0.1-ha plots of 20 x 50 m² and 10 x 100 m² wherein all stems ≥ 5 cm dbh were sampled. They calculated that 19% of inventoried species were used in traditional medicine, 10% as food, 18% for manufacturing crafts and 36% for construction purposes. Toledo and Salick (2006) sampled Bolivian lowland forests in different stages of succession by means of 1) 20 x 50 m² plots wherein all trees and lianas ≥ 5 cm dbh were recorded ("overstorey"), and 2) three nested subplots of 2 x 5 m² within each 20 x 50 m² plot to inventory the abundance of regenerating saplings, herbs, shrubs and climbers < 5 cm dbh ("understorey"). The authors calculated that, on average, 43% and 52% of the recorded species in the under- and overstorey, respectively, were used by the Bolivian Gwarayo people. The highest percentage was found in the youngest succession stage for both under- and overstorey (50 and 72%, respectively) (Toledo and Salick, 2006). Finally, Céron (1994) and Céron and Montalvo (1998) sampled similar 0.1-ha transects as ours among the Cofanes and Huarani from Amazonian Ecuador (resulting in use proportions of 99 and 100%, respectively).

The downside of studies with sampling strategies focusing on stems with dbh ≥ 10 cm is that they might fail to represent unequivocally the overall usefulness of vegetation, as nontree habit groups make up most of the species sampled in Amazonian forest plots (Gentry and Dodson, 1987a). Based on data from seven one-hectare plots in Guyana, van Andel (2000) showed that between 20 and 60 percent of all useful species was found in the understorey. Nevertheless, the plant use percentages of the nested sampling strategy of van Andel are within the same range as those obtained by studies measuring trees with dbh ≥ 10 cm: 16-23% of species were used as food, 19-27% as medicine and 23-36% for construction purposes. In analogy, our results demonstrate that 56% of all useful species in transects had dbh < 10 cm. The large majority of medicinal plants (69%) and plants with social uses (72%) are found in this diameter class, but also material, fuel, construction and food species are represented by more than half of all useful species collected in transects (61, 56, 55 and 54%, respectively). Hence, the understorey (dbh < 10 cm) seems to be slightly more useful than the overstorey (dbh ≥ 10 cm), especially so for the categories of medicinal and social uses.

Table 9.1 shows that ranking of transects according to the mean use value per stem corresponds more or less with a ranking of the percentage of useful species and individuals. Although differences in overall use values of transects are rather small, they are significant ($p=0.015$, ANOVA). Floodplain and *varzea* forest transects are more useful than *terra firme* forest according UVs values (figure 9.2). However, this difference is only significant for the San Antonio *terra firme* transect ($p<0.01$; ANOVA post hoc Duncan test).

In a study in the Peruvian Tambopata rainforest, Phillips *et al.* (1994) noted that a significantly higher mean use value was obtained for the floodplain forest than for *terra firme* or swamp forests. Contrary to the latter authors' findings, the higher utility of floodplain and *varzea* forests in our study cannot be ascribed to a high density of a few particularly useful (palm) species. As shown by table 9.2, the most useful species are quite evenly represented in the four transects we sampled. Rather, higher averaged use values are obtained for floodplain and *varzea* transects because they contain more individuals of species with higher use values, whereas in *terra firme* forests species with lower use values are better represented.

Table 9.1: Usefulness of forest types with the proportion of useful species and average overall use values of transects

Forest type	Species inventoried	Stems inventoried	Mean use value per stem	% useful species	% useful individuals
terra firme San Antonio	186	414	1.26	74.2	85.3
terra firme Carmen	183	395	1.43	79.2	89.9
varzea	170	404	1.46	74.1	87.9
floodplain	148	351	1.51	81.8	91.7

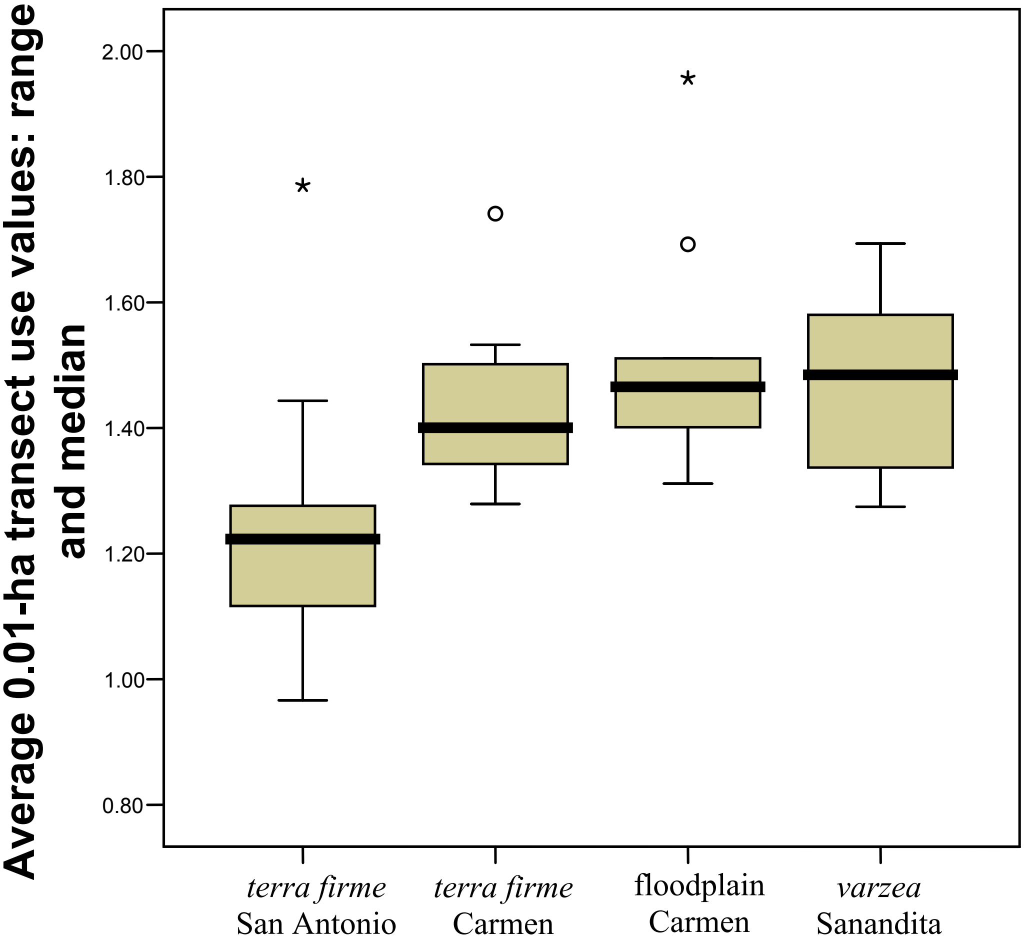

Figure 9.2: Usefulness of forest types compared: range and median of component 0.01-ha transect averaged use values. Differences between 0.1-ha transects are significant at p=0.015 (ANOVA) (° and * represent outliers).

A better understanding of the differences between the usefulness of forest types is provided by breaking down each transect's average use value into its component use categories: construction, fuel, food, medicine, materials and social uses (figure 9.3). Construction, fuel and food use dominate all forest types. High construction use values in the present study reflect the contribution of Annonaceae, Myristicaceae, Anacardiaceae, Arecaceae and Lecythidaceae, in analogy with results from the study by Phillips *et al.* (1994). High food use values are mainly a consequence of a high abundance of Arecaceae, Anacardiaceae, Myrsinaceae, Sapotaceae, Myrtaceae, Fabaceae (*Inga*) and Moraceae. More in particular, the floodplain transect contained proportionally more species of these families. Medicinal uses appear to be slightly more important in *varzea*, and to a lesser extent in floodplain forest, which is due in part to the abundance of the medicinal species *Cyathea pungens*, *Triplaris americana*, *Hura crepitans*, *Uncaria tomentosa* and *Guarea macrophylla.* Ethnomedical properties of these species are listed in Thomas and Vandebroek, 2006.

Table 9.2: The ten species with the highest use value and density in the four sampled transects. The total number of individuals by which these species are represented yield relatively similar results for all transects.

Scientific name	**family**	***varzea***	**floodplain**	***terra firme* Carmen**	***terra firme* San Antonio**	**UV_s**
Attalea butyracea	Arecaceae	1	0	1	0	5.8
Duguetia hadrantha	Annonaceae	0	2	0	0	5.0
Jessenia bataua	Arecaceae	0	0	0	1	4.6
Guarea macrophylla	Meliaceae	4	5	1	1	4.2
Myroxylon balsamum	Fabaceae	0	1	1	1	3.8
Unonopsis guatterioides	Annonaceae	1	0	0	0	3.5
Socratea exorrhiza	Arecaceae	3	2	0	4	3.4
Hura crepitans	Euphorbiaceae	2	3	1	0	3.3
Clarisia racemosa	Moraceae	2	2	3	2	3.2
Iriartea deltoidea	Arecaceae	12	14	23	11	3.2
	SUM	25	29	30	20	

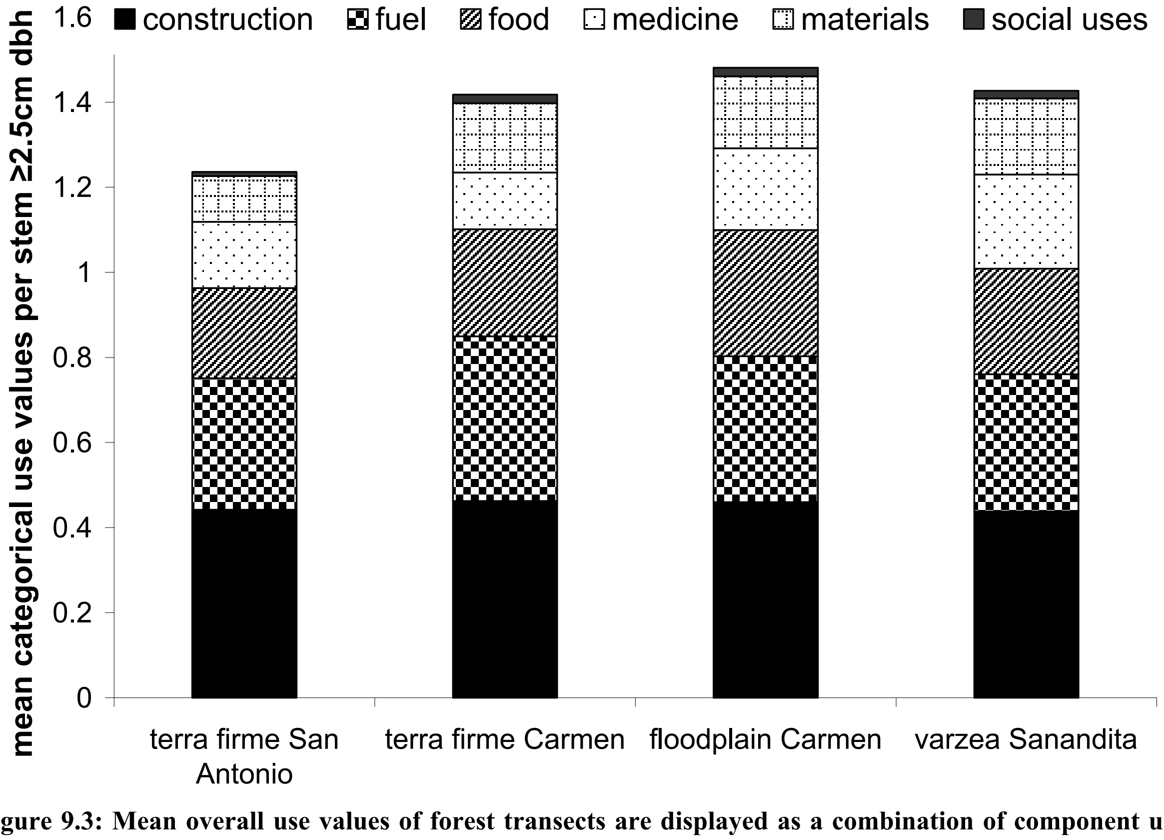

Figure 9.3: Mean overall use values of forest transects are displayed as a combination of component use categories. Use categories *environmental uses* and *poison* are not listed as their contribution is negligible. Significant differences in categorical use values between forest types are found for materials, fuel and social uses ($p<0.01$, $p=0.014$ and $p=0.013$, respectively; ANOVA). Mean medicinal and food use values are only significantly different at the 10% level ($p= 0.09$ and $p=0.1$, respectively; ANOVA). No significance is found between different forest types for construction ($p=0.92$).

These patterns are reflected in table 9.3, which enumerates the results of statistical comparisons for all use categories. Although the San Antonio *terra firme* forest transect is the most species-rich, it is the least useful for any category, except construction. The three other forests have equal usefulness in terms of materials and social uses. The Carmen *terra firme* forest is clearly most useful as a source of fuel plants while the floodplain and *varzea* forests are the only forests to yield a significantly higher mean use value than other forest types for the edible and medicinal use categories, respectively.

Table 9.3: Comparison of the usefulness of forest types: between-transect differences for different use categories

Forest type	overall	construction	fuel	food	medicine	material	social uses
terra firme San Ant.	0:0:0:3	0:1:2:0	0:0:2:1	0:0:2:1	0:1:2:0	0:0:0:3	0:0:0:3
terra firme Carm.	**1:0:2:0**	0:3:0:0	**2:1:0:0**	0:2:1:0	0:0:2:1	1:0:2:0	1:2:0:0
floodplain Carm.	**1:2:0:0**	0:2:1:0	0:2:1:0	**1:2:0:0**	0:2:1:0	1:1:1:0	1:1:1:0
varzea Sanand.	**1:1:1:0**	0:0:3:0	0:1:1:1	0:1:2:0	**1:2:0:0**	1:2:0:0	1:0:2:0

All comparisons are pairwise between forest types and for different use categories, using the ANOVA post hoc Duncan test for multiple comparisons. Results are reported in the following form: N_1 (number of significantly higher mean use values at ≤ 5% level): N_2 (number of higher mean use values, not significant): N_3 (number of lower mean use values, not significant): N_4 (number of significantly lower mean use values at ≤ 5% level). By chance alone, expect 5/100 x (3 x 7 x (4/2)) = 2.1 pairwise comparisons to be significant at 5% level; observed result is 13. The most useful forest types in each category are highlighted in bold, as are the most useful forest types for all uses combined (overall use value).

Table 9.4 compares the usefulness ascribed to the four forest types sampled by Yuracaré and Trinitario people. It shows that Trinitario people allocate a greater medicinal and social use value to most forest types than Yuracarés. By contrast, Yuracarés seem to value all forest types more for food. This is in correspondence with our findings from chapter 10, where a detailed discussion addresses possible reasons for differences in plant knowledge between Yuracarés and Trinitarios.

Table 9.4: Comparison between usefulness of different forest types by Yuracaré (Y) and Trinitario (T) people based on transects' mean categorical use values

Forest type	overall	constr.	fuel	food	medicine	material	social uses
terra firme San Antonio	Y**	Y**	Y**	Y***	N.S.	N.S.	T**
terra firme Carmen	T*	N.S.	T***	Y***	T*	N.S.	T***
floodplain Carmen	T**	T***	T***	Y***	T*	T*	T***
varzea Sanandita	Y*	Y**	N.S.	Y***	T**	N.S.	T**

All comparisons are pairwise, using independent sample t-tests. Results are reported in the following form: "Y" when the transect's mean categorical use value calculated for Yuracare participants exclusively is significantly higher than for Trinitario participants and "T" in the opposite case. Equal mean categorical use values for Yuracarés and Trinitarios are indicated with "N.S." (not significant) (Constr.= construction; *= p≤0.05; **= p≤0.01; ***= p≤0.001).

Table 9.4 also shows that significantly higher mean overall use values are obtained for the ethnic group that lives closest to each transect sample site. The San Antonio *terra firme* forest and the Sanandita *varzea* forest are situated close to Yuracaré settlements while the Carmen *terra firme* and floodplain forests were sampled in the vicinity of Trinitario settlements. However, it is not geographical distance between settlements and transect sites that explains the difference in mean overall use values. Rather, it seems to be related to the data gathering process. As indicated under "methodology", a weakness of working with non-permanent transects is that many vegetative plant species were presented to one informant only. In table 9.5, percentages of the total number of plant species occurring in transects are presented in relation to the number of participants interviewed (range from 0 to 2) on those species. It shows that between 23 and 40% of plant species in transects has not been shown to participants of either ethnic affiliation. Therefore, in the following analyses, we will base use value data for plant species sampled in transects on *all* participants, rather than on Yuracarés and Trinitarios separately.

Table 9.5: Proportions of plant species and number of participants interviewed (0-2) for different forest types and ethnic groups (T= Trinitarios; Y= Yuracarés)

participants interviewed	***terra firme*** **San Antonio**		***terra firme*** **Carmen**		**floodplain Carmen**		***varzea*** **Sanandita**	
	T	**Y**	**T**	**Y**	**T**	**Y**	**T**	**Y**
0	40	0	0	23	0	23	31	0
1	17	31	39	21	29	16	14	25
2	9	25	13	18	13	18	10	26

In spite of these methodological shortcomings, it is nonetheless highly probable that similar results (than those presented in table 9.4) would have been obtained for comparisons between average food and medicine use values of transects if an even number of Yuracarés and Trinitarios would have been interviewed for each plant species that was sampled. Moreover, a significantly higher mean medicinal use value would probably have been obtained for Trinitarios than for Yuracarés in the comparison of the San Antonio transect. There are good reason to assume this, given that significantly higher mean food use values were obtained for Yuracarés than for Trinitarios in the comparisons of both Carmen transects, even though use data from Yuracare participants are missing for more than one fifth (23%) of plant species occurring in both transects (table 9.5). Similarly, a significantly higher mean medicinal use value was obtained for Trinitarios in the comparison of the Sanandita transect, even though use data from Trinitario participants is missing for almost one third (31%) of plant species in this transect. Clearly, the 40% of plants occurring in the San Antonio transect (table 9.5) for which no use data was obtained from Trinitario participants is too high for the medicinal use value obtained for Trinitarios to outweigh the value obtained for Yuracarés.

9.3.2. Predicting Categorical Use Values of Plant Species

In analogy with our analysis in Apillapampa data (chapter 4), in this paragraph we will test several null hypotheses that investigate the extent to which use values of individual species can be predicted from a number of phylogenetic, morphological, ecological, and anthropological variables.

Ho = = use values of plant species are random with respect to their classification at the family level

To test this hypothesis, all plant species belonging to families that are represented by at least 10 species were selected (a total of 622 species and 32 families). Mean use values show a large variation among plant families for different use categories. For example, overall FUV_s values vary from 0.3 (Acanthaceae) to 3.5 (Arecaceae). To test whether this variation in FUV_s

values is statistically significant, a Kruskal-Wallis test was applied. Results presented in table 9.6 show that plant family is an extremely powerful predictor of species' use values for all use categories, except social uses.

Hence, in analogy with our case study in Apillapampa, data from TIPNIS confirm the argument of various authors that plant family is one of the dominant factors that determine a particular plant's use (value) (Phillips and Gentry, 1993b; Cotton, 1996; Moerman, 1996; Moerman *et al.*, 1999; Stagegaard *et al.*, 2002; Byg *et al.*, 2006).

Table 9.6: Kruskal Wallis test results for evaluating whether mean categorical use values of species are significantly different between families

	$UV_{\text{all uses}}$	UV_{medicine}	UV_{food}	UV_{material}	$UV_{\text{construction}}$	$UV_{\text{social uses}}$	UV_{fuel}
χ^2	**232.571**	**160.904**	**148.706**	**118.673**	**209.734**	39.902	**217.056**
p-value	0.000	0.000	0.000	0.000	0.000	0.131	0.000

Ho= use values of species are random with respect to their growth form

All plant species for which a use value was calculated (i.e. 894 species) are selected to test this hypothesis. Growth forms of plant species were divided into ten broad categories: trees (412 species), lianas (175 species), shrubs (118 species), herbs (87 species), (hemi-)epiphytes (37 species), (non-woody) climbers (34 species), graminoids (including Poaceae and Cyperaceae; 12 species), stranglers (10 species), hemi-parasites (5 species) and fungi (3 species). Mean use values of plant species grouped per growth form are shown in figure 9.4 for all relevant use categories.

Hemi-parasites and fungi are not included in figure 9.4 due to their small sample size. Fungi are mainly used as food (UV_{food}= 0.60), whereas one inedible species, *Pycnoporus sanguineus*, is used in traditional medicine (UV_{medicine}= 0.5) (Thomas and Vandebroek, 2006). Three out of five hemi-parasites inventoried are almost exclusively used for treating fractures and sprains (i.e. *Oryctanthus alveolatus*, *Phthirusa pyrifolia* and *Struthanthus acuminatus*) (Thomas and Vandebroek, 2006). These reside on branches of other tree species. The other two hemi-parasites have a tree habit (*Heisteria acuminata* and *H. nitida*) and reside on the roots of other species. They are only used as firewood. Kruskal Wallis tests reveal that plant growth form has a highly significant value in predicting a species' use value for all use categories (table 9.7).

Figure 9.4 shows that trees and graminoids have the highest mean overall usefulness of all growth forms, whereas those of epiphytes and lianas are significantly lowest ($p<0.001$; Mann-Whitney tests). In terms of mean medicinal use value, graminoids, stranglers and herbs score highest, but for the first two growth forms this result can probably be ascribed to the smaller sample sizes as compared to all other growth forms. The mean medicinal use value of trees is the lowest of all growth forms ($p<0.01$; Mann-Whitney) except for lianas that score even lower ($p=0.01$; Mann-Whitney). In chapter 8 we have shown that the best represented life form among medicinal species are trees. Hence, the present result suggests that medicinal knowledge on tree species is likely more idiosyncratic than for other growth forms.

Equal mean food use values were observed for trees, graminoids, climbers and shrubs. Stranglers and epiphytes have the lowest mean food use values ($p<0.001$; Mann-Whitney). All growth forms, except lianas ($p<0.01$; Mann-Whitney), score equal for mean material use values. As could be expected, trees and graminoids provide the most useful construction materials.

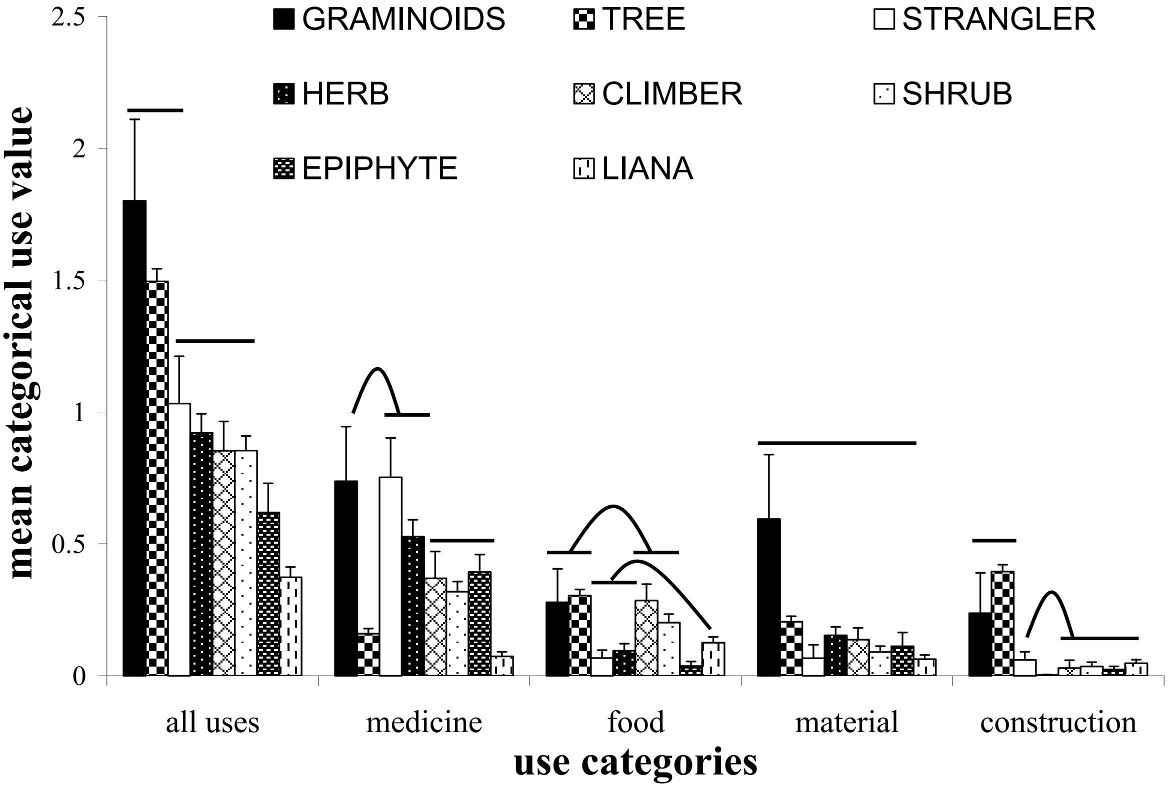

Figure 9.4: Mean categorical use values of plants for eight different growth forms. Social uses are not represented as recorded use values are very small (all UV <0.09). Species used as fuel (not shown) are basically trees (UV_{fuel}= 0.41), shrubs (0.09) and lianas (0.03). Growth forms with equal mean (categorical) use values are indicated by horizontal and curved lines (error bars represent standard errors of the mean).

Table 9.7: Kruskal Wallis test results for evaluating whether mean categorical use values of species represent significantly different growth forms

	$UV_{all\ uses}$	$UV_{medicine}$	UV_{food}	$UV_{material}$	$UV_{construction}$	$UV_{soc\ uses}$	UV_{fuel}
χ^2	**254.56**	**195.74**	**50.45**	**43.66**	**226.30**	**46.41**	**392.40**
Asymp. Sig.	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The observation that lianas are among the least useful growth form for Yuracarés and Trinitarios corresponds with findings from Phillips and Gentry (1993b). Nevertheless, the latter authors questioned this outcome, because their previous work had suggested the opposite, namely that lianas would have an especially high medicinal use value (Phillips, 1991; Gentry, 1992). Therefore, they hypothesized that the low usefulness of liana species to their *mestizo* study population reflected previous acculturation. Based upon our results, we are tempted to reject this hypothesis. Yuracarés (and to a lesser extent Trinitarios) were able to distinguish between and name most inventoried liana species but they simply do not use them as much as other life forms.

The fact that trees have a higher mean food use value, whereas herbaceous growth forms (herbs, climbers and epiphytes) have a larger mean medicinal use value is in accordance with scientific literature (Gottlieb and Borin, 2002). We will discuss this in more detail in chapter 10 (section 10.4.3.). The medicinal usefulness of graminoids is somewhat surprising. Moerman (1996), and Moerman *et al.* (1999), demonstrated that according to "global patterns of human knowledge", Poaceae and Cyperaceae systematically figure among the most frequently underutilized medicinal species, based on the number of species in their respective families. The exceptionally high medicinal usefulness of graminoids in our study may therefore be a consequence of the fact that, as opposed to most other families, we did not inventory the non-useful species of Poaceae and Cyperaceae.

Ho= use values of species are random with respect to plant density, averaged across four forest types, and their frequency in 40 component 0.01-ha transects

To address this null hypotheses, we calculated the density and frequency of 426 different plant species that were sampled in the 40 component 0.01-ha transects of the four 0.1-ha transects and for which categorical use values were calculated.

The results presented in table 9.8 show that highly positive correlations are found between the density and frequency of species and their corresponding categorical use values, thus providing strong support for the hypothesis that more accessible and abundant plants are perceived as more useful (e.g. Adu-Tutu *et al.*, 1979; Johns *et al.*, 1990; Phillips and Gentry, 1993b; Alexiades, 1999; Frei *et al.*, 2000; Casagrande, 2002; Bonet and Vallès, 2002; La Torre-Cuadros and Gerald, 2003; Laurence *et al.*, 2005; Byg *et al.*, 2006). The fact that mean density and frequency yield equal results is because they are collinear (i.e. they are strongly and significantly correlated; Kendall's τ_b=0.89 and $p<0.001$). In the following, we show that density and frequency are representative parameters for plant accessibility.

In particular, the relationship between abundance and usefulness of species might have important implications for indigenous forest management. For example, in a study among indigenous people and Andean settlers in the Peruvian Amazon, Lawrence *et al.* (2005) have shown that when a taxon becomes scarce its popularity may decline, and it may be replaced by others. This indicates a certain flexibility, not to say fatalism, in adapting to plant availability, such that explicit efforts to protect and/or manage favoured plant species in a sustainable way might become unlikely (Lawrence *et al.* 2005).

Table 9.8: Kendall's τ_b correlation coefficients with respective significance levels between predictor (density and frequency) and response variables (categorical use values) (N=465)

		$UV_{all\ use}$	UV_{med}	UV_{food}	UV_{mat}	UV_{const}	UV_{soc}	UV_{fuel}
Density	**Corr. Coeff.**	**0.25**	**0.19**	**0.15**	**0.21**	**0.21**	**0.18**	**0.15**
	Sig.	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Frequency	**Corr. Coeff.**	**0.27**	**0.20**	**0.19**	**0.24**	**0.24**	**0.17**	**0.17**
	Sig.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

med= medicine; mat= material; const= construction; soc= social uses

Galeano (2000) regressed the use value of species on their density in various Colombian coastal forest plots. Regression residual analysis, showed that a number of species in her study had higher use values than expected from their density. For our data, linear regression coefficients are so insignificantly low (R^2= 0.04 and 0.06 for regression between $UV_{\text{all use}}$ and density and frequency, respectively) that a regression residual analysis would be irrelevant.

Ho= use values of species are random with respect to their average/maximum stem diameter

The mean and maximum stem diameter, and categorical use values of 426 plant species sampled in four aggregate 0.1-ha transects were calculated. Table 9.9 shows that mean and maximum diameter also have predictive power for plant usefulness, although for fewer use categories as compared to density and frequency. The higher usefulness of larger plants may be a consequence of their better "visibility" as compared to smaller plants (Phillips and Gentry, 1993b). Indeed, apart from abundance and accessibility, salience of species is known to affect their use (Turner, 1988; Byg *et al.*, 2006). More salient species are easier to find than more inconspicuous plants. For humans, plant salience mainly depends on size and colour, although smell and structure may also be important (Turner, 1988; Jain, 2000; Byg *et al.*, 2006). According to this interpretation, mean and maximum stem diameter are salience-related attributes. Slightly different correlations are obtained between categorical uses of plant species (particularly for the material category) on the one hand and mean and maximum dbh on the other. Nonetheless, mean and maximum dbh are collinear (Kendall's τ_b=0.82 and p<0.001).

Table 9.9: Kendall's τ_b correlation coefficients with respective significance levels between predictor (mean dbh and max. dbh) and response variables (categorical use values) (N=465)

		$UV_{\text{all use}}$	UV_{med}	UV_{food}	UV_{mat}	UV_{const}	UV_{soc}	UV_{fuel}
mean dbh	**Corr. Coeff.**	**0.22**	0.01	**0.10**	0.061	**0.19**	0.0002	**0.19**
	Sig.	0.0000	0.85	0.008	0.10	0.0000	0.99	0.0000
max dbh	**Corr. Coeff.**	**0.28**	0.04	**0.13**	**0.11**	**0.24**	0.049	**0.23**
	Sig.	0.0000	0.24	0.0004	0.002	0.0000	0.22	0.0000

med= medicine; mat= material; const= construction; soc= social uses

The fact that mean and maximum dbh correlate significantly with food use value might be related to the fact that larger plants produce more fruits and hence are more valued by people. Leighton and Leighton (1982) and Nava-Cruz and Ricker (2004) have shown that fruit abundance is positively correlated with basal area and dbh. Likewise, larger trees are more useful for construction purposes, as source of material uses and fuel than smaller individuals, at least if one disposes of a chain saw. This notion was frequently confirmed by participants during ethnobotanical interviews.

It is probable that we failed to detect a correlation between mean and maximum stem diameter and the medicinal use values of plants, because trees represent the highest diameters in any forest type *and* they are the least useful growth form for herbal medicines, as demonstrated previously.

Ho= use values of species are random with respect to their Importance Value in the sampled forest types

We hypothesized that if most categorical use values of a plant species are highly predictable from its density, frequency and/or dbh, then the same should be valid for a common parameter in ecology to quantify the ecological importance of plants; i.e. the Importance Value index (IV) (Curtis and McIntosh, 1951; see chapter 6). As suspected, the IV value correlates significantly with all categorical use values of plant species (table 9.10). Hence, the higher the ecological importance of a species in forests, the higher will be its categorical use values. In analogy with our results, La Torre-Cuadros and Gerald (2003) found positive and significant relationships between a species' IV value and its use value among Maya people in Mexico. Also, De Walt *et al.* (1999) hypothesized the existence of such a positive correlation for their study among the Bolivian Tacana people, although they did not actually test it.

Table 9.10: Kendall's τ_b correlation coefficients with respective significance levels between predictor (Importance Value) and response variables (categorical use values) (N=426)

		$UV_{all\ use}$	**UV_{med}**	**UV_{food}**	**UV_{mat}**	**UV_{const}**	**UV_{soc}**	**UV_{fuel}**
Importance Value	Corr. Coeff.	**0.278**	**0.149**	**0.158**	**0.173**	**0.227**	**0.127**	**0.189**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.001	0.000

med= medicine; mat= material; const= construction; soc= social uses

Ho= use values of species are random with respect to their perceived accessibility by local participants

In analogy with research conducted in Apillapampa (see chapter 4), participants were systematically asked: "Is this plant easy to find or do you have to look for it?" Answers were coded in a binary format, whereby "1" represents easy access and "0" the opposite. Next, participants' judgments were evaluated per species and only those species that were perceived as easy to find by more than half of the participants were classified as 'easily accessible' (at least two participants per species). A similar procedure was followed for classifying plants that are perceived as difficult to find. As such, 54 species were classified as difficult to find against 108 easily accessible ones. These data allowed us to test whether frequency, mean density, mean dbh and maximum dbh are related to the perceived accessibility of plants by local participants.

Our data related to 96 species for which both accessibility data assessed by participants *and* density and frequency data measured in transects were available. Results show that plant species perceived as easy accessible by the majority of participants have significantly higher densities and frequencies than plants that were assessed as difficult to find (1.70 vs. 0.86 individuals per 0.1-ha and 11% vs. 7% of all forty 0.01-ha component transects, respectively; p=0.01 for frequency and p=0.003 for density (Mann-Whitney tests)). By contrast, no significant differences in mean and maximum dbhs were found between plants that are easy accessible and hard to find according to participants (p=0.51 and p=0.08, respectively; Mann-Whitney tests). These results suggest that plant density and frequency are good predictors of accessibility in TIPNIS, whereas maximum dbh and certainly mean dbh are not. This does, however, not question the argument we mentioned earlier that the higher usefulness of larger plants is probably due to their higher salience and visibility, basically because accessibility and salience are not necessarily correlated.

Results presented in table 9.11 show that plant accessibility as assessed by local participants is not a good predictor for mean categorical use values of plants. Only the mean medicinal value of plants that are difficult to find is significantly lower than the mean medicinal value of easily accessible plants. Analysis also shows that plants that are easily accessible have significantly higher numbers of overall and medicinal uses than plants that are difficult to find.

Table 9.11: Mann-Whitney test results for comparing the mean categorical use values of easily and badly accessible species, respectively. Only significant test results are presented. Mean use values and numbers of uses of plants in all other categories are significantly equal for easily accessible plants and plants one has to look for.

	UV $_{\text{all use}}$	**# all uses**	**UV $_{\text{medicine}}$**	**# medicinal uses**
Mann-Whitney U	2502.5	**2200.5****	**2380.0***	**2265.0***
Asymp. Sig. (2-tailed)	0.14	0.01	0.045	0.015

Ho= use values of species are random with respect to their perceived available abundance

The question remains whether the more than 1500 stems measured in four 0.1-ha transects adequately represent the abundance and frequency of species in the entire living environment of the participating communities. This can, at least in part, be tested by comparing participants' assessments about the abundance of individual plant species with their measured densities and frequencies in transects. To quantify how participants estimate the abundance of individual plant species, they were asked to determine for each plant whether it was present in local vegetation in a large, moderate or small quantity. The corresponding score (i.e. large, moderate or small) that was confirmed by more than half of the interviewed participants was assigned to every individual plant species (minimum two participants were interviewed per plant). Sixty five plant species were excluded from this analysis since no single quantity score was confirmed by at least half *and* the majority of participants. In total, 383 species were selected that had an abundance rate of large, moderate and small for 233, 11 and 139 species, respectively. Based on the limited number of plant species in the "moderate" class, the latter was excluded.

Our data related to 185 species for which both abundance data (assessed by participants) *and* density and frequency data (measured in the four 0.1-ha transects) were available. Mean measured densities and frequencies of plant species are not significantly different between indigenously assessed quantity scores (p>0.3 in both cases; Mann-Whitney tests). Hence, the measured density or frequency of plants in transects do not represent participants' abundance perceptions of the same species. This might be an indication that four 0.1-ha transects are too small to assess the local abundance of species.

Mann-Whitney non-parametric tests examined whether mean categorical use values are statistically different between species which, according to participants, are present in large or small abundances (table 9.12). Significant differences were found for *medicine*, *construction*, *social uses*, and *fuel*. Mean medicinal and social use values are higher for plants that are perceived as abundant as compared to rare plants. Mean overall, construction and fuel use values of species classified as having a “small” quantity score are significantly higher than for species with “large” quantity scores.

In a study of palm use in Amazonian Ecuador, Byg *et al.* (2006) also evaluated the correspondence between people’s perceptions of plant species’ abundance (using an ordinal scale similar to ours with “0” representing rare, “1” abundant in some places and “2” abundant) and densities of the same species they measured in nineteen 5x500 m^2 transects. Similar to our results, Byg *et al.* (2006) found no correlation between abundances assessed by local participants and measurements in transects. However, as opposed to our findings they did not find any significant correlation between people’s evaluations of species’ abundance and their use either. We agree with the latter authors that the lack of correspondence between people’s appreciation of species’ abundances and measured densities in transects may be because people’s estimations are based on different spatial scales or relate to different localities than those of transects (cf. Hellier *et al.*, 1999). In addition, there may be a large individual variation between informants with regard to the scale at which they evaluate plant abundance (Byg *et al.*, 2006). For example, Hellier *et al.* (1999) showed that people assessed abundance of well-known and frequently used species better than for species that were perceived as “useless” by people.

Table 9.12: Mann-Whitney test results for comparing the mean categorical use values of species that are represented by large and small quantities in local vegetation, respectively, according to participants

	$\text{UV}_{\text{all use}}$	$\text{UV}_{\text{medicine}}$	UV_{food}	$\text{UV}_{\text{material}}$	$\text{UV}_{\text{construction}}$	$\text{UV}_{\text{social uses}}$	UV_{fuel}
Mann-Whitney U	14484(s)	**12447*****	15980	15159	**12932*****	**15141***	**12155*****
Asymp. Sig. (2-tailed)	0.088	0.000	0.818	0.258	0.000	0.047	0.000

Ho= family use values (FUV) are random with respect to the overall density of their corresponding species in sampled transects

To address this null hypothesis, we calculated the density of the 25 different plant families that were sampled in the four 0.1-ha transects and which are represented by at least ten species. Results presented in table 9.13 show that overall, food and construction FUV values increase with increasing densities.

Table 9.13: Pearson correlation coefficients with respective significance levels between density and categorical family use values

	FUV_{all}	FUV_{med}	FUV_{food}	$\text{FUV}_{\text{material}}$	$\text{FUV}_{\text{constr}}$	FUV_{soc}	FUV_{fuel}
Correlation Coefficient	**0.48***	-0.043	**0.480***	0.322	**0.348(s)**	-0.147	0.091
Sig. (2-tailed)	0.014	.840	0.015	0.116	0.089	0.485	0.666

All= all uses; med= medicine; constr= construction; soc = social uses

*= $p \leq 0.05$; (s)= $p \leq 0.1$

Linear regression analysis between density and $\text{FUV}_{\text{all uses}}$ is highly significant and allows to identify families that have significantly higher or lower $\text{FUV}_{\text{all uses}}$ than predicted from their abundance in sampled transects. A regression residuals analysis shows (figure 9.5) that only Arecaceae has a higher overall FUVs than expected from its abundance.

In Galeano's (2000) research, Lauraceae, Sapotaceae and Annonaceae had higher FUV$_S$ than expected from their species abundances. FUV$_S$ of Sapotaceae and Annonaceae are also among the highest in the present study but they are not significantly overused as expected from measured densities in transects. Among some other explanations, Galeano (2000) hypothesized that overuse of a family based on density might be due to the fact that those families had gradually been decimated by destructive harvesting, precisely as a consequence of their utility. Applied to our data, this might be a plausible explanation for the specific case of Arecaceae. The exceptional usefulness of the palm family is irrefutable and undoubtedly increases harvest pressure on species within this family (Phillips and Gentry, 1993a; Phillips *et al.*, 1994; Macia 2001 and 2004; Stagegaard *et al.* 2002). Various authors have reported local depletion of Amazonian palm populations following overharvesting of various plant parts (e.g. Davis and Yost, 1983b; Flores and Ashton, 2000; Svenning and Macia, 2002). In chapter 10, it is discussed how *Jessenia bataua* and *Geonoma deversa* are most likely undergoing a process of local population decline in TIPNIS. In addition, there are strong indications that the same is happening for other useful palm species such as *Attalea butyracea*, whose leaves are highly prized as thatching material. We therefore suggest that the fact that the FUV of Arecaceae is higher than could be expected from measured species densities in transects might be a consequence of the high harvest pressure on this family which in turn might lead to locally decreasing populations.

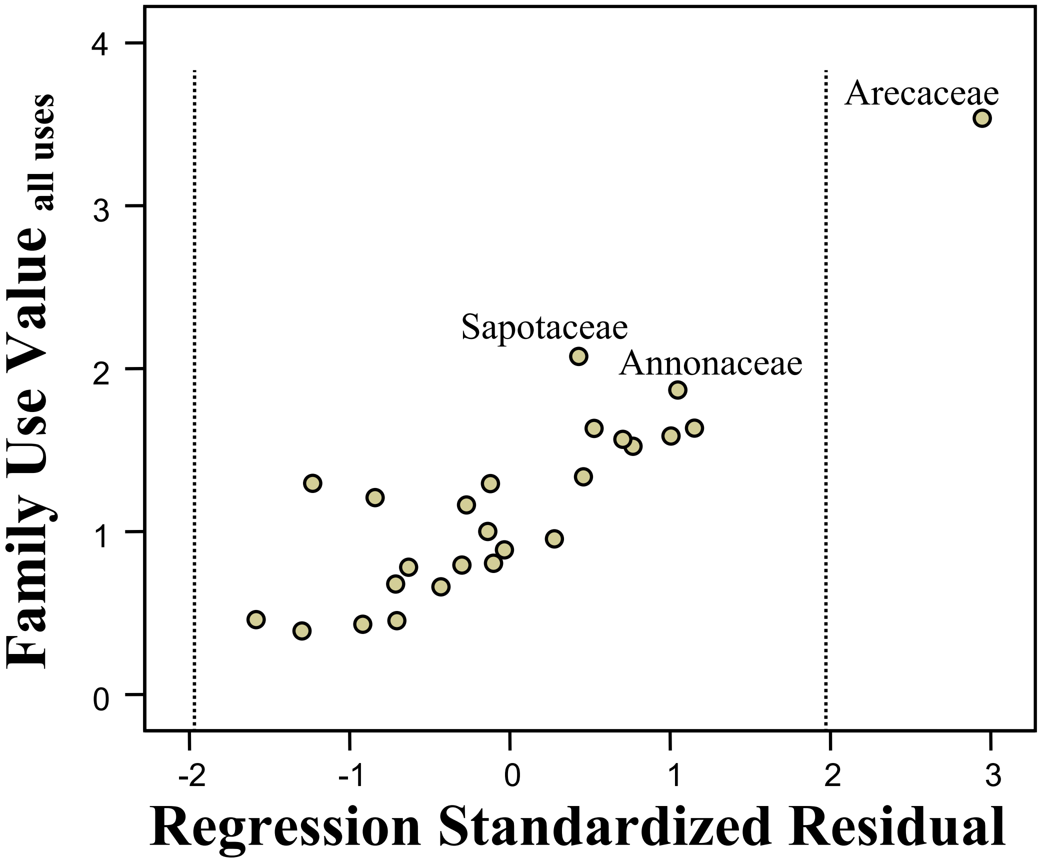

Figure 9.5: Family use values vs. standardized residuals of the regression of FUV $_{\text{all uses}}$ on the number of individuals in the family as sampled in four 0.1-ha transects. Families with standardized residuals >1.96 or <-1.96 (p=0.05; indicated by vertical dotted lines) have significantly higher, respectively lower FUV $_{\text{all uses}}$ than expected from their abundance in transects. Only families with ten or more species were selected (FUV $_{\text{all uses}}$ = 0.014 * density + 0.692; p=0.014 and r^2= 0.23)

As an alternative explanation, Galeano (2000) suggested that families that have FUVs values that are higher than would be expected from their densities could be exceptionally useful in spite of being naturally rare. However, this does not seem to apply for the Arecaceae in our study. In fact, in chapter 6 we showed that, in line with the Neotropical trend (Terborgh and Andresen, 1998; Ter Steege *et al.*, 2000), the palm family is among the six most abundant families in the four 0.1-ha transects we sampled.

Finally, it can not be ruled out that the apparent trend of statistical overuse detected by our data is an artefact of a too small sample size (cf. Galeano, 2000). In other words, results obtained from four 0.1-ha transects might not be representative for the entire study area.

9.4. Conclusions

In this chapter, we have demonstrated that Yuracarés and Trinitarios from the southern part of TIPNIS rely heavily on the forests that surround them for fulfilling subsistence needs. Proportions of used plants species and individuals in sampled transects are in accordance with most other Amazonian studies. In terms of the number of useful species, the understorey (dbh < 10 cm) was slightly more useful to local people than the overstorey (dbh ≥ 10 cm). Significantly higher percentages of plants species with medicinal and social uses were found in the understorey as compared to the overstorey.

We have found only partial support for the argument from the literature that *terra firme* forest appears to be less useful than floodplain or *varzea* forest. However, this result might be related to the scale of our sampling strategy in that four 0.1-ha transects are probably not sufficient for representing the entire study area. More conclusive results could probably be obtained from larger sampling areas and a higher number of transect repetitions. Our data did not allow for a sound comparison of the usefulness of different forest types between Yuracarés and Trinitarios. This is largely due to the fact that we worked with non-permanent transects which resulted in very uneven use knowledge data for plants in a vegetative state, obtained from Yuracarés and Trinitarios, respectively. Given that in tropical forests most plant species are vegetative at any given moment throughout the year (Phillips *et al.*, 2003) and that the recognition of vegetative plant props *ex situ* is very questionable (Thomas *et al.*, 2007), it would have been better for us to install permanent transects. Such an approach would have allowed interviewing various members of both ethnic groups about the same vegetative plants in their growing sites (i.e. *in situ* interviews). However, in addition to being much more time consuming, this approach would have been much more difficult to carry out in view of the fact that the participating Trinitario and Yuracare communities are separated in space. *In situ* interviews with members of both ethnic groups in a transect established in the vicinities of a Yuracaré community would have required Trinitario participants from other communities to travel towards it and vice versa. During the present study there was not enough time to organize such a research setup.

In spite of the bias in our transect data, some trends in plant use could be observed. The food usefulness of all forest transects was significantly higher for Yuracarés than for Trinitarios, whereas the opposite trend was obtained for the medicinal usefulness of three out of four forest transects sampled.

In this chapter, we have also demonstrated some of the correlations between categorical use values of species and several phylogenetic, morphological, ecological and anthropogenic variables. Factors that have been identified to determine (categorical) use values of plants include: plant family, growth form, density, frequency, mean and maximum dbh and importance value (IV). Indigenous assessment of accessibility and abundance of plants also co-varied with their usefulness, although for a restrict number of use categories only. Only significantly higher medicinal use values were obtained for species that were perceived by people as more easily accessible or as more abundant.

Yet, our data from TIPNIS showed that, in analogy with results obtained for Apillapampa, the correlation between density and frequency of plants in the landscape and their perceived accessibility by local people is highly significant. Therefore, it can be concluded that also in TIPNIS accessibility of plants strongly guides their usefulness.

10.

Yuracaré and Trinitario Practices of Indigenous Plant Management and Use in TIPNIS

10.1. Introduction

All human societies owe their present day existence to a variety of ancestral accomplishments. Some of these are undoubtedly related to the long-standing management of botanical diversity. In the same way as intellectual diversity continuously stimulated cultural evolution (Kimmerer, 2002), the raw material of botanical evolution has been manipulated to a varying extent throughout history. Thousands of years of human experimentation with, and management of plants have led to our current plant domesticates. The most valued domesticates or crop plants are probably those providing food. However, food occupies but a portion in the spectrum of plant-derived products, and many plants have been managed or domesticated for a variety of other purposes, including medicines, fibres, dyes, ornaments, etc. Some signs of plant management date back more than 30,000 years (Etkin, 1998). Since then it has been a process developing in different societies around the globe as an adaptation strategy in an ever-changing world. In the Americas, at least 257 species were cultivated (138 species in lowland northern South America) when Columbus arrived in 1492 (Leon, 1992; Clement 1999a and b).

It has been argued that Amazonia has been overlooked as a cradle of crop diversity (Clement, 1999b). At contact, there were probably two centres of diversity, four minor centres (one of which is the Bolivian plains of Moxos, the homelands of Trinitarios), and five or more regions of diversity in lowland northern South America, east of the Andes (Clement, 1999b). For most present-day Amazonian domesticates, wild ancestors are unknown. In any case, more than one hundred plant species have been domesticated in the Neotropics of which at least 52 in Amazonia. This is more than in any other region of the world (Brücher, 1989; Balée, 1994; Clement, 1999a). In addition, it is now clear that many crops were lost after contact (1492) as a consequence of post-contact Amazonian population decline. Therefore, it seems safe to assume that the Amazonian crop genetic heritage at contact was at least an order of magnitude greater than it is today (Clement, 1999a).

Plant management in Amazonia covers a continuum, ranging from gathering and protecting plants in wild populations, over deliberately tolerating plants in man-made habitats (also defined as disturbance habitats), to cultivating domesticates as well as non-domesticates. According to Clement (1999a), the human-plant interaction in Amazonia throughout history can be characterized as a gradual process of increasing management intensity of individual species, as well as of increasing management of the environment of species. The scale on which these management practices took place is impressive. Virtually everywhere humans live(d), they have influenced their environment and the plants occurring in it (Van den Eynden, 2004). In Amazonia, many seemingly natural landscapes appear to be the result of historical indigenous management, although this was probably largely unintentional (Denevan, 1992; Balée, 1989 and 1994; Clement, 1999a; Smith and Wishnie, 2000). For example, Balée (1989) estimated that at least 12% of *terra firme* forest in Brazil is anthropogenic.

Amazonian plant management is perhaps nowhere as intense as in homegardens and swiddens (i.e. slash and burn cultivation areas). Homegardens have been one of man's survival strategies since the Neolithicum (8,500 BC). They have played a prominent role in the management and domestication of wild plants (Soleri and Cleveland, 1991; Agelet *et al.*, 2000). Plants are managed in homegardens for a number of purposes of which the production of food and herbal medicine are often the most important ones. To a lesser extent, plants are also managed for ornamental uses and as sources of materials (Agelet *et al.*, 2000; Balée, 1994; Albuquerque *et al.*, 2005). The Ka'apor from Brazil mainly plant food crops and plants used in tool and utensil making, spices, and medicinals (Balée, 1994). Finerman and Sackett (2003) have shown that in Andean Ecuador, homegardens are overwhelmingly devoted to the cultivation of medicinal plants, operating as de facto medicine cabinets that supply women with most of the resources they need to treat family illnesses.

In homegardens, plant management is usually manifested as a combination of cultivated, domesticated and tolerated plants, whereas plant protection mostly occurs in "natural" habitats. However, it is often hard to define the exact management status of plants (Bennett, 1992; Rival, 2006), especially because some species are not restricted to a single category of resource management. Some species are cultivated in gardens whilst they may at the same time also be protected in natural vegetation. Others occur as wild species in a natural habitat and can have been transplanted to a garden where they are considered cultivated (Bennett, 1992; Van den Eynden, 2004). Although most of these management techniques have been reported for many societies (e.g. Bennett, 1992; Casas and Caballero, 1995; Bonet and Vallès, 2002; Van den Eynden, 2004), plant management can be quite variable, even within small communities. According to Van den Eynden (2004): "Management decisions are very individual and dynamic in time, as are use decisions. A plant managed by one individual is not necessarily managed by anyone else. Similarly, one particular plant species may be managed in different ways by different people, and its management may change in time."

In view of this high variability between those who manage plants and how they manage them we will first describe how different management statuses have been interpreted in the present study. We distinguish between cultivated, protected, tolerated and wild plants.

Cultivated plants

Cultivated or planted species are managed and cared for by people during their entire life cycle (Van den Eynden, 2004). They are sown as seed, multiplied vegetatively by means of stem, root or other cuttings, or transplanted from natural habitats. Apart from interfering in their abundance and distribution, people also enhance their growth through irrigation, weeding, pruning, fertilization, insect control or protection against herbivores (Bennett, 1992). Although cultivation of plants occurs most often in homegardens or swiddens, other natural or man-made habitats are taken into account as well. The most famous example is probably provided by Posey (1984) who described how the Kayapó of Brazilian scrub savannah create trails in the landscape that may be several meters wide, along the sides of which they plant seeds and tubers when they defecate.

A substantial number of cultivated plants depend (entirely) on human interference for propagation and survival. They can not be detached from human disturbance landscapes because they have lost their ecological adaptations to natural environments (Harlan, 1992; Clement, 1999a). These plant species have been identified as domesticates since "*the reproductive system of their populations has been so altered by sustained human intervention that the domesticated forms – genetically and/or phenotypically selected – have become dependent upon human assistance for their survival*" (Harris, 1989; Dufour and Wilson, 1994; Van den Eynden, 2004). For example, distribution of banana (*Musa* spp.) species in TIPNIS is completely dependent upon human interference.

There also exist cultivated plant species that propagate naturally and hence are represented by wild populations, such as *Bactris gasipaes* that is found cultivated in nearly every homegarden in TIPNIS, but also grows wild in the forest. These species clearly do not (yet) satisfy the requirements to unmistakably be called domesticates. The average phenotypic variation of the part of the population modified by human selection may diverge from the range of variation found in the wild population, but the plants retain sufficient ecological adaptability to survive in the wild if human intervention ceases (Clement, 1999a). They are often designated as semi-domesticates (Balée, 1994; Clement, 1999a). Some authors have argued that this is a confusing term because it implies that domestication would be an ongoing process, which is not necessarily always the case (Alcorn, 1981, Van den Eynden, 2004). For example, Balée (1994) calls *Annona montana* a semi-domesticate because in his study area it is only found in old fallows (as anthropogenic landscapes) and not in primary forest or other undisturbed habitats. However, in TIPNIS this species is represented by a significant wild population, as evidenced by the results of our transect sampling (chapter 6).

Hence, domesticated plants are largely, but not exclusively, a subgroup of cultivated plants: although most domesticated plants are cultivated, not all cultivated plants are necessarily domesticated (Van den Eynden, 2004). Only about 200 of the 3000 crops used by humans worldwide have ever been domesticated (Hawkes, 1983, cited in Clement, 1999a).

Tolerated Plants

Tolerated plant species are defined here as those species that are deliberately spared during weeding and land clearing activities for the benefits or usefulness they provide to humans. Hence, tolerated species include (1) species from the natural vegetation that are deliberately spared during land clearing activities (e.g. during establishments of new swiddens), as well as (2) species that develop spontaneously in man-made habitats through natural processes and that are intentionally spared during weeding activities. Unintended seed dispersal by humans as an example of zoochory is here also considered as a natural process. These include: seeds that stick to clothes or the body of humans; seeds of edible fruits that are spat out without a predetermined purpose of dispersion; or seeds of non-crop plants that get mixed with sowing seeds/planting material of crop plants. Tolerated species are not restricted to man-made landscapes. Since they do not depend on humans for reproduction, they can also prevail in natural disturbance (e.g. natural tree fall gaps, landslides…) or other habitats. Clement (1999a) called these plants ‘incipiently domesticated’ because their populations have been modified by human selection and intervention, but their average phenotype is still within the range of variation found in the wild population for the trait(s) subject to selection. Good examples of tolerated plants in TIPNIS are *Sida rhombifolia* and *Scoparia dulcis*. These opportunistic species establish spontaneously in the village environment after land clearing activities. People generally weed large part of their populations, but also spare a significant fraction for their use as brooms and in traditional medicine (Thomas and Vandebroek, 2006).

Protected Plants

A third management technique is the protection of plants that occur spontaneously in natural or man-made landscapes. Plants are then particularly protected in their most vulnerable stages when they are plantlets or seedlings. Basically, protection refers to removing competing plants or pests to enhance the target plants’ chances of survival (Casas and Caballero, 1995). Plants are most often protected for future utilitarian purposes. In TIPNIS, the rare but highly valued species *Neea* cf. *virens* and *Brunfelsia mire* (Thomas and Vandebroek, 2006) are freed of competing plants when encountered in the forest to enhance their survival chances and thus the possibility of future use.

Wild plants

As opposed to “managed” plants, “wild” plants are defined as those plants that are not manipulated genotypically or phenotypically by humans in any way (Dufour and Wilson, 1994; Clement, 1999a). They can prevail both in anthropogenic and natural environments.

Wild plants are defined by other authors (e.g. Bye, 1993; Van den Eynden, 2004) as unmanaged plants that grow naturally outside habitats disturbed by humans, whereas weeds are unmanaged plants that grow spontaneously in man-made habitats. In fact, many weeds represent a status of “incidental co-evolution”. They have adapt(ed) to human disturbance environments, possibly undergoing genetic change, but without intentional human selection (Clement, 1999a). In the present study, we did not make such a distinction for the analysis of our data because of the uncertainty to distinguish weeds from wild plants. This distinction is complicated by the fact that weeds in Amazonia are not merely herbaceous plants, but most often large trees (Balée, 1994). Examples are *Himatanthus sucuuba* and several *Cecropia* spp. Therefore, in the scope of this study we regarded unmanaged weeds also as wild plants.

In this chapter, first we present the principal plant management strategies applied by Yuracarés and Trinitarios from the southern part of TIPNIS. Some examples of plant species that are possibly harvested unsustainably from wild populations are given. A comparison is then made between the usefulness of wild and managed species, after which we shift to discussing the plants managed in Yuracaré and Trinitario homegardens and swiddens. Finally, plant use knowledge is compared between participants from both ethnic groups and an attempt is made to distinguish between plants that belong to the specific cultural sphere of either one of both ethnic groups. Results are confronted with relevant scientific literature and linked to the ethnohistorical background of both Yuracarés and Trinitarios.

10.2. Methodology

Plant Collection

All floristic data used in this chapter were obtained following the sampling techniques described in chapter 6. Plant management was particularly studied in 32 different homegardens from the five indigenous communities described in chapter 6.

Participants and Interviews

The analysis focused on plant management and plant use knowledge of Yuracarés and Trinitarios is based on use data that were obtained for the total of 894 collected botanical plant species, described in chapter 8. Use data on managed species (i.e. cultivated, protected and tolerated species) in particular were obtained for 1 to 9 Trinitario and 1 to 7 Yuracaré participants per species. On average, significantly more Trinitarios provided use data per managed species (4.4 ± 2.0 (s.d.)) as compared to Yuracarés (3.6 ± 2.1 (s.d.)) ($p<0.001$; t-test).

Management Status

In case the management status of a plant species was confusing because management practices differed between members of the same ethnic group, or depended upon the growth place, it was assigned to the highest hierarchical management status. The following hierarchical order was applied: wild, tolerated, protected and cultivated. Hence, the management status of a plant species that was protected in the forest and cultivated in homegardens was classified as ‘cultivated’. Likewise, a plant that was tolerated on swiddens by one Yuracaré participant and considered wild by another was classified as ‘tolerated’. Management statuses of plants were considered for Yuracarés and Trinitarios separately.

However, when comparing between the general usefulness of wild and managed species (i.e. for Yuracarés and Trinitarios together), the highest hierarchical management status of both classifications made by Yuracarés and Trinitarios was assigned to each plant species. For example, if a plant was labelled as wild for Yuracarés and as cultivated for Trinitarios, then its overall management status was set as cultivated.

Since we did not systematically ask for the protection status of plants in natural habitats, a number of plant species that were actually protected have probably been classified as wild. As indicated in the introduction, we did not distinguish between "weeds" and wild plants but considered all spontaneously developing and unmanaged species (including weed and perennials) in gardens and swiddens, as wild species.

Plant Use Knowledge Diversity

We applied the method proposed by Begossi (1996) to compare plant use knowledge diversity between different ethnic groups. The latter author applied the Shannon-Wiener diversity index ($H' = -\sum p_i * \log_{10}(p_i)$) to evaluate the diversity of plant use knowledge among different human populations. This index is popular in biodiversity analysis since it takes into account both number of species (alpha diversity) and the evenness (equitability) of individuals per species. We applied it in chapters 2 and 4 as a measure of plant diversity in the transects we sampled in Apillapampa. Similarly to biodiversity calculations where p_i is calculated as the proportion of individuals of the i^{th} species in a sample, Begossi (1996) interpreted it as either (1) the number of different unique uses of the i^{th} species, or as (2) the number of participants that confirms the use of the i^{th} species. Calculating the Shannon-Wiener index based on the number of participants that acknowledge categorical uses ("relative abundance") per species is equivalent to measuring diversity of knowledge (Benz *et al.*, 2000). Use knowledge diversity increases in relation to (1) the number of species considered useful by (any) member(s) of an ethnic group or community (alpha diversity); and (2) a more even distribution of the number of participants who report uses of these plant species (evenness).

For the present study we included only those species in this analysis that were shown to at least two participants per ethnic group. As indicated in chapter 9, the majority of plant species that were collected in Gentry transects was vegetative and for many of these species use information was only obtained from the one or two participants who collaborated with us during transect sampling. These species were therefore not included in the analysis.

Benz *et al.* (2000) applied the Shannon-Wiener diversity to test the hypothesis that loss of plant use knowledge correlates positively with increasing modernization. Here we calculated this index to compare the categorical plant use diversity of Trinitario and Yuracaré people. All calculations were performed in PAST programme (Hammer *et al.*, 2007).

Statistical Analyses

SPSS 12.0 was used for performing all other statistical tests on data presented in this chapter, including t-tests, χ^2-tests, Mann-Whitney tests and Kruskal Wallis tests.

10.3. Results

10.3.1. Yuracaré and Trinitario Management Techniques

Protecting and Gathering Wild Plant Species

During interview sessions, only two plant species were reported as being actively protected in the forest. When encountered in the forest, Yuracarés protect the culturally important but locally rare *Neea* cf. *virens* and *Brunfelsia mire.* However, it stands no doubt that a number of actually protected plants have not been recorded during our study because we did not systematically ask for the protection status of plants in natural habitats. For example popular food plants are often freed from competing plants or pests by Trinitarios or Yuracarés, especially along frequently used forest trails, to enhance their chances of survival. Also, rare plant species with unique medicinal or other use properties may be protected (e.g. *Aniba canelilla* and *Gallesia integrifolia*). A number of these species that are protected in the forest are also cultivated, for which their management status was classified as cultivated rather than as protected (e.g. *Rheedia* spp. or *Pouteria nemorosa*).

Protection is in many cases restricted to the first, vulnerable life phases of a species. Once a plant individual is mature, it is often sacrificed to harvest the plant products it produces. We have witnessed numerous times how fruit-bearing wild tree species (e.g. *Rheedia acuminata*, *R. gardneriana*, *Helicostylis tomentosa*, *Pouteria torta* subsp. *glabra*, *Bactris gasipaes*, etc.) were cut down in the forest by Yuracarés, and to a lesser extent by Trinitarios, to harvest their fruits. As far as we have been able to observe, decisions to cut down a tree are not based on the perceived abundance of species, but rather on the estimated time and effort investment to cut, as well as on the estimated yield of fruits. When one thinks it will take too much time or effort to cut a tree trunk, or when the quantity of harvestable fruits is rather low, tree climbing will be preferred over felling.

However, this does not mean that Trinitarios or Yuracarés will cut down trees without further considerations. Children often climb trees to harvest fruits, while adults are focusing on other activities such as the collection of material for roof thatching and house construction, or when accompanying scientists who sample Gentry transects... Ripe fruits are also collected from the ground. Trees are mostly felled systematically when special forest trips are planned, aiming at collection of large quantities of wild fruits. The main purpose is then to bring back plenty and make the effort invested in the trip worthwhile. In line with this finding, Trinitario and Yuracaré people only undertake gathering trips when highly appreciated fruits such as *Rheedia acuminata* (figure 8.14B), *R. gardneriana* or *Jessenia bataua* are known to be ripe on the tree(s). The majority of other edible species are picked and eaten as snack foods when they are seen and encountered by coincidence, but no special collection trips appear to be made anymore to harvest them.

When asked whether felling trees for their fruits had lead to local extinction of certain species, participants answered to the negative. However, there existed consensus about decreased availability of *majo* (*Jessenia bataua*). *Majo* produces edible fruits that are processed into a much-appreciated beverage and edible oil which are highly appreciated by all Yuracarés and Trinitarios (see chapter 8, section 8.3.7.4.). Unfortunately, the tree is frequently cut down to harvest its fruits, since climbing its 15 meters tall slippery stem is considered too risky.

Another species that is running the risk of local extinction is *mara* (mahogany, *Swietenia macrophylla*). This CITES appendix III species (www.cites.org) is a large forest tree and the most valued commercial timber species in Bolivia. The wild population of *mara* is actually being depleted in the park by Yuracarés and Trinitarios. Individuals from both ethnic affiliations form little groups of fellow and/or neighbouring villagers (i.e. Yuracarés, Trinitarios or even Quechuas) who they pay to cut the trees, process them into commercial-sized boards and transport the latter to the nearest truck stop. In response to perceived resource depletion on the one hand, and the high monetary value of the timber on the other, members of both ethnic groups started cultivating this species in homegardens and swiddens since recent years. These small-scale plantations are regarded as investments for the future: most adults declared that not they, but their children will be able to benefit from these trees. Some participants claimed to own hundreds of treelets. We have seen at least dozens. Propagation material is mostly obtained in the form of seedlings that are collected under the canopy of mother trees and transplanted in homegardens and swiddens. Also, small-scale seedbeds have been observed. These are laid out in dug plain soil under the branches of shrubs or small trees in order to provide shadow and lower the impact of rain. Occasionally, seeds are germinated in individual containers.

A third species that suffers from wild population decline is *jatata* (*Geonoma deversa*), a caespitose small palm that is highly valued by all inhabitants of TIPNIS as a roof thatch (figure 8.18B-D). *Geonoma macrostachys* var. *macrostachys* is even more preferred, but seldom used because of its low abundance. Roofs made with the fronds (leaves) of *G. deversa* are said to last for ten years or more. There is no vegetal alternative that does better. As indicated in chapter 8 (section 8.3.9), petioles of individual fronds of this palm species are twisted and locked between two battens made from the stems of *Gynerium sagittatum* var. *glabrum* (*chuchío*), thus producing thatching elements (panels) of more or less three meters long (figure 8.18C). On average, these panels consist of 270 individual fronds (our count). Panels are arranged imbricately on the roof. On each roof side, between nine and fifteen panels are accommodated in this way, one on top of the other. Standard Yuracaré and Trinitario houses have a length corresponding to two panels, though Trinitario houses tend to be larger. Hence, for the roof of one standard house one would need 36-60 panels or 9,720-16,200 individual fronds. During harvesting trips, we counted that each ramet (i.e. representing one ‘stem’ in the clonal life form of *G. deversa*) at any moment bears some 10-15 leaves. Hence, construction of one standard house would require at least between 972-1620 ramets to be sacrificed.

Moreover, in addition to their use in house building, panels represent a significant economic value for community members: each panel of about three meters in length yields about one euro (data from 2005; corresponding to 10 Bolivianos). This is a relatively high price, taking into account that a local daily wage in TIPNIS at that time varied from 1.5 to 3 euro. Panels are sold within indigenous communities, but also to immigrant highland farmers. Participants complained that local *jatata* populations have been decreasing strongly lately due to overharvesting. This forces people to (1) travel further distances, or (2) to switch to less sustainable alternative (in terms of durability) such as using the leaves of *Hyospathe elegans* or even *Gynerium sagittatum* var. *glabrum* (own observation and participant interviews; cf.

figure 8.18G-H). Apparently, a sustainable solution for this specific case of resource depletion does not exist or has not been identified and/or developed yet.

Cultivated plants

At least 140 plant species receive some form of management in Yuracaré and/or Trinitario homegardens and swiddens where they are cultivated (103 species; 74%) or tolerated (37 species; 26%). The majority (75%) of cultivated plant species depend upon anthropogenic interference for survival. A number of cultivated, non-domesticated species (26 species) also occurs naturally in the forest from where propagative (vegetative or seed) material is sometimes collected and (trans)planted in gardens. A few species that were claimed to be cultivated by at least one participant were never observed in any of the 32 homegardens we inspected. *Majo* (*Jessenia bataua*) for instance, was only observed growing wild in the forest. Nevertheless, several participants declared that this shade species is sometimes cultivated, despite extremely low germination and survival percentages. Cultivated plants were far from evenly distributed over the different studied homegardens either. Fourteen percent of all cultivated useful plant species was encountered exclusively in one of all 32 examined homegardens.

When communities are relocated or swiddens are abandoned, natural succession, as it is known from the original forest, takes over again and “order created by man” rapidly disappears. Still, many cultivated plants manage to survive in the resulting young to old fallows and secondary forest. During numerous forest trips, we encountered patches of fruit trees that are normally only seen cultivated (e.g. plantains, bananas (*Musa* spp.), avocado (*Persea americana*), chocolate trees (*Theobroma cacao*), *Citrus* spp., etc…) in what was recognized as young to late secondary forest. Participants explained that these were abandoned cultivation fields or previous settlements (abandoned between 10 and 30 years ago). Such abandoned fallows are of great utility to both Yuracarés and Trinitarios. Indigenous participants were frequently observed spending time in those places, harvesting large quantities of fruits from such trees that were originally cultivated.

Tolerated Plants

Yuracarés and Trinitarios weed their homegardens on an almost daily basis, basically to prevent invasion of pests such as insects, rodents and reptiles, hereby at the same time reducing snakebite incidents. During our stay we witnessed several times the killing of various snake species, encountered during weeding activities in gardens adjacent to houses. However, this does not imply that homegardens are sterile environments that are completely free of weeds, colonizing or opportunistic (wild) plants. Apart from the 103 cultivated species we counted, 31 naturally occurring species that may deliberately be spared during yard cleaning, while others are removed. The spared species are therefore identified as being tolerated. This does not mean *all* Trinitario or Yuracaré individuals spare these species at all times. Weeding does occur also among tolerated species, but generally part of the local population is left untouched. In addition, toleration is highly personal experience: what is spared by some for its usefulness is simply considered a pest by others and removed.

Some useful species of the original vegetation may be spared by Yuracarés and/or Trinitarios during the establishment of settlements and/or while clearing forest for swidden cultivation.

In all the swiddens we visited, the canopy consisted of one of more of the following multipurpose palm species: *Socratea exorrhiza*, *Iriartea deltoidea*, *Euterpe precatoria*, *Attalea butyracea* and exceptionally the less abundant *Bactris gasipaes* or *Jessenia bataua*. Of these, only *S. exorrhiza* and *I. deltoidea* are considered tolerated species because the other species were said to be sowed or planted by at least one of our participants and therefore were assigned the hierarchically higher management status of 'cultivated'. Numerous other useful (edible) species (e.g. *Chrysophyllum venezuelanense* or *Pouteria* spp*.*, *Pseudolmedia* spp.) may be spared during the establishment of new settlements of swiddens. However, the presence of these mostly rare (in terms of abundance in the entire landscape) species in homegardens or swiddens is far from consistent, and their occurrence seems to be highly dependent of the sites where settlements and/or swiddens are established. In view of the inconsistent occurrence of these species and the incompleteness of our data regarding which species are 'typically' spared and which ones are not, we classified them as wild species.

Sometimes oversized trees are left behind on swiddens, simply because they are too labour-intensive to cut down. Although not respected by all, some conservation ethics come into play as well. A Trinitario elder explained that "one should not cut down mature trees of *Hura crepitans*, *Ceiba pentandra*, *Dipterix micrantha* or *D. odorata* since they are "the mothers of the forest" that keep the soil humid, hereby allowing other plants to grow. If these trees would be cut down systematically, "the forest would die". Particularly *Ceiba pentandra*, is a tree species with a spiritual connotation. Trinitarios believe that sorcerers learn their evil magic from this tree. Felling large individuals of this species is not done as it is believed to cause mischief. We have observed various swiddens that contained spared large-sized individuals of these "mother" trees that therefore are considered as tolerated species.

Hence, although both are classified as 'tolerated', the main difference between plants tolerated in homegardens and swiddens, and plants that are spared during forest clearing is that the former are typically disturbance species whereas the latter are essential parts of the natural (climax) flora. As opposed to tolerated plants in homegardens, plants spared during forest clearing did not establish themselves naturally during a period of human occupation. They were already present when the land surface became subjected to clearing and subsequent (intensive) human management.

Finally, some useful plant species that establish in homegardens or swiddens through (un)intentional dispersion by humans, may be tolerated as well. For example, when fruits are collected from the wild, they are often brought back to the village. Seeds are spat out randomly in the surroundings of dwellings and germinate if growth conditions (soil, shadow, moisture, allelopathy….) permit it. When seedlings are identified as useful species, they may be spared during yard or crop field weeding activities and get a chance to develop into mature plants. Therefore, toleration (or in some case even protection) would be the adequate management term for these plants. As opposed to cultivated plants, they establish themselves through natural dispersion processes whereby unplanned and/or random dispersion by humans is to be regarded in the same way as seed dispersal by animals. However, our data regarding species that are tolerated this way are incomplete (as this would require long-term observations) and therefore they are not considered for our further analyses.

In sum, we identified 37 different species as being tolerated by Yuracarés and/or Trinitarios: 31 disturbance species that are occur spontaneously in homegardens or swiddens and 6 species that are spared when clearing original forest vegetation.

Wild Plants

A number of wild plant species that develop spontaneously in homegardens are not managed, in spite of their usefulness. Participants declared that there is no need to deliberately spare these plant species because "they are always there, they never disappear". When needed, they are easy to find in habitats under anthropogenic disturbance such as homegardens, trails, and young or recently abandoned swiddens. Obviously, also all other unmanaged plant species occurring in natural landscapes are considered wild.

10.3.2. Comparing the Usefulness of Wild and Managed Species

In order to compare the usefulness of wild and managed species, we calculated the mean categorical use values (see chapter 3 for terminology used) of species that are wild and managed, respectively. The resulting mean use values, presented in figure 10.1, show the superior usefulness of managed over wild species for several use categories. Indeed, the mean overall use value of managed species is nearly twice that of wild species (t-test, p<0.001). Managed plant species are especially more useful for medicine, food, materials and environmental uses (p<0.01 for all the latter categories, Mann-Whitney).

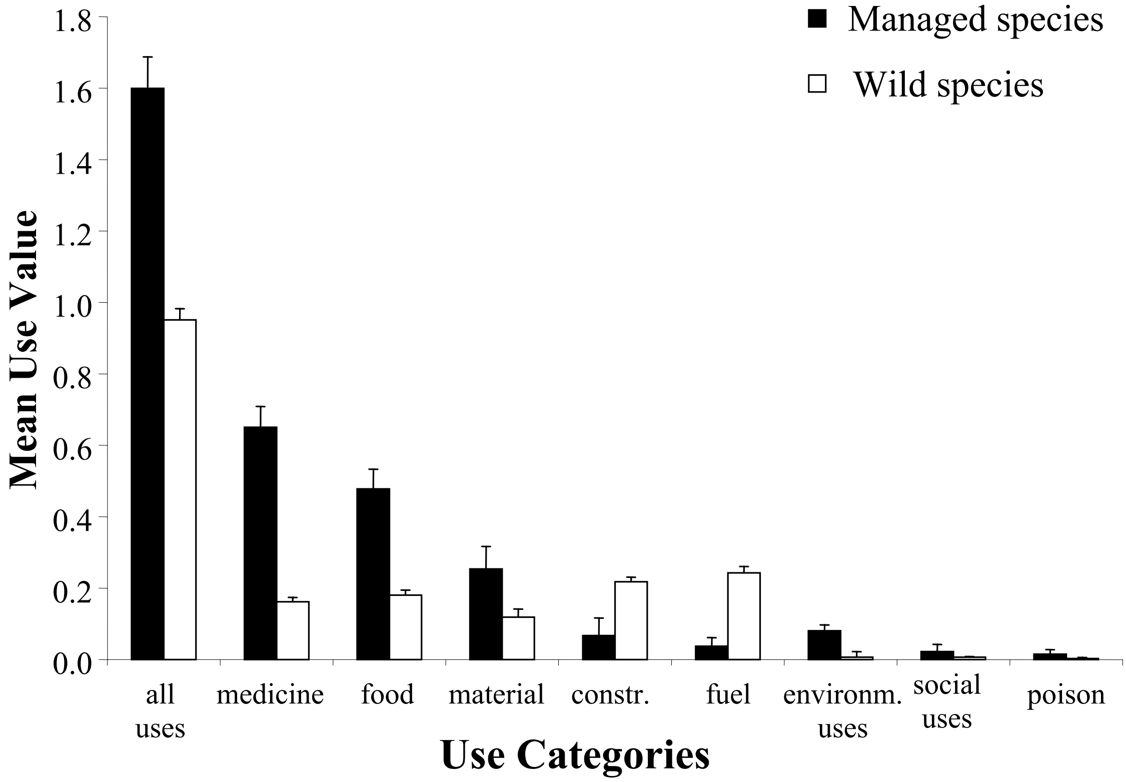

Figure 10.1: Comparison of mean categorical use values for all inventoried managed and wild plant species; error bars represent standard errors of the mean (constr. = construction; environm. uses = environmental uses)

On the contrary, wild species have significantly higher use values for construction and fuel (p<0.01 for both categories, Mann-Whitney). Mean use values for social uses and poison (p>0.05, Mann-Whitney) are equal for managed and wild species. Therefore, we will particularly focus on overall, medicine, food and material use values when performing analyses related to plant management.

The differences in the mean use values between managed and wild species are more pronounced when managed plants are separated into cultivated and tolerated plants (figure 10.2). The mean overall use value (all uses) (p<0.01, t-test) and food use value (p<0.01, Mann-Whitney) of cultivated plants are significantly higher than of tolerated species. Mean use values for medicine and material are equal for cultivated and tolerated species (p>0.01, t-test and Mann-Whitney). Hence, cultivated plants have an important food value in addition to their medicinal importance, whereas the value of tolerated plants is mainly medicinal.

Apart from managed plants, a number of species typically grows wild in environments under a regime of anthropogenic disturbance. Many of these (wild) species, such as ruderal plants, agricultural weeds, or pioneer tree species can also appear in natural environments (e.g. tree fall gaps or landslides) but their abundance/and or distribution is positively influenced by human activities. Since people spend most of their time in anthropogenic disturbance habitats, it is logical to expect that they come more into contact with the plants that grow there. The question that follows is whether these species are also considered more useful than species that grow in natural landscapes. To verify this, we made a comparison between the usefulness of plant species that typically grow in natural (699 spp.) and anthropogenic (195 spp.) landscapes, respectively. In the scope of this analysis we considered as anthropogenic landscapes: homegardens and swiddens (160 species); fallows and secondary forest (24); and ruderal environments such as roadsides or trails (11). Natural landscapes include old growth forest vegetation, as well riverine vegetation.

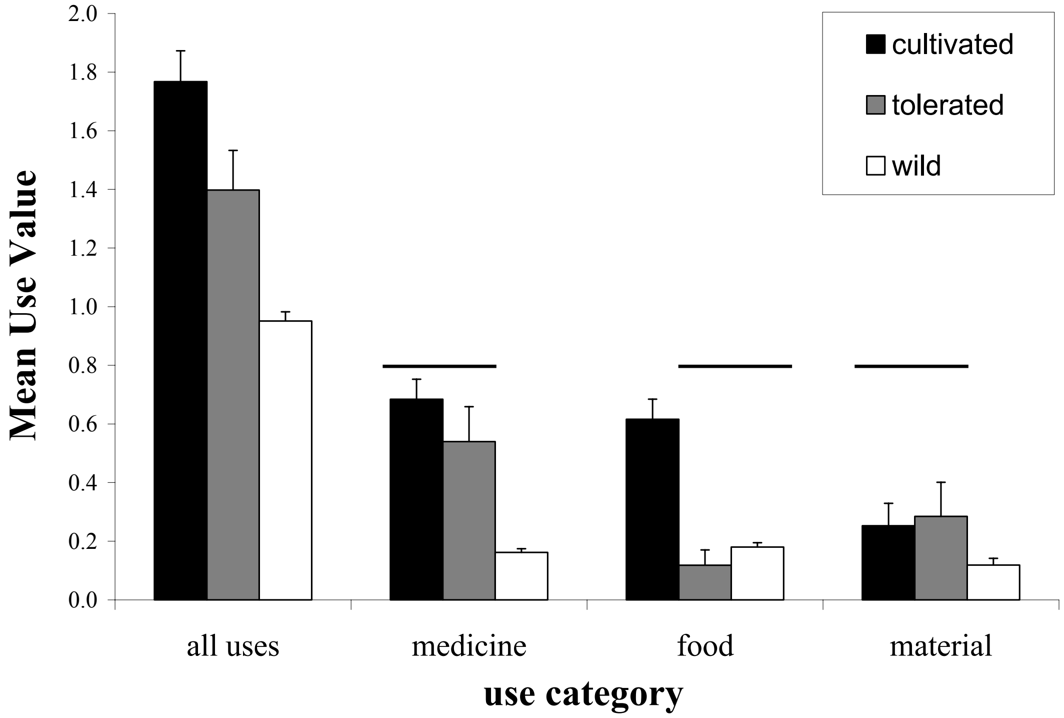

Figure 10.2: Comparison of mean categorical use values for all inventoried managed, cultivated, tolerated and wild plant species; error bars represent standard errors of the mean; significantly equal mean use values are indicated by horizontal lines

The mean overall use value of species that typically grow in anthropogenic environments is significantly higher than that of wild species (t-test, $p<0.001$). Plants species from anthropogenic environments are especially perceived as more useful for medicine, food, materials and environmental uses ($p<0.01$ for all the latter categories, Mann-Whitney). On the contrary, species from natural environments have significantly higher use values for construction and fuel ($p<0.01$ for both categories, Mann-Whitney). Hence, although actual values vary slightly, the general trend observed here greatly corresponds to that observed for the comparison of managed and wild species in figure 10.1. It is very likely that disturbance plants scored higher for these use categories mainly because of the significantly higher overall use value of managed plants, which make up the majority of disturbance plants. Therefore, we examined whether the idea that "more accessible plants are perceived as more useful by people" also holds true for wild plant species by comparing the mean use values of wild plants typically growing in anthropogenic environments (50 species) and those of wild plants growing (exclusively) in natural environments (702 species). The calculated mean overall use value of wild plants from natural environments ($UV_{\text{all uses, nat}}=0.96$) is higher than that of wild plants from anthropogenic environments ($UV_{\text{all uses, anth}}=0.81$), but this difference is not significant. However, wild plants from anthropogenic environments have a significantly higher mean medicinal use value ($p<0.01$, t-test). For all other use categories wild plants from anthropogenic environments have significantly lower mean use values as compared to wild plants from natural environments ($p<0.01$ for all pairwise Mann-Whitney comparisons), except for mean material use values that are equal.

10.3.3. Plant Management in Homegardens and Swiddens

10.3.3.1. Taxonomy and Life Forms

The 140 managed plant species encountered in Yuracaré and Trinitario homegardens belong to sixty botanical families. The best-represented families are: Fabaceae (13 species), Solanaceae (8), Arecaceae (8), Asteraceae (7), Poaceae (6), Rutaceae (5) and Euphorbiaceae (5) (figure 10.3). The relative importance of these families is also reflected in the taxonomic distribution of managed medicinal and food plants. The medicinal plant species that are managed in homegardens belong to 52 different botanical families. The best-represented families are Asteraceae (6 species), Fabaceae (6), Rutaceae (5), Solanaceae (5) and Euphorbiaceae (5). Managed edible plant species belong to 35 different botanical families. Best-represented families are Arecaceae (8 species), Fabaceae (8), Poaceae (5), Rutaceae (5), Annonaceae (4) and Solanaceae (4).

The majority of plants managed in homegardens are herbs (58 species), followed by trees (46) and shrubs (30) (figure 10.4). The same ranking is obtained for tolerated plants, while cultivated plants are represented by an equal number of herbs and trees (33 and 34 species, respectively). Four liana and one medicinal fern species are cultivated and one hemi-parasite (*Struthanthus acuminatus*) frequently growing on *Citrus* spp. is tolerated for its medicinal properties.

10.3.3.2. Plant Origin

Thirty one cultivated and two tolerated plant species (representing 30% of all cultivated and 24% of all managed species, respectively) are introduced from the Old World (Eurasia and

Africa) (see tables 10.2 and 10.3). All of these cultivated species are used by Trinitarios and all but two (*Sansevieria* cf. *trifasciata* and *Tamarindus indica*) by Yuracarés. Trinitarios use more than three times as many introduced species as medicines as compared to Yuracarés (24 vs. 7 species). In proportion, introduced plants make up around one third of cultivated food or medicinal plants, both for Yuracarés and Trinitarios (table 10.1).

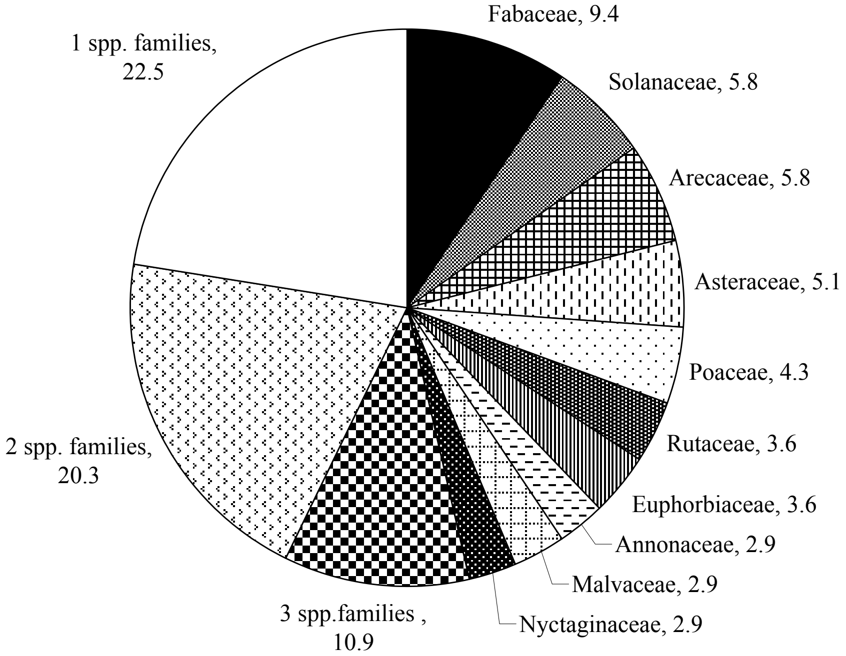

Figure 10.3: Distribution of managed species over botanical families; indicated values are percentages of the total of 140 managed species

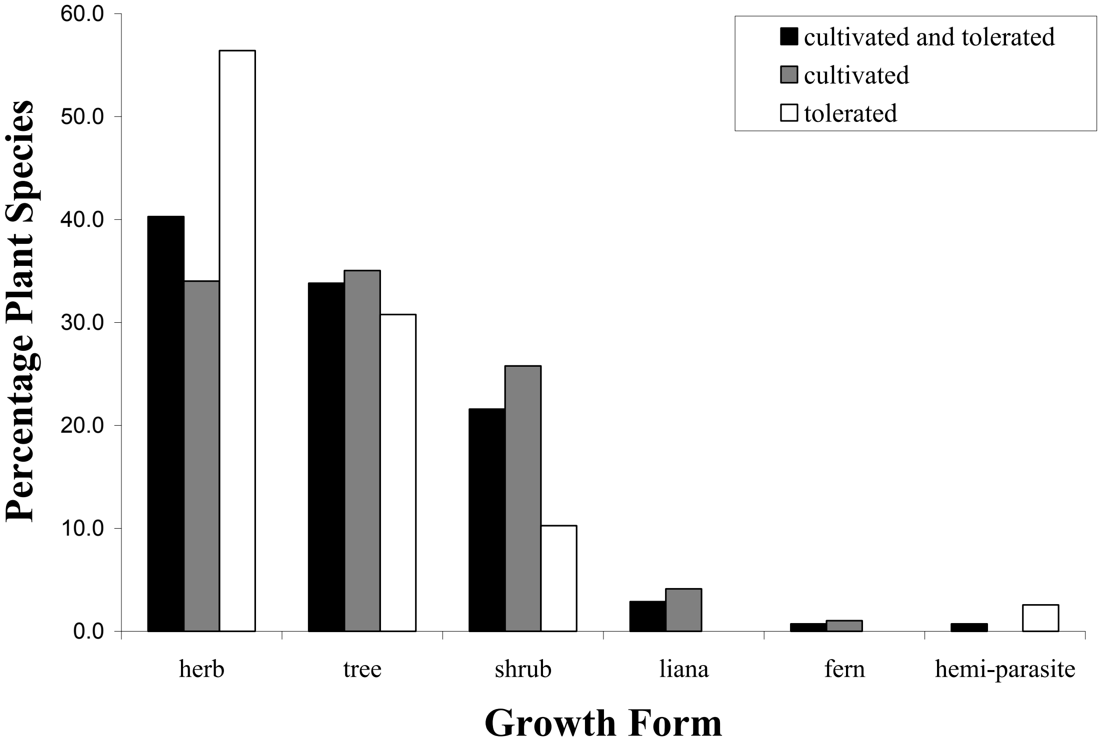

Figure 10.4: Growth form distribution of managed species. The majority of managed species are herbs, followed by trees, shrubs and lianas. The high proportion of herbaceous managed species is basically due to the fact that 56% of all tolerated plants are herbs.

Table 10.1: Absolute numbers of introduced cultivated plant species, used by Yuracarés and Trinitarios, respectively. Percentages represent proportions of species on the total number of cultivated species by each of both ethnic groups. Both Yuracarés and Trinitarios use similar proportions, but Trinitarios use more than three times as many introduced medicinal plant species.

	Yuracarés		Trinitarios	
	# species	%	# species	%
all uses	29	33	31	32
medicinal	8	33	25	35
food	18	33	19	36

As indicated in table 10.2, the majority (70%) of the cultivated species found in Yuracaré and Trinitario homegardens and swiddens are of Neotropical origin. Several of these are putatively of Amazonian origin (Balée, 1994; Clement, 1999a): cotton (*Gossypium barbadense*), annatto (*Bixa orellana*) chilli peppers (*Capsicum chinense* and *C. frutescens*), peanut (*Arachis hypogaea*), tobacco (*Nicotiana tabacum*), cherimoya (*Rollinia mucosa*), *ajipa* (*Pachyrhizus tuberosus*) and *floripondio* (*Brugmansia suaveolens)*. Many other cultivated plants are believed to have origins in other Middle or South American regions. These include: pineapple (*Ananas comosus*), guava (*Psidium guajava*), sweet potato (*Ipomoea batatas*), physic nut (*Jatropha curcas*), American yam (*Dioscorea trifida*), cashew (*Anacardium occidentale*), maize (*Zea mays*), calabash (*Crescentia cujete*), cassava (*Manihota esculenta*), papaya (*Carica papaya*), avocado (*Persea americana*), and pumpkin (*Cucurbita maxima*) (see literature review in Cardenas, 1989; Balée, 1994; Clement, 1999a and b; Vásquez and Coimbra, 2002; Plotkin, 1994).

Until recently, the origin of bottle gourd (*Lagenaria siceraria*) was subject to a great deal of uncertainty. New genetic and archaeological research now places it among the earliest domesticates of the New World. Indigenous to Africa, it reached East Asia and was brought, together with the dog, to the Americas by Paleo-Indian populations as they colonized the New World around 10,000 before present (Erickson *et al.*, 2005).

The plants mentioned in the previous paragraphs have been classified as domesticates, since they have become dependent upon human assistance for their survival. However, as we have indicated before, not only domesticates, but other species as well, are cultivated in Yuracaré and Trinitario homegardens. Some of these species might be undergoing a process of domestication, while others are not. A good example to illustrate the caution one needs to bear in mind when distinguishing between cultivated and domesticated species is provided by *Annona montana*. Written evidence that confirms cultivation of this edible fruit-producing tree dates back to the sixteenth century (Vasconcellos, 1865; cited in Balée, 1994). The Yuracarés that participated in our study still cultivate this species in their gardens and fields, but there exists an important wild population in the forest as well. Participants declared that they use seeds from wild as well as from cultivated individuals as propagative material, without any clear preference for any of both.

Table 10.2: Plant species that were reported and observed to be cultivated by Yuracaré (y) and/or Trinitario (t) participants. Thirty-one of these species have been introduced from the Old World, whereas 72 are native to the New World. 26 cultivated native species also prevail in the natural vegetation. Although listed only once, two varieties of *Gynerium sagittatum* are cultivated: G. *sagittatum* var. *subandinum* is used for shafts of arrows used by children and G. *sagittatum* var. *sagittatum* used for shafts of arrows used by adults. Plants marked with "*" were (incipiently) domesticated and semi-domesticated in Amazonia at time of contact (1492) according to Clement (1999a and b; see introduction for meaning of terminology). Principal uses are given per species, whereby Ti=timber; Fo=food; Fu=fuel; Ma=material; Me=medicine; P=fish poison; and Soc=social uses.

INTRODUCED CULTIVATED PLANT SPECIES

Scientific Name	Origin	Main Uses	Sources
Anacardiaceae			
Mangifera indica (y/t)	Indo-Malaysia	Fo/Me	Mabberley, 1990
Amaranthaceae			
Celosia argentea (y/t)	Asia	O/Fo	Steyermark, 1963
Araceae			
Colocasia esculenta (y/t)	Indo-Malaysia	Fo/Me	Mabberley, 1990
Crassulaceae			
Kalanchoe pinnata (y/t)	Old World tropics	Me	Mabberley, 1990
Cucurbitaceae			
Momordica charantia (y/t)	Old World tropics	Me/Fo/Ma	Cardenas, 1989
Euphorbiaceae			
Ricinis communis (y/t)	Ethiopia	Me/Fu	Raemaekers, 2001
Fabaceae			
Cajanus cajan (y/t)	India and/or S. Asia	Fo	Mabberley, 1990
Tephrosia vogelii (y/t)	Africa	P/Me	Mabberley, 1990
Tamarindus indica (t)	tropical Africa	Fo	Morton, 1987
Lamiaceae			
Solenostemon scutellarioides (y/t)	New Guinea	O/Me	Mabberley, 1990
Ocimum micranthum (y/t)	Old World	Me	Bennett and Prance 2000
Liliaceae			
Sansevieria cf. *trifasciata* (t)	Africa	Me/O	Mabberley, 1990
Malvaceae			
Hibiscus acetosella (y/t)	tropical Africa	O	Zeven and Zhukovsky, 1975
Hibiscus rosa-sinesis (y/t)	tropical Asia	Me/O	Mabberley, 1990
Moraceae			
Morus alba (y/t)	China	Fo	Zeven and Zhukovsky, 1975
Musaceae			
Musa paradisiaca (y/t)	Asia	Fo/Me	Raemaekers, 2001
Musa sapientum (y/t)	Asia	Fo/Me	Raemaekers, 2001
Musa velutina (y/t)	Asia	Fo/Me	INIBAP, 2001
Myrtaceae			
Syzygium malaccense (y/t)	Asia	Fo	Mabberley, 1990
Poaceae			
Coix lacryma-jobi (y/t)	SE Asia	Fo/Me	Mabberley, 1990
Cymbopogon citratus (y/t)	Sri Lanka, India	Fo/Me	Mabberley, 1990
Oryza sativa (y/t)	Asia	Fo/Me	Raemaekers, 2001
Saccharum officinarum (y/t)	India	Fo/Me	Mukherjee, 1957
Rutaceae			
Citrus aurantiifolia (y/t)	SE Asia	Fo/Me	Raemaekers, 2001
Citrus cf. *limetta* (y/t)	SE Asia	Fo/Me	Cardenas, 1989
Citrus maxima (y/t)	SE Asia	Fo/Me	Cardenas, 1989
Citrus reticulata (y/t)	SE Asia	Fo/Me	Raemaekers, 2001
Citrus sinensis (y/t)	SE Asia	Fo/Me	Raemaekers, 2001
Zingiberaceae			
Alpinia zerumbet (y/t)	Asia	O/Me/ Fo	Mabberley, 1990
Hedychium coronarium (y/t)	SE Asia	Me/O	Bennett and Prance 2000
Zingiber officinale (y/t)	India	Fo/Me	Mabberley, 1990

Table 10.2 continued

CULTIVATED NEW WORLD SPECIES

(Zeven and Zhukovsky, 1975; Mabberley, 1990; Killeen *et al*., 1993; Clement, 1999a and b; Vásquez and Coimbra, 2002)

Scientific Name	Main Uses	Also Wild	Scientific Name	Main Uses	Also Wild
Anacardiaceae			**Fabaceae**		
Anacardium occidentale (y/t)*	Fo/Me		*Arachis hypogaea* (y/t)*	Fo/Me	
Annonaceae			*Arachis pintoi* (y/t)	O/Me	
Annona montana (y)*	Fo/Me	x	*Caesalpinia pulcherrima* (y/t)	O	
Rollinia cf. *boliviana* (y/t)	Fo/Me	x	*Inga edulis* (y/t)*	Fo/Fu	
Rollinia herzogii (y/t)	Fo	x	*Pachyrhizus tuberosus* (y/t)*	Fo	
Rollinia mucosa (y/t)*	Fo		**Flacourtiaceae**		
Apocynaceae			*Casearia pitumba* (y/t)	Fo/Me	x
Thevetia peruviana (t)*	Ma/Me		**Hippocrataceae**		
Arecaceae			*Salacia impressifolia* (t)	Fo	x
Astrocaryum murumuru (y)*	Ma/Fo/Co	x	**Iridaceae**		
Attalea butyracea (y/t)	Ma/Fo/Co/Me	x	*Eleutherine citriodora* (t)	Me	
Attalea phalerata (y/t)	Ma/Fo/Co/Me	x	**Lauraceae**		
Bactris gasipaes (y/t)*	Ma/Fo/Co	x	*Persea americana* (y/t)*	Fo/Me	
Euterpe precatoria (t)*	Ma/Fo/Co/Me	x	**Liliaceae**		
Jessenia bataua (t)*	Ma/Fo/Co/Me	x	*Hymenocallis* cf. *tubiflora* (t)	O	x
Asclepiadaceae			**Malvaceae**		
Marsdenia macrophylla (y)	Ma	x	*Gossypium barbadense* (y/t)*	Ma/Me	
Asteraceae			**Meliaceae**		
Porophyllum ruderale (y/t)	Fo/Me		*Swietenia macrophylla* (y/t)	Me/Co/Ti	x
Salmea scandens (y/t)	Me		**Myrtaceae**		
Tagetes patula (t)	Me/O		*Psidium guajava* (y/t)*	Fo/Me	
Bignoniaceae			**Nyctaginaceae**		
Crescentia cujete (y/t)*	Ma/Me		*Mirabilis jalapa* (y/t)	O/Me	
Bixaceae			*Neea* cf. *spruceana* (y)	Ma	x
Bixa orellana (y/t)*	Fo/Me/Ma		*Neea* sp1(y)	Ma	x
Bromeliaceae			**Passifloraceae**		
Ananas comosus (y/t)*	Fo		*Passiflora nigradenia* (y/t)	Fo/Me	x
Cactaceae			*Passiflora nitida* (y/t)	Fo/Me	x
Cereus cf. *braunii* (t)	Me		**Phytolaccaceae**		
Pereskia sacharosa (t)	Me		*Petiveria alliacea* (y/t)	Me	
Caricaceae			**Poaceae**		
Carica papaya (y/t)*	Fo/Me		*Zea mays* (y/t)*	Fo	
Chenopodiaceae			*Gynerium sagittatum* (y/t)	Ma	x
Chenopodium ambrosioides (y/t)	Me		**Portulacaceae**		
Clusiaceae			*Portulaca grandiflora* (t)	O/Me	
Rheedia acuminata (y/t)	Fo	x	**Rubiaceae**		
Rheedia gardneriana (y/t)	Fo/Me	x	*Genipa americana* (y/t)*	Fo/Me/Ma/Fu	x
Convolvulaceae			**Sapotaceae**		
Ipomoea batatas (y/t)*	Fo/Me		*Pouteria nemorosa* (y)	Fo	x
Cucurbitaceae			**Solanaceae**		
Lagenaria siceraria (y/t)*	Ma/Me		*Capsicum chacoense* (y/t)	Fo/Me	
Cucurbita maxima (y/t)*	Fo/Me		*Capsicum chinense* (y/t)*	Fo/Me	
Cyclanthaceae			*Capsicum pubescens* (y/t)	Fo	
Carludovica palmata (t)	Ma	x	*Capsicum frutescens* (y/t)*	Fo/Me	
Cyperaceae			*Datura suaveolens* (y/t)*	Me/Soc	
Cyperus cf. *corymbosus* (t)	Me		*Nicotiana tabacum* (y/t)*	Me/Soc	
Dioscoreaceae			*Solanum mammosum* (y/t)	Me	
Dioscorea trifida (y/t)*	Fo		**Sterculiaceae**		
Elaeocarpaceae			*Theobroma cacao* (y/t)*	Fo/Me	
Muntingia calabura (y/t)	Fo/O	x	**Verbenaceae**		
Erythroxylaceae			*Lantana fiebrigii* (y/t)	Fo/Me	
Erythroxylum coca (y/t)*	Me/Fo		*Lippia alba* (t)	Me	
Euphorbiaceae					
Euphorbia pulcherrima (y/t)	Me		**PTERIDOPHYTA**		
Jatropha curcas (y/t)	Me/Fu		**Polypodiaceae**		
Manihot esculenta (y/t)*	Fo/Me		*Polypodium decumanum* (y/t)	Me	x
Phyllanthus brasiliensis (y/t)*	P/Me				

On the other hand, an excellent example of a plant species that is in the process of being domesticated is the tall grass *Gynerium sagittatum*. The natural variety, *G. sagittatum* var. *glabrum* is a plant with multiple uses, among others for manufacturing roofs (leaves and/or stems), fences (stems), sleeping mats (leaves), canoe steering-sticks (stems) and arrow shafts (flowering stems) (cf. chapter 8). Two smaller varieties are cultivated in homegardens, mostly from Yuracarés. The smallest cultivar, *G. sagittatum* var. *subandinum,* produces brittle stems and is only used for manufacturing toy arrow shafts. Small children use these arrows for practicing their shooting skills. The larger cultivar, *G. sagittatum* var. *sagittatum*, is cultivated for producing arrow shafts that (adult) people use for hunting. Even though most people prefer shotguns nowadays, bow and arrow are still used, especially for fishing (see chapter 8). The cultivated varieties of *G. sagittatum* are propagated vegetatively and do not grow in the wild. With time, these varieties could eventually evolve to two botanically distinct species. Cultivation of *G. sagittatum* has also been reported by Nordenskiöld (1924) for the Bolivian Chacobo

Table 10.3 lists all the species that are tolerated in Yuracaré and Trinitario homegardens and swiddens. Only two tolerated plant species have been introduced from the Old World: *Laportea aestuans* (Madagascar) and *Cyathula prostrata* (tropical Asia and Africa) (www.hear.org). Both weeds are tolerated for their therapeutic values. An interesting case of toleration is *Struthanthus acuminatus*, a hemi-parasite that frequently grows in *Citrus* spp., hereby negatively influencing production potential of the latter species, as we have been able to observe. The plant is tolerated because it is considered a potent remedy against sprains and fractures (Thomas and Vandebroek, 2006).

The plant origin data presented in tables 10.2 and 10.3 allowed us to test the hypothesis that native managed species are more useful than introduced managed plants. Our data show that this hypothesis is confirmed only for material, construction and fuel uses ($p<0.05$ for these three use categories; Mann-Whitney tests). Introduced managed plants have a significantly higher ornamental value ($p=0.037$; Mann-Whitney test) than native managed plants. Mean overall, medicinal, food and social use values turned out equal for both native and introduced managed plants.

10.3.3.3. Most Useful Managed Plant Species

As indicated in tables 10.2 and 10.3, managed plants serve many uses. The majority of cultivated and tolerated species are used as herbal medicine (80%), followed by food (53%), material (36%), environmental uses (16%), fuel (16%), social uses (14%) and construction (14%) (figure 10.5). Three species are used as fish poison. Similar proportions of plants per use category were obtained for cultivated species, whereas most tolerated plant species are used in traditional medicine (89%) and as sources of materials (54%).

In table 10.4, plant species are ranked according to descending overall use value. In this list of 20 most useful managed species, the majority are trees (14 species), followed by herbs (5 species). All eight managed palm species are included. When this list is compared with the twenty most useful species that were inventoried during this study (table 8.2, chapter 8), there exists an overlap with the first thirteen species from table 10.4. Hence, most, but not all species with highest use values are necessarily cultivated.

Table 10.3: Plant species that are tolerated by Yuracarés and/or Trinitarios. The two underlined species have been introduced from the Old World (source: www.hear.org), all other species are native to the New World. According to Clement (1999a) *Cissus gongylodes* and *Dioscorea dodecaneura* were (semi-) domesticated crops in Amazonia at contact (1492). Main uses are given per species, whereby Ti=timber; Fo=food; Fu=fuel; Ma=material; Me=medicine; Co= construction; and Soc=social uses.

TOLERATED PLANT SPECIES

Scientific Name	Main Uses	Scientific Name	Main Uses
Amaranthaceae		*Desmodium* cf. *adscendens* (t)	Me
Cyathula prostrata (t)	Me	*Dipterix odorata* (t)	Ti/Fo/Ma/Me/Co
Arecaceae		*Dipterix micrantha* (t)	Ti/Fo/Ma/Me/Co
Iriartea deltoidea	Ma/Co/Fo/Me	**Flacourtiaceae**	
Socratea exorrhiza	Ma/Co/Fo/Me	*Casearia sylvestris* (y)	Fo
Asteraceae		**Heliconiaceae**	
Bidens pilosa (y/t)	Me	*Heliconia lingulata* (y/t)	Ma/Me
Eupatorium macrophyllum (y/t)	Me	*Heliconia rostrata* (y/t)	O/Ma
Vernonia patens (y/t)	Fu/Me	*Heliconia stricta* (y/t)	Ma/Me
Wulffia baccata (y/t)	Fo/O	**Loranthaceae**	
Bombacaceae		*Struthanthus acuminatus* (y/t)	Me
Ochroma pyramidale (y/t)	Ma/Me	**Malvaceae**	
Ceiba pentandra (y/t)	Ma, Me	*Sida rhombifolia* (y/t)	Me/Ma
Cecropiaceae		**Oxalidaceae**	
Cecropia concolor (y/t)	Ma/Fu	*Oxalis juruensis* (t)	Me
Cecropia polystachya (y/t)	Fo/Fu/Me	**Piperaceae**	
Commelinaceae		*Pothomorphe peltata* (y/t)	Me
Aneilema umbrosum (t)	Me	**Rubiaceae**	
Dichorisandra hexandra (y/t)	Me	*Geophila macropoda* (y/t)	Me
Convolvulaceae		*Geophila repens* (y/t)	Me
Merremia macrocalyx (t)	Me	**Scrophulariaceae**	
Dioscoreaceae		*Scoparia dulcis* (y/t)	Me
Dioscorea dodecaneura (t)	Me/Fo	**Tiliaceae**	
Euphorbiaceae		*Heliocarpus americanus* (y/t)	Ma/Me
Chamaesyce hirta (t)	Me	**Urticaceae**	
Hura crepitans (t)	Me/Ma/Co/Ti	*Laportea aestuans*(y)	Me
Fabaceae		*Urera baccifera* (y/t)	Me
Bauhinia longicuspis (y)	Ma	**Vitaceae**	
Desmodium axillare (t)	Me	*Cissus gongylodes* (t)	Me

Table 10.4 also illustrates that the high overall use value of most species is basically due to the greater number of uses assigned to them by Trinitario participants. A t-test ($p<0.001$) shows that the total number of uses per species mentioned by Trinitarios is significantly higher as compared to Yuracarés for the species listed in table 10.4.

The top tens of most useful species for Trinitario and Yuracaré participants, separately (see table 10.5) show different rankings but they comprise almost exclusively species from table 10.4. Particularly palm species are most valued by members of each ethnic group. The listed overall use values of the ten most useful species according to participants of each ethnic group give the impression that they would be higher for Trinitarios than for Yuracarés. However, this difference is not significant ($p=0.08$, t-test).

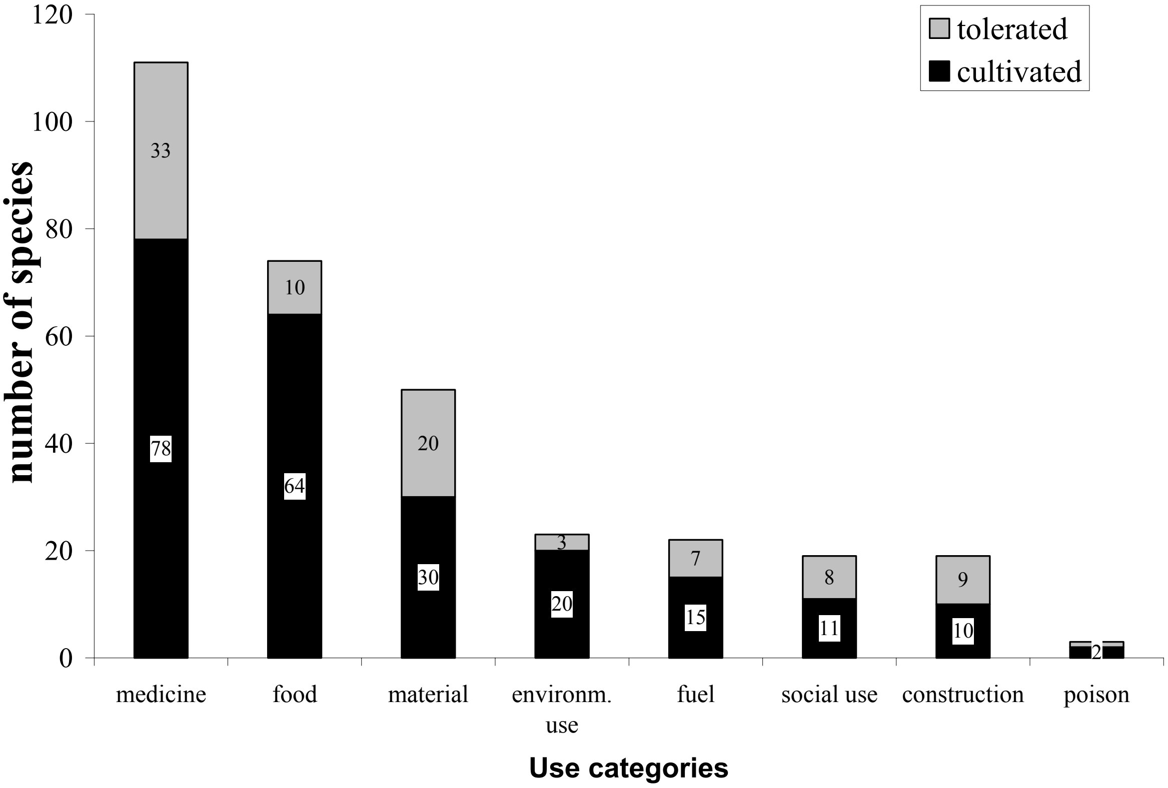

Figure 10.5: Numbers of managed species used per use category; managed plants are represented as the sum of cultivated and tolerated plants (environm. uses= environmental use)

Table 10.4: Twenty most useful managed plant species according to Trinitario and Yuracaré participants interviewed. Only species are listed for which information was provided by at least three participants. Nearly all species are cultivated. Tolerated plants are underlined. Note how the numbers of uses per species are almost always higher for Trinitarios than for Yuracarés.

Scientific Name	Family	Growth Form	# part.	$UV_{\text{all use}}$	# uses Trini	# uses Yura
Attalea phalerata	Arecaceae	tree	8	6.13	17	7
Bactris gasipaes	Arecaceae	tree	8	5.88	8	9
Attalea butyracea	Arecaceae	tree	8	5.83	11	10
Jessenia bataua	Arecaceae	tree	8	4.63	11	6
Swietenia macrophylla	Meliaceae	tree	4	4.00	11	3
Socratea exorrhiza	Arecaceae	tree	14	3.43	12	11
Genipa americana	Rubiaceae	tree	8	3.38	7	6
Hura crepitans	Euphorbiaceae	tree	12	3.33	16	8
Persea americana	Lauraceae	tree	5	3.20	10	1
Iriartea deltoidea	Arecaceae	tree	11	3.18	13	6
Theobroma cacao	Sterculiaceae	tree	6	3.17	10	1
Cissus gongylodes	Vitaceae	herb	3	3.00	5	0
Sida rhombifolia	Malvaceae	herb	7	2.71	10	1
Astrocaryum murumuru	Arecaceae	tree	12	2.67	8	10
Ochroma pyramidale	Bombacaceae	tree	11	2.64	8	4
Erythroxylum coca	Erythroxylaceae	shrub	5	2.60	7	1
Momordica charantia	Cucurbitaceae	herb	7	2.57	6	5
Nicotiana tabacum	Solanaceae	herb	7	2.57	9	1
Euterpe precatoria	Arecaceae	tree	4	2.50	8	1
Zingiber officinale	Zingiberaceae	herb	7	2.43	7	2

\# part. = number of participants interviewed
\# uses Trini = the number of uses according to all Trinitario participants
\# uses Yura = the number of uses according to all Yuracaré participants

Table 10.5: Ten most useful plant species according to Trinitario and Yuracaré participants, respectively. Only those species are listed for which information was provided by at least three participants per ethnic group. Tolerated plants are underlined, all the rest are cultivated.

TRINITARIOS

Scientific Name	Family	growth Form	#participants	$UV_{all\ use}$	# uses
Attalea phalerata	Arecaceae	tree	6	6.83	7
Bactris gasipaes	Arecaceae	tree	4	6.50	8
Attalea butyracea	Arecaceae	tree	4	6.00	11
Jessenia bataua	Arecaceae	tree	5	5.60	11
Swietenia macrophylla	Meliaceae	tree	3	4.33	11
Hura crepitans	Arecaceae	tree	7	4.00	16
Carica papaya	Caricaceae	tree	8	3.75	6
Persea americana	Lauraceae	tree	4	3.75	10
Theobroma cacao	Sterculiaceae	tree	5	3.60	10
Socratea exorrhiza	Arecaceae	tree	7	3.60	12

YURACARÉS

Scientific Name	Family	growth Form	#participants	$UV_{all\ use}$	# uses
Attalea butyracea	Arecaceae	tree	3	5.50	10
Bactris gasipaes	Arecaceae	tree	4	5.25	9
Attalea phalerata	Arecaceae	tree	3	4.00	7
Genipa americana	Rubiaceae	tree	3	3.67	6
Socratea exorrhiza	Arecaceae	tree	7	3.29	11
Jessenia bataua	Arecaceae	tree	3	3.00	6
Iriartea deltoidea	Arecaceae	tree	3	3.00	6
Astrocaryum murumuru	Arecaceae	tree	6	2.67	10
Hura crepitans	Euphorbiaceae	tree	5	2.40	8
Cecropia concolor	Cecropiaceae	tree	3	2.00	3

Ranking of the twenty most useful managed medicinal species (table 10.6) generates a different list than table 10.4. Only eight of the twenty species with highest overall usefulness (table 10.4) are also most useful medicinal species. The majority of the twenty most useful medicinal species are herbs (12 species), followed by trees (6 species). Five species in the list are tolerated, while the others cultivated. The top tens of most useful medicinal species for Trinitario and Yuracaré participants, separately (see table 10.7) show different rankings but they comprise almost exclusively species from table 10.6. Only the Yuracaré top ten comprises two species not mentioned in table 10.6. The mean use value of the ten most useful medicinal species is significantly higher for Trinitarios than for Yuracarés ($p<0.001$; t-test). Hence, Trinitarios show higher consensus and/or assign more diverse medicinal uses to their most valued medicinal plants.

Among the top twenty most useful food plants, palms are again prominently present (5 species; see table 10.8). Palm trees provide edible fruits, seeds and palm harts which can be eaten raw, cooked or processed into refreshing drinks, alcoholic beverages and edible oils (see chapter 8). The majority of the twenty most useful food species are trees (14 species). The top tens of most useful food species for Trinitario and Yuracaré participants, separately (see table 10.9) show similar rankings and they all comprise species from table 10.8, except for *Anacardium occidentale* which occurs in the top ten of Yuracarés only. The mean use values of the ten most useful food species are higher for Trinitarios than for Yuracarés, though at the border of statistical significance ($p=0.05$; t-test). Hence, Trinitarios participants shared more knowledge and/or mentioned more food uses for these species as compared to Yuracarés.

Table 10.6: Twenty most useful medicinal plant species according to Trinitario and Yuracaré participants. Only those species are listed for which information was provided by at least three participants. Nearly all species are cultivated. Tolerated plants are underlined.

Scientific Name	Family	growth Form	#participants interviewed	UV_{med}
Cissus gongylodes	Vitaceae	herb	3	3.00
Chenopodium ambrosioides	Chenopodiaceae	herb	6	2.50
Eleutherine citriodora	Iridaceae	herb	3	2.00
Sida rhombifolia	Malvaceae	herb	7	2.00
Kalanchoe pinnata	Crassulaceae	herb	8	1.88
Pereskia sacharosa	Cactaceae	shrub	7	1.86
Nicotiana tabacum	Solanaceae	herb	7	1.86
Carica papaya	Caricaceae	tree	5	1.80
Jatropha curcas	Euphorbiaceae	tree	15	1.80
Petiveria alliacea	Phytolaccaceae	herb	16	1.75
Salmea scandens	Asteraceae	herb	15	1.67
Dioscorea dodecaneura	Dioscoreaceae	herb	5	1.60
Hura crepitans	Euphorbiaceae	tree	12	1.58
Ocimum micranthum	Lamiaceae	herb	12	1.58
Zingiber officinale	Zingiberaceae	herb	7	1.57
Swietenia macrophylla	Meliaceae	tree	4	1.50
Citrus aurantiifolia	Rutaceae	tree	5	1.40
Bixa orellana	Bixaceae	tree	5	1.40
Pothomorphe peltata	Piperaceae	herb	14	1.36
Cereus cf. *braunii*	Cactaceae	shrub	3	1.33

Table 10.7: Ten most useful medicinal plant species according to Trinitario and Yuracaré participants, respectively. Only those species are listed for which information was provided by at least three participants per ethnic group. Tolerated plants are underlined, the rest are cultivated. Medicinal use values of the ten species listed for Trinitarios are significantly higher than for Yuracarés ($p<0.01$; t-test).

TRINITARIOS

Scientific Name	Family	growth Form	#participants	UV_{med}
Carica papaya	Caricaceae	tree	8	3.00
Cissus gongylodes	Vitaceae	herb	3	3.00
Chenopodium ambrosioides	Chenopodiaceae	herb	5	2.60
Kalanchoe pinnata	Crassulaceae	herb	6	2.33
Sida rhombifolia	Malvaceae	herb	6	2.33
Jatropha curcas	Euphorbiaceae	tree	8	2.25
Nicotiana tabacum	Solanaceae	herb	6	2.17
Pereskia sacharosa	Cactaceae	shrub	6	2.17
Petiveria alliacea	Phytolaccaceae	herb	9	2.11
Dioscorea dodecaneura	Dioscoreaceae	herb	4	2.00

YURACARÉS

Scientific Name	Family	growth Form	#participants	UV_{med}
Ocimum micranthum	Lamiaceae	herb	6	1.83
Petiveria alliacea	Phytolaccaceae	herb	7	1.29
Jatropha curcas	Euphorbiaceae	tree	7	1.29
Hura crepitans	Euphorbiaceae	tree	5	1.20
Salmea scandens	Asteraceae	herb	6	1.17
Pothomorphe peltata	Piperaceae	herb	8	1.13
Carica papaya	Caricaceae	tree	3	1.00
Geophila repens	Rubiaceae	herb	3	1.00
Zingiber officinale	Zingiberaceae	herb	3	1.00
Brugmansia suaveolens	Solanaceae	shrub	7	0.86

Table 10.8: Twenty most useful food plant species according to Trinitario and Yuracaré participants. Only those species are listed for which information was provided by at least three participants. All species are cultivated.

Scientific Name	Family	Growth Form	#participants interviewed	UV_{food}
Bactris gasipaes	Arecaceae	tree	8	3.00
Attalea phalerata	Arecaceae	tree	8	2.13
Attalea butyracea	Arecaceae	tree	6	2.00
Jessenia bataua	Arecaceae	tree	8	1.88
Theobroma cacao	Sterculiaceae	tree	6	1.83
Persea americana	Lauraceae	tree	5	1.80
Cucurbita maxima	Cucurbitaceae	herb	6	1.67
Ananas cosmosus	Bromeliaceae	shrub	6	1.50
Rheedia acuminata	Clusiaceae	tree	13	1.38
Arachis hypogaea	Fabaceae	herb	6	1.33
Pouteria nemorosa	Sapotaceae	tree	4	1.25
Capsicum chinense	Solanaceae	shrub	11	1.18
Musa sapientum	Musaceae	tree	6	1.17
Dioscorea trifida	Dioscoreaceae	herb	11	1.09
Astrocaryum murumuru	Arecaceae	tree	12	1.08
Syzygium malaccense	Myrtaceae	tree	4	1.00
Rheedia gardneriana	Clusiaceae	tree	9	1.00
Rollinia herzogii	Annonaceae	tree	6	1.00
Bixa orellana	Bixaceae	tree	5	1.00
Passiflora nigradenia	Passifloraceae	liana	6	1.00

Table 10.9: Ten most useful food plant species according to Trinitario and Yuracaré participants, respectively. Only those species are listed for which information was provided by at least two participants per ethnic group. Mean food use value of these species is significantly higher for Trinitarios than for Yuracarés (p=0.05; t-test).

TRINITARIOS

Scientific Name	Family	growth Form	#participants	UV_{food}
Bactris gasipaes	Arecaceae	tree	4	3.25
Attalea phalerata	Arecaceae	tree	6	2.33
Jessenia bataua	Arecaceae	tree	5	2.20
Attalea butyracea	Arecaceae	tree	4	2.00
Persea americana	Lauraceae	tree	4	2.00
Theobroma cacao	Sterculiaceae	tree	5	2.00
Ananas comosus	Bromeliaceae	shrub	5	1.60
Rheedia acuminata	Clusiaceae	tree	7	1.57
Arachis hypogaea	Fabaceae	herb	4	1.50
Capsicum chinense	Solanaceae	shrub	6	1.33

YURACARÉS

Scientific Name	Family	Growth Form	#participants	UV_{food}
Bactris gasipaes	Arecaceae	tree	4	2.75
Attalea butyracea	Arecaceae	tree	2	2.00
Attalea phalerata	Arecaceae	tree	2	1.50
Pouteria nemorosa	Sapotaceae	tree	3	1.33
Jessenia bataua	Arecaceae	tree	3	1.33
Pouteria nemorosa	Sapotaceae	tree	3	1.33
Rheedia acuminata	Clusiaceae	tree	6	1.17
Astrocaryum murumuru	Arecaceae	tree	6	1.17
Anacardium occidentale	Anacardiaceae	tree	5	1.00
Rheedia gardneriana	Clusiaceae	tree	5	1.00

10.3.3.4. Relation between Plant Growth Form and Use Value

To verify whether plant growth form is a good predictor of the categorical use values of a managed species, we examined our data statistically by means of the Kruskal-Wallis and Mann-Whitney non-parametric tests. Since managed plants in homegardens and swiddens have significantly higher mean use values for all uses, medicine, food and materials than wild plants, plant growth form distribution was only evaluated for the latter four use categories. An overall comparison between the usefulness of all inventoried plants (i.e. both wild and managed) is provided in chapter 9 (section 9.3.2.).

Overall Use Value

In relative terms, Trinitario and Yuracaré participants use proportionally more managed herb species from their homegardens and swiddens than trees, shrubs or lianas (figure 10.6A). Of all sampled managed herbs, Trinitarios use a higher number of species (51 species) than Yuracarés (39 species). As demonstrated in figure 10.6B the percentage of used species per growth form is not representative for the mean overall use value per growth form. Plant species with a tree habitus have a significantly higher mean overall use value than herbs, shrubs, or lianas ($p<0.01$, Kruskal Wallis). Overall use values of herbs, shrubs and lianas are equal ($p>0.05$, Kruskal-Wallis). Mean overall use values of trees, shrubs and herbs are significantly higher for Trinitarios than for Yuracarés ($p<0.01$ in all cases; Mann-Whitney).

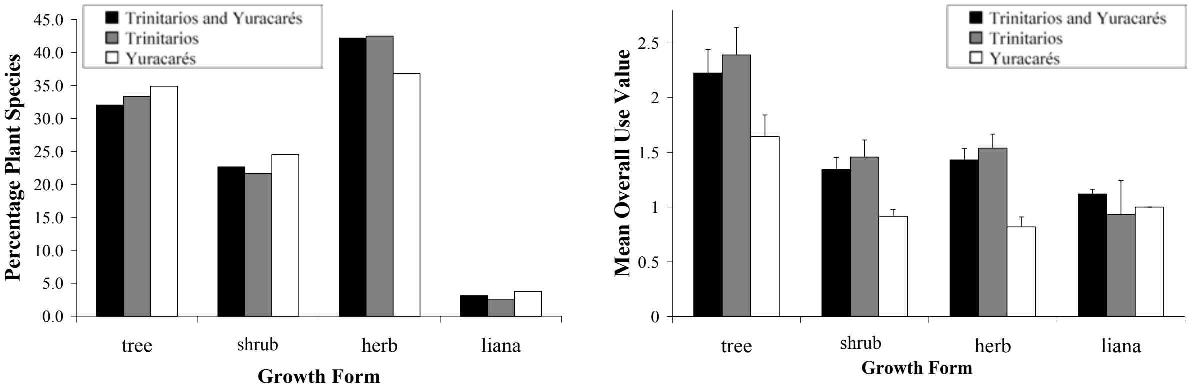

Figure 10.6 A: Growth form distribution of managed plants in homegardens with an overall use value greater than zero; B: Mean overall use value of managed plants in homegardens for different growth forms (error bars represent standard errors of the mean)

Medicinal Use Value

Of all managed plants, proportionally more herbs are used as herbal remedies (58% and 44% of medicinal plants managed by Yuracarés and Trinitarios, respectively) than trees, shrubs or lianas (figure 10.7A). Also the mean medicinal use value of herbs is higher than that of other growth forms, but this difference is not statistically significant (figure 10.7B). Yuracarés manage a far smaller number of medicinal plant species than Trinitarios (40 vs. 101 species, respectively) and assign significantly lower medicinal use values to these species than Trinitarios, independently of growth form ($p<0.01$, Mann-Whitney for all growth forms).

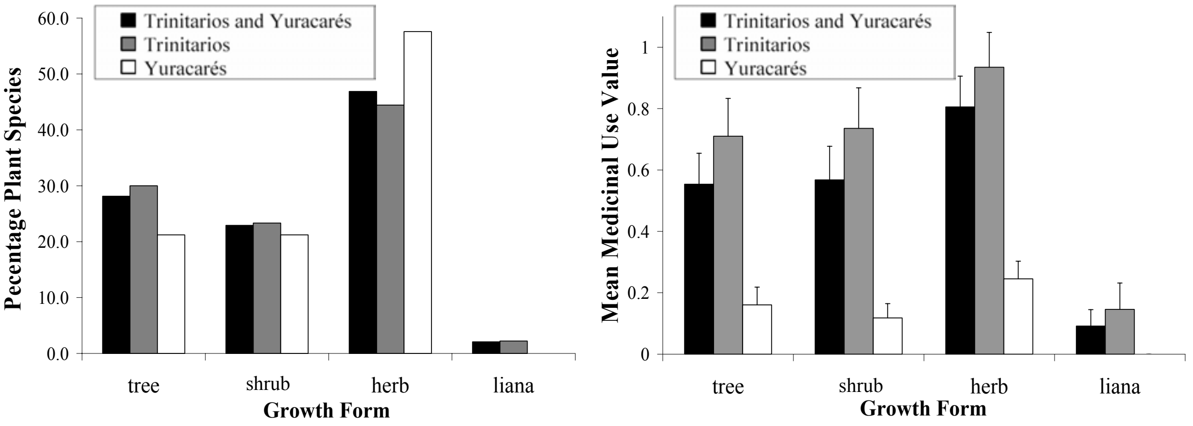

Figure 10.7 A: Growth form distribution of managed plants in homegardens with a medicinal use value greater than zero; B: Mean medicinal use value of managed plants in homegardens per growth form (error bars represent standard errors of the mean)

Food Use Value

Of a total of 74 managed food plants, proportionally more species are trees, followed by shrubs and herbs (figure 10.8A). In fact, more than three-forth (77%) of all managed tree species have food applications: they produce aromatic leaves or flowers, fruits, seeds or palm hearts that can be eaten raw, cooked or processed into refreshing drinks, edible oil, or alcoholic beverages (see chapter 8). Three of the four liana species mentioned produce edible fruits (*Passiflora* spp.). As shown by figure 10.8B, trees have a significantly higher food use value than shrubs and herbs, independently of ethnic affiliation ($p<0.01$, Kruskal-Wallis tests). The mean food use value of lianas is not significantly different from that of trees, shrubs and herbs. Although Trinitarios use relatively more tree species and less shrub and herbaceous species for food than Yuracarés, mean food use values of different growth forms do not differ significantly between both ethnic groups.

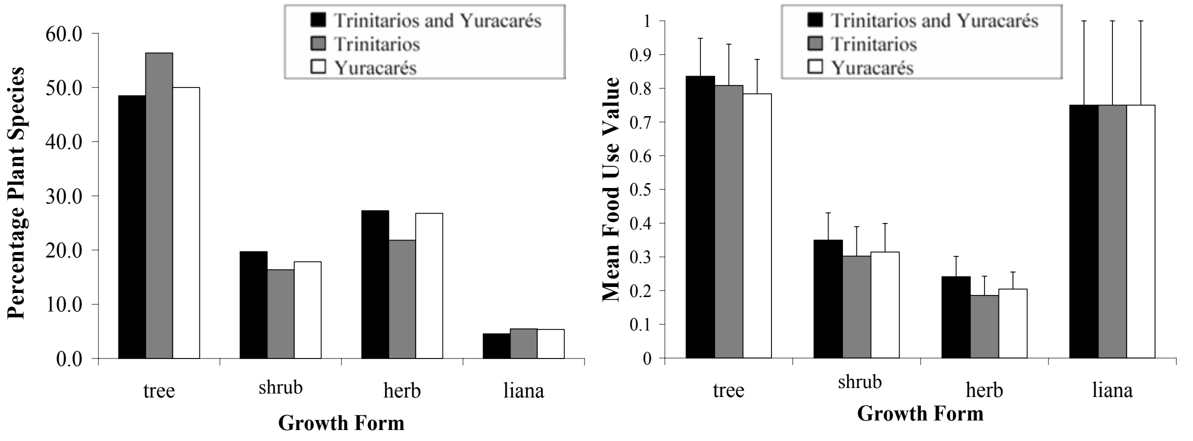

Figure 10.8 A: Growth form distribution of managed plants in homegardens with a food use value greater than zero; B: Mean food use value of managed plants in homegardens per growth form (error bars represent standard errors of the mean)

Material Use Value

In total, 50 managed plants have material uses. Relatively more plants used for materials are trees, followed by herbs and shrubs (figure 10.9A). Only one liana species is used for this purpose. Mean material use values (figure 10.9B) correspond with the trend in the data shown in figure 10.9A. Thus, the mean material use value of trees is significantly higher than that of herbs or shrubs (p=0.03, Kruskal-Wallis). The data subset of uses provided by Trinitario participants follows this trend (p=0.02, Kruskal-Wallis), whereas mean material use values for Yuracarés are not significantly different between growth forms (p=0.25, Kruskal-Wallis).

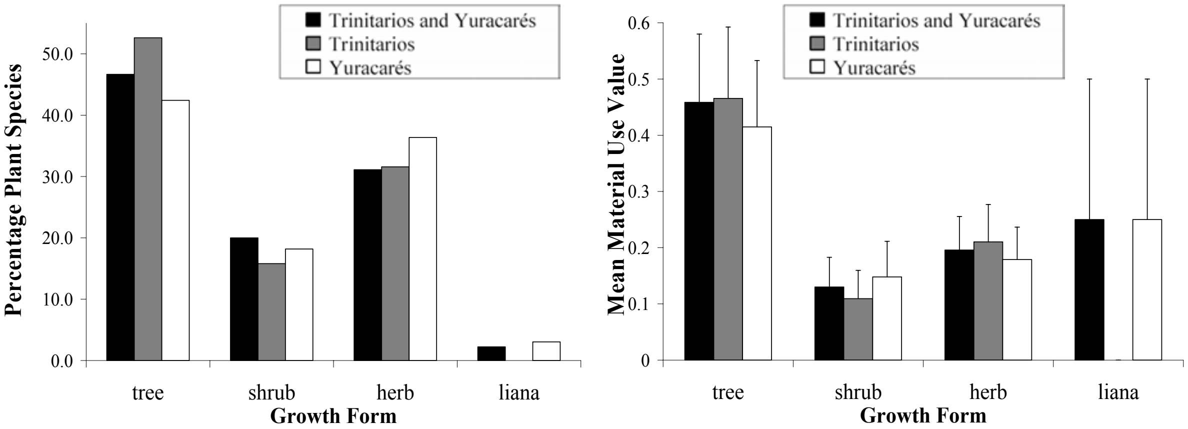

Figure 10.9 A: Growth form distribution of managed plants in homegardens with a material use value greater than zero; B: Mean material use value of managed plants in homegardens per growth form (error bars represent standard errors of the mean)

In sum, plants managed in Yuracaré and/or Trinitario homegardens are mostly herbs, followed by trees and shrubs. Nevertheless, trees have significantly higher overall use values than all other life forms and Trinitarios accredit higher overall use values to managed plants than Yuracarés for nearly all life forms. Most managed medicinal plants are herbs and again the mean medicinal use values calculated for Trinitarios are significantly higher than those for Yuracarés, independently of life form. Trees are the dominant life form among all managed edible and material species. Different life forms are valued equally by Yuracarés and Trinitarios for the food and material use categories.

10.3.4. Comparing Plant Use Knowledge between Trinitarios and Yuracarés

10.3.4.1. Overall Plant Use Knowledge

Figure 10.10 summarizes the number of plant species in different use categories according to management status for Yuracaré and Trinitario participants. The latter figure shows that Yuracarés identified more useful species (597 species) than Trinitarios (554 species) (cf. chapter 8, section 8.3.2.). This might in part be related to the fact that slightly fewer plant species were shown to Trinitario than Yuracaré participants (704 and 752, respectively). More importantly, it illustrates that Trinitarios have knowledge on the medicinal and material properties of a higher number of species, whereas Yuracarés know more edible plant species, independently of management status.

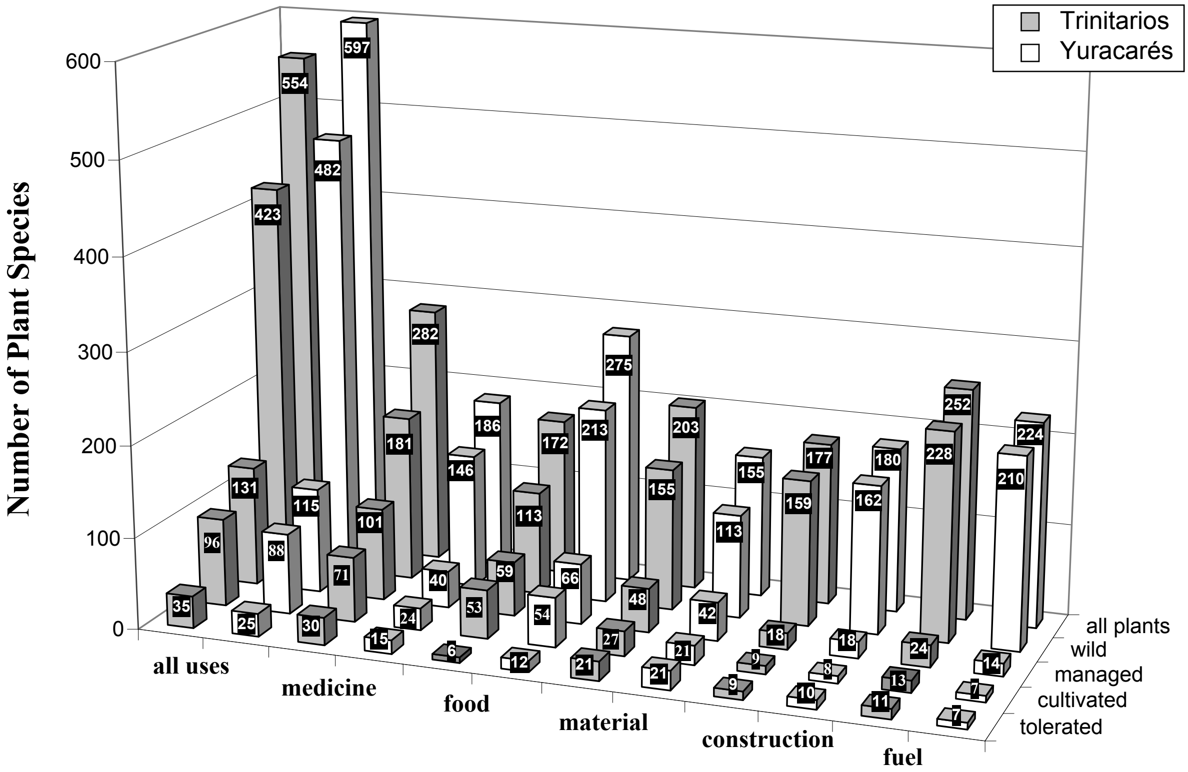

Figure 10.10: Numbers of plants used for all combinations of use category and management status; protected plants are not indicated since only two species have been identified

10.3.4.2. Managed versus Wild Plants

Wild plants

Trinitarios and Yuracarés attribute an equal mean overall and construction use value to wild plant species (figure 10.11). Use data for wild species provided by Trinitarios yield a higher mean medicinal use value as compared to Yuracarés ($p<0.01$, Mann-Whitney). Also, for materials ($p<0.01$), fuel ($p=0.03$) and social uses ($p<0.01$, Mann-Whitney) Trinitario mean use values are significantly higher than those for Yuracarés. On the other hand, the more extensive knowledge of Yuracarés about wild food plants as compared to Trinitarios is demonstrated by a mean food use value that is twice as high (0.24 vs. 0.11; $p<0.01$, Mann-Whitney).

Managed Plants

Trinitario people manage (i.e. cultivate and/or tolerate) slightly more species (131 species) than Yuracarés (115). As illustrated in figure 10.12, also the mean overall use value of managed species is significantly higher for Trinitarios than for Yuracarés ($p<0.01$, Mann-Whitney). This is mainly due to the higher mean medicinal use value of plant species managed by Trinitario people ($p<0.01$, Mann-Whitney). All other mean categorical use values have equal scores for both ethnic groups ($p<0.01$, t-tests). It is interesting to note here that *all* the medicinal plants that are managed by Yuracarés in homegardens and swiddens (40 species) are also managed by Trinitarios (101 species), whereas the opposite is not true. On the other hand, all food plant species managed by Trinitarios in homegardens and swiddens (59 species) are also managed by Yuracarés (66 species), whereas the opposite is not true.

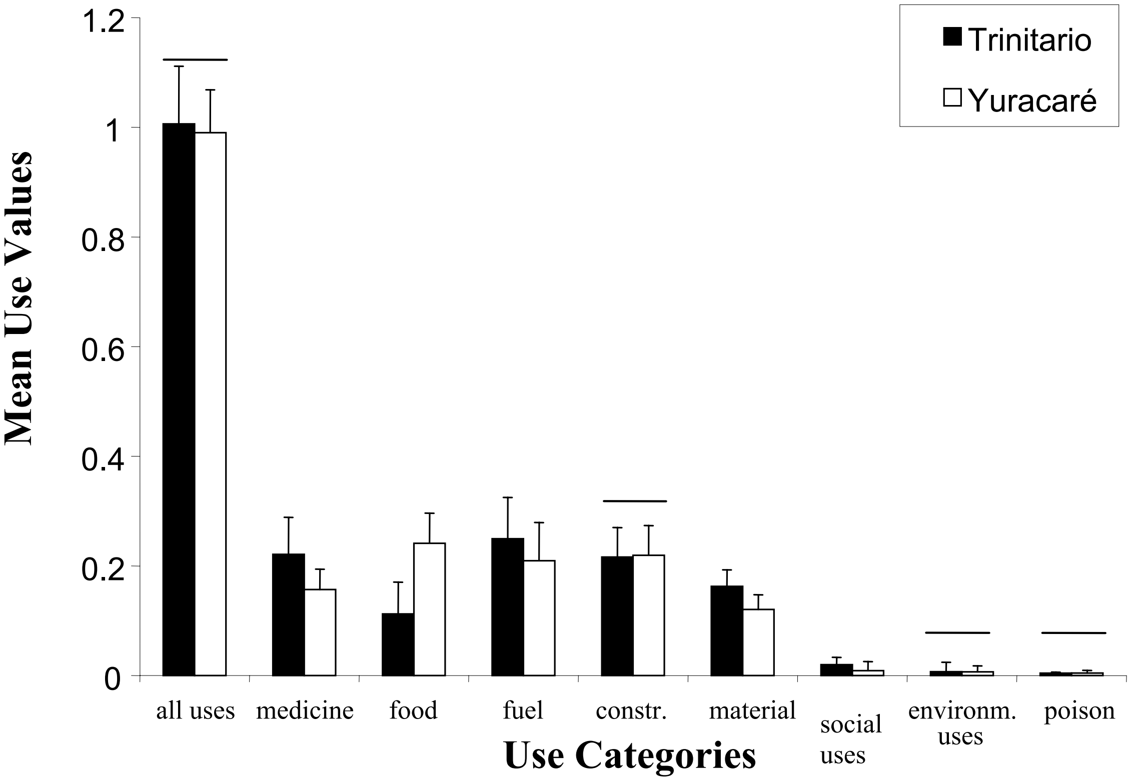

Figure 10.11: Comparison of mean categorical use values assigned to wild plants by Yuracaré and Trinitario participants. This figure shows that mean food use value of Yuracarés is twice as high as for Trinitarios. Error bars represent standard errors of the mean. Significantly equal mean use values are indicated by horizontal lines (constr. = construction; environm. uses= environmental uses).

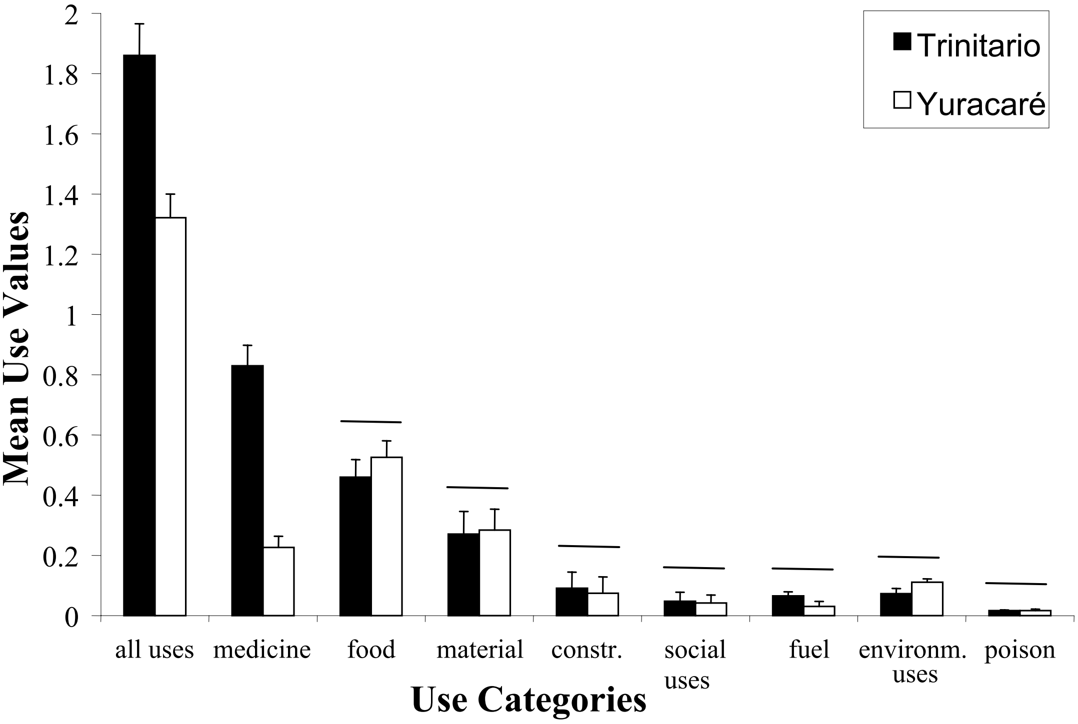

Figure 10.12: Comparison of mean categorical use values of plants managed by Yuracarés and Trinitarios. The higher mean overall use value for Trinitarios is due to a significantly higher mean medicinal use value attributed to managed plants by Trinitarios as compared to Yuracarés, since other categorical use values are equal. Error bars represent standard errors of the mean. Significantly equal mean use values are indicated by horizontal lines (constr. = construction; environm. uses= environmental uses).

Of all managed plants, a total number of 96 and 88 different plant species (with 82 species overlapping) was reported as cultivated by Trinitario and Yuracaré participants, respectively. Categorical mean use values of cultivated plants follow an almost identical trend as managed species (depicted in figure 10.12), but the actual values are higher. Trinitarios and Yuracarés tolerate 35 and 25 species (with 22 overlapping), respectively. Likewise, mean categorical use values of tolerated plants follow the same trend as managed plants, with the exception that plants tolerated by Yuracarés have a higher mean food use value than plants tolerated by Trinitarios ($p<0.01$, Mann-Whitney).

10.3.4.3. Provenance and Consensus Related to Medicinal and Food Plants

Seventy seven (77) percent (213 out of 275 species) of edible species known by Yuracarés are wild, whereas for Trinitarios this is 'only' 66 percent (113 out of 172 species) (figure 10.10). A χ^2-test (table 10.10) confirms that Yuracarés proportionally know more wild food plants than Trinitarios. When it comes to medicinal plants, a similar trend is observed. Although Trinitarios clearly outnumber Yuracarés in the number medicinal species used (282 vs. 186 species), the latter make proportionally more use of the wild flora than the former ($p=0.01$; χ^2-test). More than one fifth of medicinal and food plants used by Yuracarés are managed, whereas for Trinitarios this proportion rises to more than one third (table 10.10). If the proportions of managed medicinal and food plants in homegardens and swiddens are extended to the proportion of *all* (i.e. both managed and wild species) medicinal and food plants growing in disturbed habitats, higher results are obtained than those presented in table 10.10. Thirty two percent of medicinal plants (37 managed and 23 wild species) used by Yuracarés grow in anthropogenic disturbance habitats, while for Trinitarios this proportion is significantly larger ($p=0.03$; χ^2-test) and rises to 43% (96 managed and 24 wild species). Analogously, Trinitarios obtain a significantly higher proportion of the food plants they use from anthropogenic habitats (38%) than Yuracarés (25%) ($p<0.01$; χ^2-test).

Table 10.10: χ^2-test on the relation between medicinal and food plant provenance and ethnic affiliation. Values represent percentages of total numbers of food and medicinal species used by Yuracarés and Trinitarios, respectively

	Medicinal plants		Food plants	
	Yuracarés	Trinitarios	Yuracarés	Trinitarios
wild	78	64	77	66
managed	22	36	23	34
	$\chi^2=8.7$; $p=0.003$		$\chi^2=6.4$; $p=0.01$	

Moreover, the consensus on specific medicinal properties of plants known by Yuracaré participants is lower than for Trinitarios ($p=0.04$; χ^2-test). The use of medicinal species used by Yuracarés was confirmed by only one participant for 54% of species, whereas for Trinitarios this is 44%.

10.3.4.4. Use knowledge Diversities

Shannon-Wiener (H) use knowledge diversity values based on numbers of participants confirming categorical use of species (cf. section 10.2) are significantly higher or equal for

Trinitarios than for Yuracarés for nearly all combinations of management statuses and use categories. Notable exceptions are: (1) the overall uses of wild plants; (2) the food uses of wild plants and (3) the food uses of all plants (figure 10.13). For all management statuses in the categories of medicines, fuel and social uses, use diversities are significantly higher for Trinitarios than for Yuracarés ($p<0.001$ in all cases; t-tests). Overall use knowledge diversity of wild plants is significantly higher for Yuracarés (5.74) than for Trinitarios (5.62) ($p=0.001$, t-test). This is because Yuracaré participants named a greater number of useful wild species than Trinitarios (362 vs. 331 species) and these uses were confirmed by a more even number of participants as compared to Trinitarios (evenness 0.86 vs. 0.83). Also the diversity of food use knowledge of all plants pooled together is considerably higher for Yuracarés (5.20) than for Trinitarios (4.86) ($p<0.001$, t-test). This is basically the consequence of the higher Shannon-Wiener value obtained for wild food plants (4.97 vs. 4.43; $p<<0.001$, t-test).

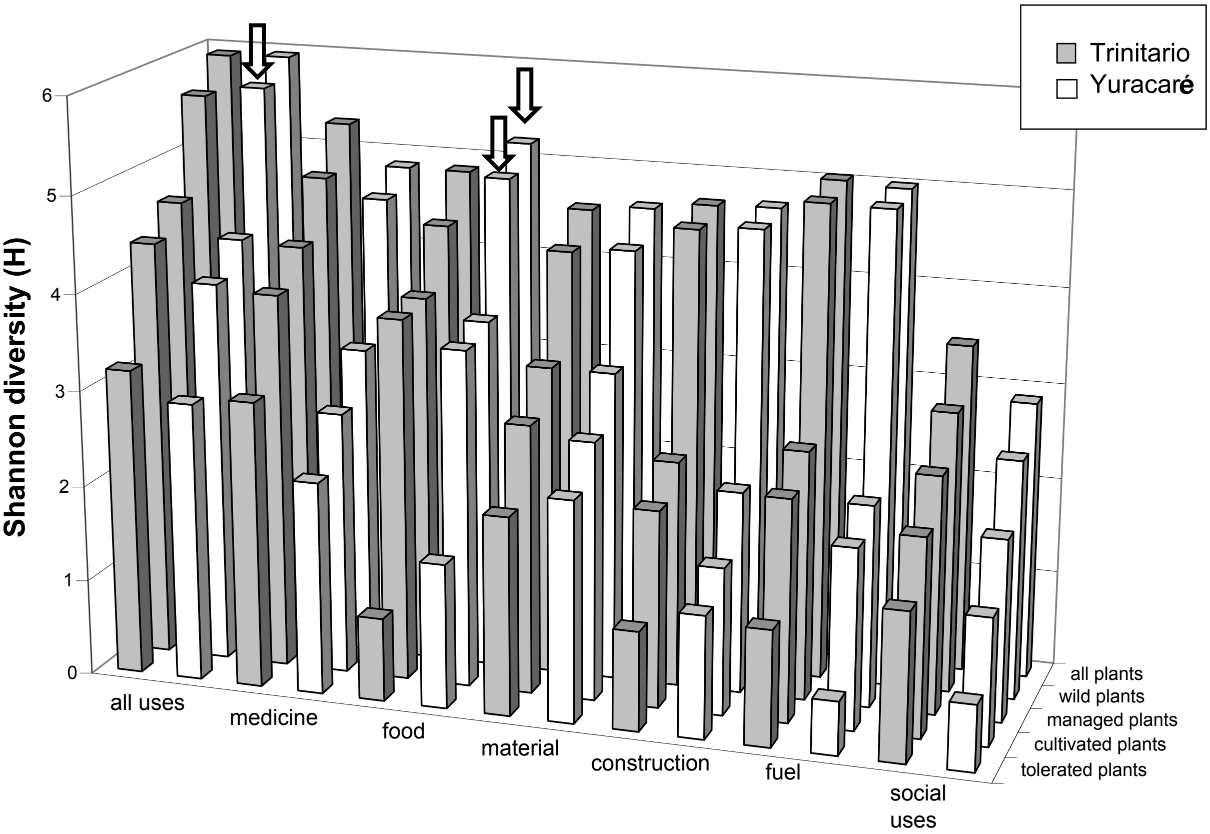

Figure 10.13: Shannon-Wiener index representing the diversity of use knowledge based on numbers of participants confirming categorical plant uses. Trinitario use knowledge diversity is significantly higher than or equal to that of Yuracarés for all, except three management and use category combinations. As indicated by the arrows, Yuracarés score significantly higher for overall use knowledge diversity of wild plants and food use knowledge diversity of wild plants and all plants.

Where figure 10.13 was constructed by calculating Shannon diversity based on numbers of participants confirming categorical uses of plants, figure 10.14 is based on the number of different unique uses per plant species. Use knowledge diversity is higher for Trinitario than for Yuracaré people for most combinations of use categories and management statuses. However, significantly higher overall use knowledge diversity values were obtained for Yuracarés for (1) all plant species together (6.08 for Trinitarios and 6.19 for Yuracarés;

p=0.03, t-test) and (2) wild plant species (5.84 for Trinitarios and 6.01 for Yuracarés; p<<0.001, t-test) (figure 10.14). Yuracaré food use knowledge diversity is also significantly higher than that of Trinitarios for (1) all species taken together (5.55 vs. 5.10; p<<0.001, t-test); and (2) wild species (5.36 vs. 4.80; p<<0.001, t-test). For the latter management statuses, higher use knowledge diversities are basically the consequence of the higher numbers of wild species used as food by Yuracaré people because equal evenness values were obtained for Yuracarés and Trinitarios. Likewise, significantly higher medicinal use diversities were obtained for Trinitarios than for Yuracarés, basically due to the higher numbers of medicinal plants used

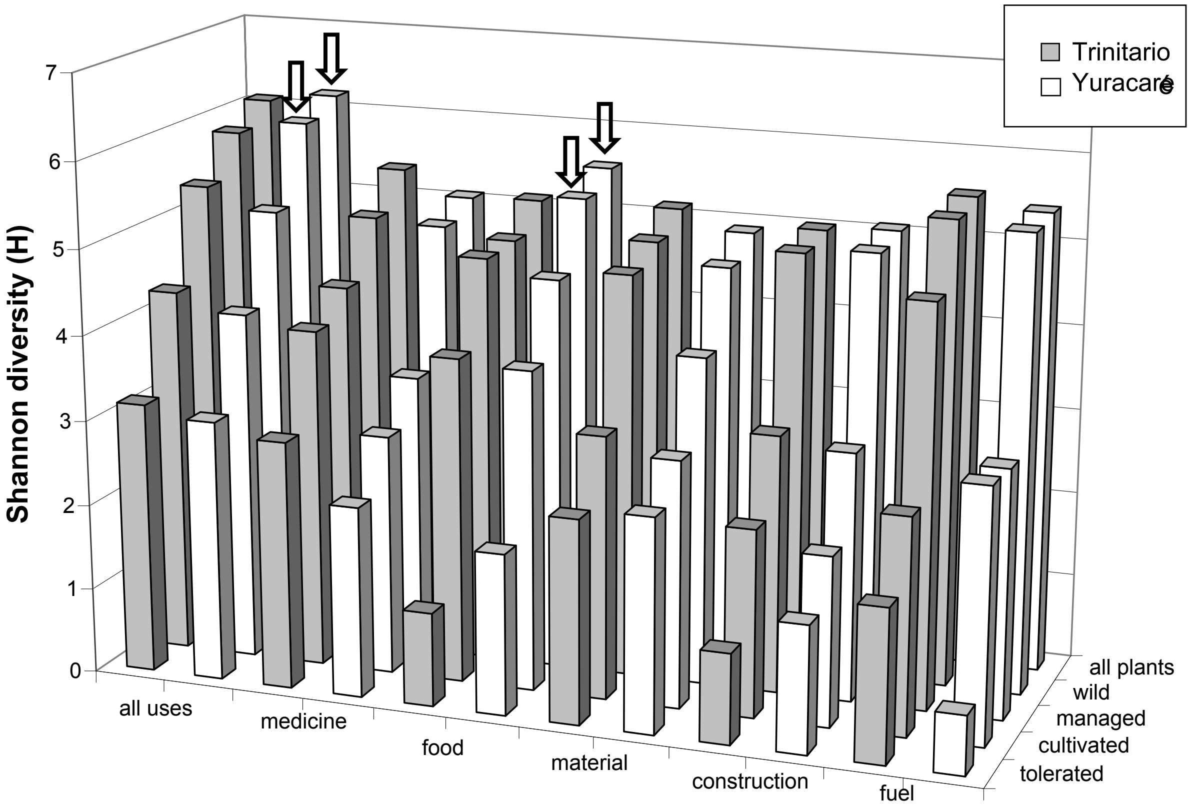

Figure 10.14: Shannon-Wiener use knowledge diversity based on the numbers of different unique uses per plant species. Trinitario use diversity is significantly higher than or equal to that of Yuracarés for all except four management and use category combinations. As indicated by the arrows, Yuracarés score significantly higher for overall use diversity of wild plants and all plants, as well as for food use diversity of wild plants and all plants.

In sum, Yuracarés have higher knowledge about useful wild species than Trinitarios who are clearly more knowledgeable on managed plant species. Yuracarés particularly know the edible wild flora better, whereas for Trinitarios mainly higher medicinal use knowledge diversity values were obtained for both managed and wild plants. For other use categories, participants from both ethnic groups show comparable levels of knowledge diversity. Nonetheless, generally higher levels of participant consensus and higher numbers of uses per species were obtained for Trinitarios than for Yuracarés.

10.3.5. Distinguishing between Typical Yuracaré and Trinitario Plants

During interview sessions on managed plant species with participants from both ethnic groups, certain plant species were frequently claimed as being a part of the cultural sphere of either one of both ethnic groups. Trinitario participants argued that some plants are Yuracaré plants and vice versa. *Phyllanthus brasiliensis* and *Tephrosia vogelii* are two shrub species that are cultivated for the ichthyotoxic properties (i.e. poisonous to fish; see chapter 8) of their leaves. Although both plants have been observed growing in gardens of both ethnic groups, the former species is recognized as a Trinitario plant and the latter as a Yuracaré plant, which is intriguing since *Tephrosia vogelii* was introduced from Africa (Mabberley, 1990).

To distinguish between plants that are more typically cultivated in Yuracaré and Trinitario homegardens and/or swiddens, respectively, we compared the number of uses for each species as attributed by participants from each ethnic group (figures 10.15-10.17). The reason for utilizing number of uses instead of use values here is that use values are averaged over all queried participant, whereas simply counting the total number of uses mentioned provides a better representation of an ethnic group's overall knowledge base. For example, if all Yuracaré (12) and Trinitario (14) participants interviewed agreed on the use of plant A for treating sprains and the only two other uses (e.g. wounds and scabies) were provided by two Trinitario healers, respectively, then plant A's use value calculated for Trinitarios ((14+2)/14= 1.14) would only be 14% higher than that for Yuracarés (12/12=1). By contrast, in terms of numbers of uses this difference is 200% (4-2=2).

As we have mentioned earlier, plant management is known to be prone to a great deal of variation and can change with time, even within small communities. Specialist healers frequently grow medicinal plants in their gardens and often they are the only ones knowledgeable about the medicinal applications of these species. In this respect, a distinction is often made between *generalist knowledge*, which is shared by the majority of community members, and *specialist knowledge* which is limited to only a few very knowledgeable people or specialists (e.g. traditional healers, midwives…). Also, the distribution of other useful species such as fruit trees or material plants in the homegardens of residents from the same village can be highly variable. We already reported that in the present study where we investigated 32 homegardens in five communities, 14% of all cultivated useful plant species was encountered in one homegarden exclusively. Hence, as calculating use values involves averaging over all participants interviewed, it favours generalist knowledge and seems less useful for determining which plants are likely to be part of the cultural sphere of either one of both ethnic groups. By contrast, the total number of uses combines specialist and generalist knowledge and might thus be better suited. For the following analyses, we hypothesized that the higher the difference in number of uses per plant species between Yuracarés and Trinitarios is, the more likely it is that those plant species have a longer or more intense management history among people from either one of both ethnic groups.

Cultivated Plants

Despite some drawbacks and limitations that will be discussed later (section 10.4.4.), comparing the number of uses per plant species between Yuracarés and Trinitarios detects the remarkably higher usefulness Trinitario participants attribute to a far larger number of managed plants as compared to Yuracarés. As shown in figure 10.15, the number of cultivated plant species for which Trinitario participants provided more uses (68 species) is nearly five times higher than the number of species for which Yuracarés provided more uses (14 species). Trinitarios attribute more uses to twenty introduced species, whereas Yuracarés to two species.

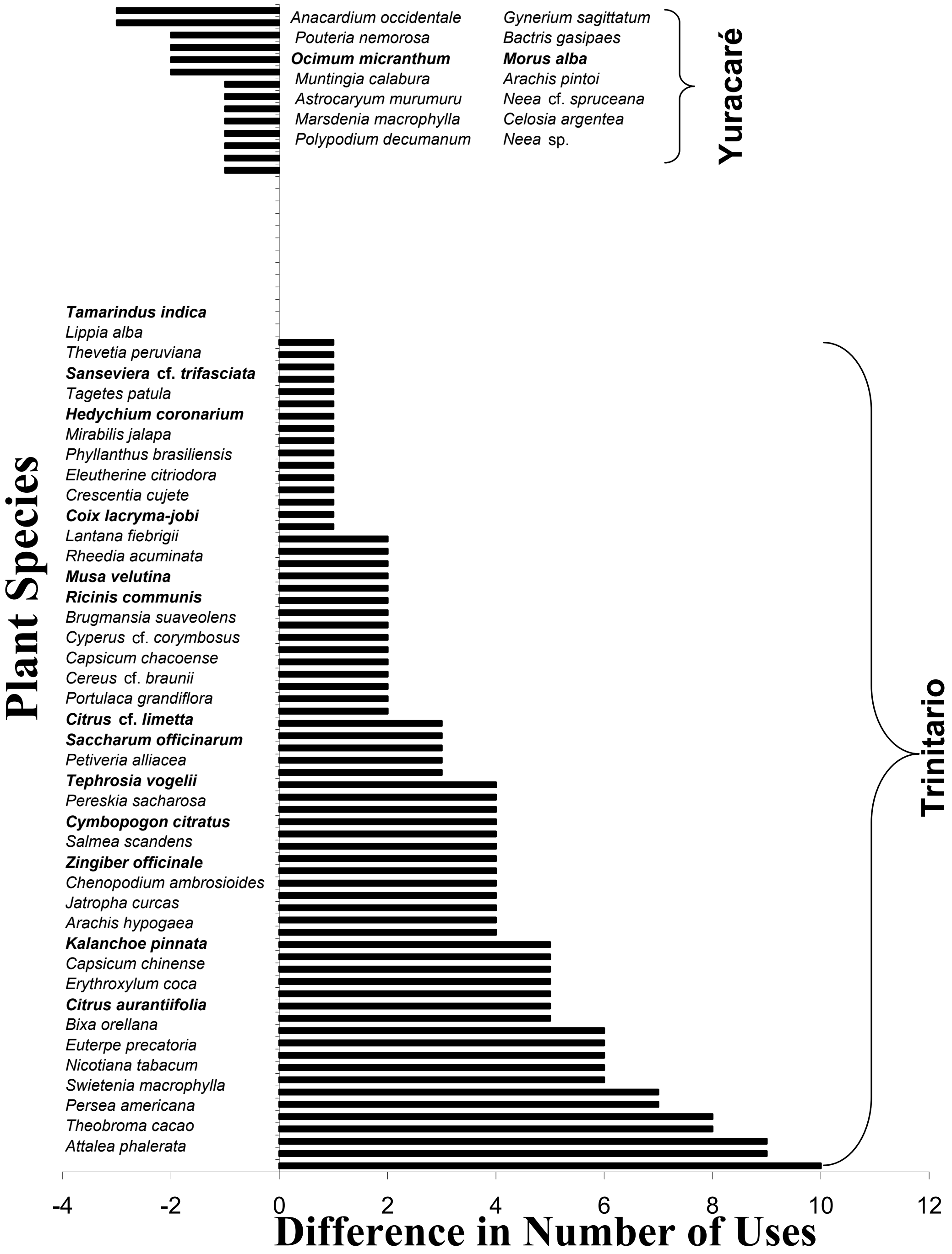

Figure 10.15: Difference in number of overall uses enumerated by Yuracaré and Trinitario participants for all cultivated plant species in homegardens and swiddens. Bars on the right and left side indicate species for which Trinitario or Yuracaré participants, respectively, named more uses. For 13 species, participants named an equal number of uses, as evidenced by the empty space between bars. For reasons of clarity, species listed in the lower part of this figure are: (1) species for which Trinitario participants reported at least three more uses than Yuracaré participants, and (2) species that have only been seen growing in Trinitario homegardens (species names do not correspond to bars). All species for which Yuracaré participants named more uses are listed in the upper part of the figure. Species that are introduced from the Old World are marked in bold.

The difference in knowledge of cultivated species is even more obvious when the numbers of uses of cultivated medicinal plants are compared between Yuracarés and Trinitarios (figure 10.16). Trinitarios know more medicinal uses for fifteen times more cultivated plants than Yuracarés (62 vs. 4 species). Fifteen of the medicinal species that are used more diversely by Trinitarios are introduced species. Yuracarés have higher knowledge on only one introduced species. However, *Porophyllum ruderale* is a New World plant (Cardenas, 1989), but was most likely introduced in TIPNIS by colonizing highland farmers. It is an aromatic herb, typically used by Quechua and Aymara settlers as a flavouring agent in food as well as for its medicinal properties. Possibly, its medicinal use has been passed on by these Andean settlers to Yuracarés but not (yet) to Trinitarios.

The list of plants with more diverse food uses in each one of both ethnic groups is much more limited. Trinitario participants named more food uses than Yuracarés for ten species, of which four are introduced (*Citrus* cf. *limetta, C. aurantiifolia, Saccharum officinarum,* and *Zingiber officinale*). The food application of these plants is also known to Yuracarés but it is less diverse. For example, Yuracarés mentioned eating the sweet seed coat of *Theobroma cacao*, which represents the single Yuracaré use for this plant. Trinitarios know this use and other uses as well: they prepare refreshing drinks and vinegar from the seed coats, whereas the seeds are processed into chocolate drinks. Yuracarés assigned more diverse food uses to six species, two of which are introduced (*Morus alba* and *Celosia argentea*).

Tolerated Plants

For tolerated plants, largely the same pattern is observed as for cultivated plants (Figure 10.17). Of the plants tolerated by Trinitarios, nearly six times more species have a superior number of overall uses as compared to Yuracarés (29 vs. 5 species, respectively). For tolerated medicinal plants, this factor rises to almost nine. The only introduced species in the list is *Laportea aestuans*. Its medicinal properties were acknowledged only by Yuracarés and not by Trinitarios.

10.4. Discussion

10.4.1. Indigenous Plant Management and Harvest in Natural Habitats

Plant protection

Although in this study only two species were explicitly labelled as being protected, we hypothesize that a systematic inquiry on this topic would lead to a much higher number of protected species. This hypothesis is confirmed by Becker and Leon (1998), who conducted a study in three Yuracaré communities that are situated along the borders of Rio Chapare. During their study, participants revealed that as a general rule “all Yuracaré must care for the forest…so the animals will come”. According to the latter authors, this caring includes protecting fruiting trees (by removing seedlings that would compete for water and nutrients), and transplanting and selectively encouraging certain tree species in order to increase densities of game. Becker and Leon (1998) recorded 52 fruiting tree species that the Yuracarés claimed to actively monitor, protect, and promote. Similar observations have been made elsewhere. In an ethnobotanical study among the Shuar of Ecuador, participants mentioned 46 tree species that they protected (Bennett, 1992).

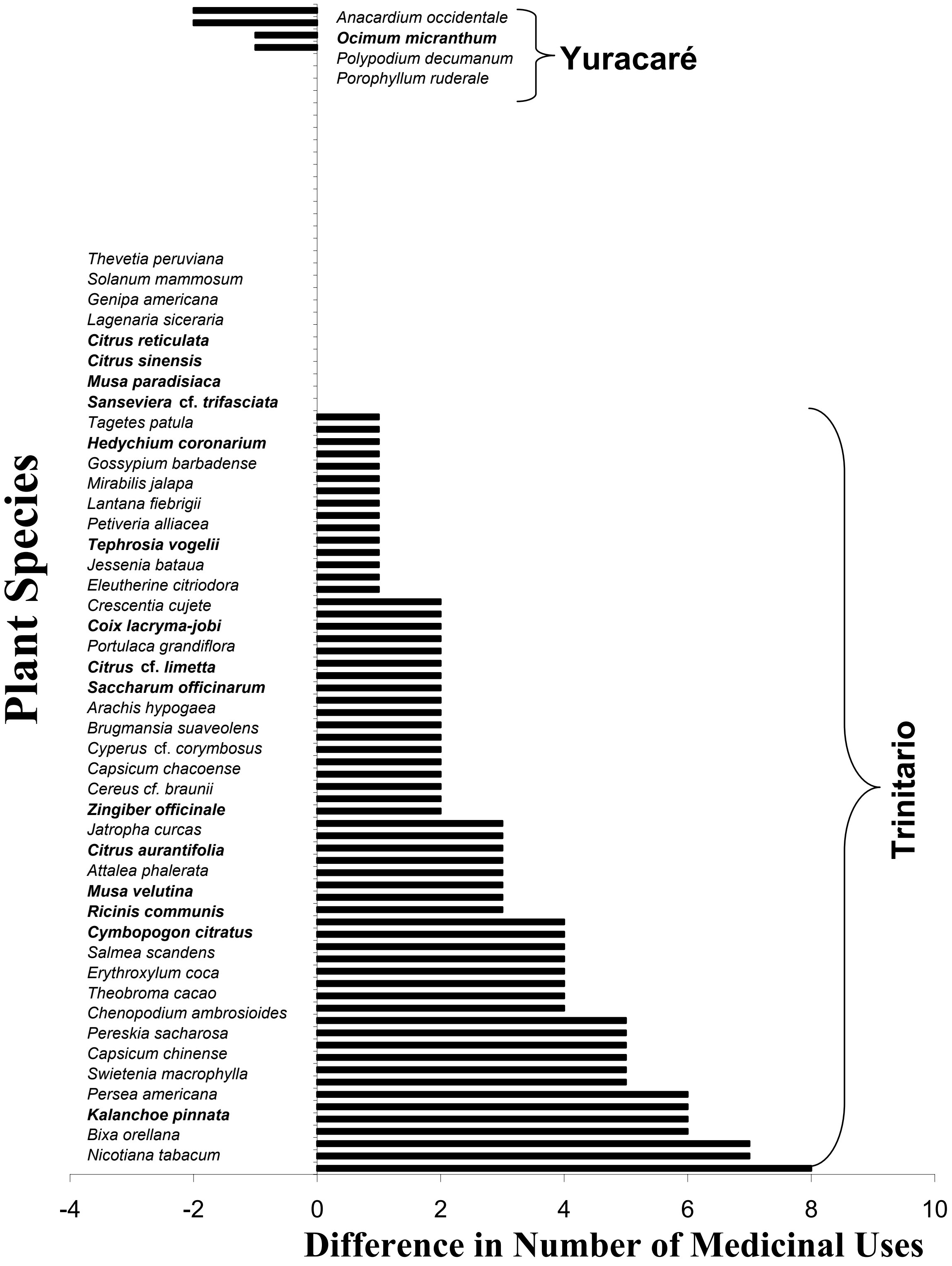

Figure 10.16: Difference in number of medicinal uses enumerated by Yuracaré and Trinitario participants for all cultivated plant species in homegardens and swiddens. Bars on the right and left side indicate species for which Trinitario or Yuracaré participants, respectively, named more medicinal uses. For 29 species participants named an equal number of medicinal uses, as evidenced by the empty space between bars. For reasons of clarity, species listed in the lower part of this figure are: (1) species for which Trinitario participants reported at least two more medicinal uses than Yuracaré participants, and (2) species that have only been seen growing in Trinitario homegardens (species names do not correspond to bars). All species for which Yuracaré participants named more uses are listed in the upper part of the figure. Species that are introduced from the Old World are marked in bold.

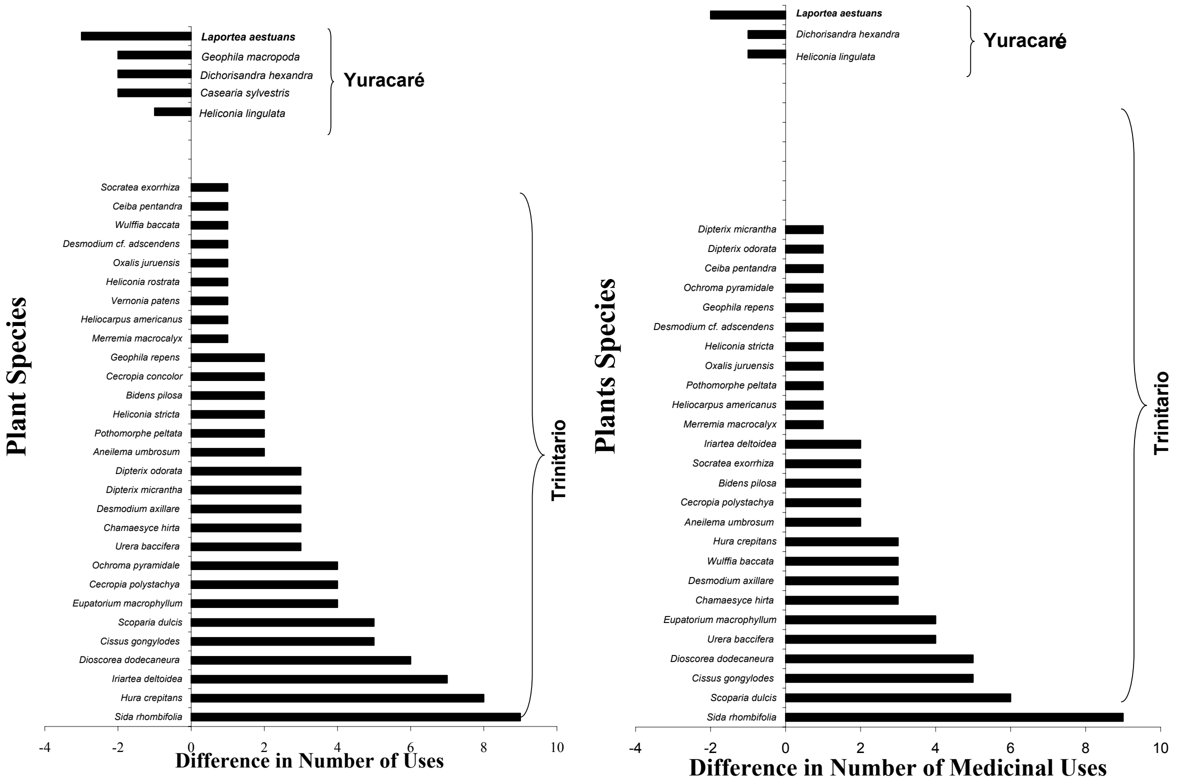

Figure 10.17: Difference in number of overall uses (left side figure) and medicinal uses (right side figure) enumerated by Yuracaré and Trinitario participants for all tolerated plant species in homegardens and swiddens. Bars on the right and left side indicate species for which Trinitario, respectively Yuracaré participants named more uses. For a number of species participants named an equal number of overall uses, as evidenced by the empty space between bars. The species in bold, *Laportea aestuans*, is introduced from the Old World.

While seemingly small-scale, indigenous plant protective measures could have important implications for forest composition and dynamics, as demonstrated by Becker and Leon (1998) for the case of Yuracaré people. Based on the outcomes of a sampling effort in 386 circular ten-meter diameter plots, the latter authors demonstrated that the mean dbhs of trees with indigenous uses was ten centimetres larger than that of commercial timber species. This result made the authors suggest that market pressure had lowered the biomass of timber species, while trees used for fruit, local building material and medicines had been conserved.

Moreover, no fruiting species showed indications of depletion (based on natural rejuvenation, assessed as the number of saplings per hectare), whereas traditional timber species did. Becker and Leon (1998) concluded that sustainable stewardship by Yuracarés was directed to those species that directly contribute to the Yuracaré food chain, while timber species were not managed as intensively. The authors hypothesized that Yuracarés' selection for large fruiting trees had led to increased basal area and biomass of these species and hence, to enhanced resources for wildlife since fruit abundance is positively correlated with basal area and dbh (Leighton and Leighton, 1982; Nava-Cruz and Ricker, 2004). As such, Yuracaré forest management is a kind of mutualism (i.e. a biological interaction between individuals of different species, where all individuals derive a fitness benefit) between humans, fruit trees and game animals (Paz *et al.*, 1995).

Unsustainable Harvest and Response

Although the chances of survival of many useful species are undoubtedly enhanced through protective measures *in situ*, in some cases the latter may not be sufficient to prevent resource depletion. Figure 10.18 shows that when forest dwellers harvest small amounts at irregular intervals, there may be little to no effect on the resilience of plant individuals or populations. However, with increasing frequency or intensity of harvest, the effects on individuals or populations may be substantial. In this chapter, we briefly discussed three species (*Geonoma deversa*, *S. macrophylla* and *J. bataua*) that might currently be subject to population decline in our study area and might eventually be facing local extinction. These three examples also demonstrate that resource depletion can be due to various reasons.

The decline in the natural populations of *G. deversa* is most probably the consequence of the sedentary lifestyle the indigenous communities adopted recently, in combination with increasing population pressure, which resulted in a higher demand for roof thatching (cf. Flores and Ashton, 2000). As historical inhabitants of the study area, Yuracarés used to live in small settlements and had a semi-nomadic lifestyle (Paz, 1991; Querejazu, 2005a). From the 1970s onwards, they were forced to share their habitat with invading Trinitarios and Andean settlers. The establishment of schools, amongst others, finally led to a (semi-)sedentary lifestyle. In a way, the declining population of *J. bataua* might also be attributed to an increased population pressure, since its fruits are also very popular among both Trinitarios and Andean settlers and are thus more heavily harvested than before (mostly through tree felling). Rather than being a subsistence food, these days it has become more of a luxury good. On the other hand, systematic extraction of all harvestable *S. macrophylla* individuals has purely been fuelled by personal financial revenue (Lilienfeld and Pauquet, 2005).

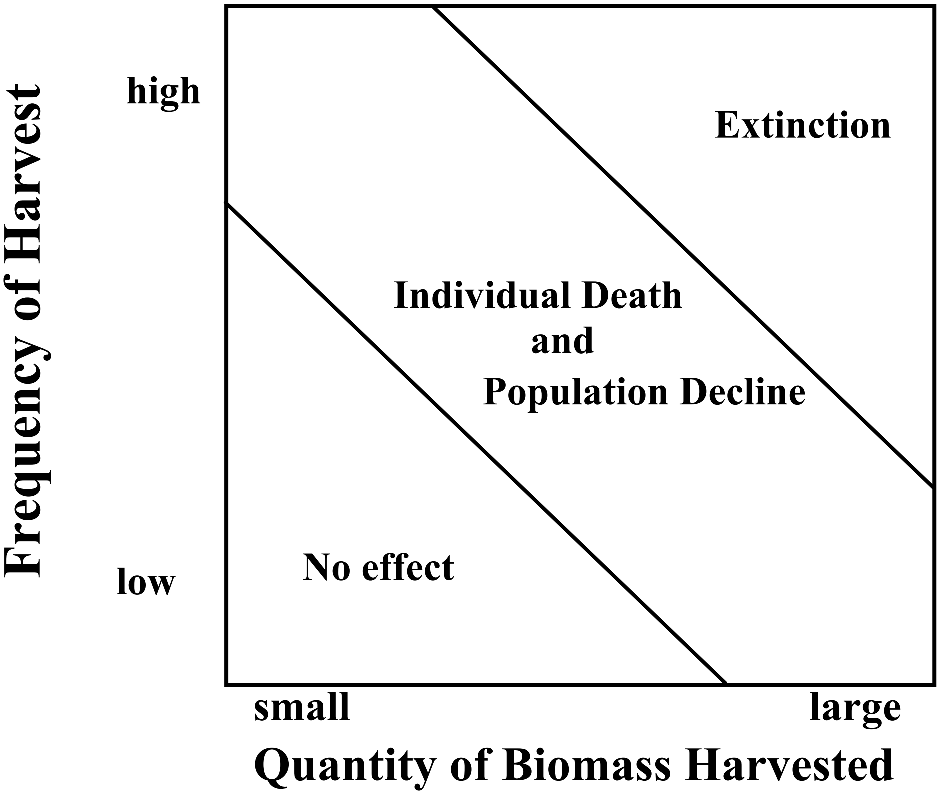

Figure 10.18: Human effects on useful individuals, species, or populations, showing the interaction between harvest frequency and harvest quantity (borrowed from Bennett, 1992)

In addition to these examples, we have also described that it is common practice of Yuracarés and Trinitarios to cut down fruit-bearing wild tree species to harvest their fruits. This unsustainable harvesting method seems to be practiced basically because the ratio of energy invested to biomass harvested is perceived higher as compared to more sustainable harvesting methods such as tree climbing or collecting fallen fruits. This philosophy, in combination with the fact that Trinitarios and Yuracarés only organize collection trips when highly appreciated fruits are known to be ripe is clearly in correspondence with the optimal foraging theory (OFT). According to the OFT, foragers will behave so as to maximize the net rate of return (of energy or nutrients) per unit foraging time (Smith, 1983; Balée, 1989). In this respect, also resource abundance influences human choice (Lawrence *et al*., 2005).

From the previous it is clear that conservation ethics are not (always) of primary concern to Yuracarés and Trinitarios. Such behaviour is far from unique among past and current Amazonian societies (Smith and Wishnie, 2000). It has been reported that certain Amazonian palm populations are being depleted through over-harvesting, in the same way as they were before the advent of Western civilization (Davis and Yost, 1983b; Flores and Ashton, 2000; Svenning and Macía, 2002). For example, in the vicinity of Iquitos (Peru) the felling of various palm species for their fruits has, within a comparatively short space of time, destroyed what was once a thriving market for these species (Vasquez and Gentry, 1989). The felling of tree species for harvesting their fruits has likewise been reported for the Brazilian Waimiri Atroari (Milliken *et al*. 1992), whereas unsustainable exploitation of *J. bataua* and *S. macrophylla* has frequently been observed in Peru and Bolivia (Vasquez and Gentry, 1989; López, 1993; Phillips, 1993; Stagegaard *et al*., 2002; Kometter *et al*. 2004).

Most Trinitarios and Yuracarés seem to be fully aware of the population decline of these species and respond to this with cultivation experiments. Such action is clearly not restricted to our study area and similar responses to resource depletion have been reported among Amazon-based Ribereño people from Peru. After depletion of major timber species (including *S. macrophylla*), Ribereños actively and autonomously engaged in planting, managing and protecting individuals of these species, leading to renewed healthy populations (Piñedo-Vasquez *et al*., 2002). Also Paz (1991) mentioned that Yuracarés from the Rio Chapare region engaged in planting seven new seedlings for every *S. macrophylla* adult they felled. As we have personally been able to witness, cultivation of *S. macrophylla* through sowing and transplanting seedlings is quite successful among the Trinitarios and Yuracarés that participated in the present study, whereas *J. bataua* responds very poorly to cultivation attempts. However, according to Clement (1999a), who identified the species as a semi-domesticated crop at contact, attempts of indigenous communities to cultivate *J. bataua* date back to pre-Columbian times.

Our third example species, *G. deversa*, has been reported elsewhere as well as locally disappearing due to overexploitation of its leaves for thatching material (Rioja, 1992; Moraes and Sarmiento, 1999; Flores and Ashton, 2000; Svenning and Macia, 2002). Quantities of leaves used for roof thatching comparable to those we calculated have been confirmed by various authors (see Svenning and Macia, 2002). As opposed to other *Geonoma* species that are more vulnerable, (e.g. *G. macrostachys* var. *macrostachys* (Svenning and Macia, 2002)), *G. deversa* is a clonal understorey palm, indicating that its survival is not affected by harvesting. Nevertheless, harvesting reduces clone size and reproductive output, and lowers the number of ramets available for the next harvest (Flores and Ashton, 2000). Hence, while the natural population of *G. deversa* in the study area might not be disappearing, it produces significantly smaller amounts of harvestable fronds. Local people's reaction to this type of resource depletion seems to be less sustainable than in the case of *S. macrophylla.* Rather than experimenting with management techniques (e.g. cultivation or protection), they tend to travel further, or switch to other species; the latter in turn can also become depleted. Similar observations have been made for the Huaoranis from Ecuador (Svenning and Macía, 2002) and the Ka'apor from Brasil (Balée, 1994). Nonetheless, the solution might not be that difficult when appropriate seedling protection measures would be taken into account. Svenning and Macía (2002) have for example demonstrated that sustainable harvesting of *G. macrostachys* var. *macrostachys* seems more possible in semi open habitats such as disturbed forest as compared to old-growth forest, mainly due to higher light regimes.

What then drives people to cultivate *S. macrophylla*, but not *G. deversa*? The reason probably relates to both the monetary value both species represent, as well as to the effort involved in propagation. The difference in return on effort investment is immensely different for both species. Where the export value in Bolivia of one cubic meter of *S. macrophylla* wood was higher than 1,000 US$ or 682 € in 2006 (www.cfb.org.bo), in TIPNIS the value of one thatching panel made from the fronds of at least 18-27 ramets (=270 fronds per panel; 10-15 fronds per ramet) was 1 € at the time of the research (2005). People don't seem to mind the latent period between seedling and harvestable tree, but rather plant *S. macrophylla* for the future benefit of their children.

Anthropogenic Forest

In spite of the, at first sight, unsustainable use of *J. bataua* and *G. deversa* in the indigenous communities studied, it has been argued before that Yuracaré language and traditional beliefs include(d) explicit prescriptions for sustainable forest management. According to Becker and Leon (1998), Yuracarés believe in the collective prescription "use of forest trees and animals without depletion". This prescription would be operationalized through an "opportunistic use of time and space" whereby families spread out the impact of timber harvesting, agriculture, hunting and gathering in time and space rather than using one specific forest area intensively. Our research can support these observations and we believe that they are valid for both Yuracarés and Trinitarios. Both ethnic groups practice swidden agriculture in small forest patches not much bigger than one hectare (cf. figure 1.6A). Preferentially they clear non-flooded areas with productive soils for cultivation, and plant these first with rice and/or sweet cassava, sometimes intercropped with maize, then bananas, and subsequently fruit trees (mango, cacao trees, papaya, orange, mandarin, lemon, avocado, grapefruit, palms, and native fruit trees). These forest gardens are used for 25 to 35 years, gradually turning into secondary forest dominated by domestic and wild fruit species, and eventually becoming mature rainforest again (Paz, 1991; Paz *et al.*, 1995; Becker and Leon, 1998; CERES, 1998). Since every family clears a new patch of land annually to triennially, the long-term impact on the vegetation is obviously impressive.

Our data contribute to the growing base of evidence that suggests that many Amazonian landscapes are not the "pristine parcels of nature's most ambitious experiment" (Voeks, 2004), but rather the outcome of centuries of intentional and accidental indigenous forest and landscape management (Denevan, 1980 and 1992; Bennett, 1992; Redford and Stearman, 1993; Balée, 1994; Foster *et al*., 1999; Clement, 1999a and 1999b; Smith and Wishnie, 2000; Erickson, 2000b; Cleary, 2001; Rival, 2006). Denevan (1992) probably takes the most extreme position in this discourse by stating that: "there are no virgin tropical forests today nor were there in 1492". According to the latter author, the American landscape of 1750 was even more "pristine" (less humanized) than that of 1492 due to the massive demise of the native population after contact. The overall hemispheric population (including European and African immigrants) in 1750 was probably about thirty percent of what it was in 1492 (Denevan, 1992). An even more pessimistic view in this respect was provided by Dobyns (1966) who estimated that 90-95% of the Neotropical population was lost within 100-200 years after contact.

Similar to the actions of Yuracarés and Trinitarios, numerous forest societies have influenced large expanses of Latin American forests through centuries of (1) clearing and burning; and (2) (indigenous) management of useful species by means of planting, transplanting, sparing and protection (Denevan, 1992; Balée, 1994; Smith and Wishnie, 2000). Recent evidence has suggested that these small-scale anthropogenic disturbance practices have not been at the expense of plant diversity in forests. Balée (1994) has demonstrated that the species richness present at old-growth forest sites is being replaced by equally rich secondary forest after a period of human occupation during swiddens cultivation. Balée (1994) sees this as an indigenous contribution to regional biodiversity as such secondary forest exists only *because of human activity*. Although the impact of hunter-gatherers on vegetation through forest clearance (by means of fire and other tools) was less than that produced by their peers who engaged in agriculture, this impact was still significant. Whereas horticulturalists created cultural artefacts in the landscape, foraging societies probably disturbed habitats in ways comparable to the effects of natural tree fall gaps, landslides and forest trails (Voeks, 2004; Rival, 2006). Brown and Lugo (1990) estimated that as a result of human clearing about forty percent of the Latin American tropical forest is secondary.

Evidence supporting the anthropogenic landscape paradigm is impressive: anthrosols (black earth or *terra preta do índio* containing charcoal and cultural waste from prehistoric burning and settlement), mounds, ridges, artificially elevated plains, canals, dams, reservoirs, etc., have been found all over South America (Smith, 1980; Denevan, 1992; Balée, 1989 and 1994; Clement, 1999a; German, 2003; Voeks, 2004). *Terra preta* soils carry distinctive vegetation as a consequence of high carbon, nitrogen, calcium and phosphorus content and are generally associated with forests that are enriched with useful species (Smith, 1980 and 1995; Clement, 1999b).

Anthropogenic forests may not be as eye-catching as the pre-Columbian landscape shaped by Trinitarios (Mojeños) in their homelands of Moxos. Nevertheless, they are unmistakable the proof of the profound influence indigenous people have on their environment. In Moxos, the Mojeños left a remarkable archaeological record of networks of artificial canals and elevated plains that can even be distinguished on aerial photographs (Nordenskiöld, 1912; Denevan, 1980; Erickson, 2000b). According to Erickson (1980), prehistoric landscape modification in the plains of Moxos could be the largest known to date. Present day Trinitarios (unconsciously) continue the process of influencing the landscape in their new haven, in the same way the Yuracarés (their "new" close neighbours) have been doing for centuries.

10.4.2. Are Managed Plants more Useful than Wild Plants?

We have shown that managed plants have a significantly higher overall, medicinal, food and material usefulness as compared to wild plants. This seems a rather logical outcome, as one could expect usefulness to be the force that drives plant management (Clement, 1999a). In addition to managed plants, a number of wild species (particularly weeds, but also typical disturbance trees and shrubs such as *Piper* spp., *Urera* spp. and *Cecropia* spp.) also grow typically in disturbance habitats. Throughout this work, we have continuously examined the validity of the hypothesis that more accessible (or more abundant) plants are perceived as more useful (Johns *et al*., 1990; Phillips and Gentry, 1993b; Frei *et al*., 2000; Casagrande, 2002; Bonet and Vallès, 2002; Van den Eynden, 2004) on our data (see chapters 4 and 9). In the present chapter we confirmed this hypothesis once more by demonstrating that plants from disturbance habitats have significantly higher mean overall, medicinal, food and material use values than plants from natural habitats. It was also confirmed that wild disturbance plants growing in anthropogenic landscapes have a higher mean medicinal use value than wild species that typically grow in natural landscapes, though the opposite was true for all other use categories.

These results are clearly in accordance with the growing consensus on the importance of disturbed landscapes in the provision of medicinal remedies (Posey, 1984; Balée, 1994; Voeks, 1996; Ankli *et al*., 1999a; Frei *et al*., 2000; Stepp and Moerman, 2001; Thomas, 2001; Etkin, 2002; Begossi *et al*., 2002; Di Stasi *et al*., 2002; Hernández Canoa and Volpato, 2004; Voeks, 2004; Grenand *et al*., 2004). In line with the hypothesis mentioned in the previous paragraph, the usefulness of moderately humanized landscapes as sources of medicinal plants is often explained by the existence of a causal link between the frequency and/or intensity of contact with certain species and their utility. As a product of human creation, the anthropogenic environment is most salient, most familiar and most accessible and therefore most likely to be learned, named and used (Brown, 1985; Turner, 1988; Phillips and Gentry, 1993b; Voeks, 2004).

Voeks (2004) takes this matter even further. He suggests that tropical pharmacopoeias are *largely* the product of human disturbance regimes, ongoing and ancient. In this view, old-growth tropical forests, while being cornucopias of wild foods, fibres, fuels and other useful primary products, would have a highly overestimated importance in the provision of medicinal plants. According to Voeks (1996, 2004), forest people mainly turn to moderately humanized landscapes such as trails, swiddens, kitchen gardens, recent forest fallows and other products of their own invention as sources of healing. This preference would be motivated by the fact that disturbance pharmacopoeias combine optimal foraging features with the natural distribution of promising plant-derived compounds as will be discussed further on.

Although we largely agree with the importance of disturbance habitats, our own results do not entirely support Voeks' (2004) hypothesis that "old-growth tropical forests are not likely to have served as the primary repositories of folk medicinals in the past, and they do not in the present". In this study we inventoried a total of 143 medicinal plant species from disturbed landscapes. Of these, 78 are cultivated (including 24 introduced), 33 tolerated (including 2 introduced) and 32 species are wild. As such, 42% of all recorded medicinal species (i.e. 340 species) come from disturbed habitats. When both the results from the present study and those from Vandebroek *et al.* (2004a and 2004b) are considered, then 44% percent of medicinal species come from anthropogenic habitats (i.e. 170 species from a total of 387 medicinal species). This is a substantial proportion, but not entirely in line with Voeks' (2004) hypothesis, because still more than half of all medicinal species come from natural landscapes. Grenand *et al.* (2004) came to comparable results as ours for the French Guyanan Wayãpi. They found that 70% of medicinal plants used by these people come from the wild. Literature references that substantiate Voeks' (2004) proposition obviously exist as well. In addition to the extensive list of studies proportionated by the author himself, we give some additional examples. Kvist (1997) calculated that Mestizos from the Peruvian Amazon collect only approximately 40% of all medicinal plant materials within the natural forest. Frei *et al.* (2000) likewise reported that Mexican Zapotec and Mixe obtain respectively 59% and 72% of medico-botanical resources from their immediate (disturbed) environment. According to Grenand *et al.* (2004), 58% of medicinal plants used by the French Guyanan Creoles are cultivated or harvested from ruderal places.

Also the fact that, according to Yuracarés and Trinitarios plants from disturbance habitats have significantly higher mean food use values than plants from natural habitats supports the hypothesis that more accessible plants are perceived as more useful. Various studies have demonstrated people's preference to collect edible plants from gardens, fields, fallows and secondary vegetation, rather than from natural habitats (e.g. Toledo *et al.*, 1995; Styger *et al.*, 1999; Van den Eynden, 2004). However, in the present study this preference is not reflected in the proportion of edible plants obtained from anthropogenic landscapes (29%) against food plants from natural habitats (71%) (see chapter 8, section 8.3.7.1.).

When results are considered separately for Yuracarés and Trinitarios, the proportion of medicinal and food plants obtained from disturbance habitats is significantly different: 43% and 38% for Trinitarios and 32% and 25% for Yuracarés, respectively. An important proportion of these plants is managed in homegardens (36 and 22% of all medicinal plants and 34% and 23% of all food plants for Trinitarios and Yuracarés, respectively). Moreover, Trinitarios cultivate almost three times as many medicinal plants than Yuracarés (71 vs. 24 spp.). Hence, Yuracarés rely proportionally and significantly more on the natural environment for extraction of medicinal and food plants than Trinitarios. Intriguingly, van Andel (2000) made very similar observations in the Guyanas. She found that Guyana Arawaks use more medicinal plant species than Caribs. Like the Trinitarios (also Arawakian), the former group relies less on wild habitats for the extraction of medicinal or other plants than the latter and cultivates almost twice as much (medicinal) plants than the Caribs. Van Andel (2000) related this difference among other factors (such as history of contact and interview bias, which we will discuss further on) to the fact that Arawaks deal with a greater variety in habitats. Applied on the case of Yuracarés and Trinitarios, we hypothesize that the observed differences in their reliance on natural versus man-made environments is related both to the (historical) life style and the provenance of both ethnic groups.

As explained higher, prior to the arrival of Trinitarios and Andean settlers in the 1970's (Paz, 1991; Querejazu, 2005a), the Yuracarés of TIPNIS engaged in a semi-nomadic lifestyle. Given the significant altitudinal (±200-1500 m.a.s.l.; Beetstra, 2005a; Querejazu 2005a) and hence floristic and ecological variation that is found across their extensive territory, this type of lifestyle is believed to stimulate a profound knowledge of the surrounding wild (medicinal) flora (Milliken and Albert, 1997). Since Yuracarés are historical inhabitants of TIPNIS, local plant use knowledge was most likely developed over centuries and passed on over generations. This basic reliance on the wild flora can in addition, be related to another intrinsic characteristic of the semi-nomadic lifestyle. Balée (1994) argued that people who engage in trekking generally do not succeed in building up and/or maintaining a repository of cultivated plants. This would be because the act of 'moving' a settlement sometimes results in the loss of cultivates (Balée and Gely, 1989; Balée, 1994).

As opposed to Yuracarés, Trinitarios have a long tradition of sedentism and relocations of villages always took place in the proximity of the same place (Parejas, 1972). However, the recent history of the Trinitario people from the participating communities is also characterized by a great deal of semi-nomadism. Whereas TIPNIS is one of the homelands of Yuracarés, Trinitarios migrated to it quite recently from the neighbouring plains of Moxos (Beni province). As explained in more detail further on, Trinitario migrations started from the nineteenth century (1887) onwards in the search for the "Holy Land" or *Loma Santa*, as a response to land pressure problems in their homeland area (Riester 1976; Lehm 1999). The Trinitario communities that participated in the present research were founded from the 1970's onwards as a result of this migration. Establishment of these communities was, however, not the result of relocation from one place (the plains of Moxos) to another (TIPNIS). It was the outcome of years of peregrinations throughout Bolivian lowlands in search of the Holy Land. Hence, contrary to the situation of the Yuracarés, these migrations were not part of the long-term cultural history of Trinitarios and neither did the territory they traversed pertain to their original habitat. As a basically sedentary people they brought along part of their society's plant-based pharmacopoeia, as well as a number of other useful plant species during these peregrinations (as testified by various Trinitario participants).

Upon arrival to their new home, Trinitarios were confronted with a distinct ecological environment. The vegetation of the Moxos plains is quite different from the high tropical forest cover of the southern part that characterizes TIPNIS. Moxos is characterized by seasonally inundated tree savannas that alternate with forested areas and higher lain "islands" that are spared from seasonal flooding (Navarro and Maldonado, 2002). Albeit a number of plant species occur both in the Moxos plains and TIPNIS, overall species composition is significantly different for both ecological zones (Navarro, 2002). As a consequence, at least in some aspects Trinitarios do not know the vegetation of their new lands quite as well as Yuracarés. This was also demonstrated in this chapter by the significantly higher Shannon-Wiener overall use knowledge diversity of wild plants obtained for Yuracarés than for Trinitarios. In spite of their ability to distinguish between different wild species, Trinitario participants have also much more difficulties than Yuracarés to name them correctly and consistently (Thomas, unpublished results).

10.4.3. Plants Growing in Homegardens and Swiddens

Homegardens and swiddens are among the most prominent regimes of human disturbance. Approximately 19% of all inventoried useful plant species (140 out of 735 species) is managed in Yuracaré (115 species) and Trinitario (131 species) homegardens and swiddens. These numbers are comparable to those found by Lamont *et al.* (1999) in three villages from the Peruvian Amazon (161 species). However, the latter authors included all useful species prevailing in homegardens with the exception of ornamentals, but without distinguishing between managed and wild species. In our own study, only four species are cultivated exclusively for ornamental purposes, whereas forty-seven wild species (i.e. unmanaged) that prevail naturally in homegardens were additionally recorded as being useful to participants of either ethnic group. Hence, homegardens of Yuracarés and Trinitarios would have higher useful species diversities (i.e. 140-4+47 = 183 species) as compared to those studied by Lamont *et al.* (1999). Our results are also comparable to Padoch and De Jong's (1991) findings. They reported 168 plant species grown in twenty-one Peruvian homegardens. High numbers of species in the relatively few Yuracaré and Trinitario communities we surveyed might be explained by their high degree of isolation. Studies on homegardens in many areas indicate that species diversity is greater in remote villages, where homegardens are an important source of subsistence products, because markets for products are unavailable (Fernandes and Nair, 1986).

Far from all most useful plant species grow in homegardens: 'only' thirteen of the twenty most useful species (in terms of use values) that were inventoried during this study are managed in homegardens and/or swiddens. The seven other most useful species are obtained exclusively from natural habitats. Reasons that impede people from managing or cultivating wild useful species can be related to (1) difficulties in plant establishment; (2) slow growth; (3) the fact that common and abundant species do not warrant protection; and (4) their minor actual importance (Bennett, 1992).

In Amazonian homegardens there appears to exist a preference for managing species that belong to certain plant families. Arecaceae, Solanaceae, Fabaceae and Rutaceae were recorded by Lamont *et al.* (1999) as the most important families in three Peruvian villages. These families belong to the top six of families in the present study. The most important family in terms of species within the top-twenty highest overall use value in our study is undoubtedly the palm family (Arecaceae). Palms have the well-established reputation of being highly useful plants for local people in Amazonia (Macía, 2004). They provide edible fruits, oils, palm harts, fibres, thatch, construction materials, domestic artefacts, tools for traditional hunting and fishing, medicines and other minor products. In a study among the Huaorani of Ecuador, eleven palm species showed the highest use values within the 30 most valued woody plants (Macía, 2001). The same trend is observed in many other ethnobotanical studies throughout Latin America (e.g. Phillips *et al.*, 1994; Stagegaard *et al.*, 2002).

The proportion of cultivated (74%) and tolerated (26%) plants that are managed in Yuracaré and Trinitario homegardens and swiddens are also in agreement with observations made elsewhere. In a study of 30 Mexican homegardens, Blanckaert *et al.* (2004) found that 68% of species was cultivated and 22% tolerated. Van den Eynden (2004) found that on average 82%

of all species occurring in 42 homegardens in southern Ecuador was cultivated (both crop and non-crop plants) while 14% was tolerated.

At first, one might be surprised by the fact that nearly one third of cultivated species is introduced. However, the literature describes plenty of cases for indigenous communities whereby introduced cultivated plants outnumber native ones (Balée, 1994; Begossi *et al.*, 2002; Hanazaki, 2006). Nevertheless, these studies have to be interpreted carefully, as some investigators (e.g. Balée, 1994; Milliken *et al.*, 1992) define introduced plants as Old World crops as well as Neotropical crops that have been introduced recently (e.g. within the last hundred years). For example, Balée (1994) argued that avocado (*Persea americana*) and cacao (*Theobroma cacao*) trees represent a 'recent' introduction to the Ka'apor homegardens because in their language they are called *karaí-ma'e* ('that which is of non-Indians'). According to Denevan (1980) *T. cacao* would likewise have been introduced to the Mojeños in the post-contact period by the Jesuits. However, here we considered only Old World crops as introduced, due to the uncertainty about the time of introduction of most Neotropical crops in Yuracaré and Trinitario societies. If introduced Neotropical plants had been included, the ratio of introduced-traditional cultivated plants would most probably be higher than the one third we calculated.

Managed plants in Yuracaré and Trinitario homegardens are most often used as sources of medicine and food, followed by materials and environmental uses (i.e. ornaments). These appear to be the main reasons why people manage plants in homegardens all over the world (Niñez, 1985; Balée, 1994; Lamont *et al.*, 1999; Agelet *et al.*, 2000; Trinh *et al.*, 2003; Finerman and Sackett, 2003; Vogl and Vogl-Lukasser, 2003; Blanckaert *et al.*, 2004; Van Den Eynden, 2004). Apparently, there exists a rough correlation between the life form of managed plants and their utility. Plants with a tree habit are more likely to be managed for their overall and food usefulness, whereas herbs are often most popular as medicines.

Yuracaré and Trinitario homegardens contain proportionally more managed useful herbs than tree or shrub species. Nevertheless, trees possess a significantly higher mean overall use value, basically due to their multipurpose nature: apart from fulfilling human needs for food and medicine they also contribute considerably as sources of materials and fuel. However, of all the services provided, the most important use of trees is for food. This trend is apparent in the top twenty of species with highest mean food use values: 70% of the twenty most useful managed food species are trees. Also 77% of all managed trees has food applications. This seems logical since trees are long-lived and hence require less labour as compared to herbaceous food producing plants that need to be sown, weeded, etc. Additionally, food harvest quantity is in most cases considerably higher for individual trees as compared to herbs. These observations are corroborated by information from literature. In a study on the use and management of edible non-crop plants in southern Ecuador, Van den Eynden (2004) demonstrated people's preference for managing trees with edible fruits, as compared to other life forms. Fruit trees are also the most frequent plants in Peruvian and Spanish homegardens (Lamont *et al.*, 1999; Agelet *et al.*, 2000), whereas in Senegalese fields, indigenous trees are mainly managed for their fruits (Lykke, 2000).

By contrast, managed herbs in Yuracaré and Trinitario homegardens have the highest mean medicinal use value of all life forms. This is confirmed by the fact that 60% of the twenty most useful managed medicinal plants are herbs. Also, the fact that most tolerated plants (89%) are used as herbal medicines can in this respect partly be related to the mainly herbaceous life forms of these plants (56% of tolerated plants are herbs). The popularity of managing herbs for therapeutic uses might not be surprising. Plants in general owe their medicinal properties in humans to the chemical defence mechanism they apply against predators that attack them: mammals, insects, bacteria, fungi, and the alike (Voeks, 2004). Plants also produce (potentially therapeutic) chemicals that inhibit germination and growth of other plants (i.e. allelopathy) but we will not go into detail about that here since it is difficult to show causal relationships in allelopathy (Zimdahl, 1999, cited in Stepp, 2004).

Plants are known to use two main types of chemical defence strategies against predators. According to a first scenario, plants reduce digestibility by producing and storing metabolically and generally non-toxic, inactive quantitative defences such as tannins and lignins. Mostly slowly growing plants with relatively long-lived leaves such as trees or shrubs make use of this strategy. The therapeutic value of such high molecular weight molecules in humans is rather low. By contrast, the products of a second plant defence mechanism have a higher probability of evocating biomedical effects in humans. These are low molecular weight secondary metabolites, such as alkaloids, terpenoids and cardiac glycosides. Opportunistic, rapidly colonizing and short-lived plant species such as herbs and pioneer species, tend to rely preferentially on such toxic and highly bioactive qualitative compounds (Feeny, 1976; Coley *et al.*, 1985; Stepp and Moerman, 2001). However, it is important to note that this does not mean that trees and shrubs would rely exclusively on quantitative instead of qualitative defence mechanisms. Plant species generally combine different strategies and obviously also numerous long-lived (tree) species and families exist that are known to produce bioactive secondary metabolites.

The amount of bioactive secondary components present in plants seems to vary roughly according to predator exposure. Levin (1976) uncovered a significant inverse relationship between the proportion of the flora that tests positive for alkaloids and the average latitude of the country. The most likely explanation for this chemical defence gradient is that there exist increasing levels of herbivory in species-rich tropical habitats (Coley and Aide, 1991, cited in Voeks, 2004; Givnish, 1999). In addition, Levin (1976) demonstrated that worldwide, alkaloids are twice as likely to appear in annuals as in perennials. The leading explanation for this phenomenon involves the dynamics of plant-predation interactions (Voeks, 2004). Because long-lived plants such as forest trees are rather static, and hence more apparent to predators, they are the focus of specialist predation and concentrate on metabolically expensive quantitative strategies such as lignins. Short-lived (successional) species are more dynamic (“they do not stick around long”) and thus less apparent to predators. That is why they direct their defence more at generalist predators and opt for qualitative metabolically inexpensive defences. Alkaloids are highly effective against generalist herbivores, but not against specialist feeders (see review in Voeks, 2004). Alkaloids are particularly relevant questioning relation to herbal medicine because they are frequently bioactive in humans (e.g. caffeine, ephedrine, etc.) and because they are so numerous.

Due to their higher potential of being effective and promissory therapeutics, more and more attention is being paid to the importance of herbaceous plants in general -and weeds in particular- in indigenous pharmacopoeias (Bennett and Prance, 2000; Stepp, 2004). Stepp and Moerman (2001) and Stepp (2004) have shown that the frequency with which weeds appear in indigenous Mexican, Native North American and modern pharmacopoeias is significantly larger than what would be predicted by the frequency of weed species in the entire floras.

10.4.4. Yuracaré and Trinitario Homegardens: Differences and Similarities

One way to compare between homegardens managed by Trinitarios and Yuracarés would start from distinguishing which plants belong to the cultural spheres of either one of both ethnic groups. This is a relevant issue since in the present study 14% of all cultivated species were encountered in only one homegarden. This percentage is conservative in comparison with large-scale homegarden surveys. In her study on the edible plants of Southern Ecuador, Van den Eynden (2004) noticed that about 60% of all edible plants were only used or known in one of the 42 villages she investigated. In Amazonian homegardens, 39% of species were found exclusively in one garden (Padoch and De Jong, 1991). Also in Austrian Tyrol, 26% of all sampled species were found in just one out of 196 homegardens investigated (Vogl and Vogl-Lukasser, 2003). At least 21% of useful species inventoried by Agelet *et al.* (2000) were present in only one of the 145 Spanish gardens they studied.

As a basis for our comparison we hypothesized that the greater the difference in the number of reported uses per species is between both ethnic groups, the more likely it is that that plant species has a longer and/or more intensive management history among members of either one of both ethnic groups. However, this is a challenging position, and simply subtracting total numbers of uses clearly has limitations. First of all, plant use knowledge is dynamic. Knowledge is transferred between members of the same or different ethnic groups, but also new applications of plants are frequently being “discovered”. Exchange of plant material and knowledge has occurred throughout Amazonia (Anderson and Posey, 1989; Bennett, 1992; Phillips and Gentry, 1993b; Milliken and Albert, 1997; van Andel, 2000). Harris (1998) noted that,‘‘for many millennia, people of different cultural traditions living in different geographical regions have obtained useful plants from each other in a long drawn-out process of cross-cultural exchange . . . ’’ (cited in Bennett and Prance, 2000). A good example to illustrate the relevance of Amazonian intercultural contact and exchange is the introduction of European fowl to the Americas. The first chickens were introduced to Brazil around 1500. These birds were rapidly distributed inland by “indigenous merchandisers” (most probably Arawakian people), well ahead of the European explorers. When the Spanish explorer, Francisco de Orellana, and his men arrived in 1541-42 to a village nearby the estuary of Rio Negro and Amazonas for the first time in history, they were surprised to find livestock of domesticated European fowl (Querejazu, 2005a).

A second critique to comparing numbers of uses per plant species, is that it is also possible that certain plant species that have been cultivated by both Yuracarés and Trinitarios over generations simply have more use applications among one ethnic group than among the other, regardless of their history of contact with these species. For example, tobacco (*Nicotiana tabacum*) and ginger (*Zingiber officinale*) have a far more diversified use among Trinitarios than among Yuracarés. Nevertheless, these plants have been described cultivated by

Yuracarés in manuscripts of early ethnographers (Von Holten, 1877; Nordenskiöld, 1924 and 2003).

The method of subtracting uses is also subject to bias related to the number and background of the participants who provide use data. Among Trinitarios, there exist various plant specialists, such as midwives, traditional healers and one shaman, whereas most Yuracaré participants were common villagers. Moreover, the fact that significantly more Trinitarios were interviewed per plant species than Yuracarés, might also have contributed to more pronounced differences numbers of uses (cf. van Andel, 2000).

Clearly a more ideal approach for distinguishing between plant species that might have had longer and/or more intensive management histories among either Yuracarés or Trinitarios would also have included a linguistic assessment of indigenous plant names. However, this fell out of the scope of the present study.

Despite these limitations, comparison of the number of uses per plant species revealed that Trinitario participants mentioned a greater number of overall and medicinal uses for a far larger number of managed plants than Yuracarés. This discrepancy is probably the consequence of a variety of factors that characterize Yuracarés and Trinitarios, such as cultural heritage, cultural customs and practices; cosmology and ontology; their ethnomedicinal systems; provenance; history of contact with outsiders; and (historical) mode of subsistence. In the following paragraphs each of these factors are discussed briefly.

Cultural Heritage and Current Cultural Practices

Obviously at least some part of plants used by indigenous cultures are a consequence of cultural heritage (Leonti *et al*., 2003a). Several studies from tropical Asia and Latin America have shown how cultural background can influence species composition of homegardens (Christanty, 1990; Rico-Gray *et al*., 1990). Reversely, homegardens are known to preserve much of the local cultural history (Blanckaert *et al*., 2004). A number of plant uses that are cultivated by Yuracarés or Trinitarios exclusively, are to be situated in the cultural heritage of either ethnic group. As we have demonstrated in chapter 8, *Neea* fruits have been used historically by Yuracarés as body paint and to print patterns on tree bark-fashioned garments. Nowadays, *Neea* fruits are used by Yuracarés as a colouring agent during water fights typically held during carnival festivities (month of February) held in entire Bolivia.

Other examples that illustrate our point are provided by *Marsdenia macrophylla* and *Thevetia peruviana* (see chapter 8). *M. macrophylla* is sometimes cultivated by Yuracarés for its stem fibres that are used to attach feathers to the arrow shaft. Trinitarios use(d) other plants for this purpose like cotton thread. *T. peruviana* on the other hand is only found cultivated by Trinitarios since it provides fruits that are used as foot-rattles during traditional dances of the *macheteros* (figure 8.31D).

Worldview and Ontology

Some ontological factors come into play regarding the cultivation of certain (medicinal) plants. We motivate this position by means of an example from Trinitario perspective. As discussed in chapter 11, Trinitarios have a worldview that still is (partly) animistic. They believe that all animal and many plant species are owned by species-specific spiritual masters or owners. For example, the owner of *'chosíjare* (*Brugmansia suaveolens*), is believed to be an old male figure. This owner can grant human beings with supernatural powers such as the ability to re-witness past actions or the power to visit places far away from the actual body's whereabouts by detaching the spirit from the body (cf. section 8.3.11.). This same practice and belief has been described by Eder (1772) for an unspecified cultivated plant species in his account on the eighteenth century plains of Moxos. In order to temporally achieve such powers, the candidate has to talk gently to the plant's owner and explain his/her motivation for ingesting the plant. One of such motives might be the unsolved robbery of property from someone's house. In this case, the plant's owner is believed to grant the power to uncover the robber's identity after ingestion of an oral preparation of leaves and/or flowers. This spiritual experience is perceived as dangerous: when taken without prior consent of the plant's owner, or in excessive quantities it can lead to insanity. Therefore, generally only "mentally strong" persons like shamans or traditional healers make use of it. Nonetheless, we also recorded testimonies of common villagers using the plant to reveal the identity of thieves who stole something (money or valuable goods). *Brugmansia suaveolens* is used for this purpose only by Trinitarios, but not by Yuracarés. Trinitarios use the plant also in a number of pharmacological applications of which just one (muscle pains) is shared by Yuracarés (Thomas and Vandebroek, 2006). These observations would suggest that *Brugmansia suaveolens* has a longer management history among Trinitario people and that Yuracarés are adopting some of its applications in their own ethnomedicinal practices.

Ethnomedical System

From a historical perspective, Trinitario people have a more developed ethnomedical system than Yuracarés. As detailed in chapter 8 (section 8.3.6.1.), the Mojeños distinguished themselves from the majority of other Amazonian societies by their hierarchic priesthood (Lehm, 1999). At the top of the hierarchy stood the *comocois* (d'Orbigny, 1845), *komokoy* (Castillo, 1676, cited by Santamaria, 1994) or *mapono* (Caballero, 1706) who obtained his divine power through killing a jaguar. He was followed in social status by the *tiharauqui* whose sole duty it was to cure the sick (d'Orbigny, 1845). The latter healer used principally spiritual or shamanistic powers for healing; medicinal plants were far less important in their curing ceremonies. The shamanistic profession still exists and the present day equivalent is addressed with the term *tkonñahi* (Trinitario) or *sobandero* (Spanish). As opposed to *sobanderos*, herbalists, traditional healers or *curanderos* make use of empirical medicine to cure disorders. Midwives or *parteras* are specialized in ethnomedical preparations related to birth and postpartum. Finally, *hueseros*, traditional bonesetters have their area of expertise in the treatment of dislocations, sprains, fractures and the alike by means of massages and herbal compresses or plasters. One specialized healer that participated in this study combined all these ethnomedical specializations.

The Yuracarés had and have a more common ethnomedical system. Like many other Amazonian societies they had shamans that cured the sick by examining saliva in their palms, blowing tobacco smoke over afflicted body parts, bloodletting (cf. figure 8.29A, chapter 8), etc. (Métraux, 1942 and 1948; Richter, 1930b; Querejazu, 2005a). Various references mention the ample knowledge of medicinal plants among the Yuracarés (Lacueva, 1918; Richter, 1930b; d'Orbigny, 1945; Querejazu, 2005a), but do not specify whether a distinction was made between shamans and herbalists. In the participating communities, there were no shamans or people with the status of herbalists. Only one of the female participants declared to act as midwife in her community. Many Yuracarés actually consult Trinitario healers when their own remedies are insufficient.

As Milliken (1997a) pointed out, the depth of knowledge of medicinal plants depends, among other factors, on the relative importance of phytotherapy (i.e. the use of plant-derived products for treating health conditions) in the group's traditional medicine (i.e. the total of healing practices applied by a group, including plant-, animal- or mineral-based remedies, as well as spiritual healing). In more specialized ethnomedical systems where different health conditions are cured by different health specialists, one would expect a higher intra-community variation in medicinal plant knowledge and hence also in homegarden composition of plant specialists.

In chapters 3 (section 3.3.4.6.) and 8 (section 8.3.6.7.) we have shown that our medicinal plant data support the well-established fact that most use knowledge of medicinal plants is highly idiosyncratic (Friedman *et al*., 1986; Barrett, 1995; Alexiades, 1999; Casagrande, 2002). According to Casagrande (2002) it are particularly emic perceptions of efficacy and, to a more limited extent, frequency of use that appear to be the variables most responsible for the distribution of medicinal plant use knowledge (Casagrande, 2002). In other words, basically only plants that are perceived as more powerful medicines and/or are used most frequently have a higher chance of being known and used by a higher number of people, while the use knowledge of most other plants is generally idiosyncratic. This is, at least in part, confirmed by our homegarden data. Eight medicinal plant species (i.e. 10% of all cultivated medicinal plants) have been observed only in one Trinitario homegarden. In Yuracaré homegardens, only two plants with medicinal properties grew exclusively in just one garden. Therefore, it is our understanding that the type of ethnomedical system in a society partly determines the composition of cultivated medicinal plants.

Provenance

The provenance of both Yuracarés and Trinitarios has a significant effect on the composition of homegardens. As argued before, probably as a consequence of their historical semi-nomadic lifestyle in TIPNIS, Yuracarés rely proportionally more on the local wild flora for obtaining medicinal and food plants than Trinitarios. Trinitarios on the other hand brought along a considerable number of (medicinal) plants during their peregrinations, and introduced them to the study area. It is not illogical to expect that Mojeños in the plains of Moxos counted with a larger crop genetic diversity than Yuracarés. The Mojeños had an advanced agricultural society (see further) and such societies are known to accumulate crop genetic resources, both importing and developing them as part of their agricultural intensification (Clement, 1999a). Through years of interchange, the Yuracarés probably learned about the uses of some of these plants and adopted them in their own homegardens. In view of the still relatively short duration of their close contact, this process is most likely ongoing.

History of Contact

A growing number of ethnobotanists (Prance, 1972; Davis and Yost, 1983a; Balée, 1993; Estrella, 1995; Milliken, 1997a; van Andel, 2000; Voeks and Sercombe, 2000; Vandebroek *et* *al*., 2004b; Izquierdo, 2005) has provided evidence that supports the hypothesis that "*the longer the history of contact of a community with western civilisation, the higher the number of medicinal plants used, as well as the higher number of ailments treated*". In this context, Estrella (1995) used the term acculturation, instead of contact history, which is erroneous in our opinion. Although intercultural contact frequently leads to acculturation, it is not an implicit consequence of it. Trinitarios have a far longer and more intense history of contact with Western society as compared to the Yuracarés that participated in the present study, but the former tend to conserve their culture better than the latter. The lower number of medicinal plants used by less contacted groups contradicts the traditional image that they are the guardians of an extraordinary therapeutic arsenal. They do use medicinal plants, but their number is relatively small (Kohn, 1992).

While criticized by some (Plotkin, 1994), the underlying mechanism of *less contact parallels less medicinal plants* is attributed by most authors to the fact that a lower degree of contact goes hand in hand with a better nutritional status, as well as with a lower level of diseases afflicting a society due to a low population density, sometimes in combination with a (semi-) nomadic existence (Davis and Yost, 1983a; Alchon, 1991; Balée, 1994; Estrella, 1995; Milliken, 1997a; Voeks, 2004; Izquierdo, 2005). The first communications on the Amazon region by missionaries mentioned abundant indigenous societies composed of strong and healthy people (Meggers, 1976 cited by Paz, 1991; Clement, 1999a). Eder (1772) observed that the population of Moxos in his time was much less afflicted by illnesses than people in Europe and that as a consequence people knew remarkably few remedies. According to Balée (1994), the natural state of pre-Columbian Indians would have demanded few remedies for treating few diseases. This was confirmed by Alchon (1991) who noted that pre-Colombian America lacked many contagious diseases of the Old World such as measles, smallpox, bubonic plague, cholera and influenza. Ethnobotanical research among recently contacted groups has indeed shown that their principal health issues were related to basic parasitic-type infections and a narrow range of bacterial diseases (Davis and Yost, 1983a; Voeks and Sercombe, 2000). Medical studies among modern-day hunter-gatherers have also corroborated the healthy forager hypothesis (Voeks, 2004).

It is suggested that introduction of epidemiological ills, initiated during the Conquest, has led to the development of ample pharmacopoeias among indigenous groups with longer contact histories (Balée, 1994). The need to "discover" new remedies for new diseases may have fuelled the assignment of medicinal applications to plants species that were formerly unknown, known only by name, or known for other purposes (Estrella, 1995). Milliken (1997a) argued that the number of plants and recipes to treat illnesses depends on the length of time a certain indigenous group has been exposed to these diseases, and the seriousness of the health consequences of these epidemics. He found that tribes in Roraima which came into contact with malaria longer ago knew more plant species to combat this infection than groups that became afflicted only recently (Milliken and Albert, 1997; Milliken, 1997a). Also, the prevalence of health conditions has been linked to the number of plants used to treat them (van Andel, 2000; Vandebroek *et al*., 2008).

This hypothesis corroborates our findings that Yuracaré medicinal plant use is significantly smaller than that of Trinitarios. The Yuracarés that live in the study area have a far more recent history of intensive contacts as compared to Trinitarios. Although the first reference made to Yuracarés dates from 1584 (Kelm, 1966; Nordenskiöld, 1924), they remained uncontacted until 1768 (Viedma (“*Informe de la provincia de Santa Cruz*”), cited in Church, 1912; Miller, 1917 and d’Orbigny, 1958). Even then, this contact was restricted to the margins of the Yuracaré habitat, especially along the rivers Mamore and Chapare (Richter, 1930a). Franciscan missions were developed but without the desired success. They never reached the heart of the region inhabited by Yuracarés and those communities that could be reached were (often violently) persuaded to live in the missions. However, Yuracarés abandoned these missions after a few years to resume their old customs (Richter, 1930a). The area enclosed by the rivers Isiboro and Securé (i.e. our study area) never became affected by Franciscan missions (Richter, 1930a; Paz, 1991; Querejazu, 2005a). As a consequence, the Yuracarés from TIPNIS greatly conserved their independence and traditional life style until the initiation of colonization waves by Trinitarios and highland settlers (Paz, 1991; Paz *et al.*, 1995; Querejazu, 2005a). In fact, the migrations of highlanders to the Bolivian lowlands occurred in three major waves, the first and the second being initiated during the first decades of the twentieth century and the 1960s, respectively. Yet, the first settlers entered TIPNIS no sooner than during the third migration wave, towards the end of the 1970s (Querejazu, 2005a). This immigration coincided with the inauguration in 1970 of the road that traverses the southern part of TIPNIS (Paz, 1991; Lilienfeld and Pauquet, 2005). This road connects Isinuta with our research area and still is the principal transport route in the southern part of the park up to date (see figure 1.2 in chapter 1). The colonist invasion was legalized in 1966 through the Bolivian “Law of Colonization” (Art. N107765) that declared the lands of the Amazon as uninhabited and open for colonization (Becker and Leon, 1998). Fortunately this law was promulgated later on (around 1991), following a period of political unrest nourished by Bolivian indigenous Amazonians.

The contact history of Trinitarios is much more copious. Already in pre-Hispanic times, the Mojeños maintained interethnic relations with many different societies (Denevan, 1980; Plotkin, 1999). Just like the early Romans, they had built out a network of tens of thousands of linear kilometres of embankments of causeways. These were used for travel on foot and during the wet season when the pampa is flooded, in combination with travel by canoe. During at least part of the dry season, canoes made use of the canals excavated at one or both sides of the embankments. It is very probable that in addition to various intra-ethnic purposes these “roads”, were used to maintain interethnic contacts, alliances etc. (Erickson, 2000a). The first Jesuitical contact was established in 1595 and Moxos became a Jesuit province for 100 years (1667-1767), during which the Mojeños were concentrated in missions together with other ethnic groups of distinct languages (Lehm, 1999). During this time, the Fathers instructed the indigenous peoples in new technologies and cultivation of European crops.

In 1686, the Jesuits introduced cattle to the region (Plotkin, 1999). They fostered among the Mojeños a dependence on cattle for both meat and hides, and probably a corresponding reduction in their dependence on wild game and fish (Block, 1980). When the Jesuits departed from the region (1768) the Mojeños were already transformed from a “Tribal Indian” to a “Modern Indian” type of culture (Wagley and Harris, 1968, cited in Wagley, s.d.). The original Jesuit missionary culture maintains itself largely among present day Mojeños (Lehm, 1999). Up until about 1850, the Mojeños either owned cattle or hunted freely from the numerous wild herds – a legacy of the Jesuits – that had multiplied and roamed the savannahs. An increasing demand for hides in Brasil led to the "period of massive cattle slaughtering" to which the Mojeños responded by large scale dispersion, away from the former mission posts (Lehm, 1999). These developments contributed to the initiation of massive migrations by Trinitario in the search for the "Holy Land" or *Loma Santa*. This messianic movement started in 1887 and would last until the last decade of the past century (Riester 1976; Lehm 1999).

Another major migration wave was initiated after a rather similar triggering economical evolution. With rising beef prices in the highlands and the availability of cheap, leftover United States warplanes for transport in the early 1950's, the cattle of Moxos suddenly came to have commercial value on a grand scale. The prospect of quick wealth again led to the immediate roundup and indiscriminate slaughter of wild cattle by "white" ranchers, as well as to forceful taking of cattle owned by Mojeños. This process was legally consolidated through the agrarian land reform of 1953, which played largely in favour of ranchers (Lehm, 1999). As a general consequence, the Mojeños that had not yet migrated were forced into a subsistence role again while trying to escape from land pressure problems associated with increasing number of ranches and cattle (Denevan, 1963; Wagley, n.d., Lehm, 1999). The stress induced by these events was perhaps best reflected in the resurgence of the messianic movement (Lehm, 1999). The Mojeños were faced with two choices: flee or face annihilation. The Trinitarios that established themselves in TIPNIS chose for a full-blown tropical forest adaptation, which basically led to the reverse transformation or "devolution" from "Modern Indians" to "Tribal Indians" again (Wagley, n.d.; Lehm, 1999). Similar processes whereby particular societies were expelled from certain habitats for any reason (e.g. warfare) have led to "devolution" from horticultural societies to hunter-gatherers throughout (pre-Columbian) history (Lathrap, 1968; Balée, 1994). The Mojeños did, however, largely manage to retain their horticultural practices.

Another consequence of intercultural contacts is that "foreign" cultivated medicinal (and non-medicinal) plants were introduced into existing pharmacopoeia (Milliken *et al.*, 1992; Milliken, 1997a; van Andel, 2000; Begossi *et al.*, 2002; Hanazaki *et al.*, 2006). According to Voeks (2004), intercultural contacts with European settlers and physicians some five centuries ago led to an early but systematically underestimated (intentional and accidental) floristic homogenization of many rural tropical societies' pharmacopoeia. Useful plants from the Old World were actively and passively distributed over the New World tropics and subtropics as a consequence of colonial horticultural endeavours. Clement (1999a) interprets the high numbers of introduced cultivated species as the result of crop genetic erosion of local species that followed the decline of the indigenous population after 1492.

Most plants were introduced originally as foods or ornamentals and relatively few for their exclusive medicinal value. Through an ongoing process of ethnomedical experimentation, the medicinal power of many ornamentals and food plants were and most likely still are being "discovered" (Bennett and Prance, 2000). The fact that the dichotomy between food and medicines is largely absent among (South American) indigenous and rural populations (Etkin, 1994; Moerman, 1994; Bennett and Prance, 2000; Voeks, 2004; Vandebroek and Sanca, 2006), may have played a beneficial role in the discovery of new herbal medicines. As a result, the pharmacopoeias of societies with long histories of contact contain numerous introduced plant species (Voeks, 2004; Thring and Weitz, 2006). Again this argumentation corresponds with our observations. Trinitarios use more than three times as many introduced plant species as medicines than Yuracarés. Of the cultivated plants for which Trinitarios named more medicinal uses than Yuracarés, 12 species are introduced, while none of the plants with more medicinal uses among Yuracarés is introduced.

Today, introduced plants play a significant role in South American pharmacopoeias (Sumner, 2001). Bennett and Prance (2000) listed 216 introduced plant species that are currently used as medicines. In the present research, only 7% of all recorded medicinal plants are introduced and the medicinal use value of introduced managed plants is equal to that of native managed plants. However, our data support Bennett and Prance's (2000) observations since the majority of introduced species with a local therapeutic value (21 species; 72%) have an additional food or ornamental value ((16 species or 55% and 5 species or 17%, respectively). Moreover, the ornamental use value of introduced managed plants is significantly higher than that of native managed plants in Yuracare and Trinitario homegardens and swiddens. One species that originally was introduced for its ichthyotoxic (*Tephrosia vogelii*) properties is also being used as an herbal medicine (Thomas and Vandebroek, 2006).

Intriguingly, the opposite phenomenon of *less contact parallels less medicinal plants* is observed for food plants. Communities or societies with a more limited contact history use the forest as an important food repository. On the other hand, wild food dependence would diminish with growing contact with the western world and its food culture (Davis and Yost, 1983a; Estrella, 1995; Ladio, 2001). Our findings indeed show that Yuracarés have a far more extensive knowledge of wild food plants than Trinitarios, which is basically the consequence of their much more profound knowledge of the wild edible flora.

(Historical) Mode of Subsistence

Not only contact, but also the mode of subsistence has consequences for the breadth of indigenous pharmacopoeias. It has been demonstrated that cultivating societies maintain significantly larger pharmacopoeias than their foraging counterparts due the wider range of manifesting illnesses (especially viral crowd diseases) (Brown, 1985; Voeks, 2004) and because high population densities are favourable for the rapid spread of epidemics (Alchon, 1991). If this is true, it could mean that Trinitarios always have had larger pharmacopoeias, or at least during the past centuries. Denevan (1980) identified the Beni (Moxos) savannas of Bolivia as one of the cradles of the most advanced pre-Colombian societies of the Amazon basin, together with the Brazilian coast and the *varzea* of the great Amazonian rivers. The Mojeños were considered one of the most advanced tribes, with a well-developed agriculture, control of the major river systems, a complex social structure, and large populations (Denevan, 1980; Erickson, 2000a; Bert *et al.*, 2004). At the time of first contact, they had domesticated ducks and practiced swidden agriculture by means of stone axes, in combination with plantations on artificially elevated plains (Erickson, 1980; Denevan, 1980). The first explorers mentioned corn cribs on pilings, numbering up to 700 in a single field, each holding 30-45 bushels of food (Denevan, 1980). Many references confirm the high population density of the plains of Moxos at the time of contact (Block, 1997; Lehm, 1999). Jesuit sources reported that several tribes inhabited Moxos. In 1696, father Eguiluz counted 19,760 Arawakan-speaking people living in Jesuit missions along with 70,000 other natives. He described more than 15 ethnic groups in a small area, all speaking distinct languages (Gantier, 1991, cited by Bert *et al.*, 2004). A few years earlier, father De Castillo (1676, cited by Santamaria, 1994) had distinguished 18 Mojo subtribes.

Evidence of the highly diverse population of Moxos is still present in the genetic material of present day Mojeños. Based on mitochondrial DNA analysis, Bert *et al.* (2004) suggested that the contemporary Moxos populations may result from the aggregation of a high number of Arawakan-speaking populations 'reduced' by the Jesuits in the sixteenth century. When taking moreover in account the cattle introduced by Jesuits as livestock, the Mojeños almost completely match the requirements (agriculture, high densities) as a focus of infectious diseases. After all, farming was and is, according to Diamond (1997), a "bonanza for our microbes" (cited in Voeks, 2004). All together, this historical evidence could even have played a role in the development of Mojeños' specialized ethnomedical system.

On the other hand, Yuracarés are known for their semi-nomadic horticultural practices, and they never lived in large communities. The social organization of Yuracarés was based on large families ("familia grande"), grouping up to ten independent nuclear families (Paz, 1991; Querejazu, 2005a). From a historical viewpoint, Yuracaré territory was inhabited by large families in a very scattered manner (Paz, 1991). As opposed to the Trinitarios, the single ethnic origin of present day Yuracarés is reflected in their genetic material (Bert *et al.*, 2004). These characteristics suggest that Yuracarés preferentially would correspond with the healthy forager profile and hence used a reduced number of medicinal plants. In addition, this might not be valid for the number of medicinal plants used alone, but also for the number of uses per plant. Balée (1994) suggested that "the lack of agriculture among foragers in Amazonia implies much more than a lack of domesticates per se. In ethnobotanical terms, it means *fewer uses* for plants also".

10.5. Conclusions

In this chapter, principal plant management techniques used by Trinitarios and Yuracarés from the southern part of TIPNIS have been discussed. Based on some specific examples, and in accordance with the general literature base on this topic, we have demonstrated that conservation ethics are not (always) of primary concern to Yuracarés and Trinitarios when harvesting wild plant species. While unsustainable harvest practices might actually be leading to local extinctions of particular species, overall current land-use practices are expected to be less harmful and are part of the process of humanization of the Amazonian landscape, in a similar way as it has been occurring throughout history.

Also, in this chapter we have brought forward support for the hypothesis that the usefulness of plants co-varies with their accessibility by demonstrating that plants growing in anthropogenic disturbance environments are perceived as more useful to people than plants from undisturbed habitats. Especially Trinitarios rely significantly more upon disturbance habitats for obtaining medicinal and food plants than Yuracarés. Obviously, the anthropogenic environment owes it higher usefulness largely to the plants that are managed in them. Nonetheless, also unmanaged plants that grow in anthropogenic landscapes proved to have a higher mean medicinal usefulness than plants from undisturbed habitats. The number of useful native and introduced plant species that are managed (i.e. cultivated and tolerated) in Yuracare and Trinitario homegardens and swiddens is relatively high, though not exceptional. The basic reasons for managing plants relate to their use as sources of herbal remedies, food and material and environmental services. The majority of managed plants are herbs and trees. Yuracarés and Trinitarios tend to manage perennial (tree) species principally for their higher usefulness as food and materials, and herbs for their higher therapeutic potential.

Our findings repeatedly demonstrated that Trinitarios know the plants that are managed in homegardens and swiddens better than Yuracarés. The former reach higher consensus and/or ascribe more diversified uses to these plants. Trinitarios use significantly more introduced (medicinal) species and are also more knowledgeable about the therapeutic value of both wild and managed medicinal plants. All medicinal plants managed in homegardens by Yuracarés are also managed by Trinitarios, whereas the opposite is not true. An inverse observation was found for food plants. Yuracarés assign higher mean food use values to plants, regardless of the management status of these plants, but they excel particularly in their knowledge of the edible wild flora. These observations add value to the growing body of evidence in literature that the duration of contact history of a particular ethnic group with western society correlates positively with the number of medicinal plants they use, as well as with the range of health conditions that are treated with medicinal plants. The opposite is believed to be the case for wild food plants and we can confirm this claim. Indeed, in the present study Trinitarios have a much longer history of contact than Yuracarés who have a contact history of approximately 35 years.

However, considering contact history as the only principal factor to explain differences in plant use and knowledge would be too limited for the case of our study population. We have put forward several other factors. Some plants and/or their uses simply represent the cultural patrimony of either one of both ethnic groups, whereas other plant uses are related to their particular worldview and/or ontology. In the present study, some differences in plant uses are also related to the different ethnomedical system of Trinitarios and Yuracarés, respectively. Historical evidence suggests that the ethnomedical system of Trinitarios was more specialised than that of Yuracarés, a difference that persists until today.

Finally, we hypothesized that also provenance and historical life style or mode of subsistence are significant factors for explaining variation in plant knowledge between Yuracarés and Trinitarios. Until some 35 years ago, the Yuracarés from TIPNIS lived in groups of maximum 10 families and engaged in a semi-nomadic lifestyle throughout TIPNIS (one of their traditional habitats). Therefore, Yuracarés have a higher knowledge of the local wild (edible) flora and match the ‘healthy forager’ profile described in literature. By contrast, the traditional homelands of Trinitario people are situated in the plains of Moxos in the Beni province that neighbour the forest habitat of TIPNIS. The Moxos plains have a significantly different vegetation cover than TIPNIS and consequently Trinitarios do not know the wild flora quite as well as Yuracarés. But what is more important, is that Trinitarios have had a sedentary agricultural lifestyle from pre-Columbian times that allowed them to maintain high population densities. From advanced agricultural societies it is known that they accumulate crop genetic resources, which would explain, at least in part, why Trinitarios possess higher knowledge of cultivated and introduced plants. Also their remarkably higher knowledge of (managed) medicinal plants, as compared to Yuracarés, can be related to this historical lifestyle. Literature has demonstrated that agricultural societies with high populations maintain significantly larger pharmacopoeias than their foraging counterparts due the wider range of illnesses (especially infectious diseases) manifesting themselves in these living conditions. In this respect, the introduction of cattle by Jesuit missionaries to Moxos in 1686 may have increased the incidence of infectious diseases and therefore contributed to stimulating the establishment of an extensive pharmacopoeia among Trinitarios.

11.

Susto Aetiology and Treatment According to Bolivian Trinitario People: a “Masters of the Animal Species” Phenomenon[1]

11.1. Introduction

Since its first description in English by Gillin (1945), much has been written on *susto*, a Latin-American folk syndrome which has generally been documented to be related to acute fright (Uzzell, 1974; O’Nell, 1975; Klein, 1978; Rubel *et al.*, 1984; Weller *et al.*, 2002). However, most publications on *susto* are focused on Central America (especially Mexico) and Peru, whereas relatively few studies addressing the theme have been reported from Bolivia (with the exception of Crankshaw, 1980; Bastien, 1987a; Crandon, 1983 and 1989; Hollweg, 1997; Absi, 2004). Nevertheless, s*usto* has been called the second most commonly recognized illness in Bolivia, after liver ailments (Bastien, 1987a). The goal of this paper is to contribute

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[1] This chapter has been submitted for publication in *Medical Anthropology Quarterly* in a shortened form and under the same title.

to bridging this gap by examining *susto* aetiology and treatment for contemporary Trinitario people.

Trotter (1982) distinguished three categories of literature on *susto*: 1) conventional ethnographic descriptions of the disorder; 2) a focus on the cause(s) of *susto* from a socio-cultural, psychological, psychiatric and/or biological perspective; and 3) studies into the epistemology of *susto*. Our own observations from the Trinitario study population fall within the first category, but in this chapter, we will also attempt to address our own research results in the framework of literature from the second category. As such, we start this chapter with a condensed literature review on the two central themes: *susto* and the "masters of the animal species". Next, we present our own research findings in relation to the importance, aetiology and treatment of susto. In conclusion, these findings are compared with and discussed in the framework of relevant information from the literature.

11.1.1. *Susto*

Aetiology

From an aetiological viewpoint, *susto* is cross-culturally most accepted as a folk illness that derives essentially from the loss of the essence known as *alma* (soul), as a consequence of a frightening event (Rubel *et al*., 1984). Although this viewpoint may have become less germane in urban environments (Glazer *et al*., 2004), it is still highly relevant for numerous rural and suburban settings in Latin America. For example, according to Absi (2004), nearly *every* Bolivian miner in Potosi has suffered at least once in his life from *susto*, as a consequence of a startling event, such as a falling stone or a sudden sound. Apart from fright, there exist other aetiological factors that are believed to induce *susto*, such as evil eye, bad wind, witchcraft, being "grabbed by the earth", and even exposure to pesticides (Kiev, 1972; Baer and Penzell, 1993; Greenway, 1998).

Classification and Symptoms

Presumed to be of pre-Columbian origin (Castro and Eroza, 1998), *susto* is considered a folk illness and classified as a "culture bound syndrome" (Hollweg, 1997). Up until now it has not been recognized by most allopathic practitioners as a distinct disease entity in strict biomedical terms (Tousignant, 1979; Rubel *et al*., 1984; Castro and Eroza, 1998; Weller *et al*., 2002). However, *susto* is a well-recognized disorder with a well-established aetiology, diagnosis and regimen of healing and it represents real pathologies (Waldstein and Adams, 2006). Rubel *et al*. (1984) have demonstrated how patients whose clinical diagnosis included *susto* would be more likely to die as a result of their condition, since they were significantly more afflicted by a cluster of systemic symptoms than other patients who did not suffer from the disorder. Although perception and experience of *susto* vary between cultural groups, villages and even among residents of the same village, there appears to be consensus about the main symptoms in those who suffer from the illness. These symptoms include physical complaints, such as weakness, somnolence, loss of appetite, fever and diarrhoea, as well as emotional complaints such as depression (Castro and Eroza, 1998).

Distribution of Susto

The consistency of *susto* appearance across otherwise distinctive cultures is impressive (Rubel *et al.,* 1984). Folk illnesses are generally not considered universal, but instead linked to particular cultures (Stein, 1981). *Susto* clearly makes the exception. Instead of being restricted to a well-defined population sharing a common language, or to a singular cultural background, it is found across many cultural groups in Latin America (Kiev, 1972; Bastien, 1987a; Rebhun, 1994). Moreover, similar characteristic conditions have been reported from the Philippines, India, China and Taiwan (see literature review by Rubel *et al.,* 1984). Holloway (1994) even showed how *susto* has the capacity to transcend mere traditional environments and manifest itself in modern societies and highly industrialized contexts.

Scientific Explanation: Psychological or Biomedical?

A number of scientific research efforts on folk illnesses have assumed that these disorders are psychiatric or psychological in nature (Pages Larraya, 1967), hereby ignoring the involvement of organic malfunctioning even when biomedical symptoms were observable (Kiev, 1968; Houghton and Boersma, 1988). It cannot be ruled out that in some cases emotional or psychological experiences may be causal factors of disease, especially since experiencing illness is a social product, whereby social, cultural, spiritual, cosmological and other worldview-related factors play a central role in shaping individuals' subjectivity (Hollweg, 1997; Greenway, 1998; Castro and Eroza, 1998).

In the case of *susto*, the frightened individual is aware that experiencing fright will probably result in illness, and therefore (s)he might seize upon any general and slight symptom of discomfort, especially when (s)he is publicly diagnosed by a local healer. The mere existence of a condition that is culturally recognized and shared among all members of a community or ethnic group precipitates an expected pattern of reactions (Foster, 1953; Uzzell, 1974). Stein (1981) remarked how in Vicos, a rural community in the Peruvian Andes, nearly every health problem could locally be diagnosed as *susto* when there existed any indication of a frightening experience in the patient's past history. O'Nell (1975) concluded that patients from his study population who were convinced to suffer from *susto* often believed their illness must have resulted from fright. Crankshaw (1980, cited by Kohrt *et al.,* 2004) drew this even further and provided an example of how entire groups can be negatively impacted by socio-cultural change by linking *susto* among *mestizos* in Bolivia to formal political changes that occurred after the 1952 *Movimiento Nacional Revolucionario*. Several scholars (*e.g.* O'Nell and Selby, 1968; Uzzell, 1974; Rubel *et al.,* 1984) have started from the hypothesis that in the mind of the individual *susto* is a kind of socio-cultural construction that permits a temporal escape from a stressful situation (provoked by social stress, role model expectations…) that is believed to have precipitated the disorder. Rubel *et al.* (1984) have shown the validity of the association between *susto* and a person's perception of his inadequacy to perform particular social roles for three Mexican societies.

For those who believe in the psychological nature of *susto*, recovery would be strictly psychological rather than biomedical (cf. Millones, 1979, cited by Stein, 1981). However, in the same investigation, Rubel *et al.* (1984) showed that *susto* patients also suffered from an uncommonly heavy burden of biological disease. Thus, rather than electing a sick role to escape from their obligations, people with *susto* are often forced to withdraw from daily routine because of the heavy load of symptoms that afflict them.

The latter observation contributes to the biomedical explanation of *susto*, which has been gaining importance from the late nineteen seventies onwards. One year after Bolton's (1981) proposition to "translate" *susto* into the western medical concept of hypoglycaemia, Trotter (1982) was among the first scholars, together with Klein (1978) to attribute a physical cause to the manifestation of *susto*. Trotter (1982) even suggested that the disorder could actually be a complex set of closely related ailments, as opposed to a single ailment. The latter author based his conclusions upon the mainly ethnopharmacological nature of *susto* treatment (mostly herbal teas, but also ingestion of sugar, vinegar and/or salt water) within the population sample of his study.

Hence, depicting *susto* as a form of unique socio-cultural behaviour on the one hand, or as a purely biomedical phenomenon on the other, may be inadequate and inappropriate (Rubel *et al.,* 1984). Most likely, it is caused by a combination of both social and biological factors. Klein (1978) described *susto* as the product of the complex interaction between the individual's state of (physical) health, the social (cf. role expectations) and cultural system in which (s)he lives, and the individual's personality.

11.1.2. Masters of the Animal Species

Since literature has demonstrated how *susto* aetiology can be strongly related to the particular worldview (*Weltanschauung* or *cosmovisión*) of an ethnic group, we will first introduce the hunter worldview from a literature perspective before presenting our own research data.

A general characteristic shared by many Amazonian hunter-gatherer societies is their hunter worldview. The latter is fully integrated into the animal world, whereby humans and animals engage in the "mutual production of each others' existence" (Tomasini, 1969-1970; Tapper, 1988). Hunter-gatherer societies represent the principles of communalism (cf. Pálsson, 1996), characterized by a lack of separation between nature and human society, and a generalized reciprocity in human-environment relations, an exchange that is often metaphorically represented in terms of intimate, personal relationships (Pálsson, 1996). The qualities of the hunter *Weltanschauung* might be best understood as: "*the thoughts of the hunter are focused on the animal – more precisely the prey – which (especially in ancient hunter times) constitutes his only means of existence, while simultaneously also being the hunter's rival that can withdraw itself from the attack through escape or defense*" (Tomasini, 1969-1970, our translation).

Starting from colonial times, the contact with Western society has drastically accelerated the transition from hunter-gatherer to agricultural societies. The subsequent transition from hunter to agricultural *Weltanschauung* does, however, not always seem to hold the same pace. Krickeberg (1922) was one of the first to notice that South American ethnic groups that practice small-scale cultivation are still completely immersed in the hunter *Weltanschauung*. This observation is supported by Zerries (1951) who states that the most important of all mixed cultural practices in South America is based on the replacement of the hunter patrimony by cultivation customs. However, according to the latter author, the nature of this replacement is essentially economic and to a lesser extent based on worldview or *Weltanschauung*. Many Amazonian tribes (especially those with shamanistic traditions – Chaumeil, 2000) indeed show a strong hunter component in their spiritual culture, which often occupies an inverse relationship to the actual economic significance of hunting in the respective communities (Zerries, 1951; La Barre, 1974).

One aspect of the hunter *Weltanschauung* that is of particular interest to our discussion is the concept of "masters or owners of the animal species" ("*dueños de los animales*" in Spanish), i.e. the spiritual divinities that are hierarchically positioned above the individual animal spirits (exhaustively described in Zerries, 1951 and 1954). Zerries uses the term "masters of the animal species" to distinguish it from "master of the animals"; the latter entity being the superior possessor of power and control over *all* the animal species that populate the forest (cf. Rosengren, 2006). By contrast, "masters of the animal species" are the specific owners or masters of all individuals of *one* particular animal species. The "masters of animal species" concept was and still is quite widespread in South America (Zerries, 1954; Auerbach *et al.,* 2004). Its philosophy is shared by Amazonian tribes as well as by Andean societies like the Aymara and Quechua people (Zerries, 1951). In most cultural groups, the masters of the animal species are protective spirits that protect a particular forest animal species. They are believed to hurt or even able to kill hunters that excessively kill their protégés (Zerries, 1951).

When interpreting Descola's (1996) line of thought, the concept of "masters of the animal(s) (species)" is to be situated within an "animic or animistic system". According to the latter author, "such systems endow natural beings with human dispositions and social attributes. They do not exploit the differential relations between natural species to confer a conceptual order on society, but rather use the elementary categories structuring social life to organize, in conceptual terms, the relations between human beings and natural species."

11.2. Methods

Research was conducted in the Trinitario communities of San José de la Angosta and El Carmen de la Nueva Esperanza that are situated in the Territorio Indigena Parque Nacional Isiboro-Sécure (TIPNIS) (Figure 11.1).

General ethnographic information on *susto* was obtained during semi-structured ethnobotanical interviews about collected plant species with eleven Catholic Trinitario participants who are locally respected for their high plant knowledge. Plant species were collected according to the methods described in chapter 6. Plant use information was obtained by means of the ethnobotanical interview techniques discussed in chapter 7 (Thomas *et al*., 2007). Participants were selected through peer referencing (Davis and Wagner, 2003). With six of these participants, more familiar relations were established and open-ended interviews were conducted, yielding more detailed information on the local meaning of *susto*. These six key participants comprised one male shaman (locally called *sobandero* (Spanish) or *tkonñahi* (Trinitario, cf. *conña'i* mentioned by Villavicencio, 1992; see chapter 8), four female herbalists and midwives, and one village elder. Additional information on *susto* aetiology and treatment was obtained through participant observation (Alexiades 1996), and during healing ceremonies and casual conversations.

Posterior to the semi-structured plant interviews, local salience of *susto* was evaluated during a short household survey in both communities. The male or female household head, or both parents (according to presence at the time of interviewing), from twenty households (representing all houses that were actually inhabited at the time of survey in San Jose (12) and El Carmen (8)) were asked to spontaneously mention through free listing (Alexiades 1996:64) those disorders or illnesses they considered most important and/or serious to afflict their family.

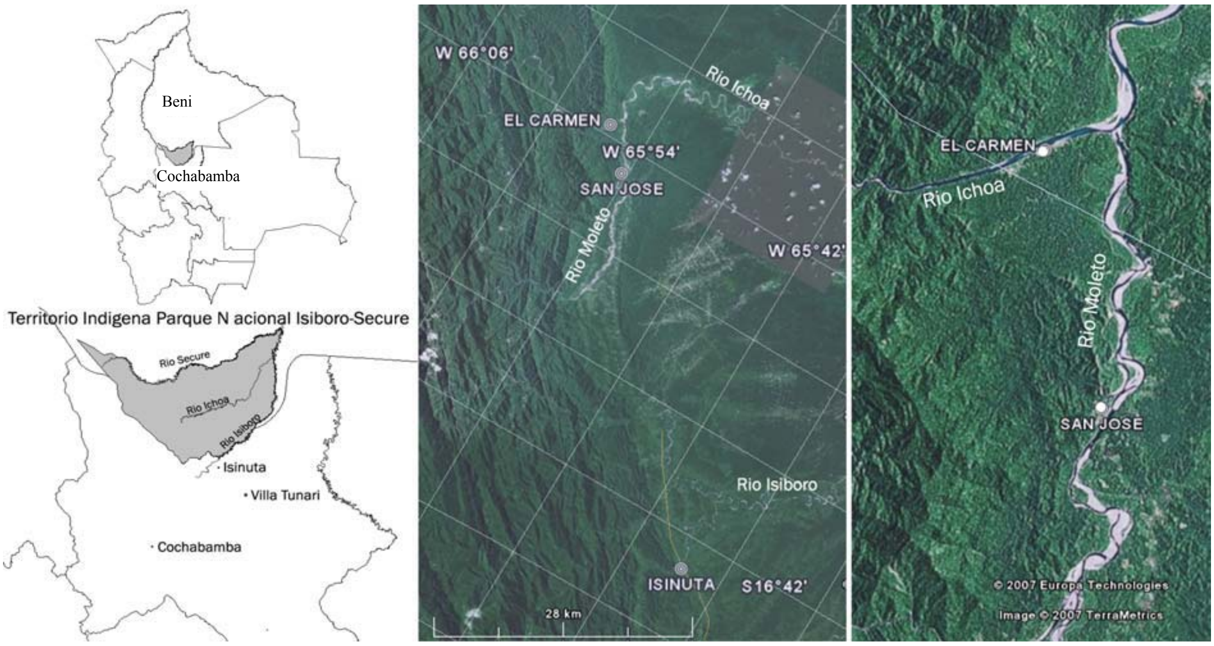

Figure 11.1: Upper left side image: location of TIPNIS in Bolivia. Lower left side image: location of TIPNIS and its main rivers on the interface between the Beni and Cochabamba departments. Villa Tunari and Isinuta are the successive main access villages to the southern part of TIPNIS. Middle image: satellite image of the research area with participating villages (El Carmen and San Jose), main rivers (Rio Moleto, Rio Ichoa and Rio Isiboro) and location of Isinuta. Right side image: Close-up of middle image (Google Earth, 12/03/2007).

11.3. Results

11.3.1. Local Salience of *Susto*

The results from the household survey in both communities provide an estimate of the relative local salience of *susto*. Participants free listed 4.7 (±1.5) illnesses or illness symptoms on average. Eight out of twenty households reported *susto* among these disorders. By order of importance, *susto* ranks fourth on a total of twenty-three disorders enumerated, after fever (14 out of 20 households), cough (11) and diarrhea (10).

11.3.2. Trinitario Ontology and Role in *Susto* Aetiology

Trinitario people believe that every living person has three souls (*almas*), also called shadows (*sombras*), or *animos* ("that what animates people"). The terms *alma* and *animo* are utilized to a limited extent, while *sombra* is in fact the predominant Trinitario term to address "the essences" that are associated with the physical body. One shadow is believed to occur in front of the body, one coincides with the body and one is situated behind the back. Each of these three shadows can become detached from the body through theft by a variety of spiritual beings that are associated with animals and different units of the natural environment. The disorder associated with the loss of one or more shadows or souls is locally called *tkovekuna* (Trinitario)*, desombro* or *susto* (both Spanish). For reasons of uniformity, we will continue to use the term *susto* throughout the text.

When the first shadow or soul – always the one in front – is lost, symptoms are rather limited. According to participants, the patient is weaker than normal and more susceptible to further soul loss. Children, who get deprived of their first shadow, typically fall on the ground unexpectedly without any apparent reason. When the second shadow or soul – always the one behind the back – is lost, the patient is afflicted by (severe) fever. (S)he feels weak and has difficulties getting out of bed. The situation gets really serious when one gets deprived of the third and last shadow – the one that coincides with the body. If and when this happens, exhausting heavy diarrhoea and vomiting impair the patient. According to local beliefs, at this stage, treatment is extremely urgent in order to avert death. Additional symptoms mentioned by participants, especially for the case of (small) children include white eyes, excessive crying, excessive thirst and restless sleeping. In some cases, patients suffer from oedema after being subjected to a water-curse (cf. chapter 8, section 8.3.11.).

Although it was not the purpose of our study to identify what section of the population is at greater risk for *susto*, locally it is regarded as a typical child's disease. Adults, and principally elder people, also seem to be susceptible to *susto*, but to a far lesser extent. Key participants declared that people who hunt excessively have a higher chance to bring *susto* upon themselves or their relatives.

Until today Trinitario people from the participating communities have a profound distrust of biomedical heath care workers and some modern medical services. Trinitario people do insist on receiving frequent visits from medical doctors from the city of Cochabamba for the treatment of common ailments such as cough, common colds, intestinal parasites, yellow fever... However, folk illnesses are believed to require treatment by *sobanderos*, *curandero(a)s* or other traditional healers in order to be successful. In such cases the expertise of biomedical doctors is completely set aside. We illustrate this with the following observation we made in San José de la Angosta in February 2006:

> One morning, the eight months old son of a local Trinitario schoolteacher became sick. The infant was diagnosed with *susto*. His father had acted imprudently a few days before. After killing a snake, he had hung it up nearby his house instead of throwing it away. The master of the snake was believed to have collected the boy's shadow. The boy's state of health was deteriorating rapidly. At that time, a group of medical doctors had arrived from the city of Cochabamba to provide general medical assistance and vaccinations. Two doctors were allowed to see the baby and noticed it was severely dehydrated. They wanted to restore its body liquids by means of an infuse, but were not allowed to proceed. Initially, the father had hesitated, but had finally been convinced by a local *curandera* and other community members to decline the doctors' treatment. The local herbalists tried to save the infant by bathing it in

aromatic decoctions and through the administration of herbal teas, but without result. A day later, the child passed away.

11.3.3. The Culprits

The Trinitario people who participated in the present study distinguish (at least) three different types of spiritual beings that are shadow- or soul-catchers: (1) masters of the animal species; (2) *takúna'i;* and (3) *'chanekuna.* Trinitarios believe that every animal species has a specific owner or master. According to local perception, "masters of the animal species" are what a rancher is to his herd of cows, horse, sheep, etc. There exists a different rancher for each animal species: a rancher for cows, another one for sheep, etc. When a Trinitario kills an animal (fish, bird or land animal, including domesticated ones), its owner or master can get upset and take revenge by collecting one of the hunter's or his kinsmen's shadows, just like a rancher would harm or kill a predator that damages his animal stock. The masters of some animal species are more vindictive than others. Masters of snake species for example locally belong to the most feared ones. In all of our key participants' families, at least one of the children had developed *susto* at some point in life after one of the parents had killed a snake. Trinitario people believe that when the master of a wild animal species has stolen someone's soul, the latter master will approach during the night to disturb the patient's sleep. This explains why people who suffer from *susto* sleep restlessly. Babies in particular can cry all night.

'Chanekuna and *takúna'i* are spirits that inhabit different units of the natural environment. They are the spiritual owners of such natural elements as a river patch, a forest, a hill or a lake. Based upon declarations from participants, we have not been able to conceptualize the difference(s) between *'chanekuna* and *takúna'i*. Both types of spiritual beings can shock or frighten people who pass by their "property" and consequently take away one of their souls. An unexpected fall often accompanies this shocking event. *Takúna'i* are also believed to be able to kill people by appearing to them in their dreams.

However, not only spiritual beings are believed to cause harm to people. Even human beings can be responsible for "un-shadowing". Especially children are susceptible to being "shocked" by humans, including by their own parents.

11.3.4. The Diagnosis

The period between the killing of an animal and the revenge by its master is very variable and can range from days to weeks. As a consequence, it is often quite difficult for laypeople to reveal the identity of the animal that stole one's shadow. Only *sobanderos* or *tkoñña'i,* Trinitario traditional and spiritual healers are believed to be able to expose the malefactors through their connections with the spiritual world. However, in recent years a "magical" mineral, locally called *millo* (identified as chrysotile (a kind of asbestos), $Mg_3Si_2O_5(OH)_4$, J. Salomez, pers. comm.), can be bought in small grocery shops that are managed by colonist highland farmers. The asbestos mineral is sold freely in the city market of Cochabamba as well, specifically for *susto* treatment. Use of *millo* for treating *susto* is well known among

Quechua people. Therefore, Trinitario people may have learned about its use through contacts with colonist highland farmers.

Millo is believed to have the power to uncover the identity of the shadow-thief by absorbing and representing its characteristics. Small bits of the fibrous mineral (figure 11.2, left side image) are therefore wrapped in pieces of cloth, bound around one of the patient's body parts like torso or abdomen and left there for about an hour or two. Afterwards, these pieces are heated in a fire, causing them to puff up. The resulting swollen, brittle figures are subsequently painstakingly interpreted to identify the shadow-thief(s) in their forms (Figure 11.2, right side image). For example, in the case of the master of a snake species, part of a figure will show a bulging tubular form. However, not only animals are represented by *millo*. When a child has been shocked (*asustado*) by a person, the image of that person will somehow be present in one of the swollen figures. In case the responsible spirit for the shadow or soul loss is the owner of a river patch (water-curse, caused by *'chanekuna* or *takúna'i*), the burned mineral will show something that is related to water such as a canoe.

Figure 11.2: Left side image: *millo* (chrysotile, $Mg_3Si_2O_5(OH)_4$); Right side image: figure in front left represents jochi (*Cuniculus paca* or *Dasyprocta agouti*), front right a dog and back right a wild swine (*Tayassu pecari* or *T. tajacu* (Emmons and Beer, 1999) (the figure in the back left was not identified)

Diagnosis of *susto* is always more difficult for small children since they are unable to explain where it hurts. In this case, the use of *millo* seems to be a prerequisite to identify the culprit and safeguard the victim's life when no *sobandero* is available for consultation.

Another, less straightforward technique that is believed to help revealing the identity of the master of an animal species that stole a victim's soul consists in interpreting one of *susto* patients' minor symptoms. Some victims show a tendency to unconsciously and unwillingly mimic that particular animal species physically or through his/her behaviour.

11.3.5. Treatments for Achieving Shadow Recovery

Ritual or Magical Treatment

Masters of the Animal Species

The Trinitario philosophy that underlies treatment of shadow loss caused by masters of the animal species is based upon the "*similia similibus curantur*" principle or "like cures like". The remedy for retrieving one's shadow from the master of a particular animal species who stole it, consists of the use of body substances (e.g. blood, fur, bones, etc.) from an individual belonging to that particular animal species. Most commonly, the patient has to bathe in the smoke produced by burning any of that species' body parts, including fur, feathers, bones, claws, scales, etc. A more exquisite remedy is considered rubbing one's body with the blood of the animal species. If the master of the dogs is held responsible for having caused *susto*, the patient's body is rubbed with a dog's slaver, or a smoke bath with a dog's fur is prepared. The availability of a wide array of animal tissue in and around Trinitario dwellings is a response to the necessity of promptly treating a patient when needed. It is quite common to see skulls of animals hung up in trees nearby Trinitario houses. If someone is in need of tissue or blood from an animal on short notice, that person will always consult the other villagers first to check whether they can provide some, before considering to go hunting.

'Chanekuna or *Takúna'i*

When shadow loss is brought about by *'chanekuna* or *takúna'i*, recovery is accomplished through demanding the spirit to give it back. A relative of the patient has to visit the place where the patient was "unshadowed" (*desombrado*) carrying a piece of the patient's clothing and call the shadow to come back to the owner of the clothes. Sometimes the relative takes along a *machete* or a whip, fiercely demanding the *'chanekuna* or *takúna'i* to release the shadow.

Materials that represent certain units of the natural landscape are sometimes used to treat *susto* as well. For example, when the spiritual owner of a river patch is held responsible for causing illness, scum that accumulates on the water surface and collected from that same place is rubbed on the patient's body to restore his shadow.

Humans

In the particular case of *susto* caused by other humans, shadows can be returned by rubbing the patient with the responsible person's sweat or saliva or by taking a smoke bath, fuelled with his or her burning hair or nails. The author of this work (ET) has been able to experience this firsthand by tossing up a boy during an act of playfulness and unwillingly startling it. When visiting the boy's house a few days later, the mother claimed that ET (unconsciously) had deprived her son of one of his shadows. The mother reported having witnessed the startling event. She urged ET to take off his sweaty shirt and cut off some of his hair. She rubbed the boy's body with ET's sweat and burned his hair while bathing her son in the smoke.

Ethnopharmacological treatment

Apart from these "spiritual" or "ritual" treatments, the Trinitario people who participated in this study reported using 38 different plant species, belonging to 19 botanical families, in ethnobotanical preparations for healing or preventing *susto* (Table 11.1). The best-represented families, based on species number, are Piperaceae (8 species) and Solanaceae (6 species). Half (50%) of these plant species used for *susto* treatment are cultivated or tolerated in homegardens. *Kh'oa*[2] and garlic (*Allium sativum*) are exclusively bought in colonist highland farmers' grocery shops. All but one plant species are used in external treatments, including herbal baths (79%), smoke baths (11%) or rubbing a preparation on the skin (18%). Only four

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[2] Identified as *Satureja boliviana* (Benth.) Briq. or *Minthostachys andina* (Britt) Epling by Macia *et al*. (2005) and Bastien (1987). Both plants are native to the Andes and are typically used in ritual and ethnomedical ceremonies of Quechua and Aymara people.

species are taken orally (11%), of which three in combination with bathing. The majority (71%) of the plant species used for treating *susto* are strongly aromatic to pungent. The use of only 21 % of plants species (8 species) to treat *susto* was confirmed by three or more participants. However, 6 of the latter plants species are strongly aromatic to pungent and 4 have a characteristic garlic odour. It is popular belief that the stench of the treatment forces the illness to escape from the patient's body.

One female traditional healer claimed *susto* treatment is most effective when the patient bathes in a decoction of twelve plant species. These twelve plant species can be arbitrarily chosen among the following 20 species: the fruit of *Annona montana* or the leaves of *Solanum morellifolium, S. mite, S. americanum, Bixa orellana*, *Citrus* cf. *limetta*, *C. aurantiifolia*, *C. reticulata*, *Cymbopogon citratus*, *Piper* spp. (7 species), *Pothomorphe peltata, Petivera alliacea*, *Gallesia integrifolia* and *Mansoa* cf. *alliacea*. Although not all plant species from this list have aromatic or pungent properties, the mixture of twelve will always result to be so.

The female traditional healers who were interviewed declared that they prepare a decoction of the leaves or seeds of *tajiragi* or *palta* (*Persea americana*), sometimes combined with *krigre* or *piñon* (*Jatropha curcas*) and/or *puékoji* or *kare* (*Chenopodium ambrosioides*) to alleviate the excessive thirst that is often associated with *susto*.

A number of plant species (*kh'oa, Petiveria alliacea, Brugmansia suaveolens, Chenopodium ambrosioides, Tagetes patula, Allium sativum, Nicotiana tabacum*) and mineral substances (sulphur and chrysotile (*millo*)) are used in curative treatments as well as in preventive rituals. Two plant species (*Capsicum chinense* and *Genipa americana*) are exclusively used to protect people against *susto*. Sulphur is burned during smoke baths, while chrysotile is hung around children's necks in small cloth sacks.

Protective measures against the masters of the animal species, *'chanekuna* and *takúna'i* are locally considered important for hunters. A Trinitario individual will theoretically never go hunting without taking along tobacco to smoke. Garlic on the other hand provides defence when it is chewed or carried along in one's pocket. Preparing a smoke bath with *Capsicum chinense* before hunting is also believed to help safeguarding the hunter. Another form of protection against *susto* that is commonly accepted is simply to go with God's blessing, a mere consequence of being a good Catholic. Furthermore, one should not exaggerate and only hunt according to the food needs of one's own family. Nothing should be wasted. This is one of the reasons why people tend to share excess game with family members or other villagers. It is allowed to kill pregnant animals, but with a greater risk to upset their masters.

Any *susto* treatment, whether magico-ritual or by means of ethnopharmacological preparations, is always followed by an obliged resting period. Patients are to stay in bed for two to three days following treatment. This was confirmed by all participants, but it was apparently so obvious to them that they frequently forgot to mention it when not explicitly asked. Nevertheless, all agreed that respecting the resting period is a key to successful recovery, independently from the type of treatment used.

Table 11.1 : Ritual and medicinal plants used in the treatment and/or preventive protection against *susto* (q= Quechua; s=Spanish; t= Trinitario)

***Scientific Name* (family) (voucher number)**	**vernacular name**	**cultivated (C), tolerated (T), purchased (P) or wild (W)**	**plant part used**	**aromatic/ pungent**	**preparation**	**administration**	**preventive (P) and/or treatment (T)**	**participant number**
Petiveria alliacea (Phytolaccaceae) (ET667)	*kutuki, jaca jaca (s)* *smopre (t)*	C	aerial parts	yes	decoction in water	bath	P,T	7
					mix with tobacco and alcohol	skin rub	T	
Cyperus cf. *corymbosus* (Cyperaceae) (ET883)	*gíino (t)*	C	nodules from root area	yes	mash, add tepid water	oral	T	1
Gallesia integrifolia (Phytolaccaceae) ET909)	*ajo ajo (s)* *choogi (t)*	W	bark and/or leaves	yes	decoction in water	bath	T	5
Pothomorphe peltata (Piperaceae) (ET665)	*matico (s)* *chope púyusi (t)*	T	aerial parts	yes	Decoction in water	bath and oral	T	2
Mansoa cf. *alliacea* (Bignoniaceae) (no voucher)	*bejuco ajo* *giewi (t)*	W	leaves and bark	yes	mash and soak or boil in water	bath	T	3
Protium cf. *meridionale* (Burseraceae) (ET1910)	*yóparagi (t)*	W	resin	yes	none	skin rub	T	2
Tagetes patula (Asteraceae) (ET1519)	*flor de santo (s)*	C	entire plant	yes	decoction in water	bath	P,T	1
Chenopodium ambrosioides (Chenopodiaceae) (ET878)	*care (s)* *puékoji (t)*	T, C	entire plant	yes	decoction in water	bath	P,T	1
Indet. (no voucher)	*kh'oa (q)*	P	entire plant	yes	none	in small bag around neck	P	3
					burn	smoke bath	P,T	
Ocimum micranthum (Lamiaceae) (ET741)	*albahaca (s)* *hpoahuasca (t)*	C	entire plant	yes	decoction in water	bath	T	1
Annona montana (Annonaceae) (ET2145)	*sinini (s)* *pochíimoya (t)*	T,C	fruit	yes	Decoction in water	bath	T	1
Citrus aurantiifolia (Rutaceae) (no voucher)	*limón (s)* *rimo (t)*	C	leaves	yes	decoction	bath	T	1
Citrus cf. *limetta* (Rutaceae) (no voucher)	*lima (s)* *rimatéesia (t)*	C	leaves	yes	decoction	bath	T	1
Citrus reticulata (Rutaceae) (no voucher)	*mandarina (s)*	C	leaves	yes	decoction	bath	T	1
Nicotiana tabacum (Solanaceae) (no voucher)	*tabaco (s)* *saware (t)*	C	leaves	yes	burn	smoking and/or smoke bath	T,P	5
Piper aduncum (Piperaceae) (ET1018)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1

Table 11.1 continued

Scientific Name **(family) (voucher number)**	**vernacular name**	**cultivated (C), tolerated (T), purchased (P) or wild (W)**	**plant part used**	**aromatic/ pungent**	**preparation**	**administration**	**preventive (P) and/or treatment (T)**	**participant number**
Piper cf. *bartlingianum* (Piperaceae) (ET896)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Piper buchtienii (Piperaceae) (ET1267)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Piper glabratum (Piperaceae) (ET676)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Piper hispidum (Piperaceae) (ET1019)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Piper longestylosum (Piperaceae) (ET684)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Piper pilirameum (Piperaceae) (ET646)	*paychané (s)* *chuikúnogi (t)*	W	leaves	yes	decoction	bath	T	1
Solanum mite (Solanaceae) (ET679)	*aji (s)* *pochetji (t)*	W	leaves	yes	decoction	bath	T	1
Solanum morellifolium (Solancaeae) (ET680)	*aji (s)* *'cheti tesmeno (t)*	W	leaves	yes	decoction	bath	T	1
Solanum americanum (Solanaceae) (no voucher)	*aji (s)* *'chetí tesmeno (t)*	W	leaves	yes	decoction	bath	T	1
Allium sativum (Alliaceae) (no voucher)	*ajo (s)* *ajosí (t)*	P	bulb	yes	mash	skin rub or chew	T,P	7
Cymbopogon citratus (Poaceae)	*paja cedrón (s)* *tijiemuiji (t)*	C	leaves	yes	decoction	bath	T	1
Guadua cf. *weberbaueri* (Poaceae) (ET794)	*tacuara (s)* *tskáano (t)*	W	stem	no	burn	smoke bath	T	3
					burn and mix with oil from cow feet	skin rub	T	
			water inside stem	no	none	bath and oral	T	
Struthanthus acuminatus (Loranthaceae) (ET1392)	*chugichko (t)*	T	entire plant	no	mash and add tepid water	bath	T	2
			leaves	no	decoction in water	bath and oral	T	
Portulaca grandiflora (Portulacaceae) (ET666)	*once horas (s)*	C	entire plant	no	mash, put outside overnight and mix with mashed nutmerg and mothballs	skin rub	T	1

Table 11.1 continued

Scientific Name **(family) (voucher number)**	**vernacular name**	**cultivated (C), tolerated (T), purchased (P) or wild (W)**	**plant part used**	**aromatic/ pungent**	**preparation**	**administration**	**preventive (P) and/or treatment (T)**	**participant number**
Tessaria integrifolia (Asteraceae) (no voucher)	*parojobobo (s)*	W	leaves	no	mash, add tepid water	bath	T	1
Zanthoxylum sprucei (Rutaceae) ET1175	*sahuco (s)* *kúuji (t)*	W	bark	no	mash and soak in tepid water	bath	T	1
Brugmansia suaveolens (Solanaceae) (ET663)	*floripondio (s)* *'chosíjare (t)*	C	leaves	no	mash	skin rub	T	1
			leaves and flowers	no	Decoction in water	bath	P,T	
Salix humboldtiana (Salicaceae) (ET993)	*sauce (s)* *choojgi (t)*	W	leaves	no	decoction in water	bath	T	1
Genipa americana (Rubiaceae) (ET1088)	*bi (s)* *yónogi (t)*	T, C	Fruit juice	no	none	paint crosses on body newborns	P	3
Sloanea laxiflora (Elaeocarpaceae) (ET1028)	*urucusillo (s)* *rigño, tshuangi (t)*	W	root	no	mash and soak in tepid water	bath	T	1
Bixa orellana (Bixaceae) (no voucher)	*urucu, achihuete (s)* *níiregi, niire (t)*	C	leaves	no	decoction	bath	T	1
Capsicum chinense (Solanaceae) (ET1093)	*aji soliman (s)* *sachemo 'cheti, much'e (t)*	C	fruits	no	burn	smoke bath	P	2

11.4. Discussion

11.4.1. Importance of *Susto*

Susto was identified as one of the important illnesses in the communities that participated in this study. *Susto* was mentioned by forty percent of households, when asked to free list the most important and/or serious disorders that can affect the family. We believe that this number is underestimated. People feel uncomfortable and suspicious to speak freely about *susto* with outsiders. It took us almost two years of frequently visiting the communities to achieve a major breakthrough on the theme. It was only after a well-respected local traditional healer had introduced us into Trinitario ethnomedical understanding of *susto* that other key participants felt confident enough to talk freely, without the risk of being judged by other community members. The obstacle to talk freely may result from the (often unintentional) negative attitude of visiting Bolivian medical doctors towards folk illnesses like *susto*. Since contacts with people who participated in household interviews were less sporadic as compared to those with key informants, lack of trust in the interviewer may also have resulted in naming principally general symptoms and illnesses and omitting folk illnesses.

11.4.2. *Susto* Ontology and Symptoms

The concept of multiple souls that are associated with the human body is clearly not restricted to Trinitario people, as e.g. Greenway (1998) and Chaumeil (2000) have demonstrated for the Peruvian Andes (Mollomarca community) and Amazon (Yagua people), respectively. Nor is the use of terms such as *sombra* and *animo,* for addressing these souls (*almas*). The term shadow or *sombra* is also mentioned by Fink (1987) and López-Austin (1988, cited in Castro and Eroza, 1998), while *animo* has been reported from Peru (Greenway, 1998). Although both terms refer to the same disorder, *susto* ("fright") or *asustado* ("frightened") refer to the assumed cause while *desombro* ("un-shadowed") directs to the resulting state that is responsible for the accompanying symptoms.

Even though Trinitario *susto* aetiology and treatment differ somewhat from what is reported by the general literature on this subject, the symptoms do match. According to the general literature, symptoms include: malaise, insomnia, restless sleep, poor appetite, and sometimes gastro-intestinal complaints such as stomach-ache, diarrhoea and vomiting, fever, difficulty breathing, frequent urination, headache, swelling of body or body parts, agitation, shaking and trembling, irritability, asthenia ("weakness"), anorexia, phobias, reduced libido, retardation, nightmares, sweating, tachycardia, other symptoms of anxiety and depression, excessive thirst, anxiety, timidity and indifference to dress and personal hygiene (Sal y Rosas, 1958, cited by Stein, 1981; Kiev, 1972; Rubel *et al.*, 1984; Weller *et al.,* 2002). An additional symptom reported for *susto* in small children is that their eyes get big (Clark, 1970, cited by Klein, 1978). The key symptoms mentioned in our own study include: diarrhoea, vomiting, fever, trembling, nightmares, excessive thirst, restless sleep, and in small children the sclera (white of the eyes) gets larger. The overlap of symptoms, and the analogy between Trinitario aetiology and treatment of *susto* with the literature, (soul loss and recovery), suggests that we are probably addressing the same folk illness.

11.4.3. The Victims

Among the Trinitario communities that participated in this study, *susto* is a typical children's or adolescents' disease, although in theory everybody is susceptible. The same remark has frequently been made elsewhere as well (e.g. Arvigo and Balick, 1998). In her publication on *susto*, Klein (1978) cites studies from Gillin (1945) and Clark (1970) who observed that *susto* attacks children (also see Greenway, 1998) more often than adults in Peru and among Mexican-Americans in California, respectively. In Gillin's study, *susto* occured most frequently in children around their first year of age when the child is weaned and starts walking. This generally represents a phase of crisis in the infant's life, and no specific fright is deemed necessary for a diagnosis of *susto*. Gillin (1945) attributed the manifestation of *susto* to dietary changes and perhaps deficiencies, changes in the parent's treatment of the child and other developmental factors. Likewise, Trinitario babies do not necessarily have to be startled either, as the master of the animal species concept predominates in Trinitario *susto* aetiology in the case of babies.

In this respect, Rivière (1974) mentions an interesting aspect of the cosmology of the Carib-speaking Waiwai from Brazil and Guyana. In Waiwai cosmology, the soul of a newborn is believed to be extremely volatile and not yet properly fixed in the child. As it is still linked to the soul of the parents, it also accompanies them during their treks in the forest and can be captured by spirits. Furthermore, because of the close spiritual ties between the child and its parents, a spiritual danger acting on the latter will affect the former (Rivière, 1974). If a similar conviction would hold true for Trinitarios (which we have not been able to verify), then it could explain why predominantly children are diagnosed with *susto*. After all, it is someone else, namely the adult, who diagnoses the disorder and not the victim (Uzzell 1974; Klein 1978). In this view, disorders of children that are recognized by Trinitario adults as *susto* might just as well be diagnosed erroneously. Higher rates of *susto* among children (and women, see O'Nell and Selby, 1968) than in adult men in the case of a startling event have been linked to the fact that that the actions of the *asustado* are generally passive and passivity is acceptable in children and women, but not in men (Uzzell, 1974). In other words: it takes a far more frightening experience for men than for children and women to get frightened.

11.4.4. *Susto* Aetiology and Trinitario Worldview

To the best of our knowledge, there exists no literature describing soul loss among Mojeños or Trinitario people. Nor did we find any Latin-American written evidence about the role of the "master of the animal species" in *susto* aetiology. In general, only some unspecified notes on soul interchange after an encounter with a jaguar and soul theft by the devil (*diablo*) in little children is reported for Bolivian silvicultural societies (Hermosa, 1986).

On the other hand, it seems to be a cross-cultural belief in Latin America to hold animal spirits (i.e. spirits of distinctive animal, bird or fish species but not the species' masters, as opposed to Trinitario beliefs) or spirits associated with different units of the natural environment (e.g. the earth, rivers, ponds, forests, a mountain, a canyon, a lonely place, a river), cosmological (e.g. the night) and climatological (e.g. lightning bolts, a storm) elements (cf. *takúna'i* and *'chanekuna*) responsible for soul theft (Valdivia Ponce, 1975, cited by Stein, 1981; Marcus and Flannery, 1978; Rubel *et al.,* 1984; Fink, 1987). The specific case of *susto*, provoked by other humans or by domesticated animals (but here the animals themselves, not their masters) as mentioned by our Trinitario participants, has been observed in a Mexican Mestizo community by Rubel and his colleagues (Rubel *et al.,* 1984).

Although no literature was found concerning *susto* or *desombro* among the Trinitarios, some (vague) references confirm that some of their spiritual beliefs have apparently become only limitedly affected by acculturation. Trinitarios are convinced that all units of the natural environment have their spiritual owners (cf "*dueños de la naturaleza*" (Santamaria 1994)). In one of the first published accounts on the theme, Wegner (1931) points out how Mojos believe(d) in "demons" associated with water, clouds and lightning. More recently, Lehm (2002) has argued that, parallel to the development of a Catholic religion, the beliefs in "masters of the forest and the waters" have remained invariable among present day Trinitarios. This notion is confirmed by Villavicencio (1992) who mentions that Trinitario traditional healers still recognize the spirits that inhabit the world: the spirits or *jichi* of hurricanes, small streams, animals, the forest and the birds. The closest explicit reference to the Trinitario landscape spirits, *takúna'i* and *'chanekuna*, can be found in Eder's (1772) description of the Moxos plains in the 18th century. This author mentions the term *achane* for the Baure (a Bolivian Arawakian tribe linguistically most related to the Mojeños (Ibarra Grasso, 1996; Calvo, 2003c)) which is translated into "spirit". In fact, *achane* represents two different types of spirits. *Achane* of the first type inhabit specific places like trees, rivers, lakes or forests, while those belonging to the second type accompany human beings. However, as opposed to our findings, Eder does not mention any effects that are harmful to health after an encounter with an *achane* from the first type. Apart from the linguistic overlap between *a**chane*** and ***chane**kuna* (linguistic cognates), both terms (*achane* of the first type and *chanekuna*) apparently also refer to spirits associated with units of the natural landscape.

Even though Trinitario people have a relatively long sedentary history of agriculture, we have been able to demonstrate that the worldview of the communities that participated in this study pertains partly to that of a hunter society with a central "masters of the animal species" concept. Yet, hunting *sensu strictu* does not belong to their most frequent activities. From the first Jesuit mission times onwards (more than three centuries and a half), and probably even longer, agricultural practices and fishing have been more important to Trinitario people than hunting (Block, 1997). Until today, fishing remains an important and almost daily activity, while hunting is more sporadic and practiced on a weekly basis. However, fishing is also a kind of hunting and may have fuelled the persistence of a worldview common to hunters and fishermen. Perhaps "hunter-fishermen worldview" might be a better term to address the Trinitario *weltanschauung*.

Some scholars (e.g. Castro and Eroza, 1998; Greenway, 1998) have argued how the subjective experience of a traditional illness is shaped both by the cultural and spiritual background of individuals, as well as by the sociological features of the cosmological setting in which these individuals live. According to this reasoning, reflection of the hunter worldview in Trinitarios' ethnomedical and aetiological interpretations of diseases in general -and *susto* or *desombro* in particular- is an anticipated consequence. Greenway (1998) states that the relationships between the individual, social and spiritual realms are reflected in the causes, meaning, and experience of illnesses like *susto.* These illnesses frequently appear to be rooted in the transgression of the boundaries between these three realms. For example, in the Peruvian Andes, local *susto* aetiology nearly always seems to be linked to a disruption of relationships between the individual and his social and/or cosmological environment.

Although the worldviews of the populations studied by Castro and Eroza (1998) and Greenway (1998) substantially differ from ours, they show that people's experience of a traditional illness may be linked both to structural features of their society, such as poverty or high rates of domestic violence, and to their general worldview. *Susto* clearly is experienced by Trinitarios in a way that parallels their worldview. They experience the disorder from a perspective in which spiritual beings associated with the animals and places that surround them, are integrated and taken for granted in their aetiological explanation of *susto*. When one upsets or merely encounters these spiritual beings, the latter can take revenge and collect one of their victims' souls or shadows.

When Descola's (1996) definition is applied on the Trinitario "masters of the animal species" concept, then the latter should be classified as an animic or animistic system as opposed to totemic systems and naturalism (see Descola, 1996 for a discussion). Descola (1996) argues that for identification purposes, animism can be specified by at least three dominant types of relation: predation, reciprocity and protection. The "masters of the animal species" phenomenon is obviously an example of reciprocity, defined by Descola (1996) as "those animic systems in which the relations between humans, as well as between humans and non-humans, are fuelled by a constant exchange of services, souls, food or generic vitality. The dominant belief in such systems is that humans have a debt towards non-humans, notably for the food the latter provide". Trinitarios indeed believe that when they kill an animal for food or other purpose (e.g. killing snakes for protection) they might upset its master who could take revenge, thus taking in an unmistakable position of debt. This debt is however not towards the animals themselves, but towards their respective hierarchic masters.

The fact that masters of the animal species (wild and domesticated), together with humans, are thought to be able to steal shadows, seems to express the equal hierarchical position of the masters of the animal species and human beings (cf. Rosengren, 2006). This equality is characteristic for an animistic system. Another aspect that contributes to the latter observation of equality is the fact that, just like humans or animals, the masters of the animal species are believed to have their own character and temperament. As mentioned before, according to Trinitarios, some masters of animal species are for example more vindictive than others, whereby masters of snake species are considered among the most dangerous ones. This negative attitude towards snakes is clearly not restricted to our study area since it has been reported by various authors (e.g. Rubel *et al.,* 1984; Vandebroek *et al.,* 2003). Roth (1915) cited by Zerries (1954) reports how the Arawak, Caribe and Warran of the Guyanas, after killing a snake or another big animal, stick arrows in the ground along the path that leads from the hunting ground to the village to prevent the animal's spirit to follow the hunter and take revenge on him or one of his kinsmen.

The concept of masters of the animals and the potential damage they can cause to human beings might be considered a kind of social taboo. Colding and Folke (2001) distinguish six types of resource and habitat taboos (RHT), including: 1) **segment taboos** that ban the use of certain species for specific time periods for human individuals of particular age, sex or social status; 2) **temporal taboos** that ban access to resources during certain time periods; 3) **method taboos** that ban certain methods for harvesting resources; 4) **life history taboos** that ban the use of certain vulnerable stages of a species' life history; 5) **specific species** that ban the use of specific species in time and space; and 6) **habitat taboos** that regulate the access and use of resources of particular habitats. Although these categories may be valid for all the cases from the literature studied by Colding and Folke (2001), our research results suggest an additional RHT category which we would call **quantity taboos**. The main difference between this category and those proposed by Colding and Folke is that it is not an absolute measure, but depends on individual interpretation. The belief that excessive hunting might result in (life-threatening) illness (i.e. hunting quantity is a measure for the degree of peril) is expected to bring about at least some positive influence on conservation, be it deliberate or not (Smith and Wishnie, 2000).

11.4.5. Trinitario *Susto* Treatment

In their work on *susto*, Rubel *et al*. (1984) describe two different Mexican interpretations for treatment of the loss of an essence or vital substance. In the first case, the soul is wandering and a cure requires it to be induced back into the victim's body. According to the other interpretation, the soul must be freed from its captors first and then induced back into the body. *Susto* that is originated by humans appears to pertain to the first scenario, whereas the second interpretation applies directly to Trinitario understanding of *susto* or *desombro* where shadows have to be freed from "masters of the animal species" or *takúna'i* and *'chanekuna*, spirits that are associated with the natural landscape.

Although magico-ritual treatments by means of ethnozoological preparations are the standard Trinitario remedy for freeing shadows from "masters of the animal species", no literature references confirming such use were found for any Latin-American society. For a number of Trinitario herbal remedies they do exist. The use of tobacco by Trinitario hunters as a protective means is confirmed by Zerries (1951). This author mentions how tobacco is used by many South American indigenous communities, for obtaining permission from the "master of the animals" to kill an animal without sanctioning. Corporal paintings with the sap of *Genipa americana* fruits for spiritual protection has been documented by Chaumeil (2000). The use of plants species belonging to the genus *Protium* and species with a typical garlic-like odour (including *Mansoa alliacea* and *Petiveria alliacea*) to chase evil spirits away has been reported by various authors (e.g. Grenand *et al.,* 1987; Arvigo and Balick, 1998). The explicit use of *Mansoa alliacea* for treating *susto* (called "manchariy" in Quechua (see also Vandebroek *et al.,* 2003)) has likewise been reported for Peru (Vasquez 1990 in Duke and Vasquez, 1994). Probably purchased garlic (*Allium sativum*) is now being used in the same way as locally naturally occurring or cultivated plants (*Gallesia integrifolia*, *Mansoa alliacea*, *Petiveria alliacea*) due to their overlapping aromatic properties.

The rituals performed by Trinitarios to retrieve shadows from *takúna'i* or *'chanekuna* seem to be common practice elsewhere as well. According to Rubel *et al*. (1984), the calling of a patient's name during *susto* treatment is a cross-cultural critical part of the procedure. These authors describe how a patient's "vital force" (cf. soul) is called for with a piece of his clothes during a traditional *susto* treatment in Mexico. Two other examples that confirm how the "lost soul" was "ordered" to return to the body during *susto* treatment are provided by Logan (1979) and Bastien (1987a) for Guatemalan Cakchiquel communities and Bolivian Kallawayas, respectively.

Another important procedure to treat *susto* among Trinitarios is based on the application of ethnobotanical remedies. According to the literature, the use of medicinal or ritual plants for treatment of *susto* is not very common. Some recent publications (e.g. Vandebroek *et al.*, 2003; Bourdy *et al.*, 2004; Macia *et al.,* 2005; Thomas and Vandebroek, 2006) mention a number of plants in Bolivian ethnopharmacopoeia that are used to treat *susto* through bathing, oral ingestion and smoke baths. The fact that the majority of ethnobotanical preparations presented in table 11.1 are applied externally (as baths, smoke baths and skin rubs) can be interpreted in (at least) two ways: plants are used either in a magico-ritual or in a biomedical context. Although magico-ritual plant use might bring about a placebo effect, there is no proven biomedical interaction between active plant principles and the human biological system.

In a second interpretation, external use of plant remedies may well be biomedically grounded through (1) actual absorption of bioactive compounds through skin contact (cf. ointments) and/or inhalation; or (2) through some kind of aromatherapy, *i.e.* the use of essential oils, extracted from plants, trees, and herbs, for therapeutic purposes (Warrenburg, 2004). The majority (71%) of plant species used to treat (listed in table 11.1) is aromatic to pungent. These plants could therefore have some aromatherapeutic potential when used in baths, smoke baths or skin rubbings (cf. Plotkin, 1994).

Ingestion of ethnopharmacological herbal preparations against *susto* is expected to have a higher chance of evocating biomedical effects. Yet, only four plant species were recorded to be used as such: *Cyperus* cf. *corymbosus*, *Struthanthus acuminatus*, *Piper peltata* and *Guadua* cf. *weberbaueri*. According to literature, oral ingestion of plant preparations for *susto* is apparently rather exceptional (except Trotter, 1982 and Bourbonnais-Spear *et al*., 2007). Nonetheless, the biomedical activity of herbal plant remedies used to treat *susto* has recently been demonstrated by Bourbonnais-Spear *et al*. (2007). The authors were able to show that at least one of the plants used in oral treatments by Q'echi' Maya healers from Belize suppressed certain components of anxiety and fear, which they argued supports the hypothesis that *susto* has a neurological/psychological component apart from physiological factors (Bourbonnais-Spear *et al*., 2007). This example shows that studying the potential biomedical activity can lead to a better understanding of *susto*, as it facilitates hypothesis testing regarding the causal factors and symptoms of the disorder. Therefore, we recommend further investigation into the potential biomedical modes of action of the ethnobotanical and ethnozoological remedies used by Trinitarios.

11.5. Conclusions

The present study contributes to the body of knowledge about the aetiology and treatment of *susto*, a cross-cultural Latin-American folk illness related to fright and soul loss that remains understudied among Amazonian societies to date. Our findings shed new light on the hypothesis that experiencing a folk illness is a social product, shaped by the social, cultural and worldview-related background of individuals. We have shown that, in spite of a long history of predominantly agricultural practices, Trinitario people are still fully immersed in the animistic worldview of hunters and fishermen. Similar to other Amazonian societies, Trinitarios experience the environment as a place that harbours physical beings (e.g. people, animals, plants) as well as spiritual entities that are associated with a variety of places and animal species. All individual animals are believed to be animated, and are in turn "owned" by species-specific spiritual masters (i.e. the masters of the animal species). These spiritual entities are held responsible for causing *susto.* Trinitario *susto* aetiology can be distinguished from other examples presently described in literature by the fact that the masters of the animal species are held responsible for steeling one (or more) of the three souls believed to be attached to every living person, hereby precipitating a cluster of serious systemic symptoms and hence provoking illness. To reinstate the soul-body equilibrium, Trinitarios apply a series of magico-ritual and ethnopharmacological treatments. The peculiar magico-ritual *susto* treatment to regain souls from the masters of the animal species appears to be restricted to the Trinitario culture in that it draws on ethnozoological preparations.

Trinitario conviction that over-hunting a particular animal species might lead to the species' master to revenge itself upon the hunter or his family may well represent a new category of social taboos, which we have defined as "quantity taboos". These taboos are characterized by a (life-threatening) peril that is attached to excessive harvesting or hunting (i.e. the quantity is a measure for the degree of peril). This type of taboo could have consequences for conservation.

12.

Discussion and Conclusions

12.1. Floristic Inventories, Ecological Sampling and Conservation Status

Floristic Inventories: General Considerations

The flora of Bolivia counts an estimated 20,000 species, many of which are still undiscovered and undescribed (Ibisch and Beck, 2003). Several botanical families have only recently been registered for the first time in Bolivia, such as Rhizophoraceae (Justiniano and Toledo, 2001) which was also included in our inventory. At present, a catalogue of the vascular plants of Bolivia is being assembled through a joint project between the Missouri Botanical Garden (MO) and the national herbarium of Bolivia (LPB). With 1347 different plant taxa, including at least six species new to science (*Philibertia globiflora* Goyder, *Bauhinia* sp. nov. ined., *Calyptranthes* sp. nov. ined., *Inga* sp. nov. ined., *Licania* sp. nov. ined. and Malvaeae sp. nov. ined.), our inventory represents an important contribution to this project and to the knowledge of the Bolivian flora in general (chapters 2 and 6). An additional asset of our work is that it confirms for the first time the presence of a number of species in the Cochabamba department (e.g. several species and subspecies of *Baccharis*; Müller, 2006) and in Bolivia (e.g. *Drymonia oxysepala* Leeuwenb.; J. Clark, pers. comm.).

TIPNIS: Ecological Sampling and Conservation status

One of the main conclusions of our ecological research is that the old-growth forest vegetation from the southern part of TIPNIS deserves much more attention than it is currently receiving. We have argued that diversity levels measured during the present study are among the highest recorded to date in Bolivia (chapter 6). These findings might have important implications for defining future conservation policies in TIPNIS. Up to date, the limited knowledge of plant diversity has not allowed defining areas with conservation priority inside the park (Lilienfeld and Pauquet, 2005). Although much more data are needed, our results represent a significant step towards a better understanding of plant diversity in TIPNIS.

Ironically, assigning areas with conservation priority within TIPNIS, which is already legally acknowledged as a ‘protected area’, is extremely important in view of the threats that are currently imposed upon the park. These include: (1) a road planned straight through the middle of the park; (2) future exploitation of hydrocarbon reserves; and (3) destructive behaviour of Andean settlers (Lilienfeld and Pauquet, 2005). Particularly the last threat is most imminent at present. Andean settlers practice non-sustainable (semi-)permanent clear-cutting of forest vegetation that unavoidable leads to diversity loss and soil degradation (Lilienfeld and Pauquet, 2005). By contrast, Yuracaré and Trinitario families practice shifting cultivation in isolated patches (swiddens) of approximately one hectare in size that are abandoned after a few years (cf. figure 1.6A). For subsistence, each family clears a new swidden after one or two years. Literature (e.g. Ruthenberg, 1980; Balée, 1994; van Andel, 2001) has demonstrated that this kind of land use is not necessarily detrimental for diversity. It might even enhance diversity as long as fallow periods are respected and the forest is allowed to recover after several years of intensive human management (chapter 10).

In this context, it is alarming that Andean settlers do not respect the border established within TIPNIS (the so-called red line or *linea roja* (Lilienfeld and Pauquet, 2005)) that separates colonized lands from indigenous (Yuracaré and Trinitario) territories. During our study, we have frequently witnessed interventions of National Protected Area (SERNAP; Servicio Nacional de Areas Protegidas) officials during disputes related to trespassing behaviour of Andean settlers, who are always in search of new land for illegal cultivation of coca (*Erythroxylum coca* Lam.), the principal cash crop in TIPNIS. Such conflicts are not expected to end soon because coca farmers are difficult to convince of the importance of conserving nature. They see TIPNIS as farmland, rather than as an area that should be protected (Lilienfeld and Pauquet, 2005).

According to Lilienfeld and Pauquet (2005), construction of the planned road crossing through TIPNIS will undoubtedly lead to a massive invasion of Andean settlers into adjoining pristine forestland. Within such a scenario, Yuracarés and Trinitarios might also become future actors of forest destruction, as the road will increase market exposure and probably stimulate marketing of cultivated products, timber and non-timber forest products (NTFPs[1]) (Godoy *et al.* 1996). According to Godoy *et al.* (1996) and Wilkie and Godoy (2001), increased income levels that result from such activities may in turn foster more forest destruction and higher demands for bushmeat among Yuracarés and Trinitarios.

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[1] Non-timber forest products are defined here as all plant and animal products that are derived from forest landscapes, including human-modified ones (Ros-Tonen and Wiersum, 2003)

Even at present Yuracarés and Trinitarios are not completely innocent of unsustainable harvest practices (chapter 10). If no action is taken soon, some of the currently applied harvesting methods might lead to local extinction of species such as *Jessenia bataua*. However, in spite of these 'minor' threats to local plant diversity, ecosystem management under Yuracaré and Trinitario custody seems to be much more adaptable to conservation than in the case of Andean settlers.

In view of the fact that many Amazonian indigenous peoples have halted the expansion of the agricultural frontier, banned logging companies and gold miners on their lands, conservation scientists are becoming increasingly convinced that indigenous territories (given their size and protected status) will be a decisive factor in the ultimate fate of Amazonian ecosystems (Peres, 1994; Schwartzman *et al.*, 2000; Pimm *et al.*, 2001; Fearnside, 2003; Borrini-Feyerabend *et al.*, 2004; Schwartzman and Zimmerman, 2005). Also in Bolivia, indigenous societies play a central role in tropical forest conservation. According to Uberhuaga (1997, cited by Pacheco, 2003), 90% of the indigenous territories in the lowlands are located in forested areas. Indigenous groups, fostered by a social mobilization that culminated in a series of protests and marches[2] in the early 1990s, have been officially recognized by the Bolivian government. They are currently in a process to acquire collective private property rights for a total land area of 22.4 million hectares, equivalent to 19 percent of the country's total land area and roughly 30 percent of the lowland region (Pacheco, 2003; Calvo, 2003a).

At the time of the present study, indigenous Yuracaré and Trinitario communities, in cooperation with the governmental organization SERNAP (SERvicio Nacional de Áreas Protegidas) were the frontline defenders of biodiversity in the southern part of TIPNIS. These indigenous communities are represented by the relatively well-organized council CONISUR (CONsejo Indígena del SUR del TIPNIS) composed of indigenous representatives from several communities) which grants them greater power to further counter the invasion of Andean settlers and timber companies into their territories[3].

In light of these developments, one can only hope that the Bolivian government, which is currently being led by a president who once was an Andean settler engaging in coca cultivation himself, will maintain and intensify the protected status of the area in TIPNIS under custody of Yuracarés and Trinitarios. High plant diversity in TIPNIS can only be conserved as long as a strict respect for the red territorial demarcation line is maintained and the project for a road through the park is reconsidered. If the Bolivian government would fall for the pressures imposed by coca farmers and the prospect of economic gains from a new road, another piece of nature's finest accomplishments will be lost forever.

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[2] There were basically two big indigenous marches that now constitute historical events since they managed to put the indigenous cause on the national political agenda. The first, called The March for Territory and Dignity", was held in 1991 and its follow up five years later, just months before the Parliament passed the new land reform which granted the groups' legal rights to their ancestral lands.

[3] At the very start of the present investigation, a heavy debate was being held between the indigenous council CONISUR and the forestry company CETEFOR regarding the assignment of some large forest concessions in TIPNIS. The indigenous leaders rejected the proposal.

Apillapampa: Ecological Sampling and Conservation Status

Vegetation in Apillapampa is much more fragmented than the vegetation of old growth forests studied in TIPNIS and in the former study area very little remains from the potential climax situation. We revealed that the current level of anthropogenic disturbance in Apillapampa has a detrimental effect on plant diversity and available biomass (chapters 2 and 5). Whereas intermediate levels of anthropogenic disturbance in TIPNIS might enhance plant diversity (chapter 6), disturbance in Apillapampa is far beyond intermediate levels and brings about negative effects on diversity. In agreement with literature, factors that most negatively influence diversity in Apillapampa include the expansion of arable lands, pasturing, overharvesting and burning activities (Kessler and Driesch, 1993; Beck *et al.*, 2001; Ibisch, 2003d; García and Beck, 2006; Kessler, 2006).

The negative impact of anthropogenic disturbance was also evidenced by our finding that site accessibility correlates negatively with the density and diversity of (sub-)woody plants (chapter 2). Furthermore, we have brought forward serious indications of unsustainable harvest practices of wild firewood species in Apillapampa (chapter 5). People from the community are conscious of vegetation degradation but they do not have straightforward solutions to counter it. Therefore, measures to lower the pressure on wild fuel plant populations through the development and use of alternative energy sources such as cultivated local firewood and/or (exotic) timber species, ought to be taken as soon as possible. Over the past decades, the NGO FEPADE has already stimulated a lower dependence of local people on the natural vegetation in Apillapampa through cultivation of fodder and timber species, multipurpose trees and market-oriented production of agricultural crops and fruits such as *Passiflora mollissima* on irrigated land. In order to further safeguard wild populations of (useful) plant species, such practices should be intensified. In our opinion, cultivation of multipurpose tree species should be extended at a larger scale throughout the agricultural landscape (cf. section 12.3).

Vegetation Maps

The ecological data gathered from transect sampling allowed for the classification of vegetation in the research areas according to vegetation types described in literature (Navarro, 2002 and Josse *et al.*, 2007). In Apillapampa, altitude is the predominant environmental factor that determines the occurrence of different ecological zones (*prepuna* and *puna*). By contrast, in TIPNIS development of different forest types is mainly controlled by substrate with a clear distinction between *terra firme*, floodplain and *varzea* forests.

Our transect data have unmistakably shown that existing phytosociological vegetation maps (Navarro and Ferreira, 2007a and b) need updating for both our study areas (chapters 2 and 6). In this sense, it has been argued that, given the understudied Bolivian flora, it is too early to apply a hierarchical phytosociological system to Bolivian vegetation (Hensen and Kessler 2001). Although it is far from our intention to question the value of Navarro and Ferreira's (2007a and b) work, we do not disagree with the observation made by Hensen and Kessler (2001) either. Our findings show that there is an urgent need for more representative vegetation samples to improve the accuracy of phytosociological maps, which are currently based on a limited data set, at least for areas such as TIPNIS and Apillapampa.

12.2. Importance of Plants for Indigenous Communities in Bolivia

A total of 1122 inventoried plant species was considered useful by Quechua, Yuracaré or Trinitario participants (chapters 3 and 8). Although it seems likely that the majority of plants used by people from the study area are covered in this thesis, our list is by no means exhaustive. The highest number of useful species was reported by Yuracarés (597 species), followed by Trinitarios (554 species) and Quechuas (387 species). As indicated in chapter 4, nearly all plant species and individuals (94-100% and 92-100%, respectively) in transects sampled in Apillapampa were considered useful. In TIPNIS, percentages were in the same order, although slightly lower: uses were assigned to 74-82% of species and 85-92% of individuals in transects (chapter 9). These numbers clearly show that the people who participated in our study still depend upon an impressive number of plant species for most aspects of their physical, cultural and spiritual lives (cf. Milliken *et al.*, 1992). The present study has also demonstrated that many of the ancient plant uses described by early missionaries and ethnographers for the Yuracarés and Trinitarios still exist today.

In Apillapampa, use categories that represent animal food, medicine, fuel and food, were most important, both in terms of the number of used species and average use values per species (chapter 3). In TIPNIS, the highest number of species was obtained for the medicinal use category, followed by fuel, food, construction and materials. Average use values of species were equal for medicines, fuel, food and construction (chapter 8). These proportions and average use values reflect the importance that different plant uses occupy in the daily life of local peoples. In Apillapampa, animal husbandry is an every day practice, whereas the use of medicinal plants has a long-standing excelling tradition. Wild fuel plants also fulfil a prominent subsistence role, since most of the daily fuel requirements for cooking are fulfilled with wild plants (chapter 5). In TIPNIS, different plant use categories have a similar importance, basically because they represent the combined knowledge of Yuracarés and Trinitarios. Plant use knowledge of both ethnic groups is complementary in the sense that Yuracarés know more about edible (wild) plants, whereas Trinitarios are more knowledgeable about the therapeutic value of a higher number of both wild and managed medicinal plants (see *infra*). Collection of firewood for cooking is an almost daily practice in TIPNIS (cf. figure 8.23G). Also, house building and repairing, in addition to manufacturing canoes are important activities of people throughout the year (figures 8.18 and 8.19).

12.3. Importance of Ethnobotany for Development Plans

In addition to the potential role that ethnobotany can play in nature conservation (see *infra*), it can undoubtedly be the basis of income-generating activities as well (Phillips *et al.*, 1994; Broekhoven, 1996; Gimenez *et al.*, 1996; Prance, 1997; Martin *et al.*, 2001; Hinojosa *et al.*, 2001; Vidaurre, 2006; Balslev, 2006). Recently, more and more efforts have been made to incorporate forest management and exploitation of non-conventional NTFPs in Bolivian development programs (Statz, 2000; FAO, 2001). Decision makers have recognized the assumption that use and trade of NTFPs can benefit social and economic development in the Bolivian tropics. The sustainable extraction of NTFPs is believed to be less destructive than most current logging practices (ecological benefits). Trade of NTFPs can complement and diversify forest-based rural incomes, as well as contribute to national export economies (economic benefits). Finally, promoting the use and trade of NTFPs can support local institution building to the benefit of marginal groups in society, such as women, the poor and the elderly (social benefits) (Statz, 2000).

The monetary value that NTFPs represent in the contemporary Bolivian economy is significant indeed. In 2005, NTFPs represented half of the monetary value of Bolivia's total forestry export according to the Bolivian Chamber of Forestry (www.cfb.org.bo). Brazil nut alone (*Bertholletia excelsa*) constituted 45% of the total forestry export of Bolivia (corresponding to almost 74 million dollars). This species was followed in importance by palm hearts (*Euterpe* spp.) (3.4% of total export or 5.7 million dollars) and cocoa (*Theobroma cacao*) (1% of total export or 1.6 million dollars). However, the 'real' total value of NTFPs tends to be underestimated, because the majority is not traded through established market channels and does not appear in official national economic statistics (de Beer and McDermott, 1996). As a result, a number of NTFPs often remain beyond the vision of policy makers and development planners (Ros-Tonen *et al*., 1995; van Andel, 2000). Moreover, in addition to 'economically important' NTFPs, the forest also provides many other timber and non-timber products that are part of household economies and that are grossly undervalued by a monetary-based perspective (Phillips *et al*., 1994; Ros-Tonen and Wiersum, 2003).

In Chapare (the province wherein our TIPNIS study site was situated), alternative development plans ("*Desarrollo Alternativo*") have tried to establish over the last decade diversified legal economies based on a variety of plant products to counter illegal coca production (FAO, 2001; Statz, 2000; Beetstra, 2005b). The most important of these are crop species including bananas (*Musa* spp.), citrus fruits (*Citrus* spp.) and pineapple (*Ananas comosus*), as well as some more conventional NTFPs, including palm hearts (*Euterpe* spp.), annatto (*Bixa orellana*) and rubber (*Hevea brasiliensis*) (Beetstra, 2005b). In recent years, there has been a growing interest in other local NTFPs that are already gaining importance in Bolivian economy, such as *Rheedia acuminata*, *R. gardneriana*, *Bactris gasipaes*, *Inga* spp. (cf. figure 8.14), *Geonoma deversa, Attalea phalerata, Passiflora edulis* f. *flavicarpa*, *Uncaria tomentosa, U. guianensis* and *Croton lecheri* (Statz, 2000; Hinojosa *et al*., 2001; FAO, 2001; Vasquez and Coimbra, 2002; Ibisch, 2003b; Moraes, 2004; Delanoy *et al*., 2007). Most of these species were also inventoried during the present study, in addition to numerous other important NTFPs. Hence, the particular value of the present study is that it provides the baseline data whereupon plant species with high local and (inter)national economic potential can be identified and selected in the framework of new crop development projects.

In Apillapampa, a potential for application of existing plant knowledge could be the development of local agroforestry systems. Agroforestry projects have already been successfully introduced elsewhere in the Bolivian Andes using numerous native multipurpose species, several of which also occur naturally in Apillapampa, such as *Dodonaea viscosa*, *Vasconcellea quercifolia*, *Acacia visco*, *A. aroma*, *Schinus molle*, *S. haenkeana* and *Tipuana tipu* (Mahboubi *et al*., 1997; FAO, 2001). All these species can play an important role in the development of agroforestry systems. However, a particularly important species for Apillapampa that is missing on this literature list is *Prosopis laevigata*. During our study, we noticed the large potential of this locally available, drought and salinity resistant tree for countering some of the principal causes that lead to ecosystem degradation in Apillapampa. According to our findings, *P. laevigata* is locally one of the most valued plant species.

Currently, people already benefit from its: (1) good quality firewood and charcoal (the calorific value of the sapwood of a related species, *P. juliflora*, is as high as 17,000-19,000 kJ/kg (FCG, 2000)); (2) highly palatable and protein-rich animal fodder (leaves and pods); (3) high quality timber for domestic constructions and handicrafts; (4) high protein and sugar content of its fruits and seeds for human consumption (Odul *et al*., 1986); (5) ethnomedicinal applications (Vandebroek *et al*., 2003); and (6) shadow. Yet, in an integrated agroforestry system, this tree could generate numerous additional benefits, including: (1) effective erosion control when planted along contour lines; (2) wind screen function leading to decreasing evapotranspiration on neighbouring lands; (3) soil enrichment through leaf litter and nitrogen fixation by symbiotically associated *Rhizobium* bacteria; and (4) apiculture (Olalde Portugal and Aguilera Gómez, 1998). In view of these qualities, we strongly recommend further research into the incorporation of *P. laevigata* in the agricultural systems of Apillapampa and similar communities.

12.4. Patterns in Plant Use and Knowledge

The present study contributes to theory-building in ethnobotany by indicating three general patterns in traditional plant use and knowledge for the Andes and Amazon: (1) patterns in plant use at the species level; (2) patterns in the usefulness of vegetation units and ecological systems; and (3) patterns in plant knowledge of indigenous participants.

Factors Guiding the Usefulness of Plants Species

This study revealed that both in the Andes and Amazon, the usefulness of particular plant species is far from entirely determined by stochastic processes, but can be predicted relatively well from a number of plant characteristics (chapters 4 and 9). Plant family and growth form are significant factors in determining the use value of particular plant species. Some families are clearly more useful than others for particular uses, although significant variation occurs according to the ecological setting (Andes versus Amazon). Woody plants tend to be more appreciated as sources of food, (construction) materials and fuel, whereas herbaceous plants generally seem to have a higher therapeutic value. These observations correspond fairly well with observations made in literature (Moerman, 1996; Stepp and Moerman, 2001; Gottlieb and De Borin, 2002; Voeks, 2004; Van den Eynden, 2004).

The fact that in Apillapampa woody plants and herbs have an equal usefulness in traditional medicine can be explained by their availability and accessibility. In addition to being distributed more continuously over the landscape than herbs (chapter 2), the relatively limited number of woody species occurring in Apillapampa is available year-round, whereas most herbaceous plants only grow during a limited period of the year (basically coinciding with the rainy season). Based on these characteristics, we hypothesized that woody plants will be better known by people and would therefore be perceived as more useful. This hypothesis has a relatively long-standing tradition in ethnobotanical investigation and it starts from the assumption that people are more likely to learn, name and use those plants that are more accessible and/or salient to them (Adu-Tutu *et al*., 1979; Brown, 1985; Turner, 1988; Johns *et al*., 1990; Phillips and Gentry, 1993b; Alexiades, 1999; Frei *et al*., 2000; Casagrande, 2002; Bonet and Vallès, 2002; La Torre-Cuadros and Gerald, 2003; Voeks, 2004; Van den Eynden, 2004; Byg *et al*., 2006).

In this respect, most scholars presume that density and frequency of plants in the landscape are representative for plant accessibility to people, but this assumption has hardly ever been tested. We confirmed its validity for both our Andean and Amazonian study sites (chapters 4 and 9) by demonstrating that density and frequency of plants in the landscape are indeed correlated with their accessibility as perceived by participants. On the other hand, salience of plants is related to their general visibility. In literature, mean and maximum dbh values of plants in forests are often taken as representative parameters for salience, assuming that larger plants are easier to locate and therefore quicker to find than more inconspicuous plants (Turner, 1988; Phillips and Gentry, 1993b; Jain, 2000; Byg *et al*., 2006). Nonetheless, salience and accessibility are not necessarily correlated, as we concluded from our study in TIPNIS.

Our research findings from the Andes and Amazon have statistically confirmed the argument made in literature that density and frequency in the landscape, as well as mean and maximum dbh (as representative parameters for plant accessibility and salience, respectively) have a definite role in predicting usefulness of plants. Yet, the trends we detected varied somewhat according to the ecological and ethnological setting. In TIPNIS, all variables co-varied with perceived plant usefulness, whereas in Apillapampa basically only plant frequency was a statistically significant predictor of perceived plant usefulness. We have further shown that, in addition to these ‘physically measurable’ parameters, indigenous assessments of accessibility and local abundance of plants also have a potential for uncovering patterns in the perceived utility of plant species. However, in order to obtain reliable results from these variables, it is important to know the geographical scale at which local participants assess abundance and accessibility (e.g. based on privately owned terrains versus the entire local environment occupied by people).

The hypothesis that more accessible plants are perceived as more useful by people and thus are used more (often) was further confirmed in TIPNIS by demonstrating that plants growing in anthropogenic disturbance habitats have a higher average usefulness than plants growing in natural environments (chapter 10). This was an expected outcome, given that (1) areas under anthropogenic disturbance are generally richer in managed species than natural ones and (2) the higher usefulness of plants is usually the driving force for actually managing (i.e. cultivating or tolerating) them (Clement, 1999a; Van den Eynden, 2004). In the same line of reasoning, our results also correspond relatively well with the growing consensus on the importance of disturbance landscapes in the provision of ethnomedical remedies (Posey, 1984; Balée, 1994; Voeks, 1996; Ankli *et al*., 1999a; Frei *et al*., 2000; Stepp and Moerman, 2001; Thomas, 2001; Etkin, 2002; Begossi *et al*., 2002; Di Stasi *et al*., 2002; Hernández Canoa and Volpato, 2004; Voeks, 2004; Grenand *et al*., 2004). In TIPNIS, some 42% of medicinal plants occur in anthropogenic disturbance habitats. In Apillapampa, this proportion is significantly lower (21%), but the severely fragmented status of the ‘natural’ vegetation makes that almost the entire landscape can be classified as anthropogenic. The usefulness of disturbance landscapes as sources of medicinal plants is often explained by the notion that disturbance pharmacopoeias combine (1) optimal foraging features (plants from anthropogenic disturbance habitats are easily accessible and better known) with (2) the natural distribution of promising plant-derived compounds (disturbance species are more likely to contain bioactive substances) (Stepp and Moerman, 2001; Voeks, 2004).

Usefulness of Vegetation Units and Ecological Systems

Some vegetation units (i.e. vegetation sampled in individual transects) are clearly more useful to people than others. Patterns in perceived usefulness of vegetation units were most notable in Apillapampa (chapter 4) where most of the variation in usefulness could be ascribed to (1) the altitude where vegetation units occurred; (2) their accessibility to local people (measured as travel time from the village centre); (3) whether or not exotic tree or shrub species had been planted in it; (4) recent burning activity; and (5) the proximity to a (temporary) river or stream. Whereas anthropogenic disturbance seems to be detrimental for plant diversity in Apillapampa, it does not necessarily have a negative impact on the usefulness of vegetation units. For example, the usefulness of vegetation units with lower diversity (such as vegetation occurring at more accessible sites or sites where exotic trees or shrubs had been planted) appears to be higher than that of other vegetation units.

Diversity of vegetation units in Apillapampa (expressed as alpha and Shannon-Wiener diversity) turned out to be a fairly good predictor of the perceived usefulness of vegetation at sampling sites. Regression slope analysis demonstrated that two groups can be distinguished in the use categories of vegetation units. In the first group (i.e. *diversity followers*, including fodder, medicine and fuel), the proportion of useful plant species in vegetation units is relatively invariable with increasing levels of diversity. In the second group (i.e. *diversity laggards*, including food and materials), the proportion of useful plant species gradually decreases with increasing levels of diversity. To explain these trends, we have hypothesized in chapter 4 that plant use in categories of diversity followers often occurs in a context of urgency or immediacy, whereby emic perception of efficacy of plants is probably of secondary importance. By contrast, plant use in categories of diversity laggards is strongly guided by emic perception of efficacy because plant use takes place in a non-urgent context whereby plants are generally not needed on a short notice.

Both in Apillapampa and TIPNIS, a comparison of usefulness based on vegetation types (i.e. "ecological systems" (Josse *et al.*, 2007)) demonstrated that from a utilitarian perspective people rate different vegetation types in their surroundings about equally. Despite some minor differences at the level of specific use categories (food, fuel and fodder), people from Apillapampa ascribed an equal usefulness value to vegetation of *prepuna* and *puna* ecological zones (chapter 4). Likewise, we showed that in TIPNIS relatively equal usefulness values were obtained for the three different forest types that were sampled (chapter 9). Nonetheless, our findings from TIPNIS also partly corroborate the hypothesis described in literature that floodplain forests have a higher usefulness for local people than *terra firme* forests (Phillips *et al.*, 1994).

Results discussed in chapters 4 and 9 highlight the necessity for local people to access each of the vegetation types that were studied if their elementary subsistence requirements are to be met. In particular for the Amazon, these findings have an important conservation message. Indeed, the usefulness of forests for indigenous peoples who rely on them has been cited as an important reason for rainforest conservation (Myers, 1982; Prance *et al.*, 1987; Phillips *et al.*, 1994; van Andel, 2000). In view of the – at first sight – non-detrimental current land use practices of Yuracarés and Trinitarios (cf. section 12.1) there exists a significant latent potential to combine local people's legitimate needs with the conservation of different forest types in TIPNIS (Phillips *et al*., 1994). Up to today, relatively few Yuracarés and Trinitarios establish their swiddens on floodplains to avoid the risk of losing crops to flooding, and because land with a high water table does not sustain as many crops as well-drained land. Floodplain forests are mainly used as hunting grounds and to harvest NTFPs for subsistence use. Such land use conditions could ensure the local protection of floodplain forests which are more susceptible to habitat destruction than *terra firme* forests because they (1) occupy much smaller surface areas throughout Amazonia (Ter Steege *et al*., 2000) and (2) tend to become deforested more rapidly than *terra firme* forests (Phillips *et al*., 1994). In Apillapampa, conservation of *prepuna* and *puna* vegetation types seems less compatible with unrestrained access and exploitation by humans. Instead, urgent measures need to be taken to lower pressure on the natural vegetation (see *supra*).

Variation in Participant-Related Plant Knowledge

In chapters 3 and 8, we have provided support for the well-documented notion that local knowledge is not evenly distributed among traditional societies and that this distribution is not random but patterned, based upon our study populations in Apillapampa and TIPNIS (D'Andrade, 1987). Division of knowledge by age, gender or social status has been reported quite widely in literature (Ellen, 1979; Berlin, 1992; Phillips and Gentry, 1993b; Bernstein *et al*., 1997; Begossi *et al*., 2002; Ladio and Lozada, 2004). Healers are generally more knowledgeable about medicinal plants than laypeople (Vandebroek *et al.,* 2004b). Also, women (Kainer and Duryea, 1992; Begossi *et al*., 2002; Stagegaard *et al*., 2002; Howard, 2003; Deda and Rubian, 2004; Lawrence *et al*., 2005) and children (Ros-Tonen *et al*., 1998; Setalaphruk and Price, 2007) often dispose of extensive knowledge on plant use, but this knowledge may remain largely invisible to outsiders.

Although some of these patterns are confirmed by our findings from the Andes and Amazon, their validity was not consistent between both areas. In our participant population of the Andes, no differences in plant use knowledge were observed based on ethnomedical specialisation (healers versus laypeople) or gender. By contrast, ethnomedical specialization and gender were the only significant factors, in addition to ethnicity, that partly explained differences in plant use knowledge between participants from the Amazon (chapter 8). In Apillapampa, participant age was the only demographic factor explaining differences in plant knowledge (chapter 3), whereas in TIPNIS its role was insignificant. However, Vandebroek *et al*. (2004b) demonstrated that among Yuracaré and Trinitario healers from TIPNIS age of initiation in traditional healing did correlate significantly with knowledge of medicinal plants.

Hence, our findings suggest that patterns in plant knowledge of local people can simply not be generalized over different ethnic groups. On the other hand, it is also possible that our sample sizes were too small to detect these trends and/or the age spectrum of participants was not sampled wide and/or evenly enough.

12.5. Ethnic Differences between Plant Knowledge and Management of Yuracarés and Trinitarios from TIPNIS

The fact that the Yuracaré and Trinitario communities included in this study share the same living environment in TIPNIS provided an excellent opportunity to compare their plant use knowledge and management practices. Our results have clearly demonstrated that homegardens and swiddens of Trinitarios contain more managed (i.e. cultivated and tolerated) plants, a higher number of which are exotic. Trinitarios also hold more knowledge about the plants they manage than Yuracarés. There exists a higher level of consensus among the former and/or they ascribe more uses to these plants. By contrast, Yuracarés know the wild flora better and rely significantly more on it than Trinitarios for obtaining medicinal and food plants.

We have argued that the observed differences in the use of the natural versus anthropogenic environment by Yuracarés and Trinitarios are, at least in part, associated with the provenance of both ethnic groups. Trinitarios migrated recently (i.e. 1970s) to TIPNIS and therefore they probably do not know the local flora as well as the Yuracarés who are native inhabitants of the park (Lilienfeld and Pauquet, 2005). Trinitarios do not seem too keen on learning about wild food plants from Yuracarés either. Trinitario participants frequently related Yuracarés' higher knowledge of the forest to their less 'civilized' status (Lilienfeld and Pauquet, 2005).

On the other hand, differences in knowledge and use of managed plants between Yuracarés and Trinitarios can also be linked to a number of other factors. Length of contact with western society is important because it allowed for the introduction of more 'new' (exotic) cultivated plant species (Bennett and Prance, 2000; Voeks, 2004). This partly explains why Trinitarios, who have a long history of contact, manage significantly more exotic plants in their homegardens and swiddens than Yuracarés who have a contact history of only approximately 35 years. However, also the scope and intensity of (pre-Columbian) interethnic contacts are important because they stimulate(d) the exchange of plant material and knowledge between indigenous societies (Anderson and Posey, 1989; Bennett, 1992; Phillips and Gentry, 1993b; Milliken and Albert, 1997; van Andel, 2000). In pre-Columbian times, Trinitarios shared their original homelands, i.e. the plains of Moxos, with numerous other ethnic groups (Gantier, 1991; Santamaria, 1994; Bert *et al.*, 2004) and they maintained interethnic relations with societies situated at larger distances (Erickson, 2000a). By contrast, Yuracarés had very few interethnic contacts and lived in groups of no more than ten families in a highly dispersed manner throughout their habitat (Paz, 1991; Kelm, 1997; Querejazu, 2005a).

Also the historic lifestyle of an ethnic group is highly relevant for establishing a repository of managed plant species. Advanced agricultural societies such as the Trinitarios are known to accumulate crop genetic resources, both importing and developing them as part of their agricultural intensification (Clement, 1999a). By contrast, (semi-)nomadic people, such as the Yuracarés, have much more difficulties to maintain a high number of cultivated plant species in their agricultural system (Balée, 1994).

Additional factors that explain differences in knowledge about managed plants between Yuracarés and Trinitarios may be related to the cultural patrimony of either ethnic group. Some specific plant uses reflect their particular worldview and/or ontology, whereas a number of differences in plant uses and management are related to differences in the more specialised ethnomedical system of Trinitarios as compared to Yuracarés.

12.6. Medicinal Plant Use in Apillapampa and TIPNIS

The results of our study have shown that mainly the Quechuas from Apillapampa and the Trinitarios from TIPNIS use a remarkably high number of medicinal plant species for treating a wide variety of health conditions. Our findings support the hypothesis that the contact history of a particular ethnic group with western society is related to the number of medicinal plants used by this group, as well as the number of health conditions that are treated with medicinal plants (Prance, 1972; Davis and Yost, 1983a; Balée, 1993; Estrella, 1995; Milliken, 1997a; van Andel, 2000; Voeks and Sercombe, 2000; Voeks, 2004; Vandebroek *et al.*, 2004b; Izquierdo, 2005).

The Spanish first arrived in the Bolivian highlands in 1532 (Torrico Prado, 1971; Bastien, 1987a). From thereon they moved to the lowlands. Hence, Andean-based Quechua and Aymara people were the first to be contacted. The first written record from the Moxos plains (i.e. the traditional homeland of the Mojeños) dates from 1562 (d'Orbigny, 1845; Block, 1980). By contrast, the Yuracarés who participated in the present study have a contact history that is limited to the last 35 years. Medicinal plant uses recorded during the present study correspond with this ranking: 341 species for Quechuas, 329 for Trinitarios and 195 for Yuracarés (chapters 3 and 8). The underlying mechanism of *less contact parallels less medicinal plants* is linked in the literature with the fact that a lower degree of contact goes hand in hand with a better nutritional status, as well as a lower number of (introduced) diseases that can afflict a society (Davis and Yost, 1983a; Alchon, 1991; Balée, 1994; Estrella, 1995; Milliken, 1997a; Voeks, 2004; Izquierdo, 2005). As a response to a higher incidence of diseases, societies with a longer contact history have developed larger pharmacopoeia consisting of native and introduced plants (Bennett and Prance, 2000; Voeks, 2004).

In this respect, also the (historical) lifestyle has important implications for the breadth of medicinal plant use. Agricultural societies with higher population densities such as those of Quechuas and Trinitarios favoured the spread of infectious diseases and probably stimulated the development of more specialised ethnomedicinal systems (see chapter 8 and Bastien, 1987a). In the case of Quechua people, there is also the confrontation with the hostile and unpredictable environment people are exposed to (characterised by problems in the sphere of hypoxia, hypothermia and malnutrition). This harsh environment is believed to have fuelled their strong cultural tradition of traditional medicine (Bastien, 1982 and 1987a; Vandebroek *et al.*, 2004b). By contrast, ethnic groups that maintained low population densities, sometimes in combination with a (semi-)nomadic lifestyle such as the Yuracarés correspond to a 'healthy forager profile', demanding fewer remedies for treating fewer diseases (Balée, 1994; Voeks, 2004).

Both in Apillapampa and TIPNIS, we observed that people tend to use large numbers of medicinal plants for treating similar health conditions, although some effective remedies appeared to be available (chapters 3 and 8). We have brought forward several possible explanations for the high number of medicinal plants known in Apillapampa and TIPNIS, most of which have been backed up by literature. First, we argued that the irregular spatial availability of most plants in Apillapampa and TIPNIS stimulates people's knowledge of a broad range of (medicinal) plants from all ecological units where they live and work. In addition to spatial factors, plant availability in Apillapampa is also strongly linked to the season which, as argued before, might have led to a better knowledge of the perennial flora that remains visible year-round (chapter 3). Second, we related the number of medicinal plants used per health condition to the local prevalence of health conditions and the number of causal factors underlying these conditions. In Apillapampa, the relationship between prevalence of health conditions and the number of medicinal plants used was demonstrated by Vandebroek *et al*. (2008). In TIPNIS, this relation was confirmed by means of a household survey conducted during the present study (chapter 8).

The sensory perception of plants (including plant use in the framework of the Doctrine of Signatures) was identified in both research areas as a third relevant factor for medicinal plant selection, although it appeared to be more pronounced in TIPNIS (chapter 8). Additional explanatory factors for the high number of medicinal plants used per health condition that are most relevant for the case of Apillapampa include: (1) the tendency of traditional healers to experiment with 'new' medicinal plants; (2) the inability to empirically test the efficacy of plants used in mixtures; and, finally (3) medicinal properties may be ascribed to plants through association with other, similar plants (chapter 3).

It is clear that up to date, the indigenous communities studied still rely heavily on medicinal plants as compared to pharmaceuticals from industrial origin for their healthcare. Based on household interviews, Vandebroek *et al*. (2004a) demonstrated that in Apillapampa an equal number of participants used medicinal plants and pharmaceuticals, whereas their relative use in TIPNIS depended on the distance of the community from the nearest village and from a physical health-care centre (PHC) with a medical doctor. In TIPNIS, Vandebroek *et al*. (2004a) also revealed a positive relationship between medicinal plant knowledge in a community and distance to the nearest village and PHC with medical doctor.

However, the fact that people in Apillapampa still use an exceptionally high number of medicinal plants in spite of the presence of a PHC in the community, strongly suggests that apart from physical distance (Baker and Gesler, 2000) some additional barriers limit the use of Western health care (products) by indigenous peoples (Bastien, 1987b and 1990; Curtis and Taket, 1996; Oths, 1998; Kinman, 1999; Vandebroek *et al*., 2004a and 2008). Most importantly, a cultural barrier prevails: local people basically hold more trust in their own healing traditions and believes. As mentioned in chapter 11, Western medical practitioners often fail to gain trust of indigenous people because they do not fully understand or do not take into consideration the local aetiology or ontology, and/or worldview-related aspects of health conditions (cf. Cocks and Dold, 2000). In addition, people may be suspicious of western treatment methods such as the administration of intravenous infusions or taking of blood samples (i.e. a psychological barrier) (Bastien, 1987). Finally, a considerable economic barrier prevails as well because many families are unable to purchase the rather expensive western medicines and medical services (Bastien, 1987).

This study contributes to bridging the gap between traditional and modern medicine, both through the publication of two medicinal plant guides (Vandebroek *et al*. (2003), and Thomas and Vandebroek (2006) for the Andes and Amazon, respectively) and through documenting a better understanding of folk illnesses. Both books list details of ethnomedical uses and plant preparations and also cite relevant pharmacological properties of the plants from literature. This information could allow professional health care workers to acknowledge certain plant uses and discourage other, more hazardous ones, or at least point to health risks associated with potentially toxic plants.

Medical health personnel in Bolivia is relatively familiar with typical Andean folk illnesses such as bad wind (*wayra*), although western medical treatments do not exist. In the lowlands, the situation is somewhat more complicated due to the high number of different indigenous societies who may all have different disease concepts. For example, in chapter 11, we have shown that fright sickness or *susto*, which is also well known in the Bolivian Andes, has a very specific interpretation in the Trinitario culture. As we have personally witnessed, *susto* makes real casualties in TIPNIS that could possibly be avoided through a proper intervention of professional health care workers. The principal barrier that currently seems to constrain involvement of modern medicine in *susto* cases is related to the lack of understanding among health care workers of its aetiological and ontological significance to Trinitario people. The same is valid for other disorders that are locally perceived as caused by witchcraft or supernatural forces and that are typically cured by Trinitario shamans. In order to gain confidence of people, health care workers should become familiar with their ethnomedical system and attempt to integrate it into modern medicinal treatments, rather than discarding it as ‘nonsense’ (Bastien, 1987a).

12.7. Modernization

Although the people who participated in this study still hold a good knowledge of the useful plants available in their living environments, modernization is spreading rapidly. Much of the traditional knowledge is no longer transmitted to the younger generation. As societies become more involved in the market economy, (especially younger) people tend to substitute traditional knowledge and plant use with cultivated or market-based consumption goods (van Andel, 2000).

However, in the present study it seemed that also the social position occupied by an ethnic group is of key importance in explaining modernization. In TIPNIS, we noticed that modernization seems to be occurring at a higher rate among Yuracarés than among Trinitarios. We hypothesize that this can partly be attributed to the submissive position Yuracarés occupy in TIPNIS, as compared to Trinitarios and Andean settlers who are clearly more dominant (Lilienfeld and Pauquet, 2005).

The fact that Trinitarios and Andean settlers are dominant ethnic groups in TIPNIS probably has its origin in the dominant positions both societies historically occupied in the Bolivian highlands and lowlands, respectively. Trinitarios and Andean settlers are proud of their culture and show a much stronger social cohesion than Yuracarés. Therefore, it is of no surprise that in general Trinitarios tend to take the lead when dealing with conflicts between Andean settlers and indigenous people in TIPNIS. By contrast, Yuracarés are somewhat marginalised by other ethnic groups and have long been considered as ‘savages of the forest’. Also, during the present study we have personally experienced on various occasions the denigrating attitude of both Andean settlers and Trinitarios towards Yuracarés. The ‘savage’ connotation of Yuracarés obviously relates to the fact that until the arrival of Trinitarios and Andean settlers in TIPNIS (1970s), the Yuracarés still engaged in a semi-nomadic life style, characterized by low population densities (Paz, 1991; Querejazu, 2005a).

As a consequence of this submissive position, Yuracarés rapidly abandoned most of their traditional customs, ashamed to be laughed at or to be insulted (Paz, 1991; Querejazu, 2005a). Most Yuracaré elders who participated in the present study are still fully knowledgeable about most of the traditional practices, customs and legends (see Appendix 3) of their people. However, transmission of this knowledge to the younger generation seems to be strongly decreasing and nowadays most Yuracaré children only learn how to speak Spanish.

Trinitario people appear to be more resistant to modernization. Nearly all Trinitario children from the participating communities first learn how to speak Trinitario before they start learning Spanish. Also, the fact that traditional customs such as the dance of the *macheteros* and shamanistic healing techniques are still actively practiced shows that the Trinitario culture has withstood hundreds of years of cultural influences relatively well.

The present study fulfils an important role in documenting the traditional knowledge of the three participating ethnic groups while it is still known and/or in use. The continuously increasing loss of traditional knowledge is a worldwide phenomenon and protocols to protect, validate and record traditional knowledge were established for the first time during the *Convention on Biological Diversity* of 1992 in Rio de Janeiro (www.cbd.int). Documentation of plant knowledge guarantees its availability for future generations of the traditional communities concerned, as well as for the scientific community at large.

The two medicinal plant guides that partly resulted from the present study were distributed in the communities from where ethnomedical data were obtained. This feedback ensures that plant knowledge remains accessible to the people who actually apply it in their daily lives. Moreover, the published plant guides (written in Spanish) can boost a renewed interest in traditional medicinal knowledge (Martin, 1995), particularly among the local youth. As a first step in this direction, both in Apillapampa and the participating communities from TIPNIS, the books are being used in local schools as part of study material. For the case of TIPNIS, the books additionally allow exchange of ethnomedical knowledge between Yuracarés and Trinitarios. Currently, a new project funded by the VLIR (Flemish Inter-University Council, Belgium) will bring traditional healers from TIPNIS together with Bolivian biomedical healthcare providers to establish an integrative healthcare initiative, using the medicinal plant guide as an instrument for training.

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Summary

This dissertation documents the ethnobotany of three different ethnic groups in Bolivia, i.e. Quechuas, Yuracarés and Trinitarios. It provides a complete survey of more than 1100 useful plant species and their uses, together with their occurrence in different local vegetation types. Chapters 2 to 5 of the dissertation are dedicated to plant knowledge of Quechua farmers from Apillapampa, a community located in the Bolivian Andes. In chapters 6 to 11, plant knowledge of five Trinitario and Yuracaré communities located in the Amazonian forest of the Indigenous Territory and National Park Isiboro-Sécure (TIPNIS) is presented and discussed. This study contributes to a better understanding of the biocultural diversity of Bolivia and provides baseline data for the development of future resource management and conservation plans.

Chapter 1 presents a brief overview of the ethnographic settings of the present study. The Quechua farmers from Apillapampa practice small-scale agriculture in combination with animal husbandry on the steep slopes of the semi-arid Bolivian Andes. The Yuracarés and Trinitarios are small-scale, village-level swidden horticulturalists. The most important cultural characteristics of all three groups are presented, in combination with a concise description of their contact history.

In chapter 2, the ecological setting in Apillapampa is described. The taxonomic composition and variation in growth forms of the 441 plant species that were inventoried are discussed and an overview is given of all cultivated plants, including agricultural crops. Apillapampa is situated at the interface of *prepuna* and *puna* ecological zones. A division between both zones, based upon our ecological data gathered in thirty six 50 x 2 m^2 transects, corresponds well with the existing phytosociological and indigenous classification systems. A detailed account of dominant plant families and species in each zone is linked with relevant floristic and ecological literature data. Our results show that there is a need to improve accuracy of the existing vegetation map of the region.

The vegetation in Apillapampa is strongly fragmented and degraded as a consequence of past and present human activities. Local participants are aware of the short-term decrease in a number of local wild plant populations, which they mainly ascribe to anthropogenic factors such as overharvesting and overgrazing. An assessment is made of the natural and anthropogenic environmental variables that best explain the variation in the abundance of plant species in the landscape. Additionally, we examined to what extent these variables can be used for predicting plant diversity at the study sites. Most anthropogenic disturbance variables, including site accessibility, cultivation of exotic species and burning of the vegetation, have a marked negative effect on plant diversity. Our results are valuable for future management and conservation plans in the region.

In chapter 3, a detailed description is given of plant uses in Apillapampa for a total of 387 species as recorded from 13 local Quechua participants. Among participants, age appeared to be the predominant demographic characteristic explaining plant knowledge. Plant uses are discussed within the framework of different use categories, including medicine, food, fuel,

animal food, materials, social uses and environmental uses. For each use category, plant species and families that are most useful to people in Apillapampa are highlighted. The most important families of useful plant species are Asteraceae, Fabaceae, Solanaceae and Lamiaceae. Species with the highest overall use values are mostly trees, including *Prosopis laevigata*, *Schinus molle*, *Acacia visco* and the exotic *Eucalyptus globulus*. A detailed account is given on the remarkably high number of medicinal plants used. A number of factors are put forward that might contribute to explaining patterns in the selection of medicinal plants and the existence of such a large pharmacopoeia in Apillapampa. These factors include availability and accessibility of plants; characteristics of specific health conditions; the dynamic and specialized nature of traditional medicine in Apillapampa; inability to empirically test the efficacy of plants used in mixtures; and sensory perception.

Villagers in Apillapampa make exhaustive use of their surrounding wild flora. Nearly all plant species and individuals (94-100% and 92-100%, respectively) encountered in transects are perceived as useful. In chapter 4, factors that guide the usefulness of plant species and vegetation units are identified. The usefulness of plant species in Apillapampa can be predicted from several phylogenetic, morphological, ecological and anthropogenic characteristics. The usefulness of vegetation units occurring at different sites throughout the landscape is determined by the altitudinal position of these sites, their plant diversity and accessibility, the presence of exotic species, signs of recent burning activity and proximity to a (temporary) river or stream. Our findings corroborate the hypothesis frequently made in literature that "the more accessible is perceived as more useful by people". Although vegetation at more accessible sites is less diverse, its perceived usefulness tends to be higher. In spite of the variation in usefulness of vegetation units, all landscape units were of high importance to people from Apillapampa. Regardless of some minor differences in categorical use values, local residents equally value the *prepuna* and *puna* ecological zones.

People in Apillapampa rely heavily on wild firewood species for their fuel needs. In chapter 5, an appraisal is made of the harvesting impact on the populations of wild firewood species by taking into account local people's assessments of (sub-)woody plant abundance, coppicing or resprouting capacity of plant species, root harvesting and firewood quality. The results suggest that wild populations of a number of (sub-)woody plant species are negatively affected by firewood harvesting. Some people do practice sustainable harvesting of firewood species, but there does not exist a socially controlled system for the promotion of sustainable harvesting. In addition to altitude, it are anthropogenic variables that explain the variation in height of different firewood species all over the landscape. Anthropogenic pressure on wild firewood species in Apillapampa also seems to parallel their abundance and accessibility in the landscape. The negative impact of harvest appears to be particularly high on more abundant and accessible firewood species.

After chapter 5 starts the second part of this thesis that deals with the plant use of Yuracarés and Trinitarios from Indigenous Territory and National Park Isiboro-Sécure (TIPNIS).

The adequate protection and management of tropical rainforests requires a basic understanding of rainforest biodiversity. To date, extremely little is known of the floristic composition and botanical diversity of the 12,000 km² large TIPNIS. Chapter 6 reviews the floristic composition, vegetation structure and diversity of *terra firme,* floodplain and *varzea* forests in the southern part of TIPNIS. All stems ≥ 2.5 cm dbh (diameter at breast height, i.e. at 1.3 m) were inventoried in four 0.1-ha transects. Floristically, these forests correspond with other representative Neotropical forests. Diversity levels are among the highest ever recorded for Bolivia, and are in line with patterns linked to precipitation and substrate. Nevertheless, the current model-based map of Amazonian *terra firme* tree diversity appears to underestimate diversity in the southern part of TIPNIS. Further research is needed to reveal whether this map needs revision for our study area. On the other hand, our study has unmistakably shown that there is a great need for updating the existing phytosociological vegetation map of the region which is based on very little data. These results are important for the identification of areas that warrant conservation priority within TIPNIS.

Nearly half (49%) of all 906 plant species and morphospecies inventoried in TIPNIS were collected outside transects in both natural and anthropogenic landscapes. In chapter 6, a description of the taxonomic composition and variation in growth forms is given for the total plant inventory.

In chapter 7, an assessment is made of the advantages and disadvantages of different interviewing methods applied during our TIPNIS study. These include *in situ* interviews during transect sampling, walk-in-the-woods and homegarden sampling, as well as *ex situ* interviews with fresh plant material, voucher specimens and plant photographs. A large part of our ethnobotanical data was obtained from photograph-based interviews. Therefore, the ability of participants to recognize plants from photographs was tested. The results demonstrate the usefulness of photographs in ethnobotanical interviews and justify our methodological approach.

Ethnobotanical interviews with 26 Yuracaré and Trinitario participants using techniques described in chapter 7, revealed a total of 735 useful species for TIPNIS. In chapter 8, a detailed description is given of all different plant uses ascribed to these species. In analogy to chapter 3, plant uses in TIPNIS are discussed within different use categories, including medicine, food, fuel, construction, materials and social uses. For each use category, plant species and families that are most useful to participants are highlighted. Species with highest overall use values are mostly palm trees, including *Attalea phalerata*, *A. butyracea*, *Bactris gasipaes* and *Jessenia batua*. The most important families of useful plant species for Yuracarés and Trinitarios are Arecaceae, Myristicaceae, Burseraceae, Sapotaceae, Poaceae, Anacardiaceae and Annonaceae.

The most notable differences between plant knowledge of Yuracarés and Trinitarios are found at the level of medicinal and edible plants. Trinitarios were clearly more knowledgeable about medicinal plants than Yuracarés, whereas the opposite conclusion can be drawn for edible plants. A comparison with studies from literature showed that the absolute number of medicinal and food plants used by Trinitarios and Yuracarés, respectively, is among the highest recorded to date for any Amazonian group. Participants of both ethnic groups held comparative knowledge of plants in most other use categories, such as fuel, construction and materials. As for Apillapampa, a more detailed account is given on the high number of medicinal plants used in TIPNIS.

In chapter 8 it is demonstrated that the Trinitario ethnomedical system, which is composed of shamans, herbalists, midwives and bonesetters, has successfully withstood hundreds of years of cultural influences. Healing customs and beliefs described in early writings of missionaries and ethnographers correspond well with contemporary ethnomedical practices. Participants who are specialized in therapeutic applications of plants were significantly more knowledgeable about the medicinal and social uses of plants than laypersons.

The usefulness of different forest types for local people is, in addition to their diversity, another strong motivation for conservation. Chapter 9 provides a quantitative assessment of the value local people assigned to different forest types. It shows that all studied forest types are of great importance to local people. High use percentages indicate that people had a profound knowledge of their forests: 74-82% of species and 85-92% of individuals in transects were considered useful to Yuracarés and Trinitarios. The percentage of useful species was slightly higher for the understorey (dbh < 10 cm) than for the overstorey (dbh ≥ 10 cm) vegetation. Particularly higher percentages of plant species with medicinal and social uses were found in the understorey.

We have found only partial support for the argument made in literature that *terra firme* forests are less useful to people than floodplains or *varzea* forests. A comparison of the usefulness of different forest types to members of both ethnic groups showed that Yuracarés tend to value the forest more for the edible plants it provides, whereas Trinitarios assigned a higher medicinal and social usefulness to it. Hence, our findings unmistakably highlight the need for local people to be able to access all different vegetation types studied, if their subsistence requirements are to be met.

In chapter 9, we further showed that also in TIPNIS there exist correlations between the usefulness of plant species and several phylogenetic, morphological, ecological and anthropogenic characteristics. The results show that the usefulness of plants to Yuracarés and Trinitarios is correlated both with the accessibility and salience of these plants in natural landscapes.

A growing number of scholars is supporting the notion that indigenous forest management in the Neotropics represents a contribution to biodiversity. Chapter 10 explores in a qualitative way the validity of this hypothesis for the case of Yuracarés and Trinitarios from TIPNIS. It demonstrates that conservation ethics are not (always) of primary concern to Yuracarés and Trinitarios when harvesting wild plant species. Even in tropical rainforest settings with high levels of plant diversity, certain species may be harvested unsustainably. Notably in this respect is people's tendency to start cultivating the overharvested timber species *Swietenia macrophylla* as an investment for the future.

In chapter 10, we have reiterated that the perceived usefulness of plants co-varies with their physical accessibility by demonstrating that plants growing in anthropogenic disturbance environments are more useful to people than plants from undisturbed habitats. Particularly Trinitarios rely significantly more upon disturbance habitats for obtaining medicinal and food plants than Yuracarés. Obviously, the anthropogenic environment owes its higher usefulness largely to the plants that are managed (i.e. cultivated or tolerated) in it. Nonetheless, also unmanaged plants prevailing in anthropogenic landscapes proved to have a higher mean medicinal usefulness than plants from undisturbed habitats. Main reasons for managing plants are their medicinal, edible and ornamental value, or their value as a source of materials. In agreement with literature, Yuracarés and Trinitarios tend to manage perennial (tree) species mainly for their higher usefulness as food and materials, and herbs for their higher therapeutic potential.

Chapter 10 also explores differences in plant knowledge between Yuracarés and Trinitarios. It demonstrates that Trinitarios are more knowledgeable about plants that are managed in homegardens and swiddens than Yuracarés. The former reach a higher level of consensus and/or ascribe more uses to these plants. Trinitarios use significantly more introduced (medicinal) species and are also more knowledgeable about the therapeutic value of both wild and managed medicinal plants. By contrast, Yuracarés assign higher mean food use values to plants and excel particularly in their knowledge of the edible wild flora. Differences in the number of managed plant species and plant knowledge between Yuracarés and Trinitarios seem to be linked mainly to their contact history with western society, traditional lifestyle and provenance. However, some plants and/or their uses simply represent the cultural patrimony of each ethnic group. A number of uses reflect their particular worldview and/or ontology, whereas differences in plant knowledge and management are also related to differences in the ethnomedical system of Yuracarés and Trinitarios.

Some folk illnesses are widespread in Latin America. *Susto* or fright sickness is such a cross-cultural syndrome that, while causing real casualties, has not been recognised by most allopathic practitioners as a distinct disease entity in strict biomedical terms. Although *susto* is well-recognised in Bolivia, very few studies have concentrated on studying its prevalence, symptoms, aetiology and/or regimen of healing. Chapter 11 is dedicated to the interpretation of *susto* in the Trinitario culture. Although Trinitarios have a long history of agriculture, their worldview is still partly one of animistic hunter and fisherman societies. This worldview is reflected in Trinitario *susto* aetiology and treatment. *Susto* is locally believed to originate from soul theft by a variety of masters of the animal species and landscape spirits. It is perceived as life threatening if not cured in time. Treatment is partly based on the “*similia similibus curantur*” principle or “like cures like” and magico-ritual ceremonies, but ethnopharmacological preparations and herbal remedies applied as (smoke) baths and skin rubbings are also well known and frequently used.

Chapter 12 summarizes and discusses the main results of this dissertation. The present study contributes to theory building in ethnobotany by confirming the validity of several patterns in traditional plant uses for both the Andes and Amazon. Our findings also hold important implications for future resource management and conservation plans. Our study in Apillapampa has pointed out the low conservation status of the local natural vegetation, which can largely be ascribed to the negative impact of anthropogenic disturbance on wild plant populations. Plant knowledge gathered during the present study offers opportunities to develop agroforestry systems based on locally available plant species that could lower human pressure on wild plant populations. The conservation status of the highly diverse forests studied in TIPNIS appears to be much higher under custody of Yuracarés and Trinitarios than when Andean settlers were to enter the area. We believe that, given the importance of the forest for the livelihood of Yuracarés and Trinitarios, the area currently demarcated in TIPNIS by the 'red line' should receive the highest conservation priority. Ethnobotanical data gathered in TIPNIS also offer baseline data that can be useful in future projects aimed at new crop development as a possible contribution to Bolivia's economic development.

Although the people who participated in this study still have a good knowledge of the useful plants available in their living environments, modernization is spreading rapidly. Much of the knowledge recorded during this study is no longer transmitted to the younger generation. Modernization appears to be occurring faster among the Yuracarés which, at least in part, can be ascribed to their submissive position as compared to the Trinitarios and Andean settlers who are dominant groups. Ironically then, precisely the Yuracarés who are most knowledgeable about the wild flora and fauna occurring in TIPNIS are most vulnerable to losing knowledge. By recording the traditional knowledge of Yuracaré, Trinitario and Quechua participants, the present study safeguards the availability of plant knowledge for future generations of the traditional communities concerned, as well as for the scientific community at large.

Samenvatting

Dit proefschrift beschrijft de etnobotanie van drie etnische groepen uit Bolivia. Het omvat een overzicht van meer dan 1100 nuttige plantensoorten, hun gebruiken en abundantie in verschillende lokale vegetatietypes. Er worden twee delen in onderscheiden. Het eerste deel (hoofdstukken 2 tot 5) is toegespitst op een analyse van de plantenkennis van Quechua landbouwers uit Apillapampa, een dorp gelegen in de Boliviaanse Andes. In het tweede deel (hoofdstukken 6 tot 11) wordt de plantenkennis van Trinitarios en Yuracarés uit vijf gemeenschappen in het Amazonewoud van het Inheems Territorium en Nationaal Park Isiboro-Sécure (TIPNIS) onder de loep genomen. Deze studie draagt bij tot een betere kennis van de nog steeds erg onderbestudeerde bioculturele diversiteit van Bolivia. Ze voorziet ook in ruwe data die gebruikt kunnen worden bij de uitwerking van toekomstige beheer- en conservatieplannen voor lokale plantaardige hulpbronnen.

Hoofdstuk 1 schetst het etnografische kader waarin het onderzoek zich afspeelt. De Quechua boeren van Apillapampa doen aan kleinschalige akkerbouw en veeteelt langs de steile hellingen van de semi-ariede Boliviaanse Andes. De Yuracarés en Trinitarios daarentegen beoefenen kleinschalige zwerflandbouw op bospercelen die eerst gekapt en afgebrand worden. De belangrijkste culturele kenmerken van deze drie etnische groepen worden besproken en hun contactgeschiedenis wordt nader toegelicht. Hoofdstuk 1 wordt afgesloten met een schets van de belangrijkste onderzoeksvragen en de uitwerking ervan doorheen dit proefschrift.

Hoofdstuk 2 voorziet in een gedetailleerde ecologische karakterisatie van het onderzoeksgebied in Apillapampa tussen 2.700 and 3.800 meter boven zeeniveau. Alle 441 lokaal geinventariseerde plantensoorten worden taxonomisch beschreven en er wordt een overzicht gegeven van alle gecultiveerde planten, inclusief landbouwgewassen. De dorpsgemeenschap van Apillapampa is gelegen op de grens tussen de *prepuna* en *puna* ecologische zones. De scheiding tussen beide zones op basis van ecologische data, verzameld in 36 transecten van 50 m x 2 m, overlapt sterk met het inheemse classificatiesysteem dat wordt gehanteerd door de mensen van Apillapampa. De dominante families en soorten worden besproken per zone en vergeleken met relevante floristische en ecologische data die beschikbaar zijn in de wetenschappelijke literatuur. Onze bevindingen laten uitschijnen dat de bestaande vegetatiekaart van de regio aan herziening toe is.

De vegetatie in Apillapampa is sterk gefragmenteerd en gedegradeerd als gevolg van historische en huidige menselijke activiteiten. De mensen van Apillapampa zijn zich bewust van de afname op korte termijn van een aantal lokale populaties van wilde planten. Ze schrijven deze achteruitgang voornamelijk toe aan menselijke factoren zoals overexploitatie en overbegrazing. Daarom wordt in hoofdstuk 2 ook een inschatting gemaakt van de natuurlijke en antropogene omgevingsvariabelen die de variatie in abundantie van plantensoorten doorheen het landschap best beschrijven. Er wordt ook nagegaan in welke mate deze variabelen gebruikt kunnen worden om de plantendiversiteit van verschillende locaties in het landschap in te schatten. De meeste menselijke verstoringsvariabelen hebben een duidelijk negatieve impact op de lokale plantendiversiteit in het landschap. Deze

omvatten de toegangelijkheid van locaties, aanplant van exoten (bv. *Eucalyptus globulus*) en het periodiek afbranden van de vegetatie. Onze observaties kunnen belangrijke implicaties hebben voor toekomstige beheersplannen voor de vegetatie in de regio.

In hoofdstuk 3 wordt een uitvoerige beschrijving gegeven van alle verschillende plantengebruiken in Apillapampa voor een totaal van 387 nutsplanten, gebaseerd op informatie verkregen van 13 lokale Quechua participanten. Leeftijd bleek het meest invloedrijke demografisch kenmerk te zijn betreffende de kennis over plantengebruik van deze participanten. De talrijke plantengebruiken worden besproken binnen het kader van verschillende gebruikscategoriën zoals geneeskunde, voedsel, brandstof, veevoeder, materialen en sociale gebruiken. Per gebruikscategorie worden de plantensoorten en families met de hoogste gebruikswaarde aangehaald. Soorten met de hoogste gebruikswaarde zijn voornamelijk bomen zoals *Prosopis laevigata*, *Schinus molle*, *Acacia visco* en de exoot *Eucalyptus globulus*. De belangrijkste nutsfamilies zijn Asteraceae, Fabaceae, Solanaceae en Lamiaceae.

Er wordt een meer gedetailleerde bespreking gegeven van het buitengewoon hoog aantal medicinale planten dat wordt gebruikt. Een aantal relevante factoren die van belang zijn bij de selectie van medicinale planten in Apillapampa en de resulterende uitbouw van een omvangrijke pharmacopee worden voorgesteld en toegelicht. Deze factoren omvatten: (1) de beschikbaarheid en/of bereikbaarheid van planten; (2) aandoening gerelateerde kenmerken; (3) de gespecialiseerde en dynamische aard van de traditionele geneeskunde in Apillapampa; (4) het onvermogen tot empirisch testen van de werkzaamheid van planten gebruikt in mengsels; (5) aspecten gerelateerd aan zintuiglijke waarneming van planten; en (6) andere meer ondergeschikte factoren.

De mensen van Apillapampa maken grondig gebruik van de wilde flora die hen omringt. Nagenoeg alle plantensoorten en –individu's (respectievlijk 94-100% en 92-100%) die werden aangetroffen in de bemonsterde transecten worden ervaren als zijnde bruikbaar. In hoofdstuk 4 worden een aantal factoren geïdentificeerd die de gebruikswaarde van enerzijds individuele plantensoorten en anderzijds gehele vegetatie-eenheden beïnvloeden. De gebruikswaarde van een plant zoals ervaren door mensen uit Apillapampa kan gedeeltelijk en in varierende mate ingeschat worden op basis van verschillende van zijn fylogenetische, morfologische, ecologische en antropogene eigenschappen. De gebruikswaarde van vegetatie-eenheden die voorkomen op verschillende locaties doorheen het landschap kan gedeeltelijk ingeschat worden a.d.h.v.: (1) de hoogteligging van die locaties; (2) hun toegankelijkheid; (3) de eventuele aanplant van exoten; (4) tekenen van brandactiviteit; (5) de eventuele nabijheid van een (tijdelijke) rivier of stroompje; en (6) de plantendiversiteit aanwezig in die vegetatie-eenheden. Onze bevindingen bevestigen de in de literatuur vaak vermelde hypothese dat "de beter toegankelijke of bereikbare plantaardige hulpbronnen een hogere gebruikswaarde hebben voor lokale mensen". Hoewel de vegetatie van meer toegankelijke plaatsen minder divers is, neigt de gebruikswaarde ervan hoger te zijn. Afgezien van de bestaande variatie in bruikbaarheid van vegetatie-eenheden doorheen het landschap, zijn alle landschapselementen van groot belang voor mensen uit Apillapampa. Vandaar ook dat de vegetaties van de *prepuna* en *puna* ecologische zones, die werden beschreven in hoofdstuk 2 een vrijwel gelijke gebruikswaarde hebben.

Hoewel de meeste mensen uit Apillapampa beschikken over gecultiveerde boomsoorten, zijn ze nog steeds sterk afhankelijk van wilde brandhoutsoorten voor hun brandstofvoorziening. In hoofdstuk 5 wordt een inschatting gemaakt van de impact van de oogst van brandhout op de populaties van wilde houtige soorten. Deze inschatting is gebaseerd op een simultane beschouwing van de beoordelingen van lokale participanten inzake (1) de afnemende abundantie van houtige planten; (2) het vermogen van planten om uit te lopen na houtkap; (3) de eventuele oogst van wortelbiomassa; en (4) de kwaliteit van het brandhout. De resultaten suggereren dat de wilde populaties van een aantal houtige plantensoorten nadelig beïnvloed worden door de oogst van brandhout. Toch houden sommige mensen er wel degelijk duurzame oogstpraktijken op na, maar omdat iedereen bij machte is te doen wat hij/zij wil op zijn/haar land, blijkt er geen algemeen aanvaard systeem te bestaan dat het duurzame gebruik van planten stimuleert.

Naast hoogteligging bepalen voornamelijk menselijke verstoringsvariablen de variatie in hoogte van verschillende brandhoutsoorten in de leefomgeving van Apillapampa. De antropogene druk op wilde brandhoutsoorten lijkt gelijke tred te houden met hun abundantie en beschikbaarheid doorheen het landschap. De negatieve impact van brandhoutoogst is met andere woorden hoger op de meer abundante en beschikbare soorten.

Vanaf hoofstuk 6 begint het tweede deel van deze thesis dat is toegespitst op het plantengebruik van Yuracarés en Trinitarios van het Inheems Territorium en Nationaal Park Isiboro-Sécure (TIPNIS).

Voor een adequate bescherming en een aangepast beheer van tropisch regenwoud is een goede basiskennis van de lokale biodiversiteit essentieel. Tot op heden is slechts weinig geweten over de floristische samenstelling en botanische diversiteit van het 12.000 km² grote TIPNIS. Hoofdstuk 6 behandelt de floristische compositie, de vegetatiestructuur en de diversiteit van *terra firme* (i.e. op goed gedraineerd substraat) en vloedbossen (inclusief *varzea* bos) in het zuidelijk deel van TIPNIS. Alle stammen ≥ 2,5 cm dbh (diameter bij borsthoogte) werden geïnventariseerd in vier 0,1-ha transecten. Floristisch gezien stemmen deze bossen goed overeen met andere representatieve neotropische bossen. Ook de gemeten diversiteitsniveau's, die behoren tot de tot op heden hoogst geregistreerde voor Bolivia, stemmen overeen met op neerslag en substraat gebaseerde patronen beschreven in de wetenschappelijke literatuur. Niettemin lijkt de huidige modelgebaseerde kaart die de bomendiversiteit van *terra firme* bossen in het Amazonegebied weergeeft, de diversiteit in TIPNIS te onderschatten. Er is nood aan verder onderzoek om te achterhalen of deze kaart al dan niet herzien dient te worden voor ons onderzoeksgebied. Anderzijds heeft de huidige studie onmiskenbaar aangetoond dat de huidige (fytosociologische) vegetatiekaart van het gebied moet geactualiseerd worden, gezien ze is gebaseerd op zeer beperkte data. Onze resultaten zijn ook van centraal belang voor de identificatie van zones met absolute behoudsprioriteit binnen TIPNIS.

Daarenboven biedt hoofdstuk 6 een algemene taxonomische beschrijving van alle 906 verschillende taxa die werden ingezameld in TIPNIS. Ongeveer de helft (49%) van deze soorten werd gecollecteerd buiten de transecten, in zowel natuurlijke als antropogene landschappen.

Hoofdstuk 7 is toegspitst op een evaluatie van de voor- en nadelen van de verschillende interviewtechnieken die zijn aangewend tijdens de onderzoeksfase in TIPNIS. Deze omvatten *in situ* interviews tijdens (1) veld-excursies (zogenaamde *walk-in-the-woods*) en bemonstering in (2) transecten en (3) tuintjes en *ex situ* interviews aan de hand van (4) vers plantenmateriaal, (5) herbarium specimens en (6) plantenfoto's. Aangezien een groot deel van de etnobotanische data werd verkregen door middel van interviews gebaseerd op plantenfoto's, werd het vermogen van de lokale participanten om planten te herkennen van foto's getest. De resultaten tonen het nut van foto's in etnobotanische interviews aan en rechtvaardigen onze methodologische aanpak.

Aan de hand van etnobotanische interviews met 26 verschillende Yuracaré en Trinitario participanten, volgens de technieken beschreven in hoofdstuk 7, werd een totaal van 735 bruikbare soorten geïdentificeerd in TIPNIS. In hoofdstuk 8 wordt een gedetailleerde beschrijving gegeven van alle verschillende gebruiken die worden toegeschreven aan deze plantensoorten. In navolging van hoofdstuk 3 worden de plantengebruiken in TIPNIS besproken in het kader van verschillende gebruikscategoriën, inclusief geneeskunde, voedsel, brandstof, constructie-benodigdheden, materialen en sociale gebruiken. Ook hier worden per gebruikscategorie de plantensoorten en families met de hoogste gebruikswaarde aangehaald. Soorten met de hoogste gebruikswaarde zijn voornamelijk palmbomen zoals *Attalea phalerata*, *A. butyracea*, *Bactris gasipaes* and *Jessenia batua*. De belangrijkste nutsfamilies zijn Arecaceae, Myristicaceae, Burseraceae, Sapotaceae, Poaceae, Anacardiaceae en Annonaceae.

De belangrijkste verschillen in kennis inzake plantengebruik tussen Yuracarés en Trinitarios hebben betrekking op medicinale en eetbare planten. Trinitarios kennen duidelijk veel meer medicinale planten dan Yuracarés terwijl het omgekeerde waar is voor eetbare planten. De aantallen medicinale en eetbare plantensoorten gekend door respectievelijk Tinitarios en Yuracarés horen bij de tot nog toe hoogst opgetekende voor eender welke etnische groep uit het Amazonegebied. De Yuracaré en Trinitario participanten hadden een vergelijkbare kennis van plantengebruik in de meeste andere categoriën zoals brandstof, constructie en materialen. Zoals voor Apillapampa wordt het medicinale plantengebruik in TIPNIS diepgaander besproken. De in hoofdstuk 3 aangehaalde factoren met betrekking tot de selectie van medicinale planten worden opnieuw bediscussieerd in de ecologische en etnografische context van TIPNIS.

In hoofdstuk 8 wordt ook aangetoond dat het etnomedische systeem van de Trinitarios, hetgeen bestaat uit sjamaanen, kruidenkenners, vroedvrouwen en massagespecialisten (i.e. traditionele 'osteopaten'), de honderden jaren van culturele invloeden goed heeft weten te doorstaan. De traditionele geneeswijzen en overtuigingen beschreven in vroege manuscripten van missionarissen en etnografen stemmen vrij goed overeen met huidige etnomedische praktijken. Participanten die gespecialiseerd waren in therapeutische toepassingen van planten hadden, zoals kon worden verwacht, ook een hogere kennis van de medicinale en sociale gebruiken van planten dan gewone dorpsbewoners.

De bruikbaarheid van verschillende bostypes voor de inheemse bevolking is, naast hun diversiteit, een belangrijk argument voor de bescherming ervan. Hoofdstuk 9 biedt een kwantitatieve beoordeling van de waarde die lokale mensen toekennen aan de verschillende bostypes beschreven in hoofdstuk 6. Deze analyse toont dat alle bostypes van groot belang zijn voor de lokale bevolking. De hoge gebruikspercentages duiden op een goede kennis van het lokale bos: 74-82% van de soorten en 85-92% van de individu's in de bemonsterde transecten hebben een nutsfunctie voor de bevraagde participanten. In termen van bruikbare plantensoorten was de ondergroei (dbh < 10 cm) iets bruikbaarder dan de bomenlaag (dbh ≥ 10 cm). Er worden vooral hogere percentages planten met medicinale en sociale gebruiken aangetroffen in de ondergroei.

De data die verzameld werden gedurende het onderzoek in TIPNIS staven slechts gedeeltelijk het argument uit de literatuur dat *terra firme* bossen minder bruikbaar zouden zijn voor mensen dan vloedbossen. Een vergelijking van de bruikbaarheid van de verschillende bostypes tussen Yuracarés en Trinitarios toont aan dat Yuracarés het bos hoger waarderen voor de eetbare planten die het bevat, terwijl Trinitarios er een grotere medicinale en sociale bruikbaarheid aan toekennen. Onze bevindingen wijzen duidelijk op de noodzaak om de lokale bevolking toegang te blijven verlenen tot alle verschillende vegetatietypes, wil ze kunnen voorzien in haar levensonderhoud.

In hoofdstuk 9 worden de voor Apillapampa aangetoonde correlaties tussen de gebruikswaarde van een plant en zijn fylogenetische, morfologische, ecologische en antropogene kenmerken (hoofdstuk 4) ook bevestigd voor TIPNIS. De resultaten tonen aan dat de gebruikswaarde van planten voor Yuracarés en Trinitarios zowel gecorreleerd is met hun beschikbaarheid als met hun zichtbaarheid in het landschap.

Meer en meer onderzoek lijkt te bevestigen dat inheems bosbeheer in de Neotropen bevorderlijk kan zijn voor de biodiversiteit. Hoofdstuk 10 onderzoekt op een kwalitatieve wijze de geldigheid van deze hypothese voor het geval van de Yuracarés en Trinitarios van TIPNIS. Het toont aan dat deze mensen niet (altijd) vertrekken van een conservatie-ethiek bij het oogsten van wilde plantensoorten. Zelfs in het tropisch regenwoud met zijn uitzonderlijk hoge diversiteit kunnen bepaalde soorten op een niet-duurzame manier geoogst worden. Opmerkelijk in dit opzicht is dat de lokale bevolking is begonnen met de cultivatie van de waardevolle houtsoort *Swietenia macrophylla*, enerzijds als respons op de lokale overexploitatie, maar anderzijds ook als een soort belegging voor de toekomst van hun kinderen.

In hoofdstuk 10 wordt andermaal bewijs geleverd voor de hypothese dat de gebruikswaarde van plantensoorten covarieert met hun beschikbaarheid door aan te tonen dat planten die typisch groeien in antropogene verstoringsomgevingen gemiddeld bruikbaarder zijn dan planten uit natuurlijke habitats. Voornamelijk de Trinitarios zijn meer afhankelijk van antropogene landschapselementen voor het verkrijgen van medicinale en eetbare planten dan de Yuracarés. Logischerwijs dankt het antropogene milieu zijn hogere gebruikswaarde voornamelijk aan de planten die erin worden beheerd. Toch blijken ook onbeheerde planten uit antropogene middens een hogere medicinale gebruikswaarde te hebben dan planten uit onverstoorde omgevingen.

De voornaamste redenen voor het beheren van planten zijn de plantaardige remedies, eetbare plantendelen, materiaalbronnen en/of de estetische waarde die ze bieden. Het merendeel van de beheerde planten zijn kruiden en bomen. In overeenstemming met de literatuur beheren Yuracarés en Trinitarios voornamelijk doorlevende (boom)soorten voor hun hogere bruikbaarheid als voedsel en materialenbron, en kruiden voor hun hoger therapeutisch potentieel.

Hoofdstuk 10 onderzoekt verder ook de verschillen in kennis over plantengebruik tussen Yuracarés en Trinitarios. Het toont aan dat de Trinitarios de planten die worden beheerd in tuintjes en zwerflandbouwpercelen beter kennen dan de Yuracarés: ze bereiken een hogere consensus over de gebruiken van deze planten en/of schrijven er meer gediversifieerde gebruiken aan toe. De Trinitarios gebruiken ook betrekkelijk meer geïntroduceerde (medicinale) planten en ze hebben een betere kennis van de therapeutische waarde van zowel wilde als beheerde medicinale planten. De Yuracarés daarentegen kennen een hogere gemiddelde voedselwaarde toe aan planten van bijna alle beheersvormen, maar ze munten vooral uit in hun kennis van de wilde eetbare flora. Verschillen in het aantal beheerde planten en in de kennis over plantengebruik tussen Yuracarés en Trinitarios lijken voornamelijk verband te houden met de contactgeschiedenis, de traditionele levenswijze en de herkomst van beide groepen. Er zijn echter ook planten en/of gebruiken die het cultureel patrimonium vertegenwoordigen van respectievelijk Yuracarés en Trinitarios. Een aantal plantengebruiken reflecteren hun specifiek wereldbeeld en/of ontologie, maar ook de verschillen tussen de etnomedische systemen van Yuracarés en Trinitarios leiden tot verschillen in plantenbeheer en -kennis.

Sommige cultuurgerelateerde ziektebeelden hebben een wijde verspreiding in Latijns-Amerika. *Susto* of de ‘schrik ziekte’ is een voorbeeld van zo’n cultuuroverlappend syndroom. Hoewel het dodelijke slachtoffers maakt, is het (nog) niet erkend door de medische wereld als een welgedefinieerde ziekte-eenheid in biomedische termen. *Susto* is goed gekend bij de lokale bevolking van Bolivia, maar toch zijn er nog maar weinig studies die zich gericht hebben op een karakterisatie van de verspreidingsgraad, de symptomen, de etiologie en/of de behandelingswijze(s) ervan. Hoofdstuk 11 is gewijd aan de interpretatie van *susto* in de Trinitario cultuur. Hoewel de Trinitarios een lange geschiedenis hebben als landbouwers, hebben ze nog steeds een wereldbeeld dat typisch is voor animistische jacht en visvangst gemeenschappen. Dit wereldbeeld is gereflecteerd in de etiologie en behandeling van *susto* volgens de Trinitarios. Lokaal gelooft men dat *susto* onstaat wanneer iemands ziel gestolen wordt door één van de vele meesters der dierensoorten of ander landschapsgeesten. *Susto* wordt ervaren als levensbedreigend indien niet tijdig behandeld. De behandeling is deels gebaseerd op het principe van “*similia similibus curantur*” (“het gelijkende zal het gelijkende genezen”) en magisch-rituele ceremonies, maar etnofarmacologische bereidingen zijn ook goed gekend en worden frequent gebruikt.

In hoofdstuk 12 worden de belangrijkste bevindingen van deze studie samengevat en besproken. De huidige studie draagt bij tot de theorievorming in de etnobotanie door de geldigheid te bevestigen van verschillende patronen in traditioneel plantengebruik, zowel in de Andes als in het Amazonegebied. Onze bevindingen hebben ook implicaties voor toekomstig hulpbronnenbeheer en –conservatie. Het onderzoek in Apillapampa wijst op de slechte conservatiestatus waarin de natuurlijke vegetatie verkeert, hetgeen grotendeels kan toegeschreven worden aan de negatieve impact van antropogene verstoring op wilde plantenpopulaties. De kennis over plantengebruik die werd verzameld gedurende de huidige studie biedt mogelijkheden voor de ontwikkeling van *agroforestry* systemen, gebaseerd op lokaal beschikbare planten, die de menselijke druk op het natuurlijke ecosysteem zouden kunnen doen dalen.

De ecologische toestand van de zeer diverse bossen onder het beheer van Yuaracrés en Trinitarios die bestudeerd werden in TIPNIS, lijkt veel sterker aan te leunen bij de climax situatie dan wanneer kolonisten uit de Andesregio het gebied zouden komen te bezetten. Daarom is het van groot belang dat een verdere invasie van kolonisten in het park wordt tegengegaan en dat het inheems gebied in TIPNIS dat is afgelijnd met de zogenaamde ‘rode lijn’ de hoogste conservatieprioriteit krijgt. De etnobotanische data verzameld in TIPNIS biedt ook de ruwe data die nuttig kunnen zijn in toekomstige projecten gericht op nieuwe teeltontwikkeling als een mogelijke bijdrage tot de economische ontwikkeling van Bolivia.

Hoewel de mensen die hebben deelgenomen aan deze studie nog steeds een goede kennis hebben van de nutsfuncties van de planten die hen omringen, is acculturatie in volle opgang. Een aanzienlijk deel van de kennis die werd opgetekend tijdens het huidige onderzoek wordt niet meer doorgegegeven naar de jongere generatie. De acculturatie lijkt zich sneller te voltrekken onder de Yuracarés dan onder de Trinitarios of Quechuas. Dit is deels te wijten aan de onderdanige positie die de Yuracarés innemen ten opzichte van de Trinitarios en de kolonisten uit de Andesregio die dominante en sociaal coherentere groepen zijn. Het is ironisch dat precies de Yuracarés, die ongetwijfeld de meeste kennis hebben van de wilde fauna en flora in TIPNIS, het kwetsbaarst zijn om hun traditionele kennis te verliezen. Door het vastleggen van de traditionele kennis van de drie ethnische groepen besproken in dit proefschrift garandeert de huidige studie de beschikbaarheid ervan voor de toekomstige generaties van de betrokken gemeenschappen, alsook voor de wetenschappelijke gemeenschap in het algemeen.

Appendix 1

Alphabetical List of Inventoried Plant Species in Apillapampa

FAMILY & SPECIES	COLLECTION NUMBERS[1]
ANGIOSPERMAE	
ACANTHACEAE	
Stenandrium dulce (Cav.) Nees	ET192 ET494
AGAVACEAE	
Agave americana L.	ET455
ALLIACEAE	
Nothoscordum andicola Kunth cf.	ET140
ALSTROEMERIACEAE	
Alstroemeria pygmaea Herb.	ET74
Bomarea dulcis (Hook.) Beauverd	ET139
AMARANTHACEAE	
Amaranthus hybridus L.	TC547
Gomphrena bicolor Mart.	ET79 ET209
Gomphrena gnaphiotricha Griseb.	ET294
Gomphrena perennis L.	ET241 ET276
Guilleminea densa (Willd.) Moq.	ET385 TC538
Iresine diffusa Humb. & Bonpl. ex Willd.	ET122 ET164 ET320A ET320B ET254 ET375
Pfaffia dunaliana (Moq.) Schinz	ET268
AMARYLLIDACEAE	
Habranthus nullipes Ravenna	ET470
Hippeastrum cybister Benth. & Hook.f.	ET499
Pyrolirion cutleri (Cárdenas) Ravenna	ET447 TC605
Zephyranthes challensis Ravenna	ET495
ANACARDIACEAE	
Schinopsis haenkeana Engl.	ET278
Schinus microphyllus I.M.Johnst.	ET177 ET308
Schinus molle L.	TC510
APIACEAE	
Apium leptophyllum (Pers.) F.Muell.	TC511
Bowlesia tropaeolifolia Gillies & Hook.	ET85 ET107 ET191
Daucus carota L.	ET434 TC596
Daucus montanus Humb. & Bonpl. ex Spreng.	ET106 ET344
Eryngium ebracteatum Lam.	ET215
Eryngium nudicaule Urb.	ET90
Eryngium paniculatum Cav. & Dombey ex Delarbre	ET309 TC517
APOCYNACEAE	
Aspidosperma quebracho-blanco Schltdl.	ET484
Mandevilla pentlandiana (A.DC.) Woodson	ET259 ET275 ET502
Vinca major L.	TC576
ARACEAE	
Spathantheum orbignyanum Schott	ET171 ET472B TC602
ASCLEPIADACEAE	
Asclepias barjoniifolia E.Fourn.	ET293 TC506
Cynanchum streptanthum Malme	ET405 ET508
Matelea boliviensis (Schltr.) Goyder	ET218
Matelea elliptica (Rusby) Morillo	ET283
Morrenia odorata Lindl.	ET358
Petalostelma sarcostemma (Lillo) Liede & Meve	ET357 ET466
Philiberta bicornuta (Griseb.) Goyder	ET415 ET509
Philibertia globiflora Goyder	ET356 ET459
Philibertia parviflora (Malme) Goyder var. parviflora	ET120
Philibertia suberecta Goyder	ET63
ASPHODELACEAE	
Aloe vera (L.) Burm.f.	ET476
ASTERACEAE	
Achyrocline ramosissima (Sch.Bip.) Britton ex Rusby	ET148
Achyrocline vauthierieriana DC.	ET413
Ambrosia arborescens Mill.	ET456 TC587
Baccharis buxifolia (Lam.) Pers.	ET70A ET210

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[1] Numbers marked with ET and TC refer to collections of Evert Thomas and Trees Cousy, respectively. "NONE" means that no collection was made in Apillapampa.

FAMILY & SPECIES	COLLECTION NUMBERS
Baccharis coridifolia DC. subsp. *bicolor* Joch.Müll.	ET426 ET513
Baccharis densiflora Wedd.	ET512
Baccharis dracunculifolia DC.	ET130
Baccharis linearifolia (Lam.) Pers. subsp. *polycephala* (Wedd.) Joch.Müll.	ET137 ET420B
Baccharis medullosa DC.	ET507
Baccharis papillosa Rusby	ET70B
Baccharis papillosa Rusby subsp. *australis* Joch.Müll.	ET515 ET516
Baccharis papillosa Rusby subsp. *papillosa*	ET421 ET514 ET517 ET518
Baccharis pentlandii DC.	ET469
Baccharis prostrata (Ruiz et Pav.) Pers.	ET116 ET136 ET161 TC524
Baccharis pulchella Sch.Bip. ex Griseb.	ET175 ET403
Baccharis sagittalis (Less.) DC.	TC516
Baccharis salicifolia (Ruiz & Pav.) Pers.	ET431 ET445
Baccharis torricoi Joch.Müll.	ET202 TC616
Barnadesia macrocephala Kuntze	TC502
Bidens andicola Kunth.	ET88 ET125
Bidens exigua Sherff	ET398 A TC546
Bidens mandonii (Sherff) Cabrera	ET109 A ET342 ET398B
Bidens pseudocosmos Sherff	ET109B ET296
Chaptalia modesta Burkart	ET287 ET311
Chaptalia similis R.E.Fr.	ET232 ET361 ET412
Chrysanthemum parthenium (L.) Pers.	
Chuquiraga parviflora (Griseb.) Hieron.	ET423 TC520
Conyza bonariensis (L.) Cronquist	ET332
Conyza deserticola Phil.	ET98 ET194 ET343
Conyza floribunda Humb.	TC562
Conyza floribunda Kunth aff.	ET462
Conyza tunariensis (Kuntze) Zardini	ET100 ET115 ET253
Coreopsis sp.	ET149
Cosmos peucedanifolius Wedd.	ET86
Erechtites hieraciifolia (L.) Rafin. ex DC.	ET437
Eupatorium clematideum Griseb.	ET331 ET359
Eupatorium hookerianum Griseb.	ET354
Eupatorium lasiophthalmum Griseb.	ET467
Eupatorium sternbergianum DC.	ET401
Eupatorium tunariense (Hieron.) B.L.Rob.	ET250

FAMILY & SPECIES	COLLECTION NUMBERS
Eupatorium viscidum Hook. et Arn.	ET235 ET350
Galinsoga ciliata (Raf.) S.F.Blake	ET303
Galinsoga parviflora Cav.	ET377 ET381
Gamochaeta americana (Mill.) Wedd.	ET179
Gamochaeta calviceps (Fernald) Cabrera	ET414
Gamochaeta sp. 1	ET457
Gnaphalium cheiranthifolium Lam.	ET200
Gnaphalium dombeyanum DC. cf.	ET316 ET524
Gnaphalium gaudichaudianum DC.	ET252 ET317
Gnaphalium melanosphaeroides Sch.Bip. ex Wedd.	ET80 ET318
Gynoxys glabriuscula Rusby	ET144 TC501
Helogyne straminea (DC.) B.L.Rob.	ET246 TC534
Heterosperma tenuisecta (Griseb) Cabrera	ET319
Hieracium adenocephalum (Sch.Bip.) Britton	ET135
Hieracium boliviense (Wedd.) Sch.Bip. s.l.	ET411
Hieracium pazense S.F.Blake s.l.	ET349
Hyaloseris quadriflora J.Kost.	ET247 ET458
Hypochoeris chillensis (Kunth) Hieron.	ET301 ET396 ET433 438 ET453 454
Hypochoeris elata (Wedd.) Griseb.	ET341 ET404
Jungia pauciflora Rusby	ET407
Jungia polita Griseb.	ET249 ET443
Lophopappus cuneatus R.E.Fr.	ET326 TC527
Mutisia acuminata Ruiz & Pav.	ET157 ET327 TC532
Mutisia cochabambensis Hieron.	ET511
Mutisia ledifolia Decne. ex Wedd.	TC504
Mutisia orbignyana Wedd.	ET40
Noticastrum sp.	ET50
Onoseris alata Rusby	ET146 ET334 ET355
Ophryosporus charua (Griseb.) Hieron.	ET61 ET110 TC521 TC617
Ophryosporus heptanthus (Sch.Bip. ex Wedd.) R.M.King & H.Rob.	ET66 ET127 ET323 ET348
Ophryosporus macrodon Griseb.	ET132 ET376
Parthenium glomeratum Rollins	ET228
Pectis sessiliflora (Less.) Sch.Bip.	ET388
Plazia daphnoides Wedd.	ET199
Porophyllum lanceolatum DC.	ET321
Porophyllum obscurum (Spreng.) DC.	ET221
Proustia cuneifolia D.Don	TC528
Schkuhria pinnata (Lam.) Kuntze ex Thell.	ET229

FAMILY & SPECIES	COLLECTION NUMBERS
Senecio clivicola Wedd.	ET402 TC507 TC526
Senecio pampeanus Cabrera	TC575
Senecio sp.	TC588
Senecio vulgaris L.	ET460
Senecio yalae Cabrera	ET255
Siegesbeckia jorullensis Kunth	ET497
Sonchus asper (L.) Hill	TC545
Sonchus oleraceus L.	ET397 TC552
Stevia bangii Rusby aff.	ET237
Stevia boliviensis Sch.Bip.	ET184 ET95A ET328
Stevia bridgesii Rusby	ET379B
Stevia galeopsidifolia Hieron.	ET183 95B ET133 ET212
Stevia kuntzei Hieron	ET379A ET444
Stevia stuebelii Hieron	ET400
Stevia tunariensis Hieron.	ET134 ET419
Stevia yalae Cabrera aff.	ET330
Tagetes pusilla Kunth	ET190 ET339
Tagetes terniflora Kunth	ET367 ET373
Taraxacum officinale (L.) Weber	ET103
Tessaria dodonaeifolia (Hook. et Arn.) Cabrera	ET481
Tessaria fastigiata (Griseb.) Cabrera	ET461
*Tithonia tubif*ormis (Jacq.) Cass. aff.	ET102 ET256
Tridax boliviensis (Wedd.) R.E.Fr.	ET390
Trixis aggregata Rusby	ET389 TC523
Verbesina semidecurrens Kuntze	ET162
Viguiera australis S.F.Blake	ET67 ET329
Viguiera fusiformis S.F.Blake	ET195
Viguiera tucumanensis (Hook. et Arn.) Griseb.	ET227
Xanthium spinosum L.	TC577
Zinnia peruviana (L.) L.	ET220
BASELLACEAE	
Ullucus tuberosus Caldas subsp. *aborigineus* (Brücher) Sperling	ET167
BEGONIACEAE	
Begonia baumannii Lemoine	ET138
BERBERIDACEAE	
Berberis boliviana Lechl.	ET76
Berberis commutata Eichler	ET129 ET435
Berberis rariflora Lechl.	ET205 ET520

FAMILY & SPECIES	COLLECTION NUMBERS
BETULACEAE	
Alnus acuminata Kunth	ET475
BIGNONIACEAE	
Jacaranda mimosifolia D.Don	
Tecoma tenuiflora (A.DC.) Fabris	ET480
BORAGINACEAE	
Cordia rusbyi Britton	ET248 ET352
Heliotropium amplexicaule Vahl	ET483
Heliotropium procumbens Mill.	ET526
Heliotropium microstachyum Ruiz et Pav.	ET234
BRASSICACEAE	
Brassica rapa L.	TC569
Capsella bursa-pastoris (L.) Medik.	TC581
Halimolobos montana (Griseb.) O.E.Schulz	ET300
Lepidium aletes J.F.Macbr.	ET452
Raphanus sativus L.	TC567
Sisymbrium irio L.	TC585
Sisymbrium officinale (L.) Scop.	TC541
BROMELIACEAE	
Puya glabrescens L.B.Sm.	ET168 ET290 ET529
Puya humilis Mez	ET519
Tillandsia bryoides Griseb. ex Baker	ET465
Tillandsia capillaris Ruiz & Pav.	TC603
Tillandsia hirta W.Till & H.Hrom.	ET464
Tillandsia sphaerocephala Baker	ET505
Tillandsia usneoides (L.) L.	ET428
BUDDLEJACEAE	
Buddleja tucumanensis Griseb.	TC535
CACTACEAE	
Cleistocactus buchtienii Backeb.	ET172 TC610
Echinopsis cochabambensis Backeb.	ET490
Echinopsis obrepanda K.Schum. subsp. *calorubra* (Cárdenas) G.Navarro	ET124
Opuntia ficus-indica (L.) Mill.	TC590
Opuntia sulphurea Gillies ex Salm-Dyck	PROV14
Opuntia vestita Salm-Dyck	ET173 TC611
Trichocereus tunariensis Cardenas	PROV18
CALYCERACEAE	
Acicarpha tribuloides Juss.	ET87
CAMPANULACEAE	
Lobelia nana Kunth	ET498
Siphocampylus tupaeformis Zahlbr.	ET522

FAMILY & SPECIES	COLLECTION NUMBERS
CARICAEAE	
Vasconcellea quercifolia A.St.-Hil.	ET170
CARYOPHYLLACEAE	
Cerastium peruvianum Muschl. cf.	ET81
Silene gallica L.	ET527
Spergula ramosa (Cambess.) D.Dietr.	ET382
Stellaria media (L.) Vill.	ET297 TC604
CELASTRACEAE	
Maytenus flagellata Rusby	TC606
CHENOPODIACEAE	
Chenopodium ambrosioides L.	TC542
Chenopodium graveolens Willd. var. *bangii* (R.P.Murray) Aellen	ET258 ET322
Chenopodium murale L. cf.	TC598
CLUSIACEAE	
Hypericum silenoides Juss.	ET525
COMMELINACEAE	
Commelina diffusa Burm.f.	ET207
Commelina elliptica Kunth	ET213
Commelina quitensis Benth. var. *mandonii* C.B.Clarke	ET169 ET325
CONVOLVULACEAE	
Convolvulus hermanniae L'Hér.	ET222 ET477
Cuscuta indecora Choisy cf.	ET374
Cuscuta sp.1	ET363
Dichondra argentea Humb. et Bonpl. ex Willd.	ET378
Dichondra sericea Sw.	ET189
Evolvulus sericeus Sw.	ET384
Ipomoea dumetorum Willd. ex Roem. et Schult.	ET371
Ipomoea pubescens Lam.	ET219 ET307
CRASSULACEAE	
Echeveria sp.	ET468
CUCURBITACEAE	
Cyclanthera hystrix (Gillies) Arn.	ET370
CYPERACEAE	
Cyperaceae sp.	ET528
Scirpus giganteus Kunth	ET312 TC513 TC519 TC620
DIOSCOREACEAE	
Dioscorea trifurcata Hauman	ET113
EUPHORBIACEAE	
Acalypha lycioides Pax et K.Hoffm.	ET272
Acalypha plicata Müll.Arg.	ET351
Chamaesyce boliviana (Rusby) Croizat	ET75
Croton baillonianus Müll.Arg.	ET280
Euphorbia prostrata Aiton	TC539
Gymnanthes schottiana Müll.Arg.	ET288
Jatropha gossypiifolia L.	ET285
FABACEAE	
Acacia aroma Gillies ex Hook. & Arn.	ET224
Acacia visco Griseb.	ET489
Adesmia miraflorensis Remy	ET65
Adesmia muricata (Jacq.) DC.	ET216 ET478
Amicia andicola (Griseb.) Harms cf.	ET340
Astragalus garbansillo Cav.	ET145
Cologania broussonetii (Balb.) DC.	ET105
Coursetia heterantha (Griseb.) Lavin	ET399
Crotalaria incana L.	ET446
Crotalaria pumila Ortega	ET380
Crotalaria sagittalis L.	ET387
Dalea alopecuroides Willd.	ET369
Dalea boliviana Britton	ET347
Dalea pazensis Rusby	ET239
Desmodium neomexicanum A.Gray	ET383
Desmodium subsericeum Malme	ET432
Erythrina falcata Benth.	ET473
Galactia montana Britton	ET274
Hoffmannseggia eremophila (Phil.) Burkart ex Ulibarri	ET244
Inga striata Benth. cf.	ET488
Lupinus alaristatus C.P.Sm. cf.	ET48
Lupinus erectifolius C.P.Sm.	ET204 ET424A
Lupinus tatei Rusby	ET424B ET21
Medicago lupulina L.	TC558
Medicago polymorpha L.	ET299 TC556
Medicago sativa L.	ET231 TC563
Melilotus albus Desr.	TC559
Melilotus indicus (L.) All.	ET108 TC561
Otholobium pubescens (Poir.) J.W.Grimes	ET333 TC529 TC613
Prosopis laevigata (Humb. & Bonpl. ex Willd.) M.C.Johnst.	TC533
Senna aymara H.S.Irwin & Barneby	ET128 TC525
Spartium junceum L.	ET362
Tipuana tipu (Benth.) Kuntze	ET286
Trifolium amabile Kunth	ET97
Vicia graminea Sm.	ET118

FAMILY & SPECIES	COLLECTION NUMBERS
Zornia reticulata Sm. vel aff.	ET386
GENTIANACEAE	
Gentiana sedifolia Kunth	ET84 TC514
GERANIACEAE	
Erodium cicutarium (L.) L' Hér. ex Aiton	ET368 TC565 TC586
Erodium moschatum L'Hér. ex Aiton	TC566
Geranium soratae R.Knuth	ET206
GROSSULARIACEAE	
Ribes brachybotrys (Wedd.) Jancz.	ET89
HYACINTHACEAE	
Oziroë argentinensis (Lillo et Hauman) Speta	ET154 ET353
Iridaceae	
Cardenanthus sp.	ET188
Sisyrinchium chilense Hook.	ET181
Sphenostigma mandonii (Rusby) R.C.Foster	ET292
KRAMERIACEAE	
Krameria lappacea (Dombey) Burdet & B.B.Simpson	ET295
LAMIACEAE	
Hedeoma mandoniana Wedd. cf.	ET73
Lepechinia graveolens (Regel) Epling	ET271
Lepechinia meyenii (Walp.) Epling	ET208
Marrubium vulgare L.	ET364
Mentha spicata L. cf.	TC555
Minthostachys andina (Britton) Epling	ET99
Salvia bangii Rusby	ET242
Salvia haenkei Benth.	ET68
Salvia haenkei x *orbignaei* Benth.	ET236
Salvia orbignaei Benth.	ET151 ET217 ET236
Salvia sophrona Briq.	ET117 ET182
Salvia sophrona Briq. cf.	ET416
Salvia tiliifolia Vahl.	ET430
Satureja boliviana (Benth.) Briq.	ET269 TC509
LILIACEAE	
Khuchia andina	ET530
LOASACEAE	
Caiophora buraeavi Urb. & Gilg	ET270
Caiophora canarinoides (Lenné & K.Koch) Urb. & Gilg	ET211
Mentzelia fendleriana Urb. & Gilg	ET240 ET304

FAMILY & SPECIES	COLLECTION NUMBERS
LORANTHACEAE	
Dendrophthora mesembrianthemifolia Urb.	ET12
Ligaria cuneifolia (Ruiz & Pav.) Tiegh.	ET279 TC508
Tripodanthus acutifolius (Ruiz & Pav.) Tiegh.	ET305 TC618
Tristerix penduliflorus Kuijt	ET406
MALVACEAE	
Anoda cristata (L.) Schltdl.	ET372
Lavatera assurgentiflora Kellogg	TC579 ET531
Malvaceae sp. nov.	ET487
Malvastrum coromandelianum (L.) Garcke	ET281B
Sida argentina K.Schum. cf.	ET281A
Sida spinosa L.	ET391
Tarasa capitata (Cav.) Bates	ET165
Tarasa tenella (Cav.) Krapov.	TC570
Urocarpidium limense (L.) Krapov. cf.	ET365 ET366
MELASTOMATACEAE	
Brachyotum microdon (Naudin) Triana	ET501
MORACEAE	
Ficus carica L.	NONE
MYRTACEAE	
Eucalyptus citriodora Hook.	NONE
Eucalyptus globulus Labill.	NONE
NYCTAGINACEAE	
Boerhavia coccinea Mill.	ET163
Colignonia glomerata Griseb. var. *glomerata*	ET267
OLEACEAE	
Menodora pulchella Markgr.	ET223
ONAGRACEAE	
Epilobium hirtum Sam.	TC574
ORCHIDACEAE	
Altensteinia fimbriata Kunth.	ET298
Pterichis sp.	ET523
OXALIDACEAE	
Hypseocharis pimpinellifolia Remy	ET78 ET131
Oxalis calachacensis R.Knuth	TC583
Oxalis eriolepis Wedd.	ET83
PASSIFLORACEAE	
Passiflora foetida L.	ET491
Passiflora mollissima (Kunth) L.H.Bailey	TC560
Passiflora umbilicata (Griseb.) Harms	TC553

FAMILY & SPECIES	COLLECTION NUMBERS
PIPERACEAE	
Peperomia galioides Kunth	ET500
Peperomia peruviana (Miq.) Dahlst.	ET141
PLANTAGINACEAE	
Plantago australis Lam.	TC557
Plantago lanceolata L.	ET101 ET429
Plantago myosuros Lam.	TC564
Plantago myosuros Lam. subsp. *myosuros*	ET439
Plantago orbignyana Steinh.	ET180
Plantago tomentosa Lam.	ET92
PLUMBAGINACEAE	
Plumbago caerulea Kunth	ET482
POACEAE	
Agrostis cf.	TC550
Arundo donax L.	NONE
Bothriochloa barbinodis (Lag.) Herter	ET395
Bothriochloa saccharoides (Sw.) Rydb.	ET336 ET442 ET450
Bromus catharticus Vahl	ET196
Calamagostris sp. 1	ET427
Calamagostris/Deyeuxia	ET174 ET408
Cortaderia rudiuscula Stapf	ET26 ET310
Cynodon dactylon (L.) Pers.	ET463
Elionurus tripsacoides Humb. & Bonpl. ex Willd.	ET313
Festuca boliviana E.B.Alexeev	ET104
Festuca copei Renvoize	ET345 ET451
Festuca fiebrigii Pilg.	ET409
Lamprothyrsus hieronymi (Kuntze) Pilg.	ET49 ET156
Muhlenbergia rigida (Kunth) Trin.	ET193 ET324
Paspalum humboldtianum Flüggé	ET314
Pennisetum villosum R.Br. ex Fresen.	ET440
Pennisetum weberbaueri Mez	ET337 ET441 ET448
Poa buchtienii Hack.	ET186
Poaceae sp. 1	ET251
Poaceae sp. 2	ET315
Poaceae sp. 3	ET335
Poaceae sp. 4	ET394
Poaceae sp. 5	ET449
Polypogon interruptus Kunth	TC595
Stipa ichu (Ruiz et Pav.) Kunth	ET69 TC597

FAMILY & SPECIES	COLLECTION NUMBERS
POLYGALACEAE	
Monnina rusbyi Chodat	ET238 ET260 ET302
Monnina salicifolia Ruiz et Pav.	ET418
Polygala cisandina Chodat	ET472A
Polygala mandonii Chodat	ET510
POLYGONACEAE	
Polygonum aviculare L.	TC544
Rumex conglomeratus Murray	
Rumex crispus L.	TC549
Rumex cuneifolius Campd.	TC543
PRIMULACEAE	
Anagallis arvensis L.	ET436 ET479 TC512
RANUNCULACEAE	
Clematis montevidensis Spreng.	ET91
Ranunculus repens var. *flore-pleno* DC.	ET214
Thalictrum decipiens B.Boivin	ET114
RHAMNACEAE	
Colletia spinosissima J.F.Gmel.	TC600
Kentrothamnus weddellianus (Miers) M.C.Johnst.	ET226
ROSACEAE	
Kageneckia lanceolata Ruiz & Pav.	ET158 TC619
Margyricarpus pinnatus (Lam.) Kuntze	ET201
Polylepis besseri Hieron.	ET425 ET521
Prunus persica (L.) Batsch	TC551
Prunus domestica L.	
Rosa x *noisettiana* Thory cf.	TC571
Rubus ulmifolius Schott cf.	TC599
Tetraglochin cristatum (Britton) Rothm.	ET77
RUBIACEAE	
Borreria eryngioides Cham. & Schltdl.	ET230
Heterophyllaea lycioides (Rusby) Sandwith	ET150
Relbunium ciliatum (Ruiz & Pav.) Hemsl.	ET119 TC503
RUTACEAE	
Ruta graveolens L.	
Zanthoxylum coco Gill. ex Hook. & Arn.	
SALICACEAE	
Populus nigra L.	ET474 TC607
Salix humboldtiana Willd.	TC580
Salix babylonica L.	

FAMILY & SPECIES	COLLECTION NUMBERS
SANTALACEAE	
Quinchamalium procumbens Ruiz & Pav.	ET143 TC615
SAPINDACEAE	
Cardiospermum corindum L.	ET273
Dodonaea viscosa Jacq.	ET159
SAXIFRAGACEAE	
Escallonia millegrana Griseb.	TC612
Escallonia schreiteri Sleumer	ET503
Escallonia tucumanensis Hosseus	TC518
SCROPHULARIACEAE	
Agalinis lanceolata (Ruiz & Pav.) D'Arcy	ET142 TC515
Agalinis reflexidens (Herzog) D'Arcy	TC609
Alonsoa acutifolia Ruiz et Pav.	ET166 TC614
Bartsia crenoloba Wedd.	ET338
Bartsia elongata Wedd.	ET410
Calceolaria aquatica A.Braun & C.D.Bouché	TC530
Calceolaria buchtieniana Kraenzl.	ET203
Calceolaria engleriana Kraenzl.	ET72 TC554
Calceolaria parvifolia Wedd. subsp. *parvifolia*	ET64
Castilleja pumila (Benth.) Wedd.	ET96
Veronica persica Poir.	TC548 TC582
SOLANACEAE	
Capsicum eximium Hunz.	ET291
Capsicum pubescens Ruiz et Pav.	TC584
Cestrum atroxanthum Kuntze	ET360
Cestrum parqui L' Hér.	ET111 ET160 TC536 TC568
Dunalia brachyacantha Miers	ET506
Lycianthes lycioides (L.) Hassl.	ET153
Nicotiana glauca Graham	ET266 TC505
Nicotiana otophora Griseb.	TC537
Salpichroa tristis Miers	ET262
Salpichroa tristis Miers var. *tristis*	ET93
Solanum acaule Bitter	ET71
Solanum betaceum Cav.	
Solanum collectaneum C.V.Morton	ET112 ET178
Solanum diflorum Vell.	ET245
Solanum megistacrolobum Bitter	ET198
Solanum nitidum Ruiz et Pav.	ET471
Solanum palitans C.V.Morton	TC601
Solanum pilcomayense Morong	ET94 ET393
Solanum pygmaeum Cav.	ET282
Solanum sect. *Petota*	ET197
Solanum sisymbriifolium Lam.	ET493
Solanum sp.1	ET263
Solanum tripartitum Dunal	TC592 TC594
Vassobia fasciculata (Miers) Hunz.	ET257 ET346 ET485
STERCULIACEAE	
Ayenia boliviana Rusby	ET277
Melochia thymifolia (C.Presl) Goldberg cf.	ET486
TROPAEOLACEAE	
Tropaeolum pentaphyllum Lam. subsp. *megapetalum* (Buchenau)Sparre	ET261
URTICACEAE	
Urtica urens L.	TC573
VALERIANACEAE	
Valeriana decussata Ruiz & Pav.	ET306
VELLOZIACEAE	
Barbaceniopsis boliviensis (Baker) L.B.Sm.	ET284
VERBENACEAE	
Aloysia gratissima (Gillies & Hook.) Tronc.	ET233
Aloysia triphylla (L'Hér.) Britton	ET496
Glandularia aristigera (S.Moore) Tronc.	ET187
Lantana balansae Briq.	ET225
Lantana camara L.	ET392
Lantana fiebrigii Hayek	ET152
Lippia boliviana Rusby	ET243
Lippia modesta Briq.	ET185
Verbena hispida Ruiz & Pav.	ET155 TC540
ZYGOPHYLLACEAE	
Kallstroemia boliviana Standl.	ET492

GYMNOSPERMAE

FAMILY & SPECIES	COLLECTION NUMBERS
CUPRESSACEAE	
Cupressus sp.	TC591
EPHEDRACEAE	
Ephedra americana Humb. et Bonpl. ex Willd.	ET289
Ephedra rupestris Benth.	ET82
PINACEAE	
Pinus radiata D.Don	TC589

FAMILY & SPECIES	COLLECTION NUMBERS
PTERIDOPHYTA	
ASPLENIACEAE	
Asplenium gilliesii Hook.	ET420A
POLYPODIACEAE	
Campyloneurum densifolium (Hieron.) Lellinger	ET422
Polypodium pycnocarpum cf. C.Chr.	ET265
PTERIDACEAE	
Adiantum orbignyanum cf. Mett. ex Kuhn	ET121B
Adiantum poiretii Wikstr.	ET121A
Argyrochosma nivea (Poir.) Windham var. *tenera* (Gillies ex Hook.) Ponce	ET126
Cheilanthes pilosa Goldm.	ET264
Cheilanthes pruinata Kaulf.	ET147
Cheilanthes scariosa (Sw.) C.Presl	ET123
Pellaea ternifolia (Cav.) Link	ET504
WOODSIACEAE	
Woodsia montevidensis (Spreng.) Hieron.	ET417

Appendix 2

Alphabetical List of Inventoried Plant Species in TIPNIS

FAMILY & SPECIES	COLLECTION NUMBERS[1]
ACANTHACEAE	
Aphelandra aurantiaca (Scheidw.) Lindl.	ET754
Aphelandra inaequalis Lindau	ET1780
Aphelandra rubra Wassh.	ET1507
Justicia appendiculata (Ruiz et Pav.) Vahl	ET789
Justicia boliviana Rusby	ET1423 ET1824
Justicia megalantha Wassh. & J.R.I.Wood	ET756 ET1230
Justicia riedeliana (Nees) V.A.W.Graham	ET1784
Justicia tenuistachys (Rusby) Wassh. & J.R.I.Wood	ET818
Mendoncia bivalvis (L.f.) Merr.	ET2094
Mendoncia glabra cf. Poepp. & Endl.	ET1502
Mendoncia glabra Poepp. & Endl.	ET1114
Mendoncia lindavii Rusby	ET2000
Pachystachys spicata (Ruiz & Pav.) Wassh.	ET964
Pulchranthus adenostachyus (Lindau) V.M.Baum, Reveal & Nowicke	ET934
Ruellia proxima Lindau	ET791
Streblacanthus dubiosus (Lindau) V.M.Baum	ET783
AMARANTHACEAE	
Amaranthus powellii S.Watson	ET1121
Celosia argentea L. 'Cristata'	ET701
Chamissoa altissima (Jacq.) Kunth	ET735 ET1164
Cyathula prostrata (L.) Blume	ET1126
AMARYLLIDACEAE	
Eucharis ulei cf. Kraenzl.	ET1306
Hymenocallis tubiflora cf. Salisb.	NONE
ANACARDIACEAE	
Anacardium occidentale L.	ET749
Astronium graveolens Jacq.	ET1962
Mauria sp./*Poupartia amazonica* Ducke	ET1496
Spondias mombin L.	ET850 ET1487
Tapirira guianensis cf. Aubl.	ET1159 ET1863 ET1906
Thyrsodium paraense cf. Huber	ET2073
Thyrsodium paraense Huber	ET1177

FAMILY & SPECIES	COLLECTION NUMBERS
ANNONACEAE	
Anaxagorea brevipes Benth.	ET1200 ET2028 ET2077
Annona montana aff. Macfad.	ET1124
Annona montana Macfad.	ET738 ET1098 ET1276 ET1894 ET2145
Crematosperma leiophyllum R.E.Fr.	ET1106 ET1517
Cymbopetalum longipes cf. Diels	ET2132
Cymbopetalum longipes Diels	ET951 ET1158 ET1592
Duguetia hadrantha (Diels) R.E.Fr.	ET1274 ET1360
Duguetia spixiana Mart.	ET924 ET933 ET1249 ET1494 ET1658 ET1725 ET1997 ET2121
Fusaea longifolia (Aubl.) Saff.	ET1451 ET1497 ET1600 ET2116
Guatteria citriodora cf. Ducke	ET1652 ET2024
Guatteria citriodora Ducke	ET1597
Guatteria trichoclonia Diels	ET732
Mosannona parva Chatrou	ET1534
Rollinia boliviana R.E.Fr.	ET736 ET1015 ET2096 ET2140 ET2161
Rollinia herzogii R.E.Fr.	ET1084 ET1380
Rollinia mucosa (Jacq.) Baill.	N37
Ruizodendron ovale (Ruiz & Pav.) R.E.Fr.	ET1300
Unonopsis floribunda cf. Diels	ET1270
Unonopsis floribunda Diels	ET1041 ET1748 ET1865 ET2113
Unonopsis guatterioides (A.DC.) R.E.Fr.	ET2022 ET2075 ET2170
Xylopia cuspidata Diels	ET2088
Xylopia cuspidata cf. Diels	ET1965
Xylopia sericea A.St.-Hil.	ET2044
Annonaceae sp. 1	ET1480
APOCYNACEAE	
Aspidosperma rigidum Rusby	ET771 ET1008
Himatanthus sucuuba (Spruce ex Müll.Arg.) Woodson	ET1952
Mandevilla hirsuta (Rich.) K.Schum.	ET1424
Mandevilla rugellosa (Rich.) L.Allorge	ET733
Matelea badilloi cf. Morillo	ET2048

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[1] All numbers refer to the collection of Evert Thomas (ET). "NONE" means that no collection was made in TIPNIS.

FAMILY & SPECIES	COLLECTION NUMBERS
Mesechites sp.	ET975
Mesechites trifida (Jacq.) Müll.Arg.	ET2092
Odontadenia laxiflora (Rusby) Woodson	ET1724
Prestonia robusta Rusby	ET908
Rauvolfia praecox K.Schum. ex Markgr.	ET1071
Tabernaemontana vanheurckii cf. Müll.Arg.	ET986
Tabernaemontana vanheurckii Müll.Arg.	ET939 ET2003
Thevetia peruviana (Pers.) K.Schum.	NONE
Apocynaceae sp. 1	ET2010
ARACEAE	
Anthurium gracile (Rudge) Schott	ET1394
Anthurium paraguayense Engl.	ET1139
Colocasia esculenta (L.) Schott	ET1123
Dieffenbachia williamsii Croat	ET762
Homalomena crinipes Engl.	ET613
Monstera dubia (Kunth) Engl. & K.Krause	ET670
Monstera obliqua Miq. var. *kroemerii*	ET720
Philodendron brandtianum K.Krause	ET944
Philodendron guttiferum Kunth	ET769 ET1374
Philodendron heterophyllum Poepp.	ET1138
Philodendron ornatum Schott	ET764
Philodendron sp.	ET671
Syngonium podophyllum Schott	ET752 ET812
ARALIACEAE	
Dendropanax arboreus (L.) Decne. & Planch.	ET829 ET1831
Dendropanax umbellatus (Ruiz & Pav.) Decne. & Planch.	ET616 ET761
Didymopanax morototoni (Aubl.) Decne. & Planch.	ET1111
ARECACEAE	
Astrocaryum murumuru Mart.	ET823
Attalea butyracea (Mutis ex L.f.) Wess.Boer	ET1902
Attalea phalerata Mart. ex Spreng.	NONE
Bactris gasipaes cf. Kunth	NONE
Bactris gasipaes Kunth	NONE
Bactris major Jacq. var. *infestans* (Mart.) Drude	ET1247B
Euterpe precatoria Mart.	ET2124
Geonoma deversa (Poit.) Kunth	ET2126
Geonoma macrostachys Mart. var. *macrostachys*	ET672 ET867
Geonoma sp. 1	ET835
Hyospathe elegans Mart.	ET627 ET1578
Iriartea deltoidea Ruiz & Pav.	ET854
Jessenia bataua (Mart.) Burret	ET936

FAMILY & SPECIES	COLLECTION NUMBERS
Socratea exorrhiza (Mart.) H.Wendl.	ET605
ARISTOLOCHIACEAE	
Aristolochia pilosa Kunth	ET1375
Aristolochia sp. 1	ET1215
ASCLEPIADACEAE	
Blepharodon pictum (Vahl) W.D.Stevens	ET731B
Marsdenia macrophylla (Schult.) E.Fourn.	ET978 ET1435
Matelea macrocarpa (Poepp. & Endl.) Morillo	ET1109
ASTERACEAE	
Bidens pilosa L.	ET1094
Clibadium peruvianum Poepp. ex DC.	ET622
Conyza bonariensis (L.) Cronq.	ET971
Eupatorium macrophyllum L.	ET773
Mikania cf.	ET873
Mikania psilostachya DC.	ET639
Porophyllum ruderale (Jacq.) Cass.	ET987
Salmea scandens (L.) DC.	ET668 ET880
Tagetes patula L.	ET1519
Tessaria integrifolia Ruiz & Pav.	NONE
Vernonia megaphylla Hieron.	ET802
Vernonia patens Kunth	ET884A
Wulffia baccata (L.f.) Kuntze	ET640
BEGONIACEAE	
Begonia glabra Aubl.	ET781
Begonia juntasensis Kuntze	ET942
BIGNONIACEAE	
Adenocalymma impressum (Rusby) Sandwith	ET1588 ET1627
Adenocalymma purpurascens Rusby	ET1744
Arrabidaea chica (Bonpl.) B.Verl.	ET1146
Arrabidaea cinnamomea (DC.) Sandwith	ET925 ET1077
Arrabidaea pearcei (Rusby) K.Schum. ex Urb.	ET744 ET1182 ET1520 ET1663 ET2056
Arrabidaea poeppigii (DC.) Sandwith	ET1024 ET2013
Ceratophytum tetragonolobum (Jacq.) Sprague & Sandwith	ET1024 ET1722
Clytostoma campanulatum (Cham.) Bureau & K.Schum.	ET2171
Clytostoma sciurpabulum (K.Schum.) Bureau & K.Schum.	ET1006 ET1081 ET1322 ET1459
Clytostoma uleanum Kraenzl.	ET1052
Crescenta cujete L.	N17
Jacaranda glabra (DC.) Bureau & K.Schum.	ET1847
Macfadyena unguis-cati (L.) A.H. Gentry	ET656 ET1332 ET1358
Mansoa alliacea (Lam.) A.H.Gentry	NONE
Mansoa verrucifera (Schltdl.) A.H.Gentry	ET1172
Paragonia pyramidata (Rich.) Bureau	ET824B ET1220 ET1264

FAMILY & SPECIES	COLLECTION NUMBERS
Schlegelia parviflora (Oerst.) Monach.	ET1363
Spathicalyx xanthophylla (DC.) A.H.Gentry	ET1621
Stizophyllum inaequilaterum Bureau & K.Schum.	ET1343
Stizophyllum riparium (Kunth) Sandwith	ET899 ET1188 ET1628
Tynanthus schumannianus (Kuntze) A.H.Gentry	ET1526
Bignoniaceae sp. 1	ET2058
Bignoniaceae sp. 2	ET2069
BIXACEAE	
Bixa orellana L.	NONE
BOMBACACEAE	
Ceiba pentandra (L.) Gaertn.	ET1405 ET1522
Matisia ochrocalyx K.Schum. s.l.	ET1148 ET2164
Matisia sp. 1	ET1672
Ochroma pyramidale (Cav. ex Lam.) Urb.	ET796
Pachira insignis (Sw.) Sw. ex Savigny	ET1336
Quararibea wittii K.Schum. & Ulbr.	ET790 ET871 ET919
BORAGINACEAE	
Cordia nodosa Lam.	ET772 ET825
Tournefortia sp.	ET1407B ET2087
BROMELIACEAE	
Ananas comosus (L.) Merr.	NONE
Billbergia sp. 1	ET1402
BURSERACEAE	
Protium meridionale cf. Swart	ET885 ET1047 ET1155 ET1565 ET1594 ET1701 ET1910 ET1969 ET1988 ET2047
Protium sp. 2	ET1960
Tetragastris altissima (Aubl.) Swart	ET1454A ET1581 ET1803 ET1857 ET1872 ET2150
Tetragastris altissima cf. (Aubl.) Swart	ET1613
Trattinnickia peruviana aff. Loes.	ET1709 ET1771
BUXACEAE	
Styloceras brokawii A.H.Gentry & R.B.Foster	ET685 ET894 ET1533 ET1809 ET1850 ET1864
CACTACEAE	
Cereus braunii cf. Cárdenas	ET2138
Epiphyllum phyllanthus (L.) Haw.	ET801
Pereskia sacharosa Griseb.	ET879
Rhipsalis baccifera (Mill.) Stearn	ET1513
CARICACEAE	
Carica papaya L.	ET774
Jacaratia digitata (Poepp. & Endl.) Solms	ET994
CARYOPHYLLACEAE	

FAMILY & SPECIES	COLLECTION NUMBERS
Drymaria cordata (L.) Willd. ex Schult.	ET990
CECROPIACEAE	
Cecropia concolor Willd.	ET2119
Cecropia engleriana Snethl.	ET1016
Cecropia membranacea cf. Trécul	ET1011
Cecropia polyphlebia Donn.Sm.	ET819
Cecropia polystachya Trecul	ET816 ET1012 ET1470
Cecropia sciadophylla Mart.	ET1017
Coussapoa villosa Poepp. & Endl.	ET947 ET1303 ET1364 ET1942
Coussapoa sp. 1 cf.	ET1800 ET1936
Coussapoa villosa cf. Poepp. & Endl.	ET1285
Pourouma bicolor Mart.	ET1736
Pourouma cecropiifolia Mart.	ET1197 ET1376
Pourouma guianensis Aubl. subsp. *guianensis*	ET996 ET1150 ET1205
Pourouma minor Benoist	ET890 ET1737
Pourouma tomentosa Miq. subsp. *persecta* C.C.Berg & Heusden	ET1752 ET1765
CELASTRACEAE	
Gymnosporia magnifolia (Loes.) Lundell	ET1403 ET1508 ET1790 ET1840 ET1973
CHENOPODIACEAE	
Chenopodium ambrosioides L.	ET878
CHRYSOBALANACEAE	
Hirtella bullata Benth.	ET952
Hirtella excelsa Standl. ex Prance	ET1718
Hirtella hispidula Miq.	ET1558 ET1704
Hirtella pilosissima Mart. & Zucc.	ET949 ET1554 ET1651 ET2166
Hirtella sp. 1	ET1165
Hirtella sp. 2	ET1994
Hirtella triandra Sw.	ET1818 ET1941
Hirtella triandra Sw. subsp. *triandra*	ET1623
Licania apetala (E.Mey.) Fritsch subsp. *apetala*	ET1838
Licania harlingii Prance	ET1345 ET1566 ET1928 ET1982 ET2025 ET2052
Licania klugii aff. Prance	ET1170
Licania micrantha Miq.	ET1708
Licania sp. nov.	ET1876
Licania sp1	ET891 ET1940
Parinari excelsa Sabine	ET1760B
Parinari klugii Prance	ET1007 ET1056
CLUSIACEAE	
Calophyllum brasiliense Cambess.	ET788 ET1243 ET1288 ET1924
Chrysochlamys weberbaueri Engl.	ET659 ET926 ET1846
Clusia amazonica Planch. & Triana	ET1337
Marila laxiflora cf. Rusby	ET1447
Marila tomentosa Poepp. & Endl.	ET1642 ET1740
Quapoya sp./*Clusia* sp;	ET1433

FAMILY & SPECIES	COLLECTION NUMBERS
Rheedia acuminata (Ruiz & Pav.) Planch. & Triana	ET784 ET2115
Rheedia gardneriana (Ruiz & Pav.) Planch. & Triana	ET1514 ET1585 ET1607 ET2114 ET2155
Symphonia globulifera L.f.	ET614 ET770 ET1030
Tovomita sp. 1	ET1698
Tovomita sp. 2	ET2168
Vismia plicatifolia Hochr.	ET636
COMBRETACEAE	
Combretum laxum Jacq.	ET1248
Combretum mellifluum Eichler	ET1130
Terminalia oblonga (Ruiz & Pav.) Steudel	ET843 ET1149 ET1284 ET1383 ET1853 ET2040
COMMELINACEAE	
Aneilema umbrosum (Vahl) Kunth subsp. *ovato-oblongum* (P.Beauv.) J.K.Morton	ET692
Dichorisandra hexandra (Aubl.) Standl.	ET693
Floscopa peruviana Hassk. ex C.B.Clarke	ET1492
Tradescantia zanonia (L.) Sw.	ET603 ET675
CONNARACEAE	
Rourea puberula Baker	ET1626
CONVOLVULACEAE	
Ipomoea opulifolia Rusby	ET699 ET723
Ipomoea quamoclit L.	ET1472
Maripa axilliflora cf. Mart. ex Meisn.	ET1798
Maripa sp. 1	ET830
Maripa sp. 2	ET1076
Maripa sp. 3	ET1656
Merremia macrocalyx (Ruiz & Pav.) O' Donell	ET2176
Merremia umbellata (L.) Hallier f.	ET1127
COSTACEAE	
Costus arabicus L.	ET606
Costus beckii Maas & H.Maas	ET943
Costus scaber Ruiz & Pav.	ET766 ET813
Dimerocostus argenteus (Ruiz & Pav.) Maas	ET979 ET1384
CRASSULACEAE	
Kalanchoe pinnata (Lam.) Pers.	ET950
CUCURBITACEAE	
Calycophysum pedunculatum cf. H.Karst. & Triana	ET841
Cayaponia citrullifolia cf. (Griseb.) Cogn.	ET1083
Cayaponia ophtalmica R.E.Schult.	ET1438
Cayaponia tubulosa Cogn.	ET966
Cucurbita maxima Duchesne ex Lam.	NONE
Gurania eriantha (Poepp. & Endl.) Cogn.	ET2103
Gurania spinulosa (Poepp. & Endl.) Cogn.	ET718

FAMILY & SPECIES	COLLECTION NUMBERS
Helmontia sp. 1	ET1282
Lagenaria siceraria (Molina) Standl.	ET1474
Momordica charantia L.	ET1476
Cucurbitaceae sp. 1	ET1062
Cucurbitaceae sp. 2	ET1330
Cucurbitaceae sp. 3	ET1898
CYCLANTHACEAE	
Asplundia peruviana Harling	ET1339
Carludovica palmata Ruiz & Pav.	ET809
Thoracocarpus bissectus (Vell.) Harling	ET721 ET820 ET1525
CYPERACEAE	
Cyperus corymbosus cf. Rottb.	ET883
Diplasia karatifolia Rich.	ET1434
Scleria sp.	ET1577
DICHAPETALACEAE	
Dichapetalum asplundeanum Prance	ET1234
Dichapetalum rugosum cf. (Vahl) Prance	ET1167
Dichapetalum spruceanum Baill.	ET2074
Tapura guianensis Aubl.	ET1893 ET2158
Tapura juruana (Ule) Rizzini	ET1222 ET1281 ET1516 ET1546 ET1812 ET1948 ET2057 ET2141
DILLENIACEAE	
Davilla kunthii A.St.-Hil.	ET1726
Davilla nitida (Vahl) Kubitzki	ET984
Doliocarpus dentatus (Aubl.) Standl.	ET1689
Doliocarpus magnificus aff. Sleumer	ET1618
Doliocarpus subandinus Aymard	ET1730 ET2032
Tetracera hydrophila Triana & Planch.	ET1636
Tetracera parviflora aff. (Rusby) Sleumer	ET2070
Tetracera parviflora (Rusby) Sleumer	ET1072 ET1313
Dilleniaceae sp. 1	ET1219
Dilleniaceae sp. 2	ET1897
Dilleniaceae sp. 3	ET1945
Dilleniaceae sp. 4	ET1887
DIOSCOREACEAE	
Dioscorea dodecaneura Vell.	ET2098
Dioscorea spectabilis R.Knuth	ET1775 ET1785
Dioscorea trifida L.f.	ET745
EBENACEAE	
Diospyros dalyom B.Walln.	ET1294
ELAEOCARPACEAE	
Muntingia calabura L.	ET739
Sloanea fragans Rusby	ET920 ET1001
Sloanea gracilis cf. Uittien	ET827
Sloanea guianensis (Aubl.) Benth.	ET1633 ET1768
Sloanea latifolia (Rich.) K.Schum.	ET2101 ET2162

FAMILY & SPECIES	COLLECTION NUMBERS
Sloanea laxiflora Spruce ex Benth.	ET1028
Sloanea obtusifolia cf. (Moric.) K.Schum.	ET1232
Sloanea picapica cf. Standl.	ET1542
Sloanea rufa cf. Planch. ex Benth.	ET1987
Sloanea sp. 1	ET1556 ET1584 ET1759
Sloanea sp. 2	ET1074
Sloanea sp. 3	ET1833
Sloanea spathulata cf. Earle Sm. (*S. rufa* Planch. ex Benth.)	ET1641 ET2063
Sloanea spathulata Earle Sm.	ET1457
Sloanea terniflora cf. (Moc.& Sessé ex DC.) Standl.	ET1839
ERYTHROXYLACEAE	
Erythroxylum citrifolium A.St.-Hil.	ET1749
Erythroxylum coca Lam.	NONE
EUPHORBIACEAE	
Acalypha scandens Benth.	ET931
Acalypha stricta Poepp.	ET852
Chamaesyce hirta (L.) Millsp.	ET1026
Croton matourensis Aubl.	ET727
Croton tessmannii Mansf.	ET1265 ET1985 ET2142
Dalechampia dioscoreifolia cf. Poepp.	ET1446
Drypetes amazonica Steyerm.	ET1231 ET1484 ET1789 ET1810 ET1830 ET1891 ET1935
Euphorbia pulcherrima Willd ex. Klotzsch	ET1122
Hura crepitans L.	ET742
Hyeronima alchorneoides Allemão	ET1429 ET2030
Hyeronima oblonga (Tul.) Müll.Arg.	ET1654
Jatropha curcas L.	ET662
Mabea anadena Pax & K.Hoffm.	ET1075 ET1355
Margaritaria nobilis L.f.	ET815 ET1252 ET1397 ET1932
Omphalea diandra L.f.	ET985 ET1590 ET1750
Pera glabrata (Schott) Baill.	ET1706 ET1756
Pera heterodoxa cf. Müll.Arg.	ET1589
Phyllanthus brasiliensis (Aubl.) Poir. ssp. *glaber* (Pax & K.Hoffm.) G.L.Webster	ET609
Richeria grandis Vahl	ET1208 ET1217 ET1453 ET1617 ET1637 ET1664 ET1727 ET2033
Ricinis communis L.	ET664
Sagotia racemosa Baill.	ET1136 ET1141 ET2006 ET2043 ET2059 ET2061
Sapium glandulosum (L.) Morong	ET1781
Sapium marmieri Huber	ET1251 ET1766
Tetrorchidium dusenii Pax & K.Hoffm.	ET1488
FABACEAE	
Abarema jupunba (Willd.) Britton & Killip	ET2062

FAMILY & SPECIES	COLLECTION NUMBERS
Acacia fiebrigii Hassl.	ET1531
Acacia glomerosa Benth.	ET1255
Acacia loretensis J.F.Macbr.	ET1086
Acacia multipinnata Ducke	ET1021
Acacia tenuifolia cf. (L.) Willd.	ET810
Anadenanthera colubrina (Vell.) Brenan	N35
Arachis hypogaea L.	N25
Arachis pintoi Krapov. & W.C.Greg.	ET748
Bauhinia brachycalyx Ducke	ET1950
Bauhinia glabra aff. Jacq. s.l.	ET872 ET1040 ET1260
Bauhinia longicuspis Spruce ex Benth.	ET714
Bauhinia longifolia aff. D.Dietr.-*ungula* Jacq.	ET1926
Bauhinia sp.	NONE
Bauhinia sp. nov.	ET1786
Caesalpinia pulcherrima (L.) Sw.	ET1117
Cajanus cajan (L.) Millsp.	ET882
Calliandra angustifolia Spruce ex Benth.	ET2109
Calliandra trinervia Benth.	ET1411
Centrosema plumieri (Turp. ex Pers.) Benth.	ET1776
Clitoria pinnata (Pers.) R.H.Sm. & G.P.Lewis	ET703
Cratylia argentea (Desv.) Kuntze	ET737
Crotalaria nitens Kunth	ET751
Dalbergia riparia (Mart.) Benth.	ET1382 ET1412
Dalbergia sp. 1	ET1953
Deguelia amazonica aff. Killip	ET1719
Deguelia scandens cf. Aubl.	ET1154 ET1183
Desmodium adscendens cf. (Sw.) DC.	ET1125
Desmodium axillare (Sw.) DC.	ET2082
Dipterix micrantha Harms	ET1834
Dipterix odorata (Aubl.) Willd.	ET1342
Enterolobium contortisiliquum (Vell.) Morong	ET1458
Erythrina dominguezii Hassl.	ET992
Erythrina poeppigiana (Walp.) O.F. Cook	ET792 ET988
Hymenaea courbaril L.	NONE
Inga acreana Harms	ET917 ET1209 ET1379 ET1901 ET2031
Inga alba (Sw.) Willd.	ET2076
Inga bourgonii (Aubl.) DC.	ET1010 ET1153 ET1266 ET1896 ET1916 ET2079
Inga capitata Desv.	ET1754 ET1791 ET1804 ET2137
Inga capitata cf. Desv.	ET1912
Inga chartacea cf. Poepp. & Endl.	ET1023
Inga chartacea Poepp. & Endl.	ET876 ET1046 ET1160
Inga cinnamomea cf. Spruce ex Benth.	ET1162
Inga edulis Mart.	ET1406B ET1661
Inga heterophylla Willd.	ET976
Inga japurensis T.D.Penn.	ET1908

FAMILY & SPECIES	COLLECTION NUMBERS
Inga laurina (Sw.) Willd.	ET877A ET1000 ET1247A
Inga longipes aff. Benth.	ET1082
Inga macrophylla Humb. & Bonpl. ex Willd.	ET799 ET1400
Inga marginata Willd.	ET797 ET1714 ET2093
Inga mathewsiana Benth.	ET2110
Inga nobilis Willd. subsp. *quaternata* (Poepp. & Endl.) T.D.Penn.	ET968 ET1307
Inga nobilis Willd. subsp. *nobilis*	ET1692
Inga peduncularis cf. Benth.	ET1911
Inga punctata Willd.	ET725 ET980
Inga ruiziana G.Don	ET1064 ET1189 ET1221 ET1309 ET1408 ET1922
Inga sp. nov.	ET2120 ET2143
Inga steinbachii Harms	ET1013 ET1069
Inga stenoptera Benth.	ET1951 ET2136
Inga tenuistipula Ducke	ET734 ET1289
Inga tomentosa Benth.	ET798 ET2016
Lecointea amazonica Ducke	ET821 ET1506 ET1794
Lonchocarpus lilloi aff. (Hassl.) Burkart	ET1582
Machaerium sp.	ET1036
Machaerium subrhombiforme cf. Rudd	ET1548 ET1659 ET1679
Machaerium subrhombiforme Rudd	ET889
Mucuna rostrata Benth	ET793
Myroxylon balsamum (L.) Harms	ET1257 ET1297 ET1760A ET1971
Ormosia nobilis Tul.	ET1512
Ormosia sp. 1	ET1296
Ormosia sp. 2	ET1406A
Pachyrhizus tuberosus (Lam.) Spreng.	ET700
Piptadenia anolidurus Barneby	ET1391
Piptadenia anolidurus cf. Barneby	ET1192 ET2054
Pterocarpus santalinoides cf. L'Hér. ex DC.	ET1996
Senna affinis (Benth.) H.S.Irwin & Barneby	ET702
Senna herzogii (Harms) H.S.Irwin & Barneby	ET1445B ET2163
Stryphnodendron purpureum Ducke	ET2118
Swartzia jorori Harms	ET817 ET922 ET1377
Swartzia simplex (Sw.) Spreng.	ET847
Tephrosia vogelii Hook.f.	ET632
Vigna caracalla (L.) Verdc.	ET2001
Zygia macrophylla (Spruce ex Benth.) L.Rico	ET1583 ET1961
Fabaceae sp. 1	ET1734
FLACOURTIACEAE	
Banara guianensis Aubl.	ET1409 ET2107
Casearia grewiifolia cf. Vent.	ET757 ET1783
Casearia duckeana Sleumer	ET1622 ET1646
Casearia pitumba Sleumer	ET973 ET1449 ET1500
Casearia sylvestris Sw.	ET750 ET1521
Hasseltia floribunda Kunth	ET923 ET1058 ET1143 ET1180 ET1338 ET1843 ET1882 ET1927
Lunania parviflora Spruce ex Benth.	ET915 ET930 ET940 ET1324 ET1691
Mayna odorata Aubl.	ET1495
Neosprucea montana cf. Cuatrec.	ET780
Prockia crucis P.Browne ex L.	ET1055 ET1140 ET1301
GENTIANACEAE	
Irlbachia alata (Aubl.)Maas	ET707
GESNERIACEAE	
Besleria longipedunculata Britton	ET652
Besleria sprucei aff. Britton	ET1432
Codonanthe uleana Fritsch	ET691
Drymonia candida Hanst.	ET1305 ET1413
Drymonia doratostyla (Leeuwenb.) Wiehler	ET643
Drymonia oxysepala Leeuwenb.	ET2091
Gloxinia sylvatica (Kunth) Wiehler	ET1998
Nautilocalyx whitei Rusby	ET1420
HELICONIACEAE	
Heliconia lingulata Ruiz & Pav.	ET1536
Heliconia rostrata Ruiz & Pav.	ET1120
Heliconia sp. 1	NONE
Heliconia stricta Huber	ET807
HIPPOCRATEACEAE	
Anthodon decussatum Ruiz & Pav.	ET1854 ET1861 ET1958 ET2055
Cheiloclinium cognatum (Miers) A.C.Sm.	ET1315 ET1561 ET2039 ET2167
Cheiloclinium hippocrateoides (Peyr.) A.C.Sm.	ET615 ET2154
Hippocratea volubilis L.	ET929
Hylenaea praecelsa cf. (Miers) A.C.Sm.	ET1841
Peritassa huanucana (Loes.) A.C.Sm.	ET1923
Pristimera celastroides cf. (Kunth) A.C.Sm.	ET1713
Salacia alwynii cf. Mennega	ET1801 ET1884
Salacia impressifolia (Miers) A.C.Sm.	ET911 ET1304 ET1723 ET1993 ET2112
*Salacia multiflora (*Lam.) DC. subsp. *multiflora*	ET1552 ET1635 ET1660
Salacia sp.	ET1371
Salacia sp./*Tontelea* sp.	ET2041
Tontelea laxiflora cf. (Benth.) A.C.Sm.	ET1963
Tontelea ovalifolia (Miers) A.C.Sm.	ET864 ET906 ET928 ET1031 ET1048 ET1295 ET1361 ET1401 ET1889
Tontelea/*Cheiloclinium*	ET1279
Hippocrateaceae sp. 1	ET1653
Hippocrateaceae sp. 2	ET2007
Hippocrateaceae sp. 3?	ET2080
HUMIRIACEAE	
Vantanea sp.	ET1816

FAMILY & SPECIES	**COLLECTION NUMBERS**
ICACINACEAE	
Calatola venezuelana cf. Pittier	ET2027 ET2037
IRIDACEAE	
Eleutherine citriodora (Ravenna) Ravenna	ET2129
LACISTEMATACEAE	
Lacistema aggregatum (P.J.Bergius) Rusby	ET1186 ET1333 ET1870 ET1931 ET1975
Lacistema cf. aggregatum (P.J.Bergius) Rusby	ET1142
LAMIACEAE	
Mentha viridis cf. L.	ET2175
Ocimum micranthum Willd.	ET741
Solenostemon scutellarioides (L.) Codd	ET1118
LAURACEAE	
Aiouea tomentella (Mez) S.S. Renner	ET1562 ET1944
Aniba canelilla (Kunth) Mez	ET1439
Aniba cylindriflora cf. Kosterm.	ET1807
Aniba sp. 1	ET2159
Aniba taubertiana Mez	ET1700 ET1717 ET1758
Beilschmiedia sp. 1	ET1675
Endlicheria aurea Chanderb.	ET1009
Endlicheria bracteata Mez	ET1678 ET1688
Endlicheria dysodantha (Ruiz & Pav.) Mez	ET620 ET1135 ET1246 ET1318
Endlicheria krukovii (A.C.Sm.) Kosterm.	ET1539
Endlicheria lhotzkyi (Nees) Mez	ET1793
Endlicheria sp. 1	ET1917
Licaria triandra (Sw.) Kosterm.	ET831 ET1002 ET1745 ET1829
Nectandra membranacea (Sw.) Griseb.	ET649
Nectandra pulverulenta Nees	ET803 ET1308 ET1929
Nectandra sp. 1	ET1549
Ocotea aciphylla cf. (Nees) Mez	ET1190 ET1211
Ocotea cernua cf. (Nees) Mez	ET1978
Ocotea longifolia cf. Kunth	ET998
Ocotea minarum s.l. (Nees & Mart.) Mez	ET1147
Ocotea obovata aff. (Ruiz & Pav.) Mez	ET1844
Ocotea sp. 1	ET857
Ocotea sp. 2	ET1669
Ocotea sp. 3	ET1005 ET1767 ET1835 ET1842 ET1955
Persea americana Mill.	NONE
Pleurothyrium intermedium cf. (Mez) Rohwer	ET2067
Rhodostemonodaphne kunthiana (Nees) Rohwer	ET845 ET1070
Lauraceae sp. 1	ET1591
Lauraceae sp. 2	ET1601
LECYTHIDACEAE	
Cariniana estrellensis cf. (Raddi) Kuntze	ET1900

FAMILY & SPECIES	**COLLECTION NUMBERS**
Eschweilera albiflora (A.DC.)Miers	ET1278
Eschweilera albiflora cf. (DC.) Miers	ET1587
Eschweilera andina (Rusby) J.F.Macbr.	ET912 ET1757 ET1851 ET1919 ET2017 ET2085
Eschweilera coriacea (DC.) S.A.Mori	ET1351 ET1605 ET1645 ET1888
Eschweilera ovalifolia cf. (DC.) Nied.	ET1057
Eschweilera sp.	NONE
LOGANIACEAE	
Strychnos darienensis cf. Seem.	ET1366
Strychnos darienensis Seem.	ET1981
LORANTHACEAE	
Oryctanthus alveolatus (Kunth) Kuijt	ET648 ET2169
Phthirusa pyrifolia (Kunth) Eichler	ET991
Struthanthus acuminatus (Ruiz & Pav.) Blume	ET1392
MALPIGHIACEAE	
Bunchosia armeniaca (Cav.) DC.	ET644 ET1529
Byrsonima sp. 1	ET1564
Hiraea fagifolia (DC.) A.Juss.	ET849
Hiraea grandifolia Standl. & L.O.Williams	ET1976 ET2065
Hirarea sp. 1	ET1061
Niedenzuella stannea (Griseb.) W.R.Anderson	ET1216
new combination	ET1699 ET1571
Tetrapterys crispa A.Juss.	ET1779
Tetrapterys crispa cf. A.Juss.	ET1033 ET1035 ET1059
Stigmaphyllon cf.	ET1837
Malpighiaceae sp. 1	ET1227
MALVACEAE	
Abutilon laxum Rusby	ET981
Gossypium barbadense L.	ET1091
Hibiscus acetosella Welwitsch ex Hiern	ET1119
Hibiscus rosa-sinesis L.	ET660
Sida rhombifolia L.	ET877B
Sida setosa Mart. ex Colla	ET969
MARANTACEAE	
Calathea capitata (Ruiz & Pav.) Lindl.	ET1471
Calathea grandiflora cf. (Roscoe) K.Schum.	ET1310
Calathea lutea (Aubl.) Schult.	ET806
Ischnosiphon puberulus Loes.	ET884B ET2146
MARCGRAVIACEAE	
Marcgravia flagellaris (Poepp. ex Wittm.) Gilg & Werderm.	ET888 ET1115 ET2029
Marcgravia macrophylla (Wittm.) Gilg	ET844 ET1415
Marcgraviastrum sp. 1	ET2038
Marcgraviaceae sp. 1	ET1869
Marcgraviaceae sp. 2	ET1939

FAMILY & SPECIES	COLLECTION NUMBERS
MELASTOMATACEAE	
Aciotis rubricaulis (Mart. ex DC.) Triana	ET706
Adelobotrys adscendens (Sw.) Triana	ET1053 ET1410
Clidemia dentata D.Don	ET694
Clidemia juruensis (Pilger) Gleason	ET765
Conostegia sp.	ET612 ET828
Henriettea stellaris cf. O.Berg ex Triana	ET1570
Loreya klugii S.S.Renner	ET1602 ET1772
Loreya spruceana Benth. ex Triana	ET2134
Loreya subandina Wurd.	ET1388 ET1796 ET1938
Miconia abbreviata Markgr.	ET628
Miconia aureoides cf. Cogn.	ET1797
Miconia aureoides Cogn.	ET1574
Miconia calvescens DC.	ET719
Miconia cannabina Markgr.	ET1393
Miconia cyanocarpa cf. Naudin	ET1603
Miconia egensis Cogn.	ET631
Miconia lamprophylla Triana	ET1335
Miconia punctata (Desr.) D.Don	ET1665
Miconia tetrasperma cf. Gleason	ET834
Miconia tomentosa (Rich.) D.Don	ET956 ET1620
Miconia trinervia (Sw.) D.Don ex Loudon	ET1225
Miconia triplinervis Ruiz & Pav.	ET875B
Mouriri cauliflora Mart. ex DC.	ET683 ET1312 ET1687
Mouriri grandiflora DC.	ET965 ET1229 ET2035
Mouriri myrtilloides (Sw.) Poir.	ET1905
Tibouchina capitata (Naudin) Cogn.	ET641
MELIACEAE	
Cedrela fissilis cf. Vell.	ET868
Guarea guidonia (L.) Sleumer	ET601 ET2127
Guarea guidonia cf. (L.) Sleumer	ET1629
Guarea kunthiana A.Juss.	ET938 ET1034 ET1060 ET1178
Guarea macrophylla Vahl	ET962 ET1184 ET1218 ET1880
Guarea macrophylla Vahl subsp. *pendulispica* (C.DC.) Penn.	ET856 ET1090 ET1105 ET1134 ET1262 ET2106
Guarea macrophylla Vahl subsp. *tuberculata* (Vell.) Penn.	ET785 ET1298 ET1690
Guarea pterorhachis Harms	ET1822
Guarea purusana C.DC.	ET1609 ET1677 ET1728 ET1762 ET1964
Guarea sp. 1	ET999
Swietenia macrophylla King	NONE
Trichilia elegans A.Juss.	ET633 ET1314 ET1323 ET1398 ET1909
Trichilia hirta L.	ET862 ET907 ET1250 ET2105
Trichilia inaequilatera Penn.	ET1236
Trichilia maynasiana C.DC.	ET1883

FAMILY & SPECIES	COLLECTION NUMBERS
Trichilia micrantha Benth.	ET629 ET1673 ET1733B ET1735 ET1761 ET1984A
Trichilia micrantha cf. Benth.	ET1557
Trichilia pallida Sw.	ET642 ET1328 ET1733A
Trichilia quadrijuga Kunth	ET903
Trichilia quadrijuga Kunth subsp. *quadrijuga*	ET1101 ET1283 ET1327
Trichilia rubra C.DC.	ET1286
Trichilia septentrionalis aff. C.DC.	ET2036
MENISPERMACEAE	
Abuta grandifolia (Mart.) Sandwith	ET618 ET967
Abuta grisebachii Triana & Planch.	ET1711 ET1802 ET2050
Abuta pahnii (Mart.) Krukoff & Barneby	ET2100
Abuta rufescens Aubl.	ET886 ET1436 ET1579 ET2049
Abuta sp. 2	ET1614
Anomospermum bolivianum Krukoff & Moldenke	ET1553 ET1729
Cissampelos tropaeolifolia DC.	ET729
Odontocarya arifolia Barneby	ET1782
Odontocarya diplobotrya Diels	ET983 ET995
Orthomene schomburgkii (Miers) Krukoff & Barneby	ET974
Odontocarya sp. 1	ET1747
Menispermaceae sp. 1	ET1753
Menispermaceae sp. 2	ET1986
MONIMIACEAE	
Mollinedia boliviensis A.DC.	ET2060
Mollinedia killipii J.F.Macbr.	ET2086
Mollinedia latifolia (Poepp. & Endl.) Tul.	ET1485
Mollinedia ovata Ruiz & Pav.	ET2089
Siparuna aspera (Ruiz & Pav. ex Tul.) A.DC.	ET621
Siparuna bifida (Poepp. & Endl.) A.DC.	ET619 ET1317 ET1373 ET1493 ET1559
Siparuna decipiens (Tul.) A.DC.	ET893 ET1079 ET1151 ET1239 ET1367 ET1370 ET1544 ET1569
Siparuna guianensis Aubl.	ET955 ET1422 ET1742
Siparuna sp. 1	ET836
Siparuna thecaphora (Poepp. & Endl.) A.DC.	ET767 ET1107
MORACEAE	
Brosimum guianense (Aubl.) Hubert	ET1650
Clarisia biflora Ruiz & Pav.	ET913B ET1344 ET1921 ET1957 ET2117
Clarisia racemosa Ruiz & Pav.	ET786 ET855 ET913A ET1108 ET1368
Ficus coerulescens (Rusby) Rossberg	ET1020 ET1244 ET1826
Ficus cuatrecasana Dugand	ET1359
Ficus donnell-smithii cf. Standl.	ET1608

FAMILY & SPECIES	COLLECTION NUMBERS
Ficus gomelleira Kunth & Bouché	ET1693
Ficus guianensis Desv.	ET945
Ficus insipida Willd.	ET600 ET824A
Ficus maxima Mill.	ET804 ET1087
Ficus paraensis (Miq.) Miq.	ET604 ET2099
Ficus piresiana cf. Vazq.Avila & C.C.Berg	ET2152
Helicostylis tomentosa (Poepp. & Endl.) J.F.Macbr.	ET1547 ET2148
Helicostylis tovarensis cf. (Klotzsch & H.Karst.) C.C.Berg (*Brosimum lactescens* (S.Moore) C.C.Berg)	ET1751
Morus alba L. var. *indica* (L.) Bureau	ET740
Naucleopsis ulei (Warb.) Ducke subsp. *subandina* C.C.Berg	ET1210 ET2005 ET2053
Poulsenia armata (Miq.) Standl.	ET916 ET1152
Pseudolmedia laevis (Ruiz & Pav.) J.F.Macbr.	ET822 ET904 ET1073 ET1808
Pseudolmedia macrophylla cf. Trécul	ET1875
Pseudolmedia macrophylla Trécul	ET1710
Sorocea briquetii cf. J.F.Macbr.	ET1560
Sorocea guilleminiana Gaudich.	ET1867
Sorocea steinbachii C.C.Berg	ET1080 ET1201 ET1545 ET1550 ET1755 ET1977 ET2019 ET2123
Sorocea steinbachii cf. C.C.Berg	ET1954
Trophis caucana (Pittier) C.C.Berg	ET1778 ET2084
Moraceae sp. 1?	ET1670
MUSACEAE	
Musa paradisiaca L.	NONE
Musa sapientum L.	NONE
Musa velutina H.Wendl. & Drude	ET669
MYRISTICACEAE	
Iryanthera juruensis Warb.	ET937 ET1112 ET1199 ET1237 ET1242 ET1369 ET1417 ET1563 ET1820 ET1979 ET2023
Osteophloeum platyspermum (A.DC.) Warb.	ET1293A ET1320
Otoba parvifolia (Markgr.) A.H.Gentry	ET875A ET1099 ET1163 ET1196 ET1290 ET1696
Virola flexuosa A.C.Sm.	ET1904
Virola peruviana (A.DC.) Warb.	ET1103 ET1268 ET1302 ET1347 ET2064
Virola sebifera Aubl.	ET1643
MYRSINACEAE	
Ardisia guyanensis (Aubl.) Mez	ET753 ET1396
Cybianthus comperuvianus Pipoly	ET954
Parathesis adenanthera (Miq.) Hook.f. ex Mez	ET1418
Stylogyne ambigua cf. (Mart.) Mez	ET1223 ET1273 ET1157 ET1537 ET1682 ET1878
Stylogyne ardisioides (Kunth) Mez	ET760 ET914
Stylogyne cauliflora cf. (Mart. & Miq.) Mez	ET1054 ET1353 ET1799 ET1828
Stylogyne cauliflora (Mart. & Miq.) Mez	ET842 ET982 ET1032 ET1326 ET1930 ET2051
MYRTACEAE	
Calyptranthes bipennis O.Berg	ET1259 ET1532
Calyptranthes sp. A	ET1319 ET1806
Calyptranthes sp. B	ET1096 ET1113 ET1238 ET1354 ET1671
Calyptranthes sp. C nov sp.	ET610 ET657 ET759 ET861 ET1241B
Eugenia acrensis McVaugh	ET1813 ET1892 ET1937 ET1947 ET2104
Eugenia florida DC.	ET1612 ET1769 ET1983
Eugenia marlierioides cf. Rusby	ET1683 ET1811 ET2066 ET2153
*Myrcia fallax (*Rich.) DC.	ET696 ET2108
Myrcia floribunda Miq.	ET1390
Myrcia multiflora cf. (Lam.) DC.	ET1599 ET1611 ET2147
Myrcia neesiana cf. DC.	ET1925
Myrcia neesiana DC.	ET859
*Myrcia silv*atica cf. (G.Mey.) DC.	ET1444
Myrcia sp.	ET2157
Myrcia sylvatica cf. (G.Mey.) DC.	ET1819
Myrciaria floribunda (West ex Willd.) O.Berg	ET900 ET1431 ET1445A ET1551 ET1632 ET1860
Plinia sp. 2	ET1116
Psidium guajava L.	ET747
Syzygium malaccense (L.) Merr. L.M.Perry	ET1095
NYCTAGINACEAE	
Guapira opposita cf. (Vell.) Reitz	ET1104
Mirabilis jalapa L.	ET881
Neea boliviana Standl.	ET674 ET711 ET755 ET1145
Neea divaricata cf. Poepp. & Endl.	ET1050 ET1202 ET1350 ET1624 ET1913
Neea hirsuta cf. Poepp. & Endl.	ET1478
Neea hirsuta Poepp. & Endl.	ET712
Neea macrophylla cf. Poepp. & Endl.	ET1595 ET1680
Neea ovalifolia cf. Spruce ex J.A.Schmidt	ET1187 ET1272
Neea sp. 1	ET1475 ET2130
Neea sp. 2	ET1694 ET1974
Neea sp. 3	ET1720 ET1934
Neea sp. 4	ET1859
Neea spruceana cf. Heimerl	ET1425 ET1662 ET1763 ET1956 ET2046
Neea steinbachiana Heimerl	ET1899
Neea virens cf. Poepp. ex Heimerl	ET1404 ET2122

FAMILY & SPECIES	COLLECTION NUMBERS
OCHNACEAE	
Ouratea macrobotrys Rusby	ET630 ET709 ET717 ET1684
OLACACEAE	
Heisteria acuminata (H.&B.)Engl.	ET1421 ET1715
Heisteria acuminata cf. (Humb. & Bonpl.) Engl.	ET1885
Heisteria nitida Engl.	ET1817
ONAGRACEAE	
Ludwigia latifolia (Benth.) H.Hara	ET697
ORCHIDACEAE	
Chaubardia klugii (C.Schweinf.) Garay	ET1498
Erythrodes sp. 1	ET673 ET1530
Gongora scaphephorus Rchb.f. & Warsz.	ET607 ET776 ET946
Kefersteinia sp.	ET1648
Maxillaria funicaulis C.Schweinf.	ET651
Vanilla planifolia cf. Andrews	ET653
Vanilla sp. 1	ET690
Vanilla sp. 2	ET1483
OXALIDACEAE	
Oxalis juruensis Diels	ET687
PASSIFLORACEAE	
Dilkea sp. 1	ET1038
Passiflora auriculata Kunth	ET1407A
Passiflora coccinea Aubl.	ET743 ET814
Passiflora mapiriensis Harms	ET1573
Passiflora nigradenia Rusby	ET1473
Passiflora nitida Kunth	ET1414
Passiflora sp.	NONE
Passiflora tricuspis Mast.	ET715 ET1440
PHYTOLACCACEAE	
Gallesia integrifolia (Spreng.) Harms	ET909
Petiveria alliacea L.	ET667
Phytolacca rivinoides Kunth & Bouché	ET970
Trichostigma octandrum cf. (L.) H.Walter	ET848 ET1233
PIPERACEAE	
Peperomia macrostachya (Vahl) A.Dietr.	ET800
Peperomia pereskiifolia cf. (Jacq.) Kunth	ET1452
Peperomia rotundifolia (L.) Kunth	ET626
Peperomia serpens (Sw.) Loudon	ET650
Peperomia sp.	ET1515
Piper aduncum L.	ET1018
Piper bartlingianum cf. (Miq.) C.DC. (*P. demeraranum* (Miq.) C.DC.)	ET896
Piper buchtienii C.DC.	ET645 ET805 ET1166 ET1267 ET2021
Piper glabratum cf. Kunth	ET1346
Piper glabratum Kunth	ET676
Piper hispidum Sw.	ET1019 ET1045 ET1161
Piper longestylosum C.DC.	ET684
Piper obliquum Ruiz & Pav.	ET832
Piper pilirameum C.DC.	ET646 ET1168
Piper reticulatum Vell. (syn. *P. amalago* L.)	ET851 ET1293B
Pothomorphe peltata (L.) Miq.	ET665
POACEAE	
Coix lacryma-jobi L.	ET1448
Cymbopogon citratus (DC.) Stapf	NONE
Guadua cf. *weberbaueri* Pilger	ET794
Gynerium sagittatum (Aubl.) P.Beauv. var. *glabrum* Renvoize & Kalliola	ET1110
Gynerium sagittatum (Aubl.) P.Beauv. var. *sagittatum*	ET1450
Gynerium sagittatum (Aubl.) P.Beauv. var. *subandinum* Renvoize & Kalliola	ET1430
Lasiacis ligulata Hitchc. & Chase	ET977
Olyra latifolia L.	ET716 ET1193
Oryza sativa L.	NONE
Paspalum conjugatum P.J.Bergius	NONE
Pharus latifolius L.	ET655
Saccharum officinarum L. var.1	NONE
Saccharum officinarum L. var.2	NONE
POLYGALACEAE	
Bredemeyera lucida cf. (Benth.) A.W.Benn.	ET1903
Moutabea longifolia cf. Poepp.&Endl.	ET1849
Moutabea sp. 1	ET1171 ET1181
Moutabea sp. 2	ET1331
POLYGONACEAE	
Coccoloba marginata cf. Benth.	ET1240
Coccoloba peruviana Lindau	ET1681 ET1918
Coccoloba scandens Casar.	ET1640
Coccoloba scandens cf. Casar.	ET1697
Coccoloba sp. 1	ET918
Coccoloba sp. 2	ET1224
Polygonum ferrugineum Wedd.	ET2095
Polygonum punctatum Elliott	ET728
Triplaris americana L.	ET1100 ET1191
Triplaris poeppigiana Wedd.	ET775 ET901
PORTULACACEAE	
Portulaca grandiflora Hook.	ET666
QUIINACEAE	
Quiina florida Tul.	ET1703 ET1980
RHAMNACEAE	
Gouania adenophora Pilger	ET961
RHIZOPHORACEAE	
Sterigmapetalum obovatum Kuhlm.	ET1657
RUBIACEAE	
Agouticarpa curviflora (Dwyer) C.H.Perss.	ET1712
Alibertia pilosa K.Krause	ET782 ET1067 ET1102 ET1169

FAMILY & SPECIES	COLLECTION NUMBERS
Amaioua guianensis Aubl.	ET1705
Basanacantha erythropoda Rusby	ET905 ET1132
Bathysa obovata K.Schum. ex Standl.	ET1638
Borojoa claviflora (K.Schum.) Cuatrec.	ET1490 ET1825 ET2014
Borreria latifolia (Aubl.) K.Schum.	ET730
Chimarrhis glabriflora cf. Ducke	ET1795 ET1999
Coffea arabica L.	N38
Faramea multiflora A.Rich. ex DC.	ET724 ET1491
Faramea tamberlikiana Müll.Arg.	ET1437
Faramea torquata Müll.Arg.	ET1580 ET1702
Genipa americana L.	ET1088 ET1523
Geophila macropoda (Ruiz & Pav.) DC.	ET602 ET811
Geophila repens (L.) I.M.Johnst.	ET1572
Gonzalagunia bunchosioides Standl.	ET634
Hamelia axillaris Swartz	ET1499
Ixora peruviana (K.Schum.) Standl.	ET1387
Ixora spruceana Müll.Arg.	ET1456
Malanea campylocarpa C.M.Taylor	ET1510
Malanea macrophylla cf. Bartl.	ET1634
Manettia cordifolia Mart.	ET1777
Notopleura leucantha (K.Krause) C.M.Taylor	ET689
Palicourea lasiantha K.Krause	ET887 ET953
Palicourea macrobotrys (Ruiz & Pav.) Roem. & Schult.	ET635 ET688 ET941
Palicourea punicea (Ruiz & Pav.) DC.	ET1586
Posoqueria latifolia (Rudge) Roem. & Schult.	ET1395
Psychotria borucana (Ant.Molina) C.M.Taylor & W.C.Burger	ET1616B
Psychotria capitata Ruiz & Pav.	ET957
Psychotria herzogii S.Moore	ET624 ET682
Psychotria marginata Sw.	ET1365
Psychotria racemosa Rich.	ET972
Psychotria sp. 1	ET839 ET1596 ET1907 ET1989
Psychotria tristis cf. H.J.P.Winkl.	ET1442
Randia oblanceolata cf. Rusby	ET2156
Ronabea emetica (L.f.) A.Rich.	ET678
Rudgea buchtienii Standl.	ET625
Rudgea sp.	ET1874
Sabicea erecta Rusby	ET638
Sabicea mattogrossensis Wernham	ET1441 ET1575
Sabicea villosa Roem. & Schult.	ET1460
Uncaria guianensis (Aubl.) J.F.Gmel.	ET637
Uncaria tomentosa (Willd.) DC.	ET870
RUSACEAE	
Sansevieria trifasciata cf. Prain	ET2174
RUTACEAE	
*Citrus aurantiifo*lia (Christm.) Swingle	NONE

FAMILY & SPECIES	COLLECTION NUMBERS
Citrus limetta cf. Risso	NONE
Citrus maxima (Burm.) Merr.	NONE
Citrus reticulata Blanco	NONE
Citrus sinensis (L.) Osbeck	NONE
Ticorea tubiflora (A.C.Sm.) Gereau	ET623 ET658 ET935 ET1228 ET1287 ET1639
Zanthoxylum aculeatissimum Engl.	ET1454B
Zanthoxylum ekmanii cf. (Urb.) Alain	ET960
*Zanthoxylum spr*ucei cf. Engl.	ET1788
Zanthoxylum sprucei Engl.	ET1175
Zanthoxylum tambopatense Reynel	ET2012
SABIACEAE	
Meliosma herbertii cf. Rolfe	ET1235 ET1984B
Meliosma herbertii Rolfe	ET1256
Meliosma sp. 1	ET2149
SALICACEAE	
Salix humboldtiana Willd.	ET993
SAPINDACEAE	
Allophylus punctatus (Poepp.) Radlk.	ET1535
Allophylus strictus Radlk	ET963 ET1051 ET863 ET869 ET1774
Paullinia alata (Ruiz & Pav.) G.Don	ET647 ET1427
Paullinia bilobulata Radlk.	ET1292 ET1666
Paullinia bracteosa cf. Radlk.	ET1173
Paullinia clathrata Radlk.	ET1269 ET1280 ET1489 ET1527 ET1738 ET1792 ET2008 ET2072
Paullinia cuneata Radlk.	ET617 ET779 ET902 ET1340
Paullinia largifolia Radlk.	ET1174 ET2026
Paullinia obovata (Ruiz & Pav.) Pers.	ET1389
Paullinia sp. 2	ET866
Paullinia spicata Benth.	ET1501
Paullinia tarapotensis Radlk.	ET1481 ET1576 ET2133
Sapindus saponaria L.	ET1511 ET1787
Serjania tenuifolia cf. Radlk.	ET1505
Serjania tenuifolia Radlk.	ET1479
Talisia hexaphylla Vahl	ET1871 ET1890
*Talisi*a sp.	ET1204
*Toulici*a sp.	ET860
SAPOTACEAE	
Chrysophyllum argenteum Jacq. subsp. *ferrugineum* (Ruiz & Pav.) T.D.Penn.	ET1823
Chrysophyllum venezuelanense (Pierre) T.D.Penn.	ET2090
Ecclinusa guianensis cf. Eyma	ET1630
Micropholis egensis (A.DC.) Pierre	ET1739 ET1805 ET1949
Micropholis guyanensis (A.DC.) Pierre	ET1212 ET1598 ET1615 ET1655 ET1881

FAMILY & SPECIES	COLLECTION NUMBERS
Micropholis venulosa cf. (Mart. & Eichler) Pierre	ET1879
Pouteria bangii (Rusby) T.D.Penn.	ET1241A ET1604
Pouteria bilocularis (H.J.P.Winkl.) Baehni	ET2004
Pouteria caimito cf. (Ruiz & Pav.) Radlk.	ET2131
Pouteria cladantha Sandwith	ET1194 ET1349 ET1541 ET1649 ET1814 ET1845 ET1972 ET1990 ET1991
Pouteria cuspidata (A.DC.) Baehni	ET1352 ET1443 ET1716 ET1856 ET1933 ET1959 ET1968
Pouteria durlandii (Standl.) Baehni	ET2083
Pouteria durlandii (Standl.) Baehni subsp.*durlandii*	ET1707 ET1866
Pouteria durlandii cf. (Standl.) Baehni subsp.*durlandii*	ET898
Pouteria hispida Eyma	ET959 ET1348 ET1631 ET1667
Pouteria multiflora cf. (A.DC.) Eyma	ET1855 ET2045
Pouteria nemorosa Baehni	ET1085 ET2139
Pouteria petiolata T.D. Pen.	ET948 ET1644
Pouteria pubescens cf. (Aubrév. & Pellegr.) T.D.Penn.	ET2015
Pouteria sp. 1	ET865 ET1868
Pouteria sp. 2	ET1329
Pouteria sp. 3	ET1676
Pouteria sp. 4	ET1852
Pouteria torta (Mart.) Radlk. subsp. glabra T.D.Penn.	ET840 ET1022 ET1486 ET1764 ET2151
Pouteria trilocularis Cronq.	ET1213
Sarcaulus brasiliensis (A.DC.) Eyma subsp. *brasiliensis*	ET921 ET1063 ET1089 ET1258 ET1263 ET1277 ET1311 ET1372 ET1836 ET1877 ET2034 ET2165
SCROPHULARIACEAE	
Scoparia dulcis L.	ET661
SIMAROUBACEAE	
Picramnia latifolia Tul.	ET838 ET1078 ET1291 ET1538 ET1827 ET1873 ET1895
Picramnia sellowii Planch. subsp. *spruceana* (Engl.) Pirani	ET611 ET708 ET763
SMILACACEAE	
Smilax febrifuga Kunth	ET1509
SOLANACEAE	
Brugmansia suaveolens (Willd.) Bercht. & J.Presl (syn. *Datura suaveolens* Willd.)	ET663
Brunfelsia mire Monach.	ET1426 ET2160
Capsicum chacoense Hunz.	ET705
Capsicum chinense Jacq.	ET704 ET1093
Capsicum coccineum (Rusby) Hunz.	ET1428

FAMILY & SPECIES	COLLECTION NUMBERS
Capsicum pubescens Ruiz & Pav.	ET1097
Capsicum sp. 1	ET1092
Cestrum mariquitense cf. Kunth	ET1773
Cestrum megalophyllum Dunal	ET1207
Cestrum sp. 1	ET1254 ET1381
Cuatresia fosteriana Hunz.	ET681
Juanulloa membranacea Rusby	ET1686
Juanulloa parasitica Ruiz & Pav.	ET731A ET778 ET2102
Lycianthes inaequilatera (Rusby) Bitter	ET710
Nicotiana tabacum L.	NONE
Solanum barbeyanum Huber	ET758
Solanum exiguum Bohs (syn. *Cyphomandra benensis* Britton)	ET2097
Solanum goodspeedii K.E.Roe	ET1014
Solanum mammosum L.	ET686
Solanum mite Ruiz & Pav.	ET679
Solanum morellifolium Bohs	ET680
Solanum nemorense Dunal	ET932
Solanum sp. 1	ET2011
Solanum sp. 2	ET1503
Solanum sp. 3	ET1455
Solanum thelopodium Sendtn.	ET746
STERCULIACEAE	
Byttneria benensis Britton	ET989
Byttneria pescapraeifolia Britton	ET958 ET2002
Byttneria sp. 1	ET853 ET2020
Guazuma ulmifolia Lam.	ET910 ET1179
Sterculia apeibophylla Ducke	ET2173
Sterculia apetala (Jacq.) H.Karst.	ET1029
*Sterculia peruvi*ana cf. (D.R.Simpson) E.L.Taylor (or *apetala* (Jacq.) H.Karst. ?)	ET1226
Theobroma cacao L.	NONE
THEOPHRASTACEAE	
Clavija lancifolia Desf.	ET846 ET1482
Clavija tarapotana Mez	ET777 ET1504
Clavija weberbaueri Mez	ET787
TILIACEAE	
Apeiba membranacea Sprice ex Benth.	ET1966 ET2078 ET1616A
Heliocarpus americanus L.	ET795 ET2081
Luehea paniculata cf. Mart.	ET1176
TRIGONIACEAE	
Trigonia boliviana Warm.	ET1732
Trigonia laevis Aubl. var. *microcarpa* (Sagot ex Warm.) Sagot	ET1741
ULMACEAE	
Ampelocera edentula Kuhlm.	ET1195 ET1555 ET1606 ET1967 ET2042
Celtis iguanaea (Jacq.) Sarg.	ET768 ET1066
Celtis schippii Standl.	ET833 ET1004 ET1137 ET1261 ET1357 ET1419

FAMILY & SPECIES	COLLECTION NUMBERS
URTICACEAE	
Laportea aestuans (L.) Chew	ET1477
Urera baccifera (L.) Gaudich.	ET608
Urera caracasana (Jacq.) Griseb.	ET808 ET2135
Urera eggersii Hieron.	ET713 ET874
Urera laciniata Wedd.	NONE
VERBENACEAE	
Aegiphila buchtienii Moldenke	ET698
Aegiphila cuneata cf. Moldenke	ET1858
Aegiphila haughtii Moldenke	ET1044 ET1252 ET1593
Aegiphila sp. cf.	ET1886
Aegiphila sp. 1	ET1065 ET1275 ET1299 ET1321 ET1362 ET1995
Bouchea fluminensis (Vell.) Moldenke	ET722
Lantana fiebrigii Hayek	ET1518
Petrea maynensis Huber	ET1133 ET1203 ET1325 ET1668 ET1970
Petrea sp.	ET1946 ET1214 ET1316
Stachytarpheta cayennensis (Rich.) Vahl	ET1129
VIOLACEAE	
Gloeospermum equatoriense cf. Hekking	ET895 ET1568 ET1695 ET1731 ET1821 ET1915
Leonia crassa L.B.Sm. & A. Fernandez	ET1992 ET927 ET997 ET1049 ET1068 ET1144 ET1156 ET1206 ET1271 ET1356 ET1721 ET1832
Rinorea apiculata cf. Hekking	ET1341 ET1674 ET1685
Rinorea lindeniana (Tul.) Kuntze	ET1043 ET1131
Rinorea pubiflora cf. (Benth.) Sprague & Sandwith	ET1185 ET1848
Rinorea viridifolia Rusby	ET654 ET897
Rinoreocarpus ulei (Melch.) Ducke	ET695 ET1567 ET1610 ET1625 ET1770
VITACEAE	
Cissus cf.	ET1815
Cissus erosa (L.) Rich.	ET1385
Cissus gongylodes (Baker) Planch.	ET2128
Cissus obliqua Ruiz & Pav.	ET726
Cissus sicyoides L.	ET1386
ZINGIBERACEAE	
Alpinia zerumbet (Pers.) Burtt & R.M.Sm.	ET1128
Hedychium coronarium J.Koenig	ET1524
Renealmia breviscapa Poepp. & Endl.	ET1540
Zingiber officinale Roscoe	ET1528

PTERIDOPHYTA

FAMILY & SPECIES	COLLECTION NUMBERS
CYATHEACEAE	
Alsophila cuspidata (Kunze) D.S.Conant	ET1003
Cyathea amazonica R.C.Moran	ET1746
Cyathea pungens (Willd.) Domin	ET826 ET1198 ET1619
DRYOPTERIDACEAE	
Bolbitis lindigii Ching	ET858
Polybotrya caudata Kunze	ET1943 ET892 ET837
POLYPODIACEAE	
Polypodium decumanum Willd.	ET1416 ET2111
THELYPTERIDACEAE	
Thelypteris subgen. *Goniopteris*	ET677

FUNGI

FAMILY & SPECIES	COLLECTION NUMBERS
MARASMIACEAE	
Marasmiellus cf. *semiustus* (Berk. & M.A.Curtis) Singer	ET2125
PHALLACEAE	
Phallus indusiatus	NONE
POLYPORACEAE	
Polyporus tenuiculus (Beauv.) Fr.	ET1245 ET2144
Pycnoporus sanguineus (L. ex Fr.) Murril	ET1025

Appendix 3

Yuracaré Narratives

The following Yuracaré narratives were told to me in Spanish by the Yuracaré Melchor Morales from the community of San Antonio de Moleto from TIPNIS. I translated them to English.

Chauwre and the Jaguars

In very remote times when planet earth was already inhabited by a limited number of people, a group of jaguars caused many casualties among them. The last living persons were a man (probably Ule) and his wife. However, this man was not really Yuracaré, he was the master of a tree species carrying this name.

One day, the woman had gone to the forest to collect fruits. When she returned home, her man was nowhere to be found. She looked everywhere but the only thing she could find was his gnawed bones. The jaguars had killed him as well. Fortunately, the woman was gifted with some magical talents. She put her man's bones anatomically in place and jumped three times over them after which her husband suddenly awoke, saying: "I must have been asleep for a long time". "You haven't been asleep" his wife responded, and she explained what had really happened. The man was not pleased to hear the story and asked his wife to bring him water in a recipient made of a *pachua* palm leaf [*Iriartea deltoidea*] to take a look at his face. When she came back, he was terrified to see the reflection of his face in the water: half of his cheek was missing as a consequence of the jaguars' attack. The man felt deeply ashamed for his wife and decided he had no other choice than to separate from her. He told her: "We will follow this path and at the end of it we will find your brothers and sisters". "You go ahead", he said, "but never look back, or else we will surely get lost." And so they started their journey, the woman in front of her man, without looking back. However, after a while the woman's attention was suddenly drawn to a strange sound behind her and she took a look. At that very same moment, the man dropped a big plant leaf in front of him so the woman could no longer see him or the path. Instead, another path had appeared. The woman was confused and did not realise this was not the original path and started walking on the new path to look for her husband.

After a long walk, she still had not found her man and at the end of the path she arrived at the house and swiddens (*chaco*) of the jaguar family that had attacked and killed her man only shortly before. Those days, all animals were different from the animals we know now. They used to live and talk like humans and wore shirts and trousers made of tree bark called *corocho* [*Poulsenia armata*]. The mother of the jaguars was home alone. When she saw the visitor approaching, she thought: "Finally someone to accompany me in my loneliness."

In fact, the jaguar mother lived there with her sons, but these went out hunting most of the time. The woman wandered around, still grieving about the loss of her man. The jaguar mother invited her inside, saying: “Come inside my child, don’t be sad, we will cook us a nice meal to make you feel better”. She gave the woman a pot to cook in, rice and some other ingredients. They ate and chatted for some time.

After a while, the jaguar sons arrived, loaded with bush meat (tapir [*Tapirus terrestris*], swine [*Tayassu pecari* and *T. tajacu*], paca [*Cuniculus paca*], aguti [*Dasyprocta agouti*]…). They were happy and their voices could be heard long before they actually arrived to the house. The jaguar mother – worried about the well-being of the woman – urged her to hide in the first floor of the house. The jaguar sons all looked quite the same, except for one. Puydra was the oldest and gifted with six eyes: two in front of his head, two on the back and two on the sides near his ears. He was more intelligent, more aware and certainly slier than his two-eyed brothers. He immediately knew something was different because he had scented the milk of a human. The woman had indeed been well-advanced in pregnancy from her husband. Her breasts were so full that sporadically small droplets of milk leaked out. Puydra asked his mother: “Did you get any visitors these days; I can smell the presence of a human being.” “No, I have been all alone since you left hunting” responded the jaguar mother. This answer did not satisfy Puydra’s suspicion and he ordered his brothers to search the whole house. Puydra himself sat down in his chair, tired of the trip. After a while the younger jaguars finally found the woman. When they shouted, Puydra jumped immediately to the first floor and asked: “Why did you come and visit our mother?” The woman responded she was in fact looking for her husband but the path she had followed had accidentally led her to the jaguar mother. The jaguar mother intervened: “Please let me keep her, I get so lonely when you leave me, she can keep me company”. “Yes, let her accompany mother” shouted the two-eyed jaguars. But Puydra did not like that idea. He threw the woman on the ground, jumped on top of her and tore her apart. His younger brothers soon followed his example under the hysterical outcries of the jaguar mother. She desperately screamed: “At least give me the unborn child from her belly to eat.” Puydra agreed and gave it to his mother who hid the baby immediately. To give her sons the impression she was eating it, she just ate the bloody umbilical cord and the placenta within their sight.

When the jaguars had finished eating, she took the baby to the river to wash it. After that, she hid it – wrapped in a tree bark cloth – inside a big tapir-skull that was hanging on one of the jaguars’ house walls. The jaguar mother carefully looked after the baby. Her sons didn’t suspect anything and soon again left hunting. The baby was gifted with magical powers, just like his mother. He grew up much faster than children normally do: after four days he could already walk and within a week the boy had a body of a four year old. The jaguar mother took good care of the child; she cuddled and rocked it continuously and treated it as if it was her own child. The baby’s name was Chauwre.

When Chauwre was old – or at least big – enough, the jaguar mother made him a bow and arrows. As she did not know of any other material to use as a string for the bow, the jaguar mother cut off a piece of her own genitals. She instructed Chauwre to kill all kinds of birds, because she liked eating birds. The arrows she gave to Chauwre were those with the round head the Yuracaré people still use to stun, but not kill, birds. Chauwre shot many birds that approached the swidden to eat all kinds of wild fruits. And every time he shot an arrow, it was accompanied by a ray of lightning.

One day – Chauwre's body was that of a twelve year old boy - the young jaguars returned from their hunting trip. They could be heard from far away as they were singing and talking loud and joyful. The jaguar mother urged Chauwre to hide in the tapir skull. When the jaguar sons arrived at the house, they saw feathers all around the place. Puydra, suspicious as always, asked his mother: "Mother how did you kill all those birds?" "Yes, I did, with this bow and arrows that I made for myself" she responded. "Show us then how you kill them" Puydra laughed ironically. Chauwre who had heard the conversation prepared his bow and arrow inside the tapir skull. And at the exact same time the jaguar mother shot an arrow, he shot one too. With every shot a bird dropped to the ground. That did not fool Puydra, however. When he saw the ray of lightning accompanying each arrow, he shouted: "There must be a human here". The jaguars started looking everywhere and if it wasn't for Puydra they would never have found Chauwre. Puydra screamed angrily at his mother: "So you fooled us again?" He threw the tapir skull on the ground and smashed it into pieces. Just when they wanted to put their teeth into Chauwre, he converted himself in a stone. Although nobody had ever told Chauwre that the jaguar sons would harm him, he already knew in his heart they were bad. The jaguars, one by one, put their teeth in the stone with fury. They kept on going until all their teeth were broken. With the teeth falling out of their mouths it was as if their life force was being withdrawn from their bodies as well. They all fell dead on the ground. At that instant, Chauwre converted himself back into his human form. The jaguar mother cried: "My poor boys! What have you done? You have to put their teeth back in again" she begged. Chauwre felt pity for the woman who had been looking after him since he was born and decided to bring them back to life again. He gathered teeth from the skulls of all kinds of prey animals that he found around and inside the house, and put those in the jaguars' mouths. After that he blew over them and straight away the jaguars regained life. From that day on the jaguars became even more skilled hunters, because their new teeth were harder than the old ones. They would bring back bushmeat in quantities never seen before.

From that moment on also, the frightened jaguars treated Chauwre with respect and decided to let him stay to accompany their mother. Off they went hunting again. Meanwhile, the jaguar mother instructed Chauwre to make a swidden (*chaco*) for sowing pumpkins (*zapallo*). So he cut all the shrubs, small trees and herbs first and thereafter the bigger trees. The jaguar mother came by to take a look at his work and unsatisfied she said: "You made the swidden too small, please make it a little bigger, my son." Chauwre accepted and urged the jaguar mother to take a little nap. While she was sleeping, Chauwre used his extraordinary powers to knock over the forest trees until he thought the swidden was big enough to please the jaguar mother. When she woke up and walked to the swidden she couldn't believe her eyes. "Incredible" she uttered, "how did you manage to do so much work in so little time?" Chauwre then let the whole swidden dry for a week and burned it. When the earth had cooled down, he planted pumpkin seeds. However, the seedlings didn't get much chance to grow well, because a female *jochi colorado* [aguti; *Dasyprocta agouti*] feasted upon them every night. The jaguar mother insisted that Chauwre kept guard with his bow and arrow to kill the *jochi colorado* in case it would appear again. So Chauwre sat on a dead tree trunk and waited until the creature showed itself. Straight away he bent his bow and shot an arrow, but missed its target. The arrow just hit the animal's long tail that now dangled on the back of its body. The *jochi colorado* ran off as fast as it could with Chauwre – following the blood trail – on its tail. Just when the animal was about to enter its house through a pipe in the ground, Chauwre grabbed its tail and tore it off. That is the reason why the *jochi colorado* doesn't have a long tail anymore nowadays. People say that the squirrel arose from that *jochi colorado's* tail.

The *jochi colorado's* husband came out of its house immediately and asked Chauwre: "Why did you cut of the tail of your grandmother?" "You have to put it on again please." Chauwre felt remorse for his act and agreed. After a while he came back with some bees' wax which he carefully placed on the jochi's body where the tail once had been. From that day on, the *jochi colorado* has the small tail put there by Chauwre. This act of kindness pleased the *jochi colorado's* husband and he invited Chauwre for dinner. While the animal's wife cooked a nice meal, her husband told the jaguars' true story. He explained Chauwre that the jaguars were vicious creatures that killed all animals and humans. He argued how they had killed Chauwre's parents and how the jaguar mother had been lying in pretending to be his mother. In fact, she was his enemy.

After his visit to the *jochi colorado* family, Chauwre returned home in a sad mood. He didn't want to go inside and sat down near the jaguar house. He didn't even respond when the jaguar mother called him in for dinner. The jaguar mother approached and asked: "They surely told you, haven't they?" "No, nobody told me anything" he responded, but with grief he thought: "I am going to kill the jaguar sons and their mother, and this time I will not resurrect them." Chauwre went to the *chaco* where the pumpkins grew and there he saw that some wasps were making their nest. He said to the jaguar mother: "Give me some matches; I want to burn this wasp nest." When she handed him the matches he continued: "Go inside the house and close the door because the wasps can get angry and sting you." Once the jaguar mother was inside Chauwre lit fire to the wasp nest and came running to the house shouting: "Mother hide under the bed, the wasps are coming". But the wasps were not coming; it was merely Chauwre's trick to make the jaguar mother stay inside. He barricaded the door so she couldn't get out and lit fire to the house. The jaguar mother smelled the smoke and started yelling in despair: "Let me out, I want to leave." Chauwre responded: "No you can't come out yet; the wasps will sting you." The whole house burnt down with the jaguar mother inside. When her body was bathing in flames, her brain suddenly exploded. Pieces of brain were projected in all directions and turned into the kind of jaguars that live on the earth until today. These creatures escaped rapidly into the forest. Chauwre thought: "Now it is the turn of the jaguar sons. I will wait for them at their drinking spot". While sitting there well-hidden, he could see one of the jaguar sons approaching. He killed the jaguar with his powerful bow and arrow and threw its dead corpse off a ravine. The other jaguars thought: "Rain is coming". First they had seen lightning, produced by Chauwre's arrow shot, followed by a loud crack – what they thought to be a thunderclap – produced by the fall of their brother in the ravine. The same story happened to all the other jaguar brothers, except for Puydra. The latter had smelled danger and Chauwre could merely shoot him in the back of his body a few inches away from his tail. Puydra ran away as fast as he could to the moon. There, he asked her: “Dear moon, hide me please because Chauwre is trying to kill me.” The moon – whose arms and legs were covered with bracelets – accepted his cry for help and hid him as a tick on her arm between the bracelets. When Chauwre arrived he asked the moon: “Have you seen a wounded jaguar? He must have come this way.” The moon answered she had not seen the jaguar. Although Chauwre did not see Puydra sitting as a tick on the moon’s arm, he felt suspicious and decided to hide out of sight of the moon. And indeed, after a little while, Puydra started asking the moon: “Did he leave yet?” After hearing this conversation, Chauwre immediately came back and asked the moon with irritation: “Why do you hide that evil jaguar? Don’t you know he is bad? He will surely beat you if you keep protecting him. Give hive over to me”. But the moon did not give into Chauwre’s request. And indeed, the Yuracarés believe that from that day on the moon is not as bright anymore as it used to be. And especially when Puydra is beating the moon black spots can be seen on the moon.

After these events, Chauwre wandered around for a long time in all possible directions. During this period of loneliness, he encountered many animals that nowadays don’t exist anymore. In those days, there were no humans but the animals talked and lived like humans. Every time Chauwre bumped into one of those creatures, he asked what animal he or she wanted to be. As such, Chauwre created all the animals that exist today on earth. He met a horse that wanted to be a tapir, so Chauwre squeezed his muzzle together and turned it into a tapir. On another occasion, he met with a female creature with long hair while she was harvesting hot peppers. She told him she wanted to be a *mutun* (*Mitu tuberosa*; a rainforest bird that looks like an oversized black chicken with a toucan-like peak), and so it was. He even created the “barbaric” forest people out of an animal form. This work took him many years, and Chauwre began to feel very lonely. He was dying to have a friend to keep him company. So Chauwre cut off his big toe, buried it more or less and went off. In no time, this toe transformed into a human being named Carro. Carro ran after Chauwre and they became best friends. They walked around together for some time and one day decided to make a *chaco*. On their *chaco*, they planted many peanuts (*mani* [*Arachis hypogaea*]). These peanuts represented the hearts of the Yuracarés. If a Yuracaré would grow old, he was able to burry his peanut for a short time and rejuvenate again. In this way, the peanuts would provide the Yuracarés with eternal life.

When the peanuts had the size of seedlings, Chauwre ordered Carro to go check on them. He said: “go take a look at the sprouts but do not touch them”. Carro agreed, but the rascal in him couldn’t resist the temptation and started pulling out the sprouts. That day, the Yuracaré people lost eternal life due to Carro’s roguery. Now they suffer and die like other people. Upon his return Carro told Chauwre: “The peanuts have withered and are already dead.” Chauwre immediately realised what Carro had done and shouted in despair: “Why did you kill those plants? I just told you to take a look, that’s all.” “Now our sons will be vulnerable, they will die and not recover” he cried in tears. This day marked a scar in Chauwre’s life and he never really lost his anger at Carro. Until one day, as we soon will learn.

Weeks and even months had passed when one day, Carro had been observing parrots. He saw they lived in pairs of male and female. He felt a deep desire for a female companion and asked Chauwre: “Why can parrots have offspring and I can not?” The following days he wandered around sadly. Chauwre felt compassion and decided to do something about it. That night, while they were sleeping side by side, Chauwre woke up, took one of Carro’s ribs and transformed it into a woman. That is why men have one rib less than women. The next morning, Carro woke up with his wife in his arms.

The three of them lived in harmony for several years and Carro and his wife had four children. The children passed their days bathing and playing in the river. Each day, Chauwre got more irritated by the continuous shouting and playing of the children. One day he went to the river where they were playing and converted them into ducks. They immediately tried to escape, but Chauwre managed to kill one of them with his bow and arrow. He brought the duck back home and cooked it. When the meat was ready to eat, he called Carro: “Carro, come and join me. I’ve shot a duck and want to share it with you.” Both friends feasted on the duck and once they were satiated, Chauwre said: “that was really nice meat, don’t you think so?” Carro nodded with satisfaction. “You have just eaten one of yours sons” Chauwre added. Carro couldn’t believe this and burst out in tears. “Why did you do this to me” he howled in despair “are we even now?” Chauwre had taken revenge for the peanuts. Deep sadness filled Carro; he stayed in bed and wept for days. He almost died of sorrow. Chauwre felt remorse for his act and caught various animals such as *maneches* (howler monkeys [*Alouatta seniculus*]). He told Carro to look after them just as he had done with his children to alleviate his pain. This made Carro recover a bit and after a long while he finally managed to forgive Chauwre for his cruel act.

Both friends and Carro’s wife moved around again without anger or plans of revenge. Time healed all wounds and Carro’s wife gave birth to other children who also had children of their own, and so on. These people were the ancestors of the Yuracaré people who still live today. Chauwre and Carro went away to another land far away. They live on until today. People say Chauwre comes to Cochabamba each year during the feast of Carmen to look for his kinsmen, the Yuracarés. The story goes that in past days, soldiers arrested Chauwre in Cochabamba and took him away to prevent him from finding Yuracaré people.

Fire Man

Once, the earth was populated with many Yuracaré people until judgement day came. The earth was destroyed by immense fires. That is why the earth is unstable now. Before the fire came it was more solid. Earthquakes didn’t exist before the fire. The only creatures that managed to escape from the fire were a Yuracaré boy and his little sister – every other living creature was destroyed. When the children saw the fire approaching, the boy started digging a hole in the earth, deeper and deeper, with his little sister on his back. The boy kept on digging out of fear that the heat from the fire would cook them alive. They remained one week underground, with no other provisions than some water. When the fire was completely extinguished, they finally dared to come out. They were very sad to see everything in ashes.

Shadow was nowhere to be found as a protection against the burning sun. They were weeping in each others' arms when suddenly their attention was drawn. In the distance, an impressive figure bathing in flames and seated on a big horse was approaching rapidly with fury. The fire man asked them firmly: "Where do you come from and where are your parents." They explained that they escaped underground from the fire that burned their parents and the rest of their family. The fire man felt pity for the two children and gave them seeds of all kinds of crop plants he urged them to grow, such as banana, rice and maize. But the fire man imposed one condition: the boy and girl had to marry and have children; or else the fire would come back and destroy everything again. The fire man went off and 'sowed' all plants and animals that used to live on the earth. After one week, the earth was covered again with a rich forest, filled with (game) animals. The children could smile again: there was food, plenty of shadow and rivers to bathe in. At first, brother and sister were apprehensive to start a family, but with time they realised they didn't have much choice if they wanted to survive. The woman gave birth to many children and the earth would soon be populated with Yuracaré people again. The Yuracarés are thankful until today that the boy and girl obeyed the demands of the fire; or else the fire would have come back and their race would have become extinct.

Aysa and Embëmütë

Many years later, when the earth was populated again with many Yuracaré people, Aysa was born. He seemed a normal boy, but was gifted with magical powers. One day, Aysa went hunting in the forest with his two brothers. When the night fell, they decided to camp at the borders of a giant lake. What they didn't know was that they had made their camp in the middle of the trail of a giant snake. That night, Aysa couldn't sleep. Suddenly, he heard a hypnotizing humming, produced by the giant snake. Aysa tried to wake his brothers but the humming sound had a paralysing effect on them, intensifying their state of unconsciousness. He burned their skin with a burning log from the fire, but even that could not wake them from their comatose condition. As the giant snake approached, the humming sound grew stronger and stronger and it made Aysa almost deaf. Aysa realised he couldn't save his brothers and decided to transform himself into a needle. The snake was enormous: the height of a house and some 20 to 30 meters long. For movement, she used four tentacles at each side of her mouth. These tentacles coiled – like a monkey's tail – around trees and other objects in front of the snake and pulled its ponderous body forward. This beardy snake was called Embëmütë by the Yuracaré people.

On this occasion, Embëmütë had smelled human flesh and was hungry. When it arrived at the camping spot, it didn't hesitate to devour Aysa's sleeping brothers at once. Aysa, still transformed into a needle, was being crushed by the snake's weight on top of him. He started to prick embëmütë in the belly to make it move away. The snake thought: "There were three humans and I just ate two, where could the third one be?" At that very moment it felt the pricking sensation in its belly and bawled: "Is that you stabbing me, Aysa?" Aysa kept quiet but, embëmütë moved away and saw the needle. It knew immediately that it had to be Aysa. The giant snake grabbed the needle with one of its tentacles and gripped it tightly. Embëmütë said to the needle: "Aysa there is no way to escape, transform yourself into a person." Aysa responded: "I will do so if you let me defecate, it's urgent. After that you can eat me" The snake agreed and stretched its tentacle so that Aysa could go behind the bushes. Aysa said to the snake: "Loosen me a bit more, so I can defecate comfortably." "You are comfortable enough" Embëmütë responded. Behind the bushes, Aysa saw four big white snails that were grazing there. He asked the snails: "Can you please take my place for a moment, while I get my bow and arrows to kill Embëmütë?" The snails agreed. And each time Embëmütë yelled: "Aysa are you done yet?", the snails responded: "No, just a little more." Meanwhile, Aysa was long gone. He ran as fast as he could to his deceased father's house to get his arrow with the round head. After a while, the giant snake got bored of waiting and looked at the tentacle holding Aysa. When Embëmütë realised what had happened it burst out in anger and followed Aysa's trail.

In the meantime, Aysa had already found his father's arrow and halfway back on the trail he planted the arrow shaft in the ground and sat on its round head. The arrow grew into a *tembe* tree [*Bactris gasipaes*]. That is why the Yuracaré call arrows with a round head "*tembe*". Aysa was sitting on the vertex of the tree, between its leaves. When Embëmütë arrived at the tree, it was already very tall and the snake started pulling itself up with its tentacles. Just when it was about to reach Aysa, the latter cut off one of its tentacles with a small axe he had brought with him from his father's house. With the tentacle chopped off, the snake couldn't hold its own weight anymore and fell on the soil. Once more, it tried to climb up. But Aysa was well-prepared and when Embëmütë tried to grab him, he cut off another tentacle of its beard. The ponderous beast fell on the ground again. But this still did not stop it from climbing up again. Again in vain because Aysa chopped off all its remaining tentacles. It is said that *Embëmütë'*s coiling tentacles transformed in a liana once cut off. This liana, commonly called monkey's ladder, is therefore called embëmütë *poso* ("embëmütë*'s beard*" literally [*Bauhinia* sp.]). Now that Embëmütë had no means to move itself anymore, it lay spiralled at the foot of the *tembe* tree. Aysa's brothers were getting cooked inside the snake's gut by the acids working on their skin. Aysa realised he had to get help if he wanted to save his brothers and remained seated on top of the *tembe* tree that kept on growing up to the gates of heaven.

The tree moved back and forth heavily because of the strong wind and the cold made Aysa almost freeze to death. Fortunately, Aysa managed to survive and entered the gate of heaven. Behind this entrance, Aysa found a giant lake inhabited by *dada*, animals that live in the water, and *chimpo*, a spider that walks on the water. Aysa saw that the *dada* had fire, but they refused to share it with him. Aysa asked *chimpo*: "Please bring me some fire, I am freezing to death." *Chimpo* was much more generous and wanted to help Aysa. He asked the *dada* to give him fire but they declined him as well. So *chimpo* hid a piece of *chuchillo* (a giant kind of reed [*Gynerium sagittatum*]) under his feet. And out of the blue (or from the fire of the dada?), a spark fell down on his piece of *chuchillo*. Chimpo escaped with Aysa and his burning torch over the water of the lake. Called upon by the authority of the *dada*, the *dorado* fish [*Salminus* sp.] that inhabited the lake tried to stop them, but *chimpo* hit them with his torch of fire. They both escaped and found safety in *chimpo*'s house. *Chimpo* immediately started a fire with the burning torch so that Aysa could warm himself. Once well warmed up, Aysa started explaining about the reason of his visit. *Chimpo* understood the situation and said they had to get the help of the *chuvi*, the eagles and the woodpeckers. He invited all these birds to his house. They agreed to help Aysa, also in part because the idea of snake meat made their mouth water. Embëmütë was considered like *venton* (a fish species Yuracarés like to eat), by the eagles and woodpeckers. After producing large quantities of arrows they started the descent to earth well-armed. The birds used their wings, while Aysa sat on the *tembe* vertex that shrunk rapidly towards the ground.

Arriving at the foot of the *tembe* tree, the eagles and woodpeckers simultaneously shot a swarm of arrows and killed Embëmütë in no time. When Aysa reached the ground they were already disembowelling the giant animal. They took out Aysa's two brothers that had already started decaying: their skin was covered with large and severe burn-like wounds. Aysa brought them immediately to the river, washed them delicately and dressed them. He then placed them on a rug and blew over them, after which they revived uttering: "Aaargh, we must have been asleep for a long time." Aysa explained to them what had really happened. When the two brothers saw the battered condition of their faces and skin, they felt deeply ashamed and decided to separate ways with Aysa. Meanwhile the eagles and woodpeckers were already preparing *charke* (dried meat) from *Embëmütë'*s remainings. The meat of the giant snake was very delicious and tasted just like the fish *surubi* [cf. *Pseudoplatystoma fasciatum*]. The birds called the Yuracaré brothers farewell and returned home with all the *charke* they could carry.

Aysa and Pëpëzu

After a few days, the brothers (of the previous tale), whose embarrassment grew stronger by the day, went through with their decision to separate from Aysa. Aysa wandered around alone in the forest for a long time. One day, he was sitting like a parrot on top of a *shonote* tree [*Pourouma bicolor*], eating its sweet black fruits. While doing so, fruits kept falling on the ground. At that exact moment, an evil creature (*gente maldita* in Spanish) called Pëpëzu was just passing by. Thinking it was a parrot feasting on *shonote* fruits, Pëpëzu yelled: "Hey parrot, don't be so selfish and throw me some fruits as well." Without saying anything, Aysa immediately threw down some fruits. While Pëpëzu was picking up the fruits, his eye fell on the small axe left by Aysa near the tree trunk. He thought: "Could it be Aysa up there and not a parrot?" He shouted: "Hey Aysa my friend, please come down so we can talk a bit." Aysa responded with the voice of a parrot, fearing Pëpëzu was planning to eat him: "No, I haven't finished eating yet; I will stay here for a little longer."

Pëpëzu got annoyed and threatened to cut down the tree with Aysa's axe. But because Pëpëzu was made out of stone, he was not very handy with the axe and hit his own tibia (*canilla*), causing the axe to break. When Aysa saw this, he screamed: "Hey Pëpëzu look out, don't break my axe." Instantly Aysa came down and claimed his axe. Pëpëzu gave it back and said: "Ha, my friend, nice of you to come down. I recently met your grandmother and she told me she wanted to see you. Come on, I will take you to her in my *chipa* [a net used to carry cargo on one's back, manufactured from the bark fibres of *Cecropia concolor*). Aysa was immediately suspicious of Pëpëzu's fraud but went along with his game. He said: "And why do you want to take me on your back, I am not a baby?" "But you will get hurt by all the spines we will encounter on our way", Pëpëzu responded. "Are you making fun of me or what?" Aysa responded in turn. Finally, after some argueing, Aysa agreed and sat in the *chipa* on *pëpëzu's* back. Aysa, aware of the dishonest intentions of his carrier, asked him: "Could you please walk under those trees in the shadow, the sun is burning on my head." Pëpëzu did as requested and on the first opportunity, Aysa broke off the branch of a *putipo* tree [*Inga marginata*]. Straight away he started twisting the stick between his two hands and into Pëpëzu's skin to make fire. Pëpëzu didn't feel anything, but heard the noise of the branch chafing his neck. He asked: "What is that sound I am hearing?" Aysa replied it was a parrot that he had brought along as a present for his grandmother that made the noise. Once the *putipo* stick passed *pëpëzu's* skin, it lit fire. Aysa instantly jumped off. The fire spread rapidly and Pëpëzu*'s* brain exploded from the heat. Aysa felt pity for his enemy and brought him back to life.

From then on, Pëpëzu realised Aysa was too powerful for him and offered his friendship. Aysa accepted and they continued their way to Pëpëzu*'s* house. The house had been constructed with giant stones which only Pëpëzu was able to move in order to enter it. Pëpëzu is what the Yuracaré call: master of the stones or *dueño de las piedras*. Aysa refused to go in, in spite of the insistence of his new friend. Pëpëzu came back out and offered Aysa three of his daughters. They looked like common people but each had an awful mouth of teeth. Moreover, their genitals were like those of the *carachupa* [*Didelphis virginiana* or *D. marsupialis*], i.e. sac-shaped. Aysa wanted to have intercourse with them the way humans do using the vagina, but Pëpëzu forbade this and said he had to do it using the sac-shaped organ. Aysa was not at all pleased by this.

Afterwards, Pëpëzu took Aysa fishing. Aysa was astonished to see *Pëpëzu* fish: he only shot dead tree leaves that were floating on the water with his bow and arrow. Aysa bawled angrily: "Why do you shoot dead leaves? They will not satisfy our appetite." But Pëpëzu simply responded: "How can you say that, this is delicious fish." Slightly annoyed, Aysa started fishing *sabalos* [*Prochilodus nigricans*], a common and tasty fish species, with bow and arrows, while trying to ignore the stupidities of his companion. After a while, both had gathered numerous fishes and leaves each on his side. They made fire and started barbecuing (*chapapear*) their catch. Aysa feasted on his fish and some *yuca* [*Manihot esculenta*], while Pëpëzu ate grilled leaves together with a kind of soft stone which was like potato or *yuca* to him. Pëpëzu got irritated seeing Aysa eating *yuca*. He said: "Why are you eating a stick with your so-called fish, you should eat this", pointing to the soft stone. Aysa replied grouchily: "This is not a stick; it is the delicious root of a plant. You'd better eat this instead of the stones you're devouring." And so both friends kept on discussing, both annoyed about the eating habits of the other. When Pëpëzu's leaves were dry enough, Aysa deliberately let them burn without warning him. Pëpëzu roared loudly: "Why didn't you look after my fish!" And off he went looking for new leaves. When he came back, Pëpëzu said: "listen, the jaguar is singing!" "Are you crazy" Aysa responded, "that is no jaguar, it is just a toad." He went off to look for the animal and brought it back to Pëpëzu. Pëpëzu looked at the animal and yelled anxiously: "why do you bring that jaguar to me." Toads were like jaguars and jaguars like toads to Pëpëzu. Wanting to get even, Pëpëzu brought a jaguar to Aysa while he was sleeping. Terrorised, Aysa woke up screaming: "Get that jaguar away from me!" "That is not a jaguar, it's just a toad" Pëpëzu laughed amused. After his adventures with Pëpëzu, Aysa decided to go and look for a safer place.

Melchor Morales concluded his story by claiming that the earth we live on is not safe. That is why Aysa didn't want to stay here. The end of the world is near: it will be destroyed by water or fire. There are three worlds: a heaven above, the earth where we live and an underground. The heaven is the safest place, followed by the underground, but eventually everything will be destroyed. The earth will fall on top of the underground and heaven will do so on top of the earth. Everything will die. The lord will punish us for all our fighting and arguing. The end of the world is near.

Curriculum Vitae

Personal Information

Surname: Thomas
Name: Evert
Nationality: Belgian
Address: Ottergemsesteenweg 87
9000 Gent, Belgium
Telephone: (+32)(0)486/34.53.59
e-mail: evert.thomas@gmail.com
Date of birth: 12-06-1978
Marital Status: married (spouse: Verónica Carrasco)

Education

Ghent University, Sint-Pietersnieuwstraat 25, 9000 Gent, Belgium:

- 2002-2008: PhD in Applied Biological Sciences, titled "*Quantitative Ethnobotanical Research on Knowledge and Use of Plants for Livelihood among Quechua, Yuracaré and Trinitario communities in the Andes and Amazon Regions of Bolivia*"

- 2001-2002: Complementary Studies in Agricultural Development
  Magna Cum Laude (High Distinction)

- 1996-2001: M.Sc. Bioscience engineering, specialization environmental technology
  Degrees: 1996-1997: *Magna Cum Laude* (High Distinction)
  1997-1998: *Cum Laude* (Distinction)
  1998-1999: *Cum Laude* (Distinction)
  1999-2000: *Cum Laude* (Distinction)
  2000-2001: *Magna Cum Laude* (High Distinction)

  Erasmus: 15/2/2000-15/7/2000 at the Universidad Politécnica in Valencia, Spain

  Title Thesis: Ethnobotanical Investigation of medicinal plants in Apillapampa (Bolivia) as a selection method for the pharmacological evaluation of their biologically active components

Jan-Van-Ruusbroekcollege, Forumlaan 4, 1020 Brussels, Belgium
1990-1996: High school degree in Latin-Mathematics

Additional Training

Leguminosae systematics under supervision of Dr. Lourdes Rico (Kew Botanical Gardens (UK)), Herbario Forestal Nacional Martín Cárdenas, Bolivia (2003)

Professional Experience

1/11/2002-present: Doctoral Research Associate, Bioscience engineering at Ghent University, Belgium.

Skills

Software Proficiency

- Good knowledge Windows XP and the internet
- Good knowledge 'MS-Office 2003' programmes Word, Excel, Access, and PowerPoint
- Good knowledge Photoshop 6.0
- Good knowledge SPSS 12.0
- Good knowledge biodiversity programmes, including PC-ORD, CANOCO, Biodiv Pro, PAST, etc.
- Experience with GIS software such as Idrisi, Arc-view en DIVA-GIS

Language Skills

Dutch:	Mother Tongue
English:	Fluency in speaking, reading and writing
Spanish:	Fluency in speaking, reading and writing
French:	Satisfactory speaking, reading and writing
German:	Basic knowledge of speaking and reading

Driving Licence

Prizes

Development Co-operation Prize 2002 (to the value of 1,250 €), presented by State Secretary of development co-operation, E. Boutmans at the Africa museum in Tervuren, Belgium (www.devcoprize.africamuseum.be/en/).

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