The real voyage of discovery
lies not in seeking new land,
But in seeing with new eyes

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Adoption Potential of two Agroforestry Technologies: Improved Fallows and Domestication of Indigenous Fruit Trees in the Humid Forest and Savannah Zones of Cameroon

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**Adoptiepotentieel van twee Land-en Bosbouwtechnieken:
Verbeterd Braakland en Domesticatie van Inheemse Fruitbomen
in de Vochtige Bos- en Savannestreken in Kameroen**

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Front cover: Patrice Ondobo with honey from beehives in his calliandra fallow plot
Back cover: Diversity of indigenous tree products in a Cameroonian market

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CONTENT

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SAMENVATTING

Achtergrond en doelstellingen

West- en Centraal-Afrika kampt met snelle bosdegradatie, verslechtering van de bodemvruchtbaarheid en schrijnende armoede. Het *World Agroforestry Centre* (ICRAF) voert daarom onderzoek uit naar land- en bosbouwtechnieken die als doel hebben de bosdegradatie en vermindering van de bodemvruchtbaarheid tegen te gaan. Van 1987 tot 1998 was het onderzoek gericht op de ontwikkeling van verbeterde braaklandtechnieken door middel van het planten van vluggroeiende en stikstoffixerende bomen en struiken die de bodemvruchtbaarheid sneller herstellen dan de spontane braakvegetatie. In 1999 herorienteerde ICRAF haar onderzoek in de vochtige tropen van Afrika. Nu is het centrum actief in de domesticatie van inheemse fruit en medicinale boomsoorten. Dit onderzoeksprogramma heeft als doelstelling het inkomen van de plaatselijke bevolking te verhogen, te stabiliseren en te diversifiëren en de gezondheidszorg in landelijke streken te verbeteren, en dit zonder de biodiversiteit en het milieu schade te berokkenen. De onderzoeksmethode die daartoe gebruikt wordt, legt de nadruk op de actieve participatie van de doelgroep in de ontwikkeling en evaluatie van nieuwe technieken met het oog op een hogere adoptiegraad.

De evaluatie van het adoptiepotentieel van innovaties maakt integraal deel uit van een participatief en doelgroepgeoriënteerde onderzoeks- en ontwikkelingsmodel. Het verbetert de doeltreffendheid in de ontwikkeling en vulgarisatie van nieuwe technieken, helpt in de documentatie van de geboekte vooruitgang en levert nuttige informatie op die de onderzoeks- en vulgarisatieprogramma's kan verbeteren. Het laat eveneens toe de politieke en andere factoren die leiden tot suksesvolle ontwikkeling van technieken te bepalen, evenals de factoren die het bereiken van de vooropgestelde doelstellingen belemmeren.

De hier voorgestelde studie heeft als hoofddoelstelling het adoptiepotentieel van land- en bosbouwtechnieken door boeren in de vochtige bos- en savannestreken in Kameroen na te gaan. Tevens worden methodes ter verbetering en versnelling van deze adoptie voorgesteld.

Verschillende aspecten die de adoptie van land- en bosbouwtechnieken beïnvloeden, worden bestudeerd, zich inspirerend op de literatuur i.v.m. "besluitvorming in het aanvaarden en adopteren van innovaties":

- de karakteristieken van de technieken zelf, namelijk biofysische doeltreffendheid en technische vereisten, graad van complexiteit, financiële rentabiliteit, aanvaardbaarheid, waarneming van de gebruikers betreffende voor- en nadelen, relevantie en verenigbaarheid met andere landbouwpraktijken; en
- de bestaande landbouwsystemen en levensonderhoudstrategieën van de boeren, met het oog op het bepalen van interventiepunten voor de voorgestelde innovaties.

In de studie wordt ook aandacht geschonken aan de participatieve aanpak die gebruikt werd in de ontwikkeling van nieuwe land- en bosbouwtechnieken met de bedoeling de onderzoeksmethodes te verbeteren.

Onderzoeksmethodes

De manier waarop het adoptiepotentieel van landbouwtechnieken geëvalueerd wordt, is in de laatste decenia grondig geëvolueerd. De huidige kennis over het proces van besluitvorming i.v.m. innovaties en adoptie van nieuwe technieken vraagt om een holistische benadering van de dynamische noden, doelstellingen, persoonlijke kenmerken en communicatiemogelijkheden van de doelgroep, naast de studie van de technische karakteristieken van de vernieuwing zelf. Franzel *et al.* (2002) pleitten voor een combinatie van methodes voor het evalueren van het adoptiepotentieel, bestaande uit een bepaling van de biofysische mogelijkheden van de technieken in reële situaties, hun rentabiliteit en aanvaarbaarheid voor de boeren.

Dit studiewerk combineert verschillende onderzoeksmethodes en –middelen, zowel kwantitatieve als kwalitatieve, om een holistisch beeld te krijgen van de biofysische en socio-economische omgeving waarin de boeren beslissen om de voorgestelde land- en bosbouwtechnieken te aanvaarden dan wel te weigeren. We legden ons eerst toe op een beter begrip van de levensonderhoudstrategieën van de boeren en de bredere contekst waarin zij leven. Hiertoe werd als onderzoeksmethode het kader van duurzame levenswijze (*sustainable livelihoods framework*) gevolgd. Participatief onderzoek werd uitgevoerd in de velden en boomkwekerijtjes van de boeren met als doel de biofysische prestatie van de land- en bosbouwtechnieken onder een brede waaier van omstandigheden te testen. Een reeks van socio-economische studies beoogden de verzameling van informatie over problemen waarmee experimenterende boeren te maken hebben bij de toepassing van de nieuwe technieken, hoe ze denken over de voor- en nadelen van deze technieken en hoe de innovatie zich verspreidt. De rentabiliteit van de innovaties werd bepaald door het berekenen van de netto financiële opbrengst. Verder werd ook de deelname van kwetsbare categorieën (vrouwen, jongeren en de armsten onder de boeren) aan het experimenteren met de nieuwe land- en bosbouwtechnieken en de specifieke moeilijkheden die ze hebben om deze technieken te adopteren, bestudeerd. Uiteindelijk werden ook werkwinkels georganiseerd waarin de experimenterende boeren en andere deelnemers hun opinie gaven over de verwachte effecten van de innovaties op hun dagelijkse leven.

Levenswijze en socio-economische omgeving van de boeren

De traditionele Kameroense land- en bosbouwsystemen in de vochtige bos- en savannestreken, waren tot voor kort erg afhankelijk van twee exportgewassen, namelijk cacao en koffie. De fluctuerende wereldmarktprijzen van deze producten maakten de boeren zeer kwetsbaar. Als reactie legden de boeren zich meer en meer toe op de teelt van voedselgewassen, wat de ontginning van grotere bosoppervlakten teweegbracht daar waar het nog mogelijk was, en een verkorting van de natuurlijke braakperiode in streken met gebrek aan bosreserves. Dit gaf onvermijdelijk aanleiding tot degradatie van de bodemvruchtbaarheid, terwijl de huishoudens nog steeds te kampen hadden met seizoensgebonden schommelingen en gebrek aan liquiditeit omwille van de lage toegevoegde waarde van de verbouwde voedselgewassen, zoals bijvoorbeeld maniok en maïs. Rekening houdend met wat voorafgaat, wordt nu algemeen aanvaard dat de strijd voor betere levensomstandigheden zich moet toespitsen op: (1) een verhoging van de productiviteit van de landbouw en van de natuurlijke bronnen door de ontwikkeling en verspreiding van verbeterde technieken; en (2) een diversificatie van de inkomstenbronnen, met als doel deze afhankelijkheid en seizoensgebonden kwetsbaarheid weg te werken. Nochtans worden onderzoeks- en ontwikkelingsprogramma's in zuidelijk Kameroen belemmerd of op zijn minst vertraagd door een aantal structurele tekortkomingen. We noteren o.a. arbeidskrachten met onvoldoende of onaangepaste opleiding, een slecht draaiende gezondheids- en onderwijssector, degradatie van de natuurlijke hulpbronnen, onvoldoende en slecht onderhouden infrastructuur en een institutionele en politieke omgeving die onvoldoende rekening houdt met de armoedeproblematiek in de regio.

Verbeterde boom- en struikbraaktechnieken

Tijdens een diagnostiek in de vochtige tropen van Kameroen identificeerden onderzoekers en vulgarisatoren de daling in bodemvruchtbaarheid als een ernstig probleem voor de landbouw dat enkel met aangepaste land- en bosbouwtechnieken opgelost kon worden. Daarom richtte ICRAF haar onderzoeksactiviteiten tussen 1988 en 1998 op de ontwikkeling en participatieve evaluatie van verbeterde braaklandtechnieken, gebruik makend van stikstoffixerende bomen en -struiken die de bodemvruchtbaarheid vlugger herstellen dan de spontane vegetatie. Ondanks bevredigende biofysische prestaties van braakland met stikstoffixerende bomen in vergelijking met de natuurlijke vegetatie in ICRAF's onderzoeksstation, was de interesse van de boeren voor de techniek laag. Redenen hiervoor kunnen gevonden worden in de eerder beperkte verhoging van de gewasopbrengsten (< 40 %) en de lage rentabiliteit van de techniek, wegens de zware investeringskosten bij het planten van de bomen en de hoge arbeidsvereisten voor het beheren van de techniek. Bovendien was het verbeterde braakland met bomen, en meer bepaald de "*hedgerow intercropping*" techniek, oorspronkelijk ontwikkeld met de bedoeling om 3 problemen op te lossen, namelijk lage bodemvruchtbaarheid, gevaar voor bodemerosie en gebrek aan dierlijk voeder. Hoewel deze problemen daadwerkelijk bestaan, worden ze tot op heden door het merendeel van de boeren in het studiegebied nog niet als cruciale belemmeringen voor de landbouw beschouwd.

Experimenten met verbeterde struikbraak, gebruik makend van *Cajanus cajan,* hebben bewezen dat de techniek, in vergelijking tot natuurlijk braakland, de gewasopbrengsten aanzienlijk verhoogt en dit zowel in het onderzoeksstation als bij de boeren. Bovendien toont de kosten- en batenanalyse aan dat de techniek rendabel is, wat laat vermoeden dat het adoptiepotentieel van verbeterde struikbraak hoger ligt dan voor verbeterde boombraak. De struikbraaktechniek blijkt bijzonder geschikt voor boeren die geen landeigenaar zijn en voor vrouwen, daar Cajanus-struiken beter passen in hun landbouwpraktijken.

Terwijl de meeste boeren in zuidelijk Kameroen nog steeds over genoeg land beschikken om natuurlijke braak te gebruiken, is er vanuit wetenschappelijk oogpunt en voor het welzijn van de gemeenschap, dringend nood aan nieuwe technieken die de bodemvruchtbaarheid verbeteren en verder verlies aan bodemnutriënten en bodemdegradatie tegengaan. De korte tijdshorizon (of hoge verdisconteringfactor) van de boeren maakt het hen echter moeilijk om bodemverbeterende praktijken in hun levensonderhoudstrategieën in te bouwen. De grootste uitdaging hier bestaat erin oplossingen voor problemen die door de boeren niet worden waargenomen of die van minder belang zijn, te koppelen aan oplossingen voor problemen die voor hen duidelijk waarneembaar en topprioriteit zijn. Verbeterde boombraak, bijvoorbeeld, levert een aantal producten en diensten op korte termijn, die door de boeren gewaardeerd worden. Onze studie toonde aan dat de boeren verbeterde boombraak in de eerste plaats adopteerden omwille van deze bijproducten (honing, plantstaken, brandhout, onkruidbestrijding) en niet voor de verbetering van de bodemvruchtbaarheid. Wanneer de adoptie van verbeterd braakland vergeleken wordt in landen die zich in verschillende stadia van landbouwintensificatie bevinden, noteren we dat zuidelijk Kameroen een intermediaire positie inneemt, omdat er een toenemende druk is op landbouwgrond, wat op zijn beurt tot een verkorting van de braakperiodes leidt. In deze situatie is het waarschijnlijk dat het adoptiepotentieel van verbeterde braaklandtechnieken in de nabije toekomst verhoogt. Het is daarom van uiterst belang dat boeren goed ingelicht worden over de baten van verbeterd braakland, zeker in gebieden waar de natuurlijke braakperiodes drastisch verminderen, waar de bodem oorspronkelijk nutriëntenarm is en waar onkruid de landbouwproductie ernstig belemmert. Deze voorlichting kan gebeuren door demonstratievelden op te zetten, opendeurdagen en studiereizen te organiseren, technische handboeken en brochures ter beschikking te stellen, enz. Terzelfdertijd moet aandacht besteed worden aan het installeren van zaadproducerende eenheden op alle niveaus, daar gebrek aan plantmateriaal een ernstige belemmering vormt voor de grootschalige verspreiding en adoptie van verbeterd braakland.

Domesticatie van Inheemse Fruit- en Medicinale Boomsoorten

Vandaag de dag wijst alles erop dat strategieën met het oog op armoedebestrijding in de vochtige tropen van West- en Centraal-Afrika niet alleen de problemen i.v.m. verkorting van de natuurlijke braakperiode en de daling van de bodemvruchtbaarheid moeten aanpakken, maar evenzeer moeten gericht zijn op de vermindering van de kwetsbaarheid van de boeren en van hun financiële afhankelijkheid van enkele exportgewassen. In die zin wordt verwacht dat de domesticatie van inheemse fruit- and medicinale boomsoorten een bijdrage kan leveren tot de verhoging en diversificatie van huishoudinkomens. Onze studie beperkt zich tot een evaluatie van de eerste stappen in het domesticatieproces, namelijk de selectie en vermenigvuldiging, omdat de nodige informatie met betrekking tot de daaropvolgende stappen (integratie van de bomen in het landschap en marketing) nog niet beschikbaar is.

Evaluatie van participatieve domesticatie in kwekerijtjes op het platteland demonstreerde de haalbaarheid van vegetatieve vermenigvuldiging, zij het d.m.v. stekken of marcottage, van een aantal inheemse boomsoorten. De boeren waarderen vegetatieve vermenigvuldiging, omdat deze technieken een aantal voordelen vertonen in vergelijking met generatieve vermenigvuldiging, bijvoorbeeld laagstammige bomen die vroeger vruchten dragen en de reproductie van bomen met gewenste karakteristieken (exacte copies van de moederboom). Toch zal de wijde verspreiding van de vegetatieve vermenigvuldigingstechnieken waarschijnlijk bemoeilijkt worden door de relatief hoge kost van de kwekerij-infrastructuur en -materiaal. Nochtans toont de kosten-baten analyse aan dat vegetatieve vermenigvuldiging in plattelandskwekerijtjes rendabel is, op voorwaarde dat de volle capaciteit van de infrastructuur gebruikt wordt en dat ongeveer 75 % van de geproduceerde planten verkocht kan worden. Het adoptiepotentieel zou bijgevolg verhoogd kunnen worden door de kosten voor de installatie van een kwekerijtje te verlagen en de plantproductie te verhogen. Verlaging van de kosten zou eveneens tot gevolg hebben dat kwetsbare categorieën en de armsten onder de boeren ook kunnen deelnemen aan de domesticatie van inheemse bomen. Hiertoe zijn echter aangepaste voorlichting en adequate communicatiekanalen nodig.

Aanbevelingen

Bovenvermelde resultaten laten ons toe een aantal prioriteiten voor verder onderzoek aan te wijzen, en aanbevelingen voor het verhogen van de adoptie van verbeterde boom- en struikbraaktechnieken in de vochtige bos- en savannastreken van Kameroen, te formuleren ter attentie van vulgarisatiediensten en politici. Naast het verzekeren van de bevoorrading aan boom- en struikzaden, moet vooral meer onderzoek gebeuren naar de duurzaamheid van verbeterde braaktechnieken en de complementariteit met andere bodemverbeterende maatregelen. De vulgarisatie van verbeterde braaktechnieken moet zich richten op gebieden waar natuurlijke braakperiodes snel verkorten, waar de bodem al arm is aan voedingsmiddelen en waar onkruid ernstige problemen oplevert voor de verbouwing van voedselgewassen.

Wat de domesticatie van inheemse fruit- en medicinale boomsoorten betreft, moet internationaal onderzoek zich toeleggen op de ontwikkeling van "domesticatiestrategieën" voor *model*-boomsoorten, zodat nationale onderzoeksinstellingen en andere gebruikers deze strategieën kunnen toepassen op een groot aantal andere boomsoorten waarin boeren geïnteresseerd zijn. Bovendien moet verder onderzoek zich toespitsen op het op punt stellen van integratie-opties voor deze vegetatief vermenigvuldigde bomen. Tevens moet gewerkt worden aan de valorisering en commercialisatie van bomen en boomproducten.

Een andere belangrijke uitkomst van deze studie is dat "*agroforestry*" (land- en bosbouw), als een milieuvriendelijke en economisch interessante optie voor kleinschalige boeren, lange tijd verwaarloosd werd door beleidsvoerders. Dit is gedeeltelijk waar omwille van het multi-disciplinaire en -institutionele karakter van land- en bosbouw, waardoor het vaak door de mazen van institutionele netten valt. Bijgevolg zijn vulgarisatiediensten vaak slecht voorbereid en onvoldoende gewapend om land- en bosbouwtechnieken te verspreiden bij de boeren. We pleiten er daarom voor dat vulgarisatiediensten, NGO's en andere ontwikkelingsactoren aktief betrokken worden bij de design en evaluatie van land- en bosbouwinnovaties, zo dat wijde verspreiding van de technieken later gemakkelijker kan verlopen en meer kans geeft op adoptie door kleinschalige boeren in de tropen.

EXECUTIVE SUMMARY

Background and Objectives

In response to rapidly degrading forests, declining soil fertility and persevering poverty in West and Central Africa, the World Agroforestry Centre (ICRAF) has been looking for agroforestry technologies that can reduce deforestation and soil depletion (ICRAF 2000a). From 1987 to 1998, research was oriented towards the development of improved fallow management methods, consisting of planting of fast-growing nitrogen-fixing trees and shrubs that replenish soil fertility quicker than the natural vegetation (ICRAF 1995; ICRAF 1996). In 1999, ICRAF reoriented its research in the African Humid Tropics region towards the domestication of indigenous fruit and medicinal tree species with an aim to increase, stabilise and diversify farmers' income and to improve health care in rural areas, while at the same time safeguarding biodiversity and the environment (Tchoundjeu *et al.* 1999; ICRAF-AHT 2002; ICRAF-AHT 2003). The research approach emphasised farmers' active involvement in the development of new technologies in order to facilitate their adoption.

Assessment of adoption potential is a key element of a participatory, farmer-centred model of research and development. It improves the efficiency of the technology development and dissemination process, helps document progress made in disseminating new practices, provides farmer feedback for improving research and extension programmes, and helps to identify the policy and other factors contributing to successful technology development programmes as well as the constraints limiting the achievements (Franzel *et al.* 2001).

The main objective of the present study was to assess adoption potential of agroforestry technologies by farmers in the humid forest and savannah zones of Cameroon and to suggest means to ameliorate and accelerate adoption.

Inspired by literature on "innovation-decision processes" and "adoption of innovations" (Rogers 1995; Reeds 2001; Franzel *et al.* 2002; Place and Swallow 2002), different aspects affecting adoption of agroforestry technologies were studied:

- Characteristics of the technologies themselves, i.e. biophysical performance and technical requirements, complexity, profitability, acceptability and users' perception of benefits and disadvantages, relevance and compatibility;
- Existing land-use systems and farmers' livelihood strategies in order to determine entry points for the proposed innovations.

In addition, a closer look was given to the participatory approach of the research and development of new agroforestry technologies with an aim of improving methodologies.

Methodology

Approaches used to assess the adoption potential of agricultural practices have evolved considerably in the last couple of decades (Franzel *et al.* 2002). Today's understanding of the process of innovation-decision and adoption calls for a holistic view of dynamic farmer needs, objectives, personal characteristics, capital assets and communication, in addition to the technological characteristics of the innovations themselves (Rogers 1995; Reed 2001). Franzel *et al.* (2002) argue that assessing the adoption potential of the technology involves determining its biophysical performance under farmer's conditions, its profitability and its acceptability to farmers.

This study combined various research methods and tools, both quantitative and qualitative, to get a holistic view of the biophysical and socio-economic context in which farmers make the decision whether to adopt or reject the proposed agroforestry technologies. First, we focused on understanding farmers' livelihoods and the broader context in which farmers earn their living, using the sustainable livelihoods framework (DFID 1999). To evaluate the performance of the agroforestry technologies under a wide range of conditions, collaborative adaptive research was carried out in farmers' fields and nurseries. Feedback about constraints in the establishment and maintenance of the improved technologies, as well as farmers' perceptions on advantages, disadvantages and the spread of the technologies was gathered through socio-economic surveys. Net financial benefits were calculated in order to determine the profitability of the technologies to farmers. As part of the evaluation, we also studied participation of vulnerable groups in agroforestry pilot groups and identified specific constraints that these categories face in adopting the proposed technologies. Finally, ex-ante impact assessment workshops were held with stakeholders in order to obtain farmers' views on impact indicators and to elicit their expectations of magnitudes of impact and constraints in achieving these levels.

Farmer Livelihoods

Tree-crop or forest-based farming systems in the humid forest and savannah areas of Cameroon were, until recently, highly dependent on cocoa and coffee. This made farmers extremely vulnerable to fluctuations in world market prices. Consequently, farmers turned their attention to food cropping, thereby opening up new forest land where possible and shortening fallow periods elsewhere. This inevitably led to soil fertility problems, whereas rural households were still suffering from seasonality effects and cash shortages, due to the low added value of food crops. To address these two problems, poverty reduction strategies must thus focus on: (1) raising agricultural and natural resource productivity through the generation and dissemination of improved technologies and, (2) diversifying income sources in order to reduce dependency on few crops that are prone to price fluctuations and to smoothen seasonal fluctuations in income and consumption. However, the Central African region in general and southern Cameroon in particular, faces some major weaknesses that impede or, at least slow down research and development efforts. These include a weak human capital base, degradation of the natural resource base, insufficient and poorly maintained rural infrastructure and inappropriate pro-poor policies and institutions.

Improved Tree and Shrub Fallows

Declining soil fertility was identified during a diagnosis in the humid tropics of Cameroon by researchers and developers as a problem area that agroforestry could address. Between 1988 and 1998, ICRAF's research activities thus focused on developing and testing with farmers improved fallow systems using N-fixing trees and shrubs that would replenish soil fertility quicker than natural fallows. Despite satisfactory biophysical performance of tree fallows compared to natural fallows on-station, farmers' interest in the technology remained low. Major reasons were very modest yield increases under farmers' conditions (< 40 %) and low profitability of the technology, because of high upfront costs for tree establishment and important labour requirements for tree management. In addition, hedgerow intercropping was originally designed to solve 3 main problems, i.e. low soil fertility, risk of soil erosion and lack of fodder, diagnosed by researchers and extensionists. However, most farmers in the study sites do not yet perceive them as major production constraints. Shrub fallows with *Cajanus cajan,* on the other hand, have proven to increase crop yields more significantly both on-station and under farmer management. Furthermore, cost-benefit analysis demonstrated the profitability of the technology, which indicates higher adoption potential than tree fallows. The technology is particularly interesting to households with insecure land tenure and to women, because Cajanus fits better into their cropping system.

While many farming households in southern Cameroon still have enough land to practise natural fallows, from a scientific point of view and in the interest of society, soil fertility improving technologies are urgently needed to avoid further soil nutrient loss and degradation. However, farmers' short-term horizon (or high discount rate) makes it difficult to incorporate soil fertility enhancement in their livelihood strategies. The main challenge here is to link the solution of unperceived or low priority problems to the solution of perceived, high priority problems. For example, tree fallows in the short term provide by-products or services that are appreciated by farmers. Our study has shown that farmers adopt tree fallows in the first place because of the additional benefits (honey, stakes, fuel wood and weed suppression) and not for soil fertility improvement *per se*. Comparing adoption of improved fallows in countries with different stages of agricultural intensification, southern Cameroon presents an intermediate situation where increasing pressure on agricultural land leads to declining fallowing periods. This is a stage where adoption potential of improved fallows is likely to grow in the near future. Therefore, there is an urgent need to raise farmers' awareness on the benefits of improved fallows through demonstration plots, field days, study visits, technical manuals, etc., especially in those areas where fallow periods are rapidly shortening, where soils are poor and where weed incidence is a serious problem. At the same time, seed-production units should be established at different levels, as lack of planting material is a major bottleneck to the wider adoption of improved fallows.

Agroforestry Tree Domestication

Evidence today indicates that strategies to combat poverty in the humid tropics of West and Central Africa should not only tackle problems of shortening fallows and declining soil fertility, but also reduce farmers' vulnerability and dependence on a few cash crops. Domestication of local fruit and medicinal trees is expected to contribute to increasing and diversifying households' income. Our study focuses on the first stages of tree domestication, i.e. tree selection and propagation, because we do not yet have sufficient information on subsequent phases, i.e. tree integration and marketing. Evaluation of vegetative propagation in farmer pilot nurseries in the humid forest and savannah zones of Cameroon showed that farmers are able to propagate a number of agroforestry species, either through rooting of cuttings or marcotting. Farmers appreciate vegetative propagation because the techniques present several advantages compared to propagation by seeds, for example shorter trees that fruit early and reproduction of trees with desired traits (exact copies of mother tree). However, wide-scale adoption of vegetative propagation is likely to be constrained by the cost of nursery infrastructure and materials, although cost-benefit analysis shows that farmer-managed vegetative propagation units are profitability provided infrastructure is used to full capacity and about 75 % of the produce can be effectively sold. Measures to enhance adoption potential would thus include reducing nursery costs and increasing production of improved propagules. Cost reduction would also enhance participation of vulnerable groups in tree domestication activities, although appropriate communication messages and channels remain a must if these categories are to be fully involved.

Recommendations

Based on the above results, the study concludes by identifying further research needs and formulating recommendations for development and policy actions with an aim to enhance adoption of improved fallows and tree domestication in the humid forest and savannah zones of Cameroon. Apart from ensuring tree and shrub germplasm supply, research on improved fallows should focus on their sustainability and look at other complementary soil amending measures. Dissemination of improved fallows should be targeted to areas with shortening fallow periods, where soils are poor and where weed incidence is a serious problem.

Related to tree domestication, international research should focus on the development of "domestication strategies" for *model* species, so that national research systems and other clients could easily apply them to the multitude of agroforestry species of interest to farmers. Other research topics still to be looked into are integration options for improved propagules and marketing of agroforestry trees and tree products.

One of the major outcomes of this study is the fact that agroforestry, as an ecologically sound and economic viable option for small-scale farmers, has long been neglected by developers. This is in part due to the multidisciplinary and multi-institutional nature of agroforestry, which makes it to fall between the gaps of institutions. As a result, extension agents are usually ill prepared to disseminate agroforestry innovations in the field. We therefore argue that more active involvement of extensionists in the development of agroforestry innovations, using a participatory approach, will facilitate subsequent dissemination on scale.

RESUME

Contexte et Objectifs

Face à la dégradation rapide des forêts, la baisse de la fertilité du sol et la pauvreté sévère en Afrique de l'Ouest et Centrale, le World Agroforestry Centre (ICRAF) s'est attelé à développer des technologies agroforestières qui visent à réduire la déforestation et la dégradation des sols. De 1987 à 1998, la recherche était orientée vers le développement des méthodes d'amélioration des jachères, qui consistent à planter des arbres et arbustes fixateurs d'azote, supposés restaurer la fertilité des sols plus rapidement que les jachères naturelles. Mais alors, en 1999, ICRAF réoriente sa recherche dans la zone des tropiques humides d'Afrique vers la domestication des arbres fruitiers et médicinaux locaux, avec comme but d'augmenter, de stabiliser et de diversifier les revenus des paysans et d'améliorer les soins de santé dans les zones rurales, tout en préservant la biodiversité et l'environnement. L'approche recherche-développement utilisée vise à impliquer activement les paysans dans le développement des nouvelles techniques afin de faciliter leur adoption.

L'évaluation du potentiel d'adoption est un élément clés dans un modèle de recherche-développement participatif. Elle améliore l'efficacité du processus de développement et de transfert des technologies, aide à documenter le progrès fait dans la vulgarisation des nouvelles pratiques, capte les perceptions des paysans permettant d'améliorer les programmes de recherche et d'extension, et aide à identifier les politiques et autres facteurs qui contribuent au succès ou qui limitent les programmes de développement des technologies.

L'objectif majeur de cette étude est d'évaluer le potentiel d'adoption des technologies agroforestières par les paysans dans les zones de forêt et savane humide du Cameroun et de suggérer des voies et moyens pour améliorer et accélérer cette adoption.

Se basant sur la littérature relative aux « processus des innovations-décisions » et sur « l'adoption des innovations », différents aspects qui affectent l'adoption des technologies agroforestières sont étudiés :

- Les caractéristiques des technologies, c'est-à-dire la performance biophysique et les exigences techniques, la complexité, la rentabilité, l'acceptabilité et la perception de l'utilisateur par rapport aux bénéfices et inconvénients, la relevance et la compatibilité ;
- Les systèmes d'utilisation des terres et les stratégies de production existantes afin de déterminer les points d'entrée pour les innovations proposées.

Aussi, une attention particulière est donnée à l'approche participative de recherche-développement des technologies agroforestières visant à améliorer ces méthodes.

Méthodologie

Les approches utilisées pour évaluer le potentiel d'adoption des pratiques agricoles ont considérablement évoluées ces dernières décennies. Notre compréhension actuelle du processus de l'adoption des innovations demande une prise en compte holistique des besoins dynamiques, des objectifs, des caractéristiques personnelles, des capitaux paysans et la communication, en plus des caractéristiques techniques des innovations mêmes. Ainsi, Franzel *et al.* (2002) proposent d'évaluer le potentiel d'adoption d'une technologie par la détermination de sa performance biophysique sous des conditions réelles, sa rentabilité et son acceptabilité par les paysans.

Cette étude combine plusieurs méthodes et outils, aussi quantitative que qualitatives, pour gagner une vue holistique du contexte biophysique et socio-économique dans lequel les paysans décident d'adopter ou de rejeter les technologies agroforestières proposées. D'abord nous nous attelons à comprendre les conditions de vie des paysans et l'environnement dans lequel ils vivent, en utilisant le cadre des « *Sustainable Livelihoods* ». Afin d'évaluer la performance des technologies agroforestières sous une gamme de conditions, de la recherche collaborative est menée dans les champs et pépinières des paysans. Les enquêtes socio-économiques permettent de collecter le feedback des paysans sur les difficultés dans la mise en place et la gestion des technologies, ainsi que leurs perceptions des avantages et contraintes des nouvelles pratiques et de la diffusion spontanée des technologies. La rentabilité des technologies est déterminée en calculant les bénéfices financiers nets. Nous étudions aussi la participation des catégories vulnérables aux groupes pilotes d'agroforesterie afin d'identifier les contraintes spécifiques qu'elles rencontrent dans l'adoption des technologies proposées. Enfin, des ateliers des parties prenantes pour évaluer l'impact potentiel (*ex-ante*) des techniques agroforestières sont organisés. Ces ateliers ont comme but d'obtenir les perceptions des paysans sur les indicateurs d'impact, d'élucider leurs attentes par rapport à l'importance de ces effets et d'identifier les contraintes qui pourront diminuer ces effets.

Stratégies de Production et Environnement des Paysans

Dans les zones de forêt et savane humides du Cameroun, les systèmes de production arboricole ont longtemps été basés sur quelques cultures de rente, telles que le café et le cacao. Ceci a rendu les paysans extrêmement vulnérables aux fluctuations des prix de ces cultures au marché mondial. En réponse, les paysans se sont tournés vers les cultures vivrières en défrichant plus de forêt pour ouvrir de nouveaux champs la où cela était encore possible, et en réduisant les périodes de jachères ailleurs. Cette évolution inévitablement cause des problèmes de baisse de fertilité des sols, sans résoudre les problèmes de vulnérabilité des ménages ruraux qui continuent à souffrir des périodes de soudure alimentaire et financière. Afin de résoudre ces deux problèmes, les stratégies de réduction de la pauvreté dans la région doivent se focaliser sur : (1) augmenter la productivité de l'agriculture et des ressources naturelles par la génération et la dissémination des technologies améliorées et, (2) diversifier les sources de revenus pour réduire la dépendance de quelques cultures dont les prix fluctuent beaucoup et pour alléger les effets saisonniers dans la consommation et les revenus des ménages. Cependant, la région de l'Afrique Centrale entière et le Sud du Cameroun en particulier, est victime d'un nombre de faiblesses qui freinent, ou au moins ralentissent, les efforts de recherche et de développement. Nous constatons un capital humain faible, une dégradation accrue des ressources naturelles, une infrastructure rurale insuffisante et mal entretenue et des politiques et institutions de lutte contre la pauvreté, mal adaptées au contexte actuel.

Les Jachères Arboricoles et Arbustives Améliorées

Un diagnostic mené par les chercheurs et vulgarisateurs dans les tropiques humides du Cameroun a identifié la baisse de fertilité des sols comme problème prioritaire à résoudre par l'agroforesterie. Ainsi, entre 1988 et 1998, les activités de recherche de l'ICRAF s'intéressaient au développement et à l'évaluation participative des jachères améliorées par la plantation des arbres et arbustes fixateurs d'azote qui restaurent la fertilité des sols plus vite que les jachères naturelles. Malgré de performances biophysiques satisfaisantes des jachères arboricoles en comparaison avec des jachères naturelles en station, l'intérêt des paysans dans la technologie est resté faible. Les raisons évoquées incluent la faible augmentation des rendements de cultures (< 40%) sous gestion paysanne et le manque de rentabilité de la technologie à cause des coûts élevés pour la mise en place des arbres et les demandes importantes en main d'œuvre pour la gestion des arbres. En plus, la culture en couloirs était conçu au départ pour résoudre 3 problèmes, c-à-d la baisse de fertilité des sols, les risques d'érosion et le manque de fourrage pour animaux. Malheureusement, ces problèmes, bel et bien existants et diagnostiqués par les chercheurs et développeurs, ne sont pas encore perçus par les paysans comme des contraintes majeures à la production agricole.

Les jachères améliorées avec *Cajanus cajan* par contre, démontrent des augmentations significatives des rendements de cultures, aussi bien en station qu'en milieu paysan. En plus, l'analyse des coûts et bénéfices montre la rentabilité de la technologie, ce qui suggère un potentiel d'adoption plus élevé que pour les jachères avec arbres. La technologie avec Cajanus est particulièrement intéressante pour les ménages avec des droits fonciers pas très sécurisants, et pour les femmes, puisque le Cajanus s'intègre plus facilement dans leurs pratiques culturales.

Pendant que beaucoup de ménages dans le Sud du Cameroun disposent de suffisamment de terres pour continuer à utiliser les jachères naturelles, d'un point de vue scientifique et dans l'intérêt de la communauté, des technologies améliorées pour restaurer la fertilité du sol s'imposent afin d'éviter des pertes futures de nutriments de sol et de diminuer sa dégradation. Néanmoins, il est clair que l'horizon assez court (ou son taux d'intérêt très élevé) du paysan, rend difficile la prise en compte des techniques d'amélioration des sols dans ses stratégies actuelles de production. Le défi majeur ici se résume à lier les solutions des problèmes de faible priorité aux solutions des problèmes perçus par les paysans comme contraintes principales à sa production. Par exemple, les jachères arboricoles fournissent à court terme des produits et services secondaires très appréciés par les paysans. Notre étude a montré que les paysans adoptent les jachères améliorées avec arbres premièrement pour les bénéfices « additionnels » (miel, tuteurs, bois de chauffe, suppression des mauvaises herbes) avant de considérer leur potentiel d'améliorer la fertilité du sol. Quand nous comparons l'adoption des jachères améliorées dans des pays qui ont atteint des stades différents d'intensification agricole, le Sud du Cameroun occupe une place intermédiaire où il existe une pression croissante sur les terres agricoles, causant une réduction des périodes de jachère. A ce stade, le potentiel d'adoption des jachères améliorées est supposé de croître rapidement dans les années à venir. En conséquence, il est urgent de sensibiliser les paysans sur les bénéfices des jachères améliorées arboricoles et arbustives au travers des champs de démonstration, les journées porte ouverte, des visites d'étude, les manuels de formation et d'extension, etc. Ceci doit être fait en priorité dans les zones avec des raccourcissements des jachères naturelles, avec les sols naturellement pauvres et avec une occurrence préoccupante des mauvaises herbes. En même temps, des unités de production de semences doivent être mises sur pied à tous les niveaux (paysans, agences de vulgarisation, centres de recherche), car le manque de semences est l'obstacle le plus important dans la dissémination et l'adoption des jachères améliorées.

La Domestication des Arbres Agroforestiers

Aujourd'hui, nous savons que la lutte contre la pauvreté dans les tropiques humides de l'Afrique de l'Ouest et Centrale ne passe pas uniquement par les solutions à la réduction des périodes de jachères et la fertilité des sols, mais devrait également atténuer la vulnérabilité des ménages et leur dépendance de quelques cultures de rente. C'est à cet effet que la domestication des arbres fruitiers et médicinaux locaux est supposée augmenter et de diversifier les revenus des ménages. A cause des informations insuffisantes sur les stades consécutifs (intégration des arbres et commercialisation), notre étude se limite aux premiers stades du processus de la domestication, c-à-d la sélection et la multiplication des arbres. L'évaluation des techniques de multiplication végétative dans les pépinières villageoises des forêts et savanes humides du Cameroun montre que les paysans sont capables de multiplier un nombre d'espèces agroforestières, soit par bouturage ou par marcottage. Les paysans apprécient la multiplication végétative parce qu'elle présente certains avantages par rapport à la multiplication par graine, par exemple des arbres plus petits qui fructifient plus tôt et la possibilité de reproduire les caractéristiques désirées trouvées sur l'arbre-mère. Cependant, la vulgarisation à large échelle des techniques de multiplication végétative risque de se heurter aux coûts assez élevés de l'infrastructure et le matériel de pépinière. Cependant l'analyse des coûts et bénéfices montre la rentabilité des pépinières villageoises, pourvu que la capacité de la pépinière soit pleinement utilisée et que 75 % de la production soit effectivement vendue. Les mesures à prendre pour améliorer le potentiel d'adoption devraient donc inclure la réduction des coûts de pépinières et l'augmentation de la production des propagules améliorées. La réduction des coûts améliorerait aussi la participation aux activités de domestication des catégories vulnérables. Cependant, une communication appropriée utilisant des messages et des canaux adaptés reste toujours indispensable pourqu'une participation effective des jeunes, des femmes et des plus pauvres soit obtenue.

Recommandations

Suite aux résultats obtenus lors de cette étude, nous concluons par l'identification des besoins de recherche futurs et nous formulons des recommandations pour les actions de vulgarisation et de politique visant une augmentation de l'adoption des jachères améliorées et de la domestication des arbres agroforestiers dans les zones de forêt et savane humide du Cameroun. En plus d'assurer l'approvisionnement en semences des arbres et arbustes, la recherche devrait se pencher sur la question de durabilité des jachères améliorées et investiguer leur complémentarité avec d'autres mesures d'amendement des sols. La dissémination des jachères améliorées devrait viser les zones où les jachères naturelles deviennent de plus en plus courtes, là où les sols sont extrêmement pauvres et où l'invasion des mauvaises herbes freine la production agricole.

En ce qui concerne la domestication des arbres agroforestiers, la recherche internationale se doit de développer des stratégies de domestication pour les espèces modèles, de sorte que les systèmes de recherche nationaux et autres clients puissent les adapter à la panoplie d'autres espèces qui intéressent les paysans. D'autres thèmes de recherche qui demandent de l'attention sont le développement des options d'intégration des propagules améliorées et le marketing des arbres et des produits d'arbres.

Un des résultats importants de notre étude est le constat que l'agroforesterie, comme option écologique et économique pour les paysans, a été trop longtemps ignoré par le monde de développement. Ceci est dû, en partie, à l'aspect multidisciplinaire et multi-institutionnel de l'agroforesterie, qui fait que son mandat tombe entre les mailles des institutions existantes. En conséquence, les agents de vulgarisation sont souvent mal préparés pour disséminer des innovations agroforestières sur le terrain. Pour remédier à cela, nous suggérons que les agents de vulgarisation et des utilisateurs finaux soient activement impliqués dans la conception et l'évaluation participative des innovations agroforestières, afin de faciliter leur adoption plus tard.

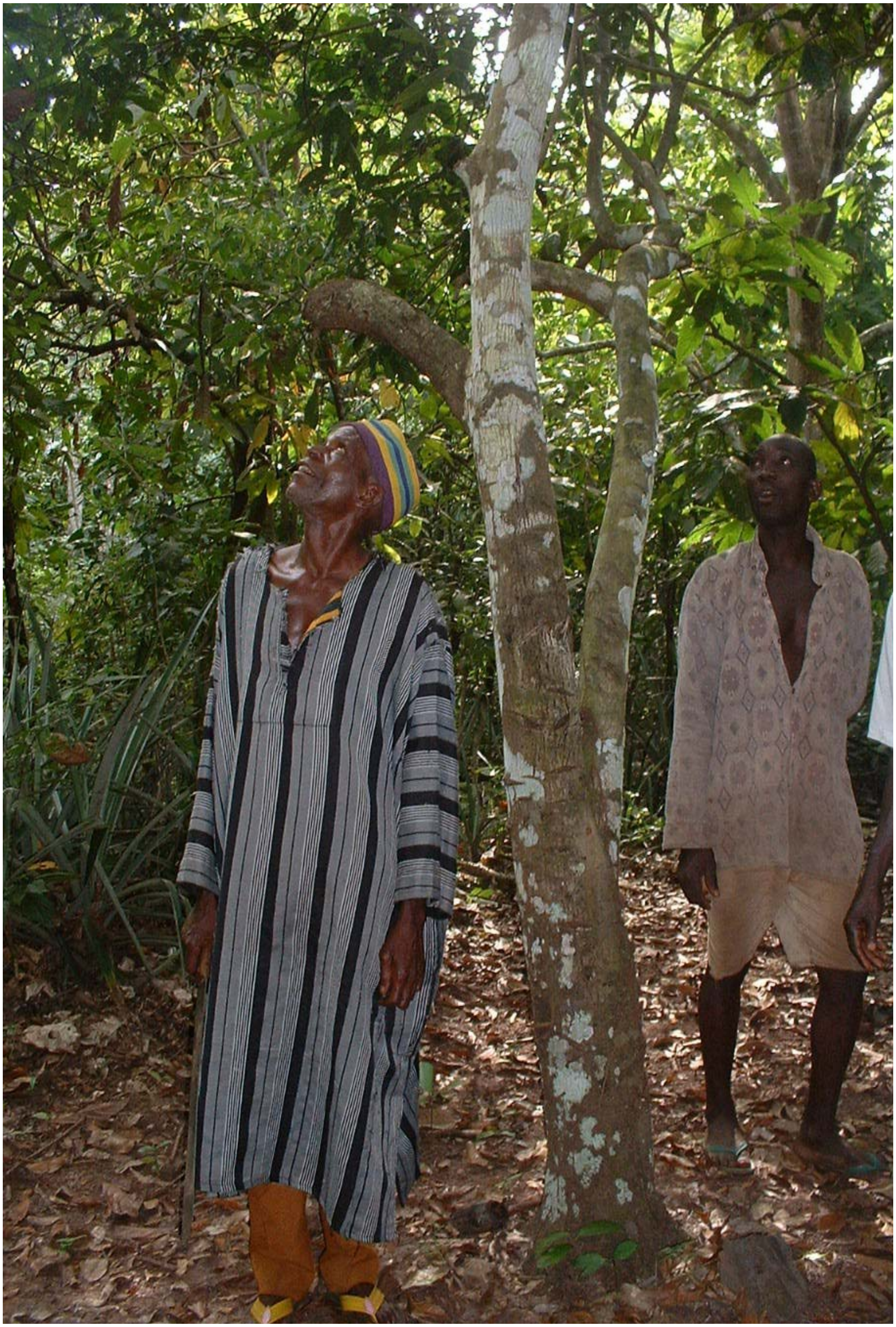
FIGURES

TABLES

TEXT BOXES

ACRONYMS AND ABBREVIATIONS

ASB	Alternatives to Slash and Burn
CEMAC	Communauté Economique et Monétaire de l'Afrique Centrale
CFA	Communauté Financière Africaine
CGIAR	Consultative Group on International Agricultural Research
CIG	Common Initiative Group
DFID	Department for International Development, United Kingdom
FAO	Food and Agriculture Organisation
FCFA	Francs de la Communauté Francophone d'Afrique
ICRAF	World Agroforestry Centre (International Centre for Research in Agroforestry)
ICRAF-AHT	World Agroforestry Centre - African Humid Tropics Regional Programme
IITA	International Institute for Tropical Agriculture
IRAD	Institut de Recherche Agricole pour le Développement, Cameroon
IRR	Internal Rate of Return
MINEF	Ministry of Environment and Forestry, Cameroon
NGO	Non-Governmental Organisation
NPV	Net Present Value
ODI	Overseas Development Institute, United Kingdom
PNVRA	Programme National de Vulgarisation et de Recherche Agricole, Cameroon
RHI	Rotational Hedgerow Intercropping
USAID	United States Agency for International Development
VVOB	Flemish Association for Cooperation and Technical Assistance, Belgium



Farmer in Southeast Nigeria is indicating
indigenous fruit trees in his cocoa farm

CHAPTER ONE

GENERAL INTRODUCTION

Ann Degrande

'The whole science is nothing more than a refinement of everyday thinking'
Albert Einstein

1.1 Background

The forests of West and Central Africa, rich in flora and fauna, are degrading rapidly due to timber exploitation and devastating slash and burn agriculture from farmers in search of new farm land to respond to ever increasing population numbers (ASB 2003). For the specific case of Cameroon, UNDP (2003) recorded that 33.4 % of the Cameroonian population is living below the poverty line of USD 1 a day. In the forest areas, this proportion rises to 66 % of the population. Rural poverty was exacerbated in the early 1990s by the devaluation of the CFA franc and slumping coffee and cocoa prices in the world market, until then major income generators for farmers in the region (ASB 2003).

Traditional slash and burn cultivation, although it has shown its worth in the past, is becoming increasingly unsustainable today with the growth in population. According to MINEF (1996), slash-and-burn agriculture is considered responsible for almost 85 % of annually deforested surface area in Cameroon. Moreover, average yearly increase in Cameroon's population now stands at 2.2 % (World Bank 2002). In the context of unchanged farming systems, this growth rate implies that in the near future more land will have to be made available to farmers if they are to continue to produce enough food to feed the growing population. Responding to this land pressure, farmers have shortened their fallow period from 15-20 years to 3-4 years and less (Tonye *et al.* 1988), leading to soil degradation, declining soil fertility and thus crop yields and increasing weed infestation. Technologies are therefore urgently needed to sustain production systems based on short fallows.

In response to these evolutions, the 'International Centre for Research in Agroforestry' (ICRAF), now called 'World Agroforestry Centre', has been looking for agroforestry technologies that can reduce deforestation and soil depletion in the humid tropics of West and Central Africa (ICRAF 2000a). From 1987 to 1998, research was oriented towards the development of improved fallow management methods (ICRAF 1995; ICRAF 1996). The techniques that were tested and evaluated in collaboration with farmers included planting of fast-growing and nitrogen-fixing trees and shrubs that replenish soil fertility quicker than the natural vegetation (ICRAF 1995; ICRAF 1996).

However, soon it became clear that tackling the problems of shortening fallows and declining soil fertility alone would not raise farmers of the region out of poverty. This concern was much in accordance with the growing consensus among researchers and policy makers worldwide that poverty alleviation in the tropics can only be achieved through combining increased agricultural production with increased and diversified income for rural households (IFAD 2001a). In 1999, ICRAF reoriented its research towards the domestication of indigenous fruit and medicinal tree species (Tchoundjeu *et al*. 1999; ICRAF 2003). The main objective of this research programme was to increase, stabilise and diversify farmers' income and to improve health care in rural areas, while at the same time encouraging the development of sustainable agroforestry practices that rehabilitate degraded farmland, sequester carbon and other greenhouse gases and enhance both biodiversity and the functioning of agroecosystems (ICRAF-AHT 2002; ICRAF-AHT 2003; Leakey *et al*. 2003). The research approach also emphasised farmers' active involvement in the development of new technologies in order to facilitate their adoption.

1.2 Rationale

Research and extension have always been challenged to develop and diffuse agricultural technologies which are adoptable by farmers. However, in the past too much attention in technology development has been given to biophysical aspects of system stabilisation and restoration and not enough to their socio-economic aspects (Franzel *et al*. 2002). Other factors affecting adoption, for example returns to labour required for implementing these technologies, farm resource endowment, institutional environment - which includes input and output markets -, and the performance of extension services have not sufficiently been studied (Buresh and Cooper 1999). As a result, farmer adoption has often remained below expectations.

According to Franzel *et al*. (2002), "*assessing the adoption potential of a technology is multifaceted, requiring an understanding of biophysical performance under farmers' conditions, profitability from the farmers' perspective and its acceptability to farmers*". Therefore, the present study combines various research methods and tools, both quantitative and qualitative, to obtain a holistic view of the biophysical and socio-economic context in which farmers make the decision whether to adopt or reject the proposed agroforestry technologies. This is in contrast with previous studies that focused on particular aspects of adoption, such as property rights (Adesina *et al*. 1997; Lawry *et al*. 1992) or socio-economic characteristics of adopters (Onu 1991; Carter 1995b; David and Swinkels 1994), whilst others employed specific methods like econometric analysis, as in Adesina *et al*. (2002). Moreover, whereas most adoption studies are carried out at one point in time, we were able to gain confidence and build up truthful relationships with experimenting farmers because of ICRAF's long presence (1987 to date) in the sites where our studied were held.

We also examine the adoption potential of two different agroforestry technologies that were tested and evaluated in the same research sites and often with the same farmers. This has the advantage of being able to assess specificities and complementarities of both technologies in solving farmers' problems.

1.3 Objectives and Research Questions

The main objective of the present study is to assess adoption potential of agroforestry technologies by farmers in the humid forest and savannah zones of Cameroon and to suggest means to ameliorate and accelerate adoption.

Different aspects affecting adoption of agroforestry technologies are studied:
- characteristics of the technologies themselves, i.e. biophysical performance and technical requirements, complexity, profitability, acceptability and users' perception of benefits and disadvantages, relevance and compatibility;
- existing land-use systems and farmers' livelihood strategies in order to determine entry points for the proposed innovations.

In addition, a closer look is given to the participatory approach of the research and development of new agroforestry technologies with an aim of improving methodology.

1.4 Outline of the thesis

The thesis has 7 chapters. After this general introduction (Chapter 1), Chapter 2 reviews the fundamentals of adoption of innovations by summarising existing literature on innovation and diffusion of technologies, adoption behaviour, factors affecting adoption in general and adoption of agroforestry technologies in particular. Chapter 3 describes the participatory approach that is used by ICRAF to evaluate and test agroforestry technologies with farmers in the humid forest and savannah zones of Cameroon. This methodology chapter presents experimental design and survey tools that were used in our study to assess adoption potential of improved fallow management and tree domestication techniques. In order to situate the proposed agroforestry innovations in their biophysical and socio-economic context, Chapter 4 describes farmer livelihoods in the humid forest and savannah zone of Cameroon. The information is presented using the sustainable livelihoods framework approach, developed by the Department For International Development (DFID), UK. Chapter 5 looks at the adoption potential of improved fallow management, presenting subsequently the biophysical performance, feasibility, acceptability and profitability of tree and shrub fallows. In Chapter 5 we also examine how farmers integrate improved fallow management in their livelihoods and what impacts can be expected from the use of tree and shrub fallows in the long run. Likewise, Chapter 6 investigates the adoption potential of another agroforestry intervention, i.e. domestication of local fruit tree species, following the same outline as chapter 5. Finally, Chapter 7 puts together the findings of the thesis and formulates ways to ameliorate and accelerate adoption of the two agroforestry practices that are evaluated here, i.e. improved fallow management and tree domestication, by farmers of the humid forest and moist savannah zones of Cameroon.

Comfort Lo'ah is diffusing tree domestication techniques to a women's group in Belo, Northwest province of Cameroon

Chapter Two

The Fundamentals of Diffusion and Adoption

Ann Degrande

"Be not the first by whom the new is tried, nor the last to lay the old aside"
Alexander Pope, An Essay on Criticism, Part II

2.1 Innovation, Diffusion and Adoption

To increase the scale of adoption and the impact of innovations, action must be based on an understanding of the dynamics of adoption and the critical factors that determine whether farmers accept, do not accept, or partially accept innovations.

2.1.1 The Innovation-Decision Process (Rogers 1995)

First of all, what constitutes adoption? Rogers (1995) described adoption by individuals as an 'innovation-decision process', consisting of five stages (Figure 2-1):

- *knowledge*. The individual is exposed to the existence of the innovation and gains some understanding of how it functions.
- *persuasion*. The individual forms a favourable or unfavourable attitude towards the innovation.
- *decision*. The individual engages in activities that lead to a choice to adopt or reject an innovation.
- *implementation*. The individual puts an innovation into use.
- *confirmation*. The individual seeks reinforcement for the innovation decision with the option of reversing that decision based on increased experience with the innovation.

The innovation-decision process can lead to either adoption, a decision to make full use of an innovation as the best course of action available, or to rejection, a decision not to adopt an innovation. Such decisions can be reversed at a later point. For example, discontinuance is a decision to reject an innovation after it was previously adopted. It is also possible for an individual to adopt an innovation after a prior decision to reject it. Adoption of a new technology can be defined in several ways. In all cases, the definition of 'adoption' needs to be agreed upon. According to Place and Swallow (2002), farmers may undertake rather lengthy experimental processes before deciding whether to adopt a technology. In this perspective it is helpful to distinguish testers from adopters. An adopter may be one who has expanded the level of use over a number of years (Place and Swallow 2002). However, the most common way of measuring technology adoption is through the use of a binary variable indicating its current presence or not on a particular plot. This method, however, leaves unanswered questions and may group households with quite dissimilar behaviour. For instance, a household that has planted only one tree may be treated similar to a household that has planted 1,000 trees. Variants on binary measurements involve incorporating evidence of prior expansion or willingness to expand in the future into criteria for adoption (Place and Swallow 2002).

Sometimes it may be sufficient to report on the proportion of farmers using the technology. In other cases, quantifying the level of adoption is necessary. For instance, the actual proportion of fields or area, either relative or absolute, under the new technology need to be estimated. Other possible adoption parameters in the specific domain of agroforestry (Place and Swallow 2002; Adesina and Zinnah 1993) are:

- farmers planting a few rows of trees, proposed by extension;
- farmers planting a certain minimum proportion of their field with trees, proposed by extension;
- adherence to management practices, i.e. how closely do farmers follow recommendations with respect to managing the technology (e.g. timing and frequency of pruning trees);
- adherence to input recommendation: the application of inputs falls within the rate and timing recommended by extension (e.g. incorporation of specified amounts of green manure).

Quantifying adoption, however, raises challenges, including evaluating the quality of the technological investment (Place and Swallow 2002). Some investments, such as the number of trees planted, are easily quantified but here too this can become costly if there are many different tree species and within each species many different dates of planting, etc.

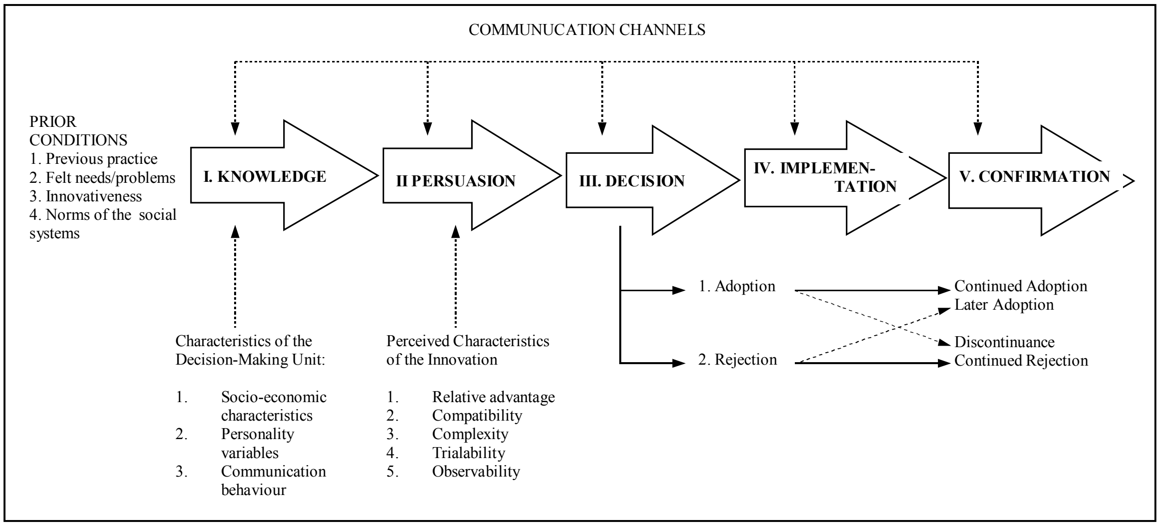


Figure 2-1: A Model of Stages in the Innovation-Decision Process
(*Source*: Rogers 1995, p 163)

2.1.2 Rate of Adoption (inspired by Rogers 1995)

The innovation-decision period is the length of time taken to go through the whole process. This varies between individuals. Adopter categories, i.e. the classification of members of a social system on the basis of innovativeness, include (i) innovators, (ii) early adopters, (iii) early majority, (iv) late majority and (v) laggards. Innovators are active information-seekers about new ideas. They have a high degree of mass media exposure and their interpersonal networks extend over a wide area, reaching outside their local social system. Innovators are able to cope with higher levels of uncertainty about an innovation than are other adopter categories. The late majority, on the other hand, is of low social status, makes little use of mass media channels, and learns about most new ideas from peers via interpersonal channels. Nevertheless, it would be erroneous to think that individual innovativeness (correlated with formal education, farm size, income, cosmopoliteness and mass media exposure) alone is sufficient to explain different rates of adoption between people and that successful adoption is always achieved by simply changing human behaviour. Frequently we make the mistake of defining adoption problems solely in terms of "*individual blame*", though often it is the system that is at fault. For example, change agents often feel that 'late adopters and laggards' are 'traditionally resistant to change' and 'irrational'. A more careful analysis, however, may show that the innovation was not so appropriate for later adopters, perhaps because of their smaller-sized farms and more limited resources. In that case, they may have been extremely 'rational' in not adopting. Recognising that the source or the channel of innovations (i.e. the research centre in our case) might be at fault for not providing adequate information, for promoting inappropriate innovations, or for not being fully informed about the actual life situation of the later adopters, requires a different approach to technology development that puts more emphasis on "*system blame*".

It is useful to distinguish between adoption, which is measured at one point in time, and diffusion, which is the spread of a new technology across a population over time. The rate of adoption is the relative speed with which members of a social system adopt an innovation. Much of the literature on diffusion assumes that the cumulative proportion of adoption follows a S-shaped curve (Figure 2-2), in which there is slow initial growth of the new technology, followed by a more rapid increase and then a slowing down as the cumulative proportion of adoption approaches its maximum. In fact, at first, only a few individuals adopt the innovation in each time period; these are the innovators. But soon the diffusion curve begins to climb, as more and more individuals adopt in each succeeding time period. Eventually, the trajectory of adoption begins to level off, as fewer and fewer individuals remain who have not yet adopted the innovation. Finally, the S-shaped curve reaches its asymptote, and the diffusion process is finished. The reason why the adoption curve has an S-shape rests on the role of information and uncertainty reduction in the diffusion process. Individuals learn a new skill, or item of knowledge, or set of facts, through a learning process that, when plotted over time, typically follows a normal curve. When an individual is confronted with a new situation in a psychologist's laboratory, the subject initially makes many errors. After several trials, the errors decrease until a certain learning capacity has been reached. When plotted, these data yield a curve of increasing gains at first and later become a curve of decreasing gains. This nature of the learning curve provides a reason to expect an adopter distribution to be normal.

Most innovations have a S-shaped rate of adoption. But there is variation in the slope of the 'S' from innovation to innovation. Some new ideas diffuse relatively rapidly and then the S-curve is quite steep. Other innovations have a slower rate of adoption, and then the S-curve is more gradual, with a slope that is rather lazy. The rate of adoption is usually measured by the length of time required for a certain percentage of the members of a system to adopt an innovation. There are also differences in the rate of adoption for the same innovation in different social systems. Rogers (1995) argues that the system has a direct effect on diffusion through its norms and other system level qualities, and also has an indirect influence through its individual members.

2.1.3 Variables to Predict Rate of Adoption

On the other hand, it should not be assumed that all innovations are equivalent. The characteristics of innovations, as perceived by individuals, help to explain their different rate of adoption (Rogers 1995):

- *relative advantage*. The degree to which an innovation is perceived as better than the practice it replaces may be measured in economic terms, but social prestige, convenience and satisfaction are also important factors.
- *compatibility*. An idea that is consistent with existing norms and values of the social system, past experiences and needs of potential adopters, will be more rapidly adopted since it will not require prior adoption of a new value system.

- *complexity*. Innovations that are readily understood and easy to use by most members of the social system will be adopted more rapidly than innovations that require the adopter to develop new skills and understandings.
- *trialability*. New ideas that can be tried on an instalment plan or can be experimented with on a limited basis will generally be adopted more quickly than innovations that are not divisible.
- *observability*. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt it. This is related to the magnitude (size) of the effect. The more important the effect of the innovation, the higher the likelihood that it will be adopted.

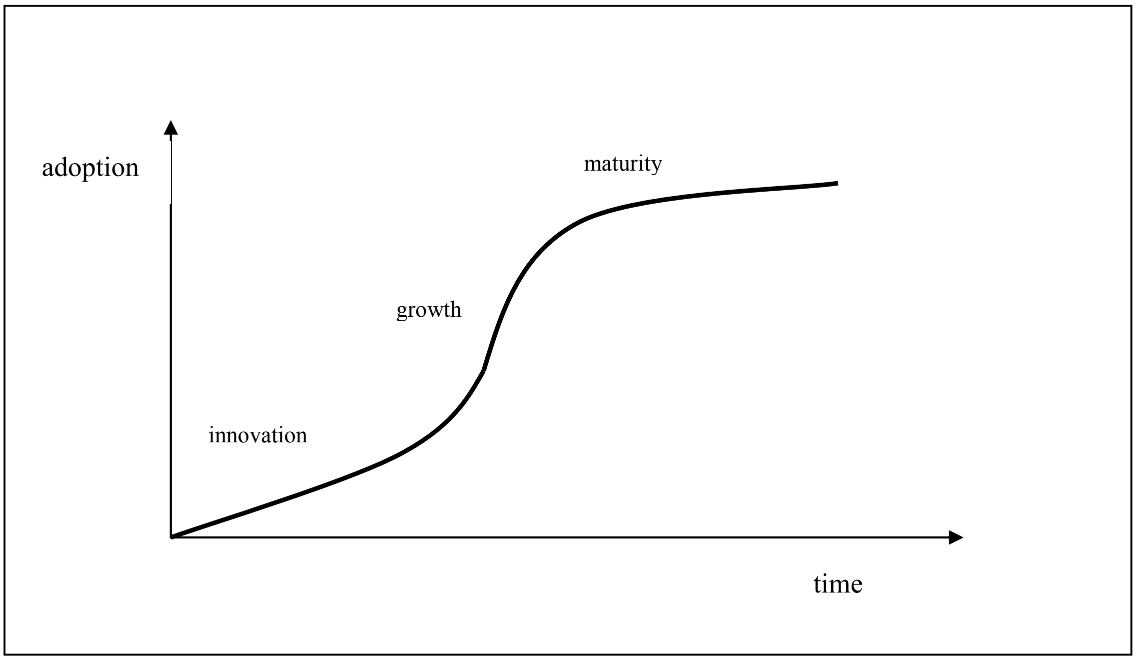


Figure 2-2: S-shaped curve of innovation adoption (*Source*: after Rogers 1995)

In addition to these 5 attributes there exist a number of other variables that determine the rate of diffusion and adoption of innovations in a social system (Figure 2-3).

First, Rogers (1995) recognises the importance of *communication* for innovations to spread. The nature of the information-exchange relationship between individuals determines the conditions under which a source will or will not transmit the innovation to the receiver, and vice-versa. At the same time, this relationship will influence the effect of the transfer. Diffusion investigations show that more effective communication occurs when two or more individuals are homophilous, i.e. when they share common opinions, a mutual language, and are alike in personal and social characteristics. However, when two individuals are identical regarding their technical grasp of an innovation, no diffusion can occur between them. Ideally, the two individuals should be homophilous on all other variables, even though they are heterophilous regarding the innovation. This is difficult, but evidence indicates that there is a general tendency for followers to seek information and advice from opinion leaders who are perceived as more technically competent than themselves. But yet, this difference should not be too pronounced, as a high-status opinion leader might be an inappropriate role model. Yet, these findings suggest the possibility of employing paraprofessional aides, such as local facilitators or farmer group leaders, in farmer-to-farmer diffusion of new technologies in order to accelerate adoption.

As mentioned above, there are also differences in the rate of adoption for the same innovation in different *social systems*. Many aspects of diffusion cannot be explained by just individual behaviour. The social structure of the system affects the innovation's diffusion in several ways. Compared to other aspects of diffusion research, however, there have been relatively few studies of how social or communication structures affect adoption of innovations in a system. Indeed, it is a rather tricky business to untangle the effects of a system's structure on diffusion, independent from the effects of the characteristics of individuals that make up the system. For example, norms of a system tell an individual what behaviour is expected and norms can be a barrier to change. Furthermore, opinion leaders and change agents, who are often at the centre of interpersonal communication networks, are members of the social system and their role in diffusion of innovations will depend on their credibility and acceptance by the other members of the system.

The social system has yet another important kind of influence in the diffusion of new ideas. Innovations can be adopted or rejected by an individual member of a system, or by an entire social system. Rogers (1995) distinguishes three different types of innovation decisions: optional, collective and authority innovation decisions. However, in the case of agroforestry practices, most choices to adopt or reject an innovation are made by an individual independent of the decisions of other members of the system (optional). Nevertheless, a number of agroforestry choices, such as tree planting for erosion control or watershed protection, may need consensus among the members of a social system and are therefore collective innovation-decisions (Knox *et al.* 2002a).

A final way in which a social system influences diffusion is consequences, i.e. the changes that occur to an individual or to a social system as a result of the adoption or rejection of an innovation. Change agents usually introduce innovations that they expect will have consequences that will be functional, an immediate response to the innovation, recognised and intended. But often such innovations result in at least some unanticipated consequences that are indirect and undesirable for the system's members, though only evidenced *a posteriori*.

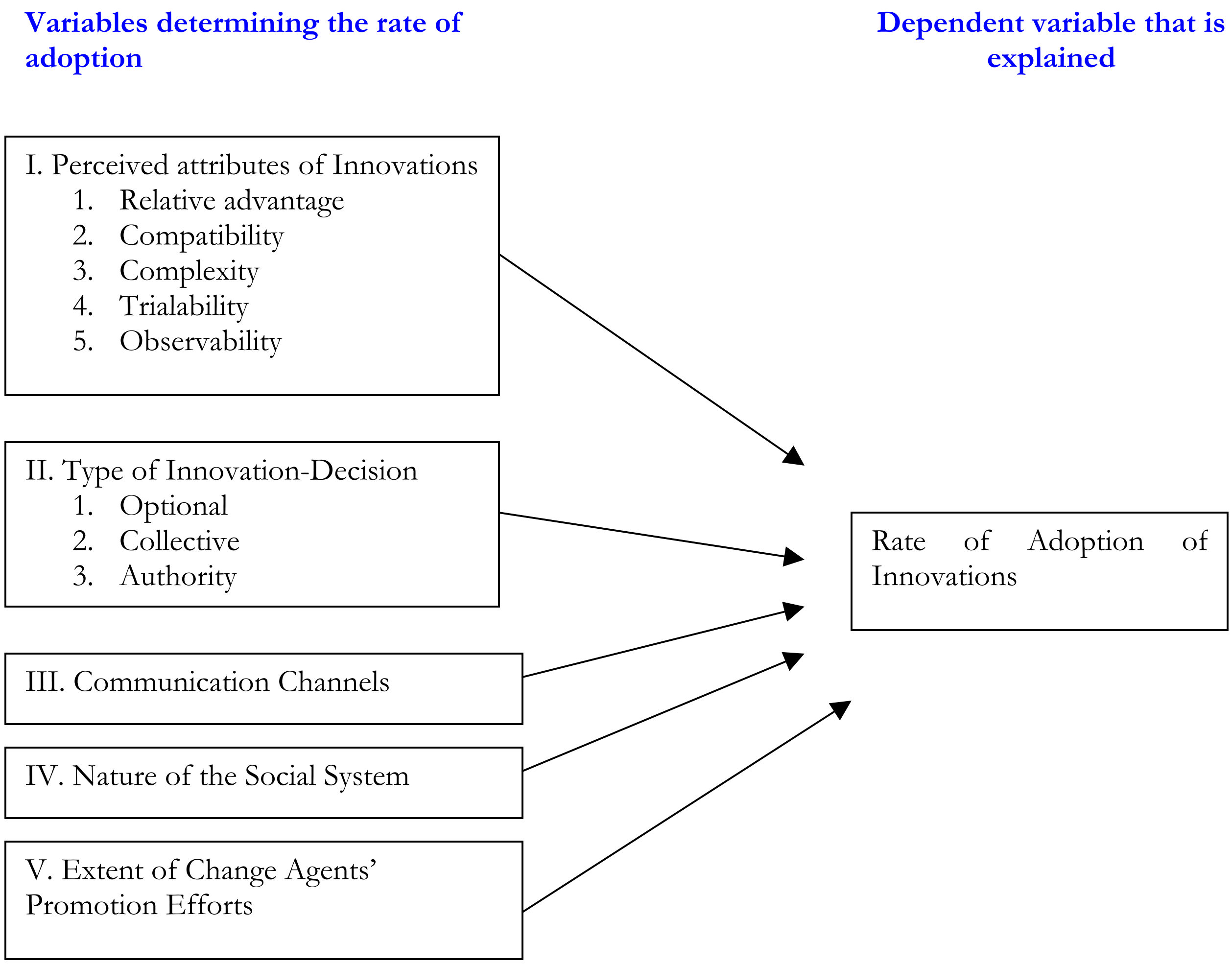


Figure 2-3: Variables determining the rate of diffusion and adoption of innovations in a social system (Source: Rogers 1995, p 207)

2.2 Adoption of Agroforestry Practices

2.2.1 Categorising Factors Affecting Adoption

Review of literature on the adoption of agroforestry practices has been useful for identifying the main factors that seem to affect adoption behaviour. Raintree (1983) has divided these factors in three categories.

> First, the likelihood of adoption of agroforestry practices is determined by **characteristics of potential adopters themselves**, including their situational constraints, limitations and potentials. This implies that factors such as *characteristics of the household and its members* are considered to play an important role in the decision whether to adopt a particular agroforestry practice or not. These household characteristics include household size (labour availability), characteristics of the household head, such as: age, gender, education, ethnic group, wealth, membership in associations, culture and experience in farming, in addition to decision-making patterns (e.g. who decides on resource allocation, production objectives, etc.) and the domestic development cycle[1] of the household. *Farm characteristics* are deemed equally important to adoption. They comprise of farm and plot size (land availability), main farm and off-farm enterprises (farmer livelihoods), the slope and nature of soils (degradation and fertility status), the prevailing climate and the access to markets. Furthermore, one common and important barrier to adoption is lack of secure *property rights*, particularly for longer-term investments in such items as tree crops or improvements to natural resources, such as improving soil fertility. For technologies and natural resource management practices that require farmers to make joint decisions and cooperate in implementing them, inadequate and ineffective institutions for managing *collective activity* can also be a constraint to adoption.
>
> The second category of factors influencing adoption involves the **nature of the innovation itself**. Rogers (1995) argues that the 5 characteristics of innovations, (relative advantage, compatibility, trialability, observability and low technical complexity) as perceived by individuals, are the most important in explaining their rate of adoption. In the case of agroforestry, difficulties arise from the long time frame associated with tree production and the impact of trees on e.g. the soil resource base. This tends to reduce the relative economic advantage, the triability, and the observability of tree-based innovations (Raintree 1983). Another fundamental challenge here is to ensure that the proposed technology is technically sound (Pannell 1999). Does it in fact deliver with sufficient reliability the biological and physical benefits that are sought? In the case of agroforestry, this entails aspects of both the tree component (species and cultivar choice, tree establishment) and the crop component (crop yields, crop combination).

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[1] With time, households typically go through different stages, called the domestic development cycle: establishment, expansion, consolidation, fission and decline. David and Swinkels (1994) recognise that the domestic development cycle of households influences resource endowment, the extent and intensity of work on the farm, crop production, access to resources and consequently affects the potential to adopt agricultural technology.

Third, the **manner in which the innovation is communicated** to potential users, i.e. the extension method, is important in explaining the adoption process. Lack of contact with extension services and inadequately trained extension workers often have been identified as impediments to effective adoption of technologies. Therefore, it is important to document and assess the significance of different actors and organisations as potential uptake/dissemination pathways for agricultural technologies; this implies finding out the sources of information farmers have access to, frequency of use and their views on how reliable the sources are. Users vary, both between and within categories of users, in the pathways they have access to or make use of (Garforth 1998). A study in 4 districts of Kenya (Rees *et al.* 2000) illustrated the diversity and complexity of smallholder farmers' agricultural knowledge and information systems (AKIS). The major sources of knowledge for smallholders were local (neighbours, family, markets and community-based organisations), followed by government extension, NGOs, churches and chief's barazas (community meetings) and agricultural companies. However, sources of information varied significantly with agricultural enterprise, agroecology, and from district to district. Garforth (2001) made the same observation in Hagaz, Ethiopia, where distinct differences in information seeking behaviour and in information and knowledge needs were found between villages, and between gender and socioeconomic categories within them. In both studies, farmers' most pressing information requirement was information on technical details of farming, hence the need to put increased focus on the formulation of research outputs into technical information materials for farmers, and the development of teaching and training-of-trainers materials for intermediate users. In general, farmer-to-farmer dissemination is important in spreading agricultural technologies. Franzel *et al.* (2004) demonstrated that whereas groups play an important role in spreading the adoption of fodder shrubs in central Kenya, group members, acting as individuals, do far more in distributing information and planting material than do the groups themselves. With formal extension systems in decline throughout Africa, this information can help policy makers understand the degree to which farmer-to-farmer dissemination can substitute for or complement formal extension services.

The list of factors above underscores the importance of looking at adoption in a holistic way. This implies studying at the same time aspects of the innovation itself and characteristics of the users and their environment.

There exists a wealth of empirical evidence on the factors that influence farmers' adoption of agroforestry interventions in the humid and sub-humid tropics. The following section reviews some of this literature and attempts to identify specific challenges for the present study.

2.2.2 Identifying Factors Affecting Adoption of Agroforestry Practices

Characteristics of Potential Adopters

In many studies, characteristics of agroforestry adopters are similar to those of innovators, as identified by Rogers (1995). Adopters of agroforestry in Senegal for example, were found to have control over substantial resources (land and labour) and the ability to absorb losses resulting from potential unsuccessful innovations (Caveness and Kurtz 1993). However, studying adoption of Gliricidia intercropping in southern Malawi, Thangata and Alavalapati (2003) found that the technology was rather wealth-neutral. This may be because the objective behind the promotion of this technology was to alleviate the problems associated with the use of high cost fertilizers. Adesina and Baidu-Forson (1995) concluded that two farmer characteristics were significant in explaining adoption decisions: the age of the farmer and farmers' participation in on-farm testing of the new technology. In southern Malawi, younger farmers were more likely to adopt agroforestry (Thangata and Alavalapati 2003). The same authors found that their findings were in accordance with other studies of adoption. On the other hand, Adesina *et al.* (1997) found that the effect of age on adoption was inconclusive in literature. Although younger farmers have longer planning horizons and may be more inclined to invest in soil improvement, with age, farmers may also accumulate more experience and capital resources, which enhance their ability to bear adoption risks. Older farmers may also be among the opinion leaders in the community and often have more privileged access to information about new technologies in the village.

Results from Thangata and Alavalapati (2003) also showed that an additional working member in a household increases the likelihood for agroforestry adoption. This finding concurs with Ghadim and Pannel (1999) that a farm with a larger number of workers per hectare is more likely to try and adopt a new technology.

One obvious possibility for boosting adoption rates, at least in the short term, would be to only work with the upper part of the adoption curve ('innovators' and 'early adopters'), but this strategy has many pitfalls (Raintree 1983). The main danger is that the technologies developed for and often refined with the help of the early adopters - because of their specificities - may not, in the end, be adoptable by the majority of less-advantaged farmers. A more effective strategy is to concentrate on developing technologies for the broad majority of farmers while judiciously involving the innovators and early adopters in the programme as early demonstrators of the new technology. Moreover, Reij and Waters-Bayer (2001) concluded that innovations are not regarded as arising out of a vacuum, but rather as emerging naturally from common community knowledge. The relationship of the innovator to the community and its values thus influences the local perception, and eventually adoption potential of the innovation.

Labour

An important economic dimension of adoptability is the labour intensity of agroforestry technologies. Raintree (1983) supports the idea that subsistence-oriented farmers economise on the use of their own labour and tend to resist more labour-intensive technologies as long as less labour-requiring technologies are available which are capable of satisfying their basic needs. It is only when yields per unit of labour input begin to decline, usually as a result of population-pressured degradation of the resource base, that farmers are willing to adopt more land- and labour-intensive technologies. However, the author also argues that this thesis is less successful in predicting technological change in non-subsistence-oriented production systems and situations of imperfect knowledge of technological options. Therefore, if increasing adoptability is the main concern, candidate technologies should not require much more labour than what is normally expected in the existing system. Incremental increases in labour input can only be tolerated if the relative advantage of the new technology is made clear, particularly in systems under pressure.

There exists evidence of highly productive, permanent tree-based systems that have low labour requirements. For example, Leakey (2001) states that in high-population areas of Nigeria (>1000 people km^{-2}), 29 % of the cultivated area is devoted to compound gardens, which produce 59 % of total crop output. In monetary terms, the outputs of these gardens are five to ten times greater than those of crop fields. This is coupled with returns to labour that are also four to eight times greater than for staple food crops. In 1996, mean annual returns from 127 person-days labour per family in mature damar (*Shorea javanica*) agroforests in Indonesia were USD 682 from damar and USD 464 from fruits and timber (de Foresta and Michon 1997).

Another dimension of labour is timing. For example, standard alley farming is extremely sensitive to pruning management. When this is properly done, its production potential is confirmed, but when a farmer is not able to do so at the right moment, the consequences of such failure are severe. Versteeg *et al.* (1998) observed that while at their station in southern Benin, *Gliricidia sepium* and *Leucaena leucocephala* hedgerows had been pruned three times, 26 % of farmer alleys were only pruned once, while the second pruning by the rest of the participants was on average very late. Furthermore no farmer pruned more than twice. Failure to follow the recommended pruning regime resulted in a 23 % yield loss compared to the no-alley plot. This yield depression in the alley plots is due to a negative tree competition effect. Similarly, in western Kenya, farmers reported that coppicing creates a labour bottleneck because this task coincides with the time for land preparation (David 1992). The main reason cited by trial farmers for non-expansion of hedges for soil fertility improvement in the past or future was labour shortage (David 1995). Similarly, Swinkels and Franzel (1997) found out that labour requirements for pruning hedgerows coincided with peak season labour use in western Kenya.

Gender

FAO (1985) states that African women perform around two-thirds of all the hours spent on agriculture-related work, even though they own only one percent of property. Literature on women's activities and responsibilities clearly indicates that West and Central African women possess resources and responsibilities distinct from those of men and face different constraints on their resource-management. Thus, women's control over the components and products of agroforestry systems will be subject to different rules than those for men. Adesina *et al.* (2000) reported that male farmers in Cameroon were more likely to adopt alley cropping than women. According to Stienbarger (1990), women's rights to trees tend to be derivative in nature, similar to their access to land. This implies that a woman depends on her spouse or her own kinship group for access to trees, especially to commercial trees. For example, in Cameroon women are rarely allowed to plant cocoa, even though they provide labour for their spouses' cocoa farms. Most women farmers acquire their farms as gifts from husbands or fathers. Also, findings suggest that widows generally possess a greater level of autonomy in decision-making. Stienbarger (1990) reports that women alley farmers, surveyed in the southeast of Nigeria, were all widows.

In contrast to their limited access to commercial trees, women are much more heavily involved in the collection and use of fuelwood and minor tree products. According to Stienbarger (1990), this reliance on often called 'secondary uses' of trees makes women particularly vulnerable to tenure changes that transform subsistence tree products into commercial goods that are then co-opted by men. In forecasting the gender-impact of tree planting projects, trees must be differentiated according to species or function.

As a general rule, intra-household decision-making processes have serious implications for the adoption of agroforestry technologies (David 1992). Yet, understanding complex distributional and organisational issues is often neglected by research and extension teams and 'women's issues' are often considered outside of the household's context. David (1992) stresses the importance of looking at intra-household dimensions, particularly when the proposed agroforestry technology is complex due to its composite nature, the new tasks it introduces and its multiple outputs, as is the case for hedgerow intercropping. She discovered that several issues regarding the management of hedges provide potential grounds for intra-household decision-making conflicts. For example, in southwestern Nigeria, men primarily plant hedges (mainly *Leucaena leucocephala*) for mulch while their wives use the foliage to feed the livestock. In situations where small tree plots cannot provide sufficient foliage, it is certain that some level of bargaining between spouses will come into play, but very little information on how this is effectively done is available. In western Kenya, hedgerows are spatially located on the female fields and are thus bound to have an impact on women's area of responsibility of providing food for the household. It is possible that these hedges may prevent women from planting food crops or may curtail the growth of wild plants used as food or medicine. Therefore, the impact of a technology on gender-defined areas of responsibility needs to be investigated since the implications for adoption may be important. Three questions emerge from this finding: (1) whose work is intensified by the new technology?; (2) how does the technology affect decision-making between spouses or within the household in general?; and (3) how are the outputs of the technology distributed between spouses and other household members?

Another mistake often made in assessing the uptake of technologies by women is that women are treated as a homogenous group (Bonnard and Scherr 1994). In a study on adoption of improved tree fallows in Eastern Province of Zambia, Phiri *et al.* (2004) differentiated between single women and female heads of households who were married. They found no significant difference between the proportions of women and men planting improved fallows, nor were there differences between single women and female heads of households who were married, suggesting that the technology is gender-neutral. In contrast, Bonnard and Scherr (1994) found that married women in Kenya tended to plant more trees than single women.

Wealth

Farmer surveys documenting the adoption of new technology rarely assess the association of wealth with adoption, mainly because the income of rural households is difficult to assess. Where wealth groups are defined, the indicators and groupings are often arbitrary as researchers use proxies based on their own definitions of wealth and wealth groups. Therefore, Phiri *et al.* (2004) used participatory wealth ranking, in which community members defined wealth criteria and classified themselves according to the criteria. Community members then assessed which households were using improved tree fallows and the association between use of this practice and differing wealth categories. Results showed that there was some evidence of association between planting improved fallows and wealth. However, that 22% of the 'poor' group and 16% of the 'very poor' group were planting improved fallows suggests that there are no barriers preventing low-income households from doing so. Poor farmers appreciated the technology because it permitted them to substitute small amounts of land and labour for cash, which is their most scarce resource.

In agrarian societies, natural resources are key assets; therefore, wealth is strongly linked to property rights over natural resources. Knox *et al.* (2002b) highlight that asset control has a strong effect on people's options with regard to technology. Those who possess a higher quantity and quality of endowments will place a higher future value on the medium- and long-term benefits produced by investment in technologies. This is because they are less constrained by food insecurity and risks that undermine the ability to meet basic needs than low-wealth actors. Furthermore, social structure and within community power distributions bias technologies and the flow of technical information in favour of the wealthy, shaping adoption outcomes accordingly. The latter authors therefore conclude that the adoption of more advanced technologies requiring "lumpy" investments can be facilitated by collective action. By investing and acting collectively, groups spread out the costs associated with a particular technology among their members and lower individual risk exposure. When people apply collective action to enhance resource access, wealth is less of a constraint to obtaining rights to resources and adopting technologies.

Knox *et al.* (2002b) summarised the conditions under which yield-enhancing technologies are likely to be equitable as follows:

1) a scale-neutral technology package that can be profitably adopted on farms of all sizes;
2) an equitable distribution of land with secure ownership or tenancy rights;
3) efficient input, credit, and product markets so that farms of all sizes have access to necessary modern farm inputs and receive comparable prices for their products;
4) a mobile labour force that can migrate or diversify into the rural non-farm economy and;
5) policies that do not discriminate against small farms.

Credit

Access to credit by small farmers has been a key determinant in the rate and success of technology adoption in many cases, particularly as the latter has often depended on the use of modern inputs. Lele (1996) therefore argues that micro-finance provision to small farmers needs to be substantial in order to facilitate technology adoption. However, it is not often well understood which mechanisms for providing access to rural financial services could contribute to improved land-use practices. The relationship might be either direct (funds are directly used for land use intensification through fixed investments or purchased external inputs) or indirect (funds are used for activity diversification or income stabilisation). Ruben and Clercx (2004) cite some authors who state that credit streams could undermine the investments in ecologically sound production systems because the additional resources are likely to be used for the purchase of yield-increasing inputs. On the other hand, access to rural financial services can provide important incentives to invest in improved land-use practices; both directly through the availability of liquidity and indirectly through reduced uncertainty. Ruben and Clercx (2004) also argue that financial services fulfil different functions during different phases in the transition of land-use and production systems in the Lempira region of Honduras. First, access to financial services allows households to purchase yield-increasing external inputs (e.g. fertilizers and herbicides). Once a minimum level of food security is obtained and guaranteed, subsequent borrowing tends to be used for income diversification purposes. Finally, in-depth investment in improved land-management practices takes place. Ruben and Clercx (2004) thus conclude that financial services put in place in order to reduce vulnerability of rural households in early stages of their development, are an important precondition for stimulating subsequent investments in sustainable natural resource management. Scherr and Franzel (2002), on the other hand, argued that lack of financial credit was not a constraint to widespread adoption among smallholders in Africa due to small farm size (and hence a small scale of operation), farmers' incrementalist approach to tree establishment, and their preference for strategies that reduce cash costs and reduce risks.

Property Rights and Collective Action

Knox *et al.* (2002a) claim that lack of secure property rights is a common and important barrier to adoption, particularly for longer-term investments in such technologies as tree crops and improvements to natural resources. For technologies and natural resource management practices that require farmers to make joint decisions and cooperate in implementing them, inadequate and ineffective institutions for managing collective action can also be a constraint to adoption. The links between technology adoption and property rights and collective action (PRCA) are best understood in a dynamic rather than static context. Besides the effects that PRCA introduces, technological change and the resulting changes in agricultural productivity, poverty, and the environment can redefine underlying economic and social forces and induce changes in PRCA institutions themselves, as is illustrated in Figure 2-4.

The distribution and exact nature and scope of land and tree tenure obviously affect the attractiveness of agroforestry practices to a given individual. If that individual does not have the right to plant trees or the right to use the products of these trees, then there is very little incentive to adopt such an innovation. Although this appears straightforward initially, evaluating the real impact of land and tree tenure on adoption of agroforestry practices is often much more difficult, especially when one enters the realm of partial and overlapping rights.

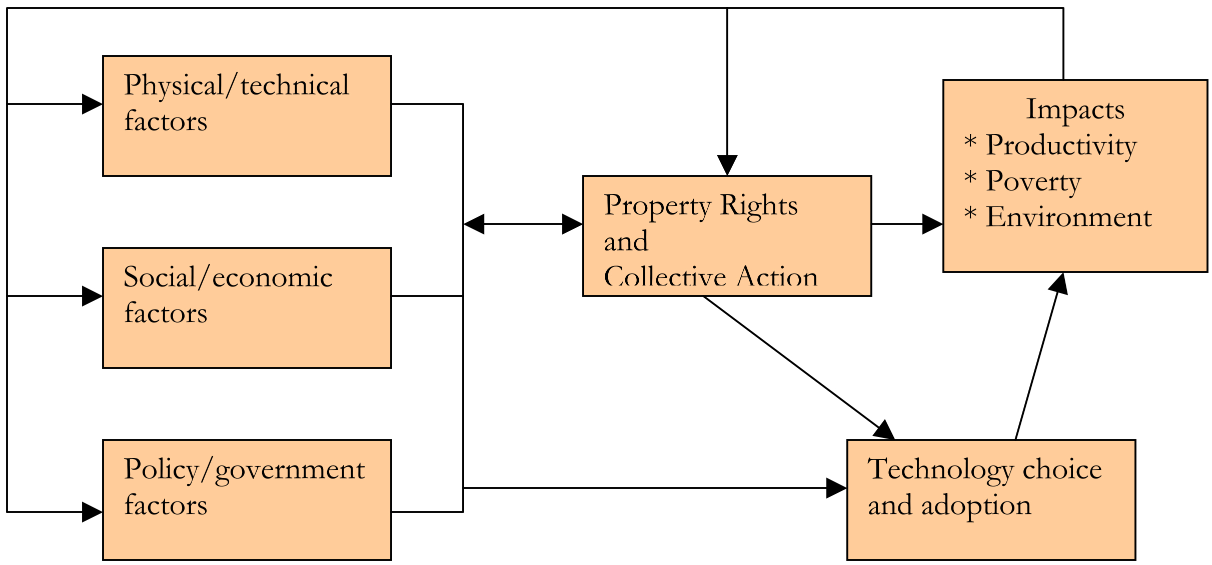


Figure 2-4: Conceptual framework linking property rights, collective action and technology adoption (Source: Knox *et al.* 2002a, p 13)

A survey of present land tenure systems in Nigeria, Cameroon and Togo, carried out by Lawry *et al.* (1992), showed that respectively 66 %, 54 % and 36 % of farming land was under tenure systems that provided long-term security. These therefore presented good opportunities for adoption of alley farming. The study also showed that most of the land under continuous alley farming was under more secure tenure than land where alley farming was discontinued after its introduction. Although the discontinuation could not always be directly related to tenure status as such, it appeared that unfavourable land tenure played a significant part. It is possible that farmers gave less attention to alley farms under less secure tenure leading to poor performance and discontinuation. On-farm research in Nigeria revealed that land and tree tenure played major roles in determining who adopted alley farming techniques and which parcels of land were given over to alley farming (Stienbarger, 1990). Buresh and Cooper (1999) also highlighted the fact that unclear or overlapping property rights can prove a disincentive to planting fallow trees and shrubs. Caveness and Kurtz (1993) found that land security (number of plots under secure tenure, which is highly correlated with total hectares and average plot size) favourably contributed to adoption of agroforestry practices in the Arrondissement de Koumpentoum, Tambacounda region in Senegal.

Access to and control over land also becomes an important issue when looking at differences in adoption behaviour between husband and wife and between generations in the same household. Stienbarger (1990) demonstrated that, in most parts of Central and West Africa where patrilineal systems dominate, women are rarely allocators of land rights. Even their rights to use land generally come through men, either from a husband as a part of his holdings or from other male family members. This normally means that women take little part in land management decision-making processes, even though they are likely to be directly affected by such decisions. The same is true for male children. Often land is apportioned to adult sons temporarily before a final allocation is made, the latter often occurring after the father dies. Under this uncertainty, investing in trees is quite a risky business.

Adding on to the complexity of tenure and its impact on adoption of agroforestry practices is the fact that the rights to trees and their products may be held separately from the land they grow on. Right to trees may also depend on how the trees are used, who plants them, what species they are, what spatial planting arrangements are used, and what form of land tenure applies (Stienbarger 1990). In general, rights to trees can be divided into 4 categories (Diaw 1997): (1) the right to own or inherit trees; (2) the right to plant trees; (3) the right to use trees or tree products (right to gather certain products, to harvest produce, to cut the whole tree or parts of it); and (4) the capacity to dispose of trees by destroying, lending, leasing, mortgaging or pledging, selling or giving them away. Adesina *et al.* (2000) concluded that security of tree rights is more important for the adoption of alley farming in Centre, Southwest and Northwest Provinces of Cameroon than security of land. This suggests that generalisations on the effects of land tenure security in influencing the adoption of alley farming should be avoided, as the effects may vary depending on the country, socio-economic, institutional and cultural contexts.

With respect to collective action, Adesina *et al.* (2000) found that, in Centre, Southwest and Northwest Cameroon, adoption of alley cropping was higher for farmers belonging to farmer associations. In Senegal (Arrondissement de Koumpentoum, Tambacounda region), farmers associations have been active contributors to agroforestry information dissemination since 1988. Members were encouraged to experiment with agroforestry and communicate ideas to friends and family. The association also maintained group agroforestry plots that served as demonstration units to members and non-members (Caveness and Kurtz 1993). According to Onu (1991), adoption of improved soil conservation technologies by farmers in Southeast Nigeria was positively and significantly correlated with farmers' participation in social activities. This indicates that social organisations can serve as a forum through which farmers would exchange ideas and learn about new farm practices.

Nature of the Innovation

Relative Advantage

To ensure its widespread adoption, it is important that an innovation is profitable. Profitability means that the new farming system is economically superior to the current farming system. It is not sufficient for it to generate benefits in excess of input costs. It must also cover opportunity costs, i.e. the profits from alternative uses of resources, which must be foregone in order to use the resources in the new way (Pannell 1999). For a complex farming system, assessing an innovation's profitability can be a much more difficult task than often recognised because of the many factors affecting relative profitability and the challenges involved in measuring and quantifying them.

Raintree (1983) stressed the importance to recognise that yields per hectare are not the only, and often not the most relevant, criterion to judge an agroforestry design. The unit of success or failure in agroforestry is the enterprise, not the plot. Yield per hectare will be the best index of productivity of agroforestry systems only where land is the most limiting factor. In labour-scarce economies, like in many areas of the humid tropics, technologies that give higher returns to labour will have greater perceived advantage.

One potential threat to the actual profitability of an innovation is that there are likely to be substantial costs in establishing and maintaining the new technology. This is particularly true of systems involving trees, which are usually characterised by high up-front costs and benefits that only occur some time in future (Pannel 1999) . High initial investment costs have been identified as important obstacles to adoption of agroforestry practices. This requires repeated attention from research to lower costs. For example, Buresh and Cooper (1999) mention that easy, inexpensive, and simple establishment methods have proven to greatly enhance adoption of improved fallows. Another factor in estimating profitability of some agroforestry practices is the opportunity cost of losing land for cropping during one or more seasons because the field is abandoned to tree or shrub fallow, whereas this loss is not offset by additional increased yields. This has proven to be a key factor in farmers' decision to adopt, for example, *Mucuna pruriensis* cover cropping in Ghana (Fischler and Wortmann 1999).

Buresh and Cooper (1999) found that adoption of improved fallows is enhanced when they provide benefits in addition to improved soil fertility and when a broad range of crops show to respond. The ability of *Mucuna* to suppress *Imperata* grass was the major reason for its adoption in southern Benin, but *Mucuna* fallows also have other benefits such as improving soil fertility and soil erosion control, which were the initial reasons for its introduction. In a livestock development project in northern Benin, farmers adopted *Mucuna* more than other legumes (Fischler and Wortmann 1999), probably also because of its weed suppression capacities. Adoption of alley cropping in southwest Cameroon was higher for farmers in areas facing fuel wood scarcity, demonstrating the additional benefit of trees in providing firewood. However, its adoption was lower for farmers in areas with very high population pressure. This can be explained by the competition for light, nutrients and moisture between trees and food crops (Adesina *et al*. 2000).

Unfortunately, a new technology may also have negative impacts, which must be set against the expected benefits of the innovation in order to reach a realistic assessment of its value (Pannell 1999). Examples of negative impacts are harbouring weeds, pests, or diseases, directly competing with crops for light, nutrients and moisture (e.g. in alley cropping) or physically obstructing other farm activities (e.g. constraining grazing by livestock in order to avoid damage to seedlings).

Observability

One of the requirements for technology adoption is that benefits must be observable. In terms of direct, saleable output from the system, this is usually not a problem. However, if a significant part of the benefits of the innovation stem from reductions in resource degradation (e.g. erosion control) or other such indirect benefits - as is often the case with agroforestry - the issue of observability can be critical. Moreover, as Pannel (1999) explains, there are other factors that further delay the true recognition of benefits and confound the impacts attributable to the innovation, such as variability over time and space in climatic conditions, soil characteristics, occurrence of weeds/pests/diseases and management practices. In general, farmers will not believe what researchers or extension workers tell them. They have to see results for themselves to be convinced. A practical demonstration on another farmer's property can be convincing provided the situation is not too different from their own situation in terms of soils, topography, labour, scale or tools (Pannell 1999). Furthermore, tree-based technologies are generally characterised by the time lag between the tree planting and the observation of the benefits generated by the trees (Raintree 1983).

Compatibility

In seeking to maximise the compatibility of agroforestry innovations, it is preferable to make incremental improvements in existing land-use systems. The existing land-use system is the basis on which innovation can be most easily grafted. This was demonstrated by Buresh and Cooper (1999), who found that the adoption of improved fallows was enhanced when they build on indigenous knowledge and existing practices. Therefore, an innovation that does not agree with community values will be difficult to disseminate. For instance, Reij and Waters-Bayer (2001) reported that in a village in Ethiopia the community criticized some young farmers who planted marginal hillside plots with eucalyptus trees, because they feared that the reafforested land would be claimed by the government and would be lost to the community.

Discrete technical interventions are not only more compatible with existing practice and their relative advantage more easily perceived, but also they are more likely to be technically simpler, more easily submitted to trial, and their effects more readily observed and understood by farmers (Raintree 1983).

Complexity

The difficulty of achieving widespread adoption is increased if the innovation is complex and/or radically different from current farming practice. David (1995) for example, reported simplicity of the technology in terms of management and the number of elements or components that have to be considered, as an important predictor of agroforestry adoption. In addition, technical soundness of an innovation can be greatly affected by the quality of implementation by farmers. For example, as demonstrated before, failing to timely prune trees greatly reduces the effectiveness of hedgerow intercropping. Unfortunately this is most likely to be true for complex farming systems, for which the risk of poor implementation is higher. Subsistence farming systems in the humid tropics, as evidenced by Pannel (1999), are complex not only in their biology, but also in their management, in their economic impacts and in the social attitudes and perceptions which they generate. Consequently, the latter author argues that, in such circumstances, it will be more difficult to introduce innovations.

Extension Method

Buresh and Cooper (1999) found that the role of dissemination and policy in enhancing adoption of agroforestry practices has often been neglected. Caveness and Kurtz (1993) question the fact that rarely agroforestry extension is included in government programmes, although agroforestry information is increasingly available through NGO projects and farmer organisations. This is for example illustrated by a study in Kenya (Karinge 1992) revealing that, in spite of concerted efforts to promote agroforestry, the adoption rate was still rather low, even in areas where the technology was deemed technically, economically and socially attractive by researchers. This situation of low adoption seemed to be the result of three main interactive factors namely, an inadequate and inappropriate agroforestry extension system, the lack of comprehensive legal statutes in land use and of motivation among farmers. The inadequate extension system came about because of lack of a common strategy and coordination by all the agencies concerned. Researchers did not share information while the NGOs did not share their extension material and strategies, nor did they give feedback or reasons for failure or success. The majority of farmers in Kenya had little information and knowledge about agroforestry systems and were, therefore, unable to perceive the agroforestry benefits. Moreover, on the legal side, a number of administrative bylaws were introduced to discourage farmers from planting trees for their own use. These include the requirement of a permit to harvest trees planted by farmers on their own farms, the lack of compensation for trees destroyed by wildlife, the special crops act which discourages intercropping in coffee, and many other cropping systems (Karinge 1992).

Similarly, Adesina *et al.* (2000) demonstrated that adoption of alley cropping in southwest Cameroon was higher with farmers having contacts with extension agencies working on agroforestry technologies. This result is corroborated by other studies showing that continued presence of extension and research agencies in villages positively influences farmer adoption and continued maintenance of their alley farms (Whittome *et al.* 1995). Onu (1991) studied the effect of information availability, credibility, interest, usefulness and frequency of use, on adoption of improved soil conservation technologies in Imo State, Southeast Nigeria. Results tend to emphasize the importance of interpersonal influence in extension communication. However, only 5 out of 10 information sources contributed significantly to the variance in adoption behaviour, namely extension agents, radio programmes, staff of research institutes, fellow farmers and friends, and village heads. Nevertheless, these 5 sources together only explained 39.2% of the variance. Moreover, many of these sources were not very accessible to the respondents. The findings suggested that there exist many other sources not utilised by the extension services. Therefore, Onu (1991) recommended that other sources of farm information are necessary.

On the other hand, many authors (Franzel 1999; Place and Dewees 1999) have identified the availability of essential inputs, seed in particular, as an important constraint to adoption of agroforestry innovations. Likewise, Buresh and Cooper (1999) pointed out that as much as adoption of improved fallows is constrained by lack of information, farmer access to quality germplasm for fallow species and inoculants for nitrogen-fixing species is equally crucial.

Buresh and Cooper (1999) also attempted to sum up the main lessons learned for successful dissemination of improved fallow technologies from case studies presented at the International Symposium on the Science and Practice of Short-term Improved Fallows held in Malawi in 1997. They concluded that:

- The nature of the dissemination message is important and should include information on costs, benefits, and risks of improved fallows.
- Dissemination messages must be relevant to farmers' circumstances.
- Dissemination messages should present a 'basket of choices' to farmers.
- Dissemination will be more successful if farmers have been involved throughout all stages of problem identification, prioritisation, and evaluation of new technologies.
- Monitoring and evaluation is essential to obtain feedback on issues associated with scaling-up.
- It is not fully known which extension methods will work under local conditions. Yet, development organisations including NGOs should take the lead in dissemination, but the research community should play a key role in facilitating the dissemination. Farmer-to-farmer dissemination is usually highly effective, but careful selection of farmers as change agents and trainers is critical.

The same authors also went over issues related to policy interventions and highlighted that:

- Regional or country-specific policy changes can have a large impact on adoption of improved fallows (e.g. fertiliser subsidies removal, etc).
- Clear policies and strategies for tree and shrub germplasm supply systems are required.
- Local communities and traditional leaders should be more actively engaged in formulations for natural resource management, which should encompass thorough review of current land-use policies.

2.2.3 Impact of Agroforestry Adoption: Landscape and Global Scales

Adoption of new technologies is not an end in itself for agricultural researchers, policymakers, or people who employ them in farming or managing natural resources. Rather the outcome of technological change should be evaluated in terms of their contribution to broader goals of sustainable development (Knox *et al*. 2002b). Although there may be trade-offs between agricultural productivity growth, poverty reduction, and environmental sustainability, all are necessary and interlinked.

The potential of agroforestry to rehabilitate degraded land, and to conserve soil and water on the working lands of the tropics, has long been recognized. For example, Izac (2003) points out that soil nutrients and trees are part of natural capital, and natural capital generates ecosystem services which are the processes ensuring productivity, integrity, maintenance and resilience of ecosystems. Ecosystem services generated by soil nutrients include enhancement of nutrient cycles, soil fertility, plant nutrition and carbon sequestration. The ecosystem services generated by agroforestry trees include, for instance, erosion control, water cycling, pest and disease control, and biodiversity. While farmers may be quite indifferent to some of these benefits or ecosystem services, other members of society do value sustainability of food production and biodiversity and there is an international market for sequestered carbon. These environmental externalities associated with agroforestry systems and soil nutrients indicate that what is an optimal level of adoption of agroforestry practices from the viewpoint of farmers is a sub-optimal level of adoption from the perspective of national and global society. Therefore, the extent of agroforestry practices voluntarily adopted by farmers will almost certainly be inferior to that which is socially optimal. Izac (2003) continues by saying that it will not be optimal or effective or equitable to expect resource-poor small-scale farmers in tropical countries to bear the full costs of adoption, while national and global societies receive significant benefits from this adoption. The same argument is voiced by Garrity (2004) who highlights that it cannot be assumed that conservation investments will be attractive to farmers simply because they are known to protect their resource base. The challenge is to make them profitable to adopt. According to Knox *et al.* (2002), this is possible through the appreciation of less tangible economic and social dynamics, which broadens the scope of technologies deemed to be productivity-improving so that they are less biased toward concepts of efficiency that consider only physical inputs and a narrow range of outputs. Izac (2003) argues that policy measures will be needed to bridge the gap between individual and societal benefits and between individual costs and societal benefits.

Box 2-1: Summary of Fundamentals of Diffusion and Adoption

The objective of our literature review on fundamentals of diffusion and adoption was to obtain a better understanding of the dynamics of adoption and the critical factors that determine whether farmers accept, do not accept, or partially accept innovations. The review permitted us to focus our further investigation on key issues that are likely to affect adoption of the proposed agroforestry technologies by resource-poor farmers in our study sites.

Adoption can be described as an innovation-decision process, consisting of five stages: knowledge, persuasion, decision, implementation and confirmation, leading to a decision to make full use of an innovation. The most common way of measuring adoption is through the use of binary variables indicating current presence or not of the technology on a farm. Sometimes it may be sufficient to report on the proportion of farmers using the technology, whereas in other cases quantifying the level of adoption is necessary. It may also be useful to incorporate evidence of prior expansion or farmers' willingness to expand the technology in addition to current use.

Adoption follows a S-shaped curve in which there is slow initial growth of the new technology, followed by a more rapid increase and then a slowing down as the cumulative proportion of adoption approaches its maximum. This in fact reflects a learning process. There is variation in the slope of the 'S' from innovation to innovation. Some ideas diffuse relatively rapidly, in which case the S-curve is rather steep. The rate of adoption can be explained by (1) perceived attributes of innovations (relative advantage, compatibility, complexity, triability and observability); (2) type of innovation-decisions (optional, collective or authority); (3) communication channels; (4) nature of the social system; and (5) extent of change agents' promotion efforts.

Factors affecting adoption of agroforestry practices can be grouped in three categories: (1) characteristics of potential adopters, (2) the nature of the innovation and (3) the way in which the innovation is communicated.

We identified a number of characteristics of potential adopters as key factors to agroforestry technology adoption in the literature. Labour, both the amount and the timing, is often a bottleneck in the adoption of agroforestry technologies. Although they are crucial to adoption - particularly when the proposed technology is complex due to its composite nature, the new tasks it introduces and its multiple outputs - intra-household dimensions and gender-aspects are often overlooked. The mistake that is often made here is to consider women as a homogenous group, whereas there are clear differences in autonomy of decision making between for example single women and female heads that are married. Lack of secure property rights, and unclear or overlapping land tenure are also important barriers to adoption, particularly for long-term investments. In addition, rights to trees and their products may be held separately form the land they grow on and also depend on how the trees are used, who plants them, what species they are and what spatial planting arrangement are used. Furthermore, very few studies have examined the effect of wealth on adoption, although it is obvious that farmers with control over substantial resources (esp. land and labour) and less constrained by food insecurity are able to bear risks associated with trying out new technologies and will place a higher value on medium and long-term benefits. Because adoption of new technologies often requires high investment costs, access to credit has been a key determinant in the rate and success of technology adoption in many cases. More generally, access to rural financial services can provide important incentives to invest in improved land-use practices; both directly through availability of liquidity and indirectly through reduced uncertainty. Finally, the adoption of innovations seems to be higher for farmers belonging to farmer associations. This is because farmer associations disseminate information and serve as a forum for exchange and learning. Group agroforestry plots can also serve as demonstration units to members. Moreover, adoption of technologies that require lumpy investments can be facilitated by collective action, whereas some natural resource management practices require farmers to make joint decisions and cooperate in implementing them.

The first and foremost requirement for an innovation is that it should be economically and financially superior to the current farming system. However, whilst yield per hectare is the best index of productivity where land is the most limiting factor, technologies that give higher returns to labour will have greater perceived advantage in labour-scarce economies. Unfortunately, profitability of many agroforestry technologies is limited by high up-front costs and benefits that only occur some time in future. Moreover, part of the agroforestry benefits stem from reductions in resource degradation (e.g. soil erosion) or other such indirect benefits, which reduces the observability. Several studies have demonstrated the importance of compatibility of agroforestry innovations with existing land-use systems. Their adoption is further enhanced when they build on indigenous knowledge and existing practices. Another predictor of agroforestry adoption is simplicity of the technology in terms of management and number of components. The complexity of a technology will reduce the quality of implementation by farmers, which in turn, decreases the effectiveness.

Finally, the way in which the innovation is communicated considerably affects adoption. Existing literature states that agroforestry extension is rarely included in government programmes, whereas NGOs do not share extension material and strategies with researchers, nor do they give feedback or reasons for failure or success. Farmer-to-farmer dissemination is usually highly effective, but careful selection of farmers as change agents and trainers is critical. In other cases, inappropriate policy discourages farmers from planting trees or adopting natural resource management practices.

At last, adoption of new technologies is not an end in itself, but should be evaluated in terms of their contribution to broader goals of sustainable development. One crucial aspect of agroforestry is its potential to rehabilitate degraded land, and to conserve soil and water. On the other hand, because farmers are usually quite indifferent to some of these ecosystem services, their spontaneous level of adoption will almost certainly be lower to that which is socially optimal. It would, however, not be fair to expect resource-poor farmers in tropical countries to bear the full costs of adoption, while national and global societies receive significant benefits from this adoption. Therefore, policy measures will be needed to bridge this gap.

2.3 A Framework for Assessing Adoption Potential

Franzel *et al.* (2002) in their overview of methods for assessing agroforestry adoption potential, mentioned that conventional approaches to technology generation in the 1960s focused almost exclusively on biophysical variables such as a new crop variety's potential to increase yield per hectare. While this has been quite successful for fairly simple technologies and under homogeneous biophysical circumstances like irrigated rice fields of Southeast Asia, the biophysical approach has proven insufficient for the more complex, variable and subsistence-oriented farming systems of Africa. In the late 1970s and early 1980s, farming systems research emphasized the need to determine adoption potential based on priorities and circumstances of farmers (Byerlee and Collinson 1980). During the 1990s the International Centre for Research in Agroforestry (ICRAF) and other organisations devoted much effort to the design and testing of on-farm research methods, with an explicit view of understanding adoption potential. Assessment of adoption potential was evidenced to be multifaceted, requiring an understanding of biophysical performance under farmers' conditions, profitability from the farmers' perspective and acceptable to farmers (Franzel *et al.* 2002).

*On-Farm Assessment of Biophysical Performance (*Franzel *et al.* 2002)

In order to assess the biophysical performance of a technology on-farm, products and services of technologies are measured and compared among different options (also called treatments). The most difficult issue in on-farm trials is to ensure that the comparisons made are representative of those that farmers would make. Another issue that needs to be taken into consideration is the need for long-term monitoring to be able to assess the biophysical sustainability of different practices. It involves identifying key elements that will be needed over the long term to ensure that the practice will remain feasible, profitable and acceptable to farmers.

Assessment of Profitability

Franzel *et al.* (2002) divide profitability issues into three categories. The first category considers whether the financial net benefits of the new practice are greater than for alternative practices, including those that farmers currently use. Second, it is important to assess the variability of benefits across farmers and seasons, and the sensitivity of the results to changes in key parameters. Third, benefits are appraised relative to total household income in order to assess their potential for contributing to improved household welfare.

Greater financial benefits may arise through increased biophysical productivity or through reduced input costs. To this end, partial budgeting (Alima and Manyong 2000), a technique for assessing the benefits and costs of a practice relative to not using the practice, is often employed, especially for those practices that have limited impacts on the costs and returns of the enterprise as a whole. It takes into account only those changes in costs and returns that directly result from using the new practice. Net returns to farmers' production factors (land, labour and capital) are calculated by extracting purchased inputs from the production value. After subtracting farmers' capital inputs, which are generally minor, the net returns are allocated among farmers' land and labour by valuing one factor at its opportunity cost and by attributing the remainder to the other factor. This permits a calculation of the net returns to land, which is relevant for farmers whose most scarce resource is land, and the net returns to labour, relevant for those who lack labour. In evaluating agroforestry practices, data for a single period are usually inadequate. Therefore, cost-benefit analyses, also called investment appraisals, are developed for estimating resource inputs, costs and benefits over the lifetime of the investment.

Assessment of Feasibility

Farmers' ability to plant and maintain agroforestry technologies depends on three factors: available resources (land, labour and capital), whether they have the required information, experience and skills, and whether they are able to cope with any problems that may arise. Feasibility of a technology is also dependent on its perceived value. Tools for assessing feasibility of a practice include:

- resource budgets (comparing availability of resources with the needs of the practice; e.g. labour requirements);
- evaluation of general biophysical performance of the technology, e.g. survival rates of seedlings planted, amount of biomass produced, etc. and;
- informal or questionnaire surveys with farmers about the problems they experienced whilst implementing the trial.

Assessment of Acceptability

Acceptability includes profitability, feasibility and a range of criteria that are often difficult to quantify, such as risk, general compatibility with farmers' values and farmers' valuation of benefits. One way of assessing risk may be through sensitivity analysis (Alima and Manyong 2000), which assesses the effect on net present value of changes in key parameters, such as prices of inputs and outputs, changes in input-output coefficients and changes in discount rate, as influenced by farmers' time preference and ability to manage risks (Izac 2003). By appraising the effect of likely future market patterns on these sensitive parameters, the economic sustainability of the practice can be evaluated.

Another way of assessing acceptability is asking farmers whether a practice was acceptable, but according to Franzel *et al.* (2002) this is generally not very useful. Rather, acceptability is best ascertained by monitoring whether farmers continue to use and even expand their use of a practice, and whether neighbouring farmers take it up. However, Franzel *et al.* (2002) argue that using expansion or adoption as a proxy for acceptability may not necessarily give a realistic view either. First, in some cases, farmers may be interested in expanding but unable to do so because they lack access to critical information or inputs (seeds). Also, agroforestry technologies take a long time to evaluate and farmers generally need to experience a full cycle of a technology before deciding whether to continue using it.

Methods for assessing biophysical performance, profitability, feasibility and acceptability of improved fallows and vegetative propagation units are described in Chapter 3. Results are presented in Chapters 5 and 6.

In Chapter 5 we assess the biophysical performance of tree and shrub fallows using crop and tree data derived from long-term on-station and on-farm trials. We examine the profitability of tree and shrub fallows over a 10- and 6-year period, respectively. Continuous monitoring of on-farm trials and farmer surveys permitted to assess their feasibility.

Chapter 6 highlights factors affecting plant production in farmer-managed nurseries with a view of explaining the biophysical performance. Chapter 6 also presents the results of the profitability analysis of such nurseries and a summary of problems that farmers face in practicing vegetative propagation.

CHAPTER THREE

EVALUATING AGROFORESTRY TECHNOLOGIES WITH FARMERS: APPROACHES AND TOOLS[1]

Ann Degrande, Zac Tchoundjeu, Steven Franzel and Jacques Kanmegne

'Experiment is the rational foundation of all useful knowledge: let everything be tried'

Anthony Young, 1767 (cited by Pretty, 1996)

3.1 The World Agroforestry Centre's Research Programme in Cameroon

It was in 1987 that the International Centre for Research in Agroforestry (ICRAF) - since 2002 called World Agroforestry Centre - started a research programme in the humid lowlands of West and Central Africa. The programme was first established in collaboration with the Institut de Recherche Agricole pour le Développement (IRAD) as a country project in Yaoundé, Cameroon and was later expanded to other countries of the region, namely Nigeria, Gabon, Equatorial Guinea and very recently (2004) to the Democratic Republic of Congo. ICRAF's mission – alleviating poverty and reducing deforestation through the integration of trees into the cropping systems – remains as valid today as it was when the programme was started (ICRAF 1997). Cameroon is resource-rich but has many poor people. While GNP per capita was USD 575 in 2002, the last census (1996) recorded that just over one half of Cameroon's population was living below the poverty line. Cameroon ranked 141 out of 174 in the Human Development Index for 2002.

[1] Parts of this chapter have been written up in the methodology sections of the following papers: Degrande and Duguma 2000; Degrande 2001; Kanmegne and Degrande 2002; Schreckenberg *et al.* 2002; Degrande *et al*. "Farmers' strategies for growing fruit trees" (in press); Degrande *et al*. "Feasibility of farmer managed vegetative propagation nurseries" (in press)

The region is home of the continent's only substantial remaining area of tropical rainforest, an ecosystem rich in flora and fauna that is fast being depleted owing to various pressures, including increasing human population (2.3 % p.a. between 1995-2001; World Bank 2002) and the practice of shifting cultivation (ASB 2003). In fact, subsequent economic shocks had dramatic effects on Cameroon's rural areas (ASB 2003). In the second half of the 1980s, Cameroon's oil reserves ran out and the international prices of its main export commodities (cocoa and coffee) dropped. In 1989, shrinking export revenues forced the government to stop subsidising agricultural inputs and to halve the prices of coffee and cocoa offered to farmers. These measures were followed, in the early 1990s, by cuts in public sector employment and wages. Finally, Cameroon's currency was devalued in 1994. According to ASB (2003), analysis of satellite images shows that in 1986-96, annual deforestation doubled over its 1973-86 level in areas close to the capital city and quadrupled in more remote, thickly forested areas. Slash-and-burn agriculture is considered responsible for almost 85% of annually deforested surface areas in Cameroon (MINEF 1994). According to Oyono (1998) small-scale farmers have notably increased their cultivated areas, from 0.30 ha to 1.10 ha, in the last ten years.

To address its mission, ICRAF has been devoting resources to two key areas: the development of improved fallow management as an alternative to shifting cultivation; and the domestication and dissemination of local fruit and medicinal tree species (ICRAF 1997).

3.1.1 Soil Fertility Improvement (1988-1998)

In the slash-and-burn systems of the humid tropics, farmers traditionally clear naturally regenerated forest fallows and plant a mixture of crops. After 2-3 years of cropping, the land is essentially allowed to revert to fallow. Santoir (1992) evaluates the minimum period for fallows at three years for cultivation of groundnuts (*Arachis hypogaea*) and 15 years for plantain (*Musa* spp.) of for ngon (*Cucumeropsis mannii*). Nowadays, farmers are facing problems of declining soil fertility and weed infestation due to shortening fallow periods (Sanchez 1995; Gockowski *et al.* 1997). As population density increases in an area, fields are cropped more frequently, leading to a shortening of the fallow period. If the fallow period becomes too short to allow complete restoration of soil fertility, the need to clear and plant larger fields to meet a given production target rises, which in turn results in shorter fallows (Raintree and Warner, 1986). Improved market access and increasing commercialisation of agricultural produce further accelerate this process of intensification.

Food crop production in highly populated areas around major cities of the humid tropics of West and Central Africa is highly dependent on a fallow system (two-four years duration) Shortened fallows dominated by *Chromolaena odorata* have gradually replaced the traditional "bush" fallows in the area. Native to tropical America*, Chromolaena odorata* (L.) R. M. King and H. Robinson is a perennial shrub forming dense tangled bushes of 1.5-2.0 m height , reaching up to 6 m when climbing up trees. The plant was introduced to Cameroon from Nigeria in the early 1960s as a cover crop for cocoa. Nowadays, the plant is usually an aggressive competitor with food crops in southern Cameroon and is one of the dominant weed and fallow species in slash-and-burn farming areas. Ngobo *et al.* (2004) identified some of the properties that render *Chromolaena odorata* a "good" fallow plant: namely, fast development during the fallow phase, thus providing a protective cover and allowing better weed suppression than in fallow systems not dominated by *C. odorata*. However, the same authors recognise that *C. odorata* in fallows may also present serious negative constraints in repeatedly cropped agricultural systems. Its presence is associated with an increased abundance of "nuisance" weeds (such as *Sida rhombifolia* and *Stachytarpheta cayennensis*), grasses, and sedges that are problematic for the resource-poor farmers.

Using Ruthenberg's (1976) formula[2], *C. odorata* dominated fallow systems in the humid forest area of Cameroon are classified by Lanly (1985) as short fallows (R=40%). Where such fallows have been in use for some time, poor soils and grassy weeds with declining crop yields are reported (Gockowski *et al.* 1997). Under these conditions, managed fallows – in which fast growing and nitrogen fixing tree and shrub species are planted for soil fertility improvement and nutrient conservation – become attractive. In response to this, the IRAD/ICRAF collaborative project started research on improved fallows for the humid lowlands of West and Central Africa in 1988 with a programme of testing tree and shrub fallows.

Tree Fallows

In 1988, ICRAF began a long-term on-station experiment to evaluate the potential of planted tree fallows as an alternative to natural fallow regrowth as part of shifting cultivation. In the experiment, trees (*Leucaena leucocephala* and *Gliricidia sepium;* Table 3-1) were planted in rows 4 m apart with a within-row spacing of 0.25 m. From 1990 to 1996, crop yields were greater and nutrient cycling was more efficient in the systems with trees - in which a two-year fallow was followed by two years of cropping - compared to systems with no trees (ICRAF 1996; ICRAF 1997). In further species screening trials and systems improvement experiments however, *Calliandra calothyrsus* (Table 3-1) emerged as a winner for improved fallows, based on its high biomass productivity, beneficial effects on soil nitrogen replenishment and tolerance of moderately to very acid soils (ICRAF 1996; Duguma and Mollet 1997 and 1998; Kanmegne *et al.* 1999). On-station trials (Kanmegne *et al.* 2004) on degraded acid soils (pH=4.5) of southern Cameroon showed good adaptability of *Inga edulis* (Table 3-1). Inga fallows produced more biomass (between 44.5 and 62 t ha^{-1}) than the natural fallow (22 t ha^{-1}) and accumulated more C, N and Ca, but not P, K and Mg. Inga fallow with mulched residues improved the yield of succeeding maize crops fourfold over the natural bush fallow.

On-farm research on soil fertility management in Cameroon first started in 1989. Initially this work focused on assessing the biophysical performance of hedgerow intercropping in researcher-designed and farmer-managed trials. In 1995-96, a socio-economic survey of households involved in the collaborative on-farm testing of the improved fallow technology was conducted. Then, in 1996 ICRAF decided to team up with non-governmental

[2] R = (C*100)/(C+F), where R= ratio (%), C=length of cultivation period, F=length of fallow period

R<33= shifting cultivation or long fallow agriculture; 33<R<66 = short fallow, semi-permanent or stationary cultivation with occasional fallowing; R>66 = permanent cultivation (Lanly 1985) organisations and extension agents in Cameroon to evaluate the adoption of several improved agroforestry techniques. Among the options on offer to farmers were the use of contour hedgerows for erosion control and as windbreaks; improved tree and shrub fallows for soil fertility management; apiculture and fuel wood production; fodder banks for small stock management; and enrichment planting of pasture land for livestock production. (ICRAF 1997). In order to diversify the products obtained from their tree fallows and in particular to help farmers improve their income, farmers were trained in beekeeping using calliandra plots for honey production (ICRAF 1996).

Shrub Fallows

While offering a multitude of opportunities, tree fallows also have characteristics that hamper their adoption by certain farmer categories. First, farmers who do not have long-term tenure rights will not establish tree fallows because trees occupy land permanently. Either those farmers do not have the right to plant trees there or they will not be able to reap the long-term benefits of the trees planted. Second, certain cropping systems are incompatible with tree fallow management. For example, the traditional mixed groundnut fields (*afup owondo*), mainly managed by women, are completely cleared from trees and vegetation residues are burnt. Moreover, groundnut does not tolerate shade. Finally, soil fertility improvement due to trees is only observed after a number of years. Because of this time lag between investment and benefit flows, resource-poor farmers are less likely to adopt tree fallows. In response to the above constraints, a short fallow system with *Cajanus cajan* (pigeon pea) was designed. In the first year, *Cajanus cajan* is intercropped with maize at 1 m x 0.40 m. After maize harvest, pigeon pea shrubs are left in the field until the next year, when they are slashed. Cajanus shrubs are established by direct seeding and occupy the land only for a short period.

Based on promising on-station results of short-rotation shrub fallows, on-farm trials were initiated in 1996 by ICRAF. The purpose was to assess farmers' perceptions of agroforestry-based cropping and to collect biophysical and socio-economic data to evaluate the financial profitability of yield increases under farm conditions. Farmers reacted with enthusiasm and by 1998, not less than 300 farmers were testing the proposed shrub fallow technology

As on-farm activities were expanded and promotion of widespread adoption of tree and shrub fallows was underway, results showed that in areas were farmers still have adequate forestland to clear for agriculture, they are reluctant to invest in tree planting for soil fertility improvement. Instead, their demand for products that would enhance their cash income was pressing. The programme responded to this demand in 1997 by putting more emphasis on the second of the key areas, that is the domestication of high value indigenous fruit and medicinal tree species.

Table 3-1: Characteristics of some soil fertilizer tree species

Scientific name	*Leucaena leucocephala* **De Wit**	*Gliricidia sepium* **H.B. & K**	*Calliandra calothyrsus* **Meissner**	*Inga edulis* **Mart.**
Botanic Family	Fabaceae	Fabaceae	Fabaceae	Fabaceae
Origin	Mexico, probably Central America and West Indies	Central America	Central America	American humid tropics
Biophysical requirements				
- **Altitude**	Low altitude (0-800 m)	Low and mid (0-1200 m)	Mid altitude (2500-1200 m)	Up to 1600 m
- **Annual rainfall**	Humid and sub-humid	Humid and sub-humid	Humid and sub-humid	Humid (min. of 1200 mm)
- **Temperature**	20-26 °C	20-29 °C	22-28 °C	hot
Adaptability to acid soils	Unsuitable (pH > 5)	Tolerant	Very good	Very good
Biomass production*	> 7.0 tons dry foliage/ha/yr 4 tons/ha/yr of dry stakes	5.0 tons dry foliage/ha/yr 1.8 tons/ha/yr of wood	> 6.0 tons dry foliage/ha/yr 5-20 m^3/ha/yr of fuelwood	-
Other uses	- timber - fuelwood - staking material - fodder - suppression of weeds - erosion control	- shade tree - live stakes - fences - erosion control - firewood, charcoal - forage - building material and farm implements	- high-value fodder - pulp and paper production - firewood - apiculture - land rehabilitation	- shade for perennial crops, mainly cocoa and coffee - leaf litter protects soil surface and roots of other plants - fuel wood with high calorific content and little smoke - sweet, white, cottony fruit pulp is popular

* planted at 4 m inter-hedgerow and 0.25 m intra-hedgerow on soil with moderate fertility in the forest/moist savannah transition zone

Source: Adapted from Kang *et al.* (1999)

3.1.2 Tree Domestication (1998-to date)

The word *domestication* has had several definitions and interpretations since its first appearance in English language in 1639. When applied to animals it refers quite narrowly to taming wild subjects and bringing them into the homestead. With respect to plants, there is a spectrum of meanings from nurturing wild plants through plant breeding to genetic modification *in vitro* (Simons and Leakey 2004). Most commonly, the word is used with reference to annual food crop plants that have undergone selection, breeding and adaptation to/in agricultural systems. Tree domestication is a far more recent phenomenon than annual crop domestication and has mainly focused on temperate fruit trees and commercial forestry. Three striking differences between conventional timber-tree improvement and agroforestry-tree improvement exist (Simons and Leakey 2004). These are the number of taxa involved, the industrial rather than subsistence use and the number of stakeholders involved. Agroforestry is concerned with thousands of tree species and millions of subsistence farmer clients influenced by a mixture of government, private sector, community and international partners, each engaged in different and largely uncoordinated activities. In most cases, agroforestry tree improvement has been concerned with on-farm use of firewood, fodder, fruit, live fence, medicinal and fallow trees. The next large change in agroforestry worldwide, which has already started (Franzel *et al.* 2004), will probably come from a greater focus on cultivating trees for cash, and most likely for fruit, timber and medicines.

The main objective of the tree domestication research component of the World Agroforestry Centre in Cameroon is to increase farmers' incomes through the cultivation of high-value indigenous trees in agro-ecosystems. Already in 1994, ICRAF began a tree domestication initiative to bring indigenous fruit and medicinal species into wider cultivation. This initiative sought to: (1) identify priority species, (2) explore, characterise and collect germplasm, (3) capture and propagate superior material through vegetative propagation, (4) integrate the improved material into the farming system and (5) enhance marketing in order that farmers capture a greater proportion of economic rent from sales of tree products (Simons 1996; Sanchez and Leakey 1997; Leakey and Simons 1998; Tchoundjeu *et al.* 1999; Simons and Leakey 2004).

"*Domesticating agroforestry trees involves accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven and market-led process. This is an iterative procedure involving the identification, production, management, introduction and adoption of desirable germplasm and can occur at any point along the continuum from the wild to the genetically transformed state*" (Simons 1997).

Vegetative propagation, as a quick and relative straightforward technique to select, capture and multiply desirable traits in species, plays an important role in the domestication process. Consequently, in designing the tree domestication programme, rooting juvenile and mature plant material was one of the key activities. On-station experiments on rooting of juvenile cuttings in low-cost non-mist propagators (Leakey *et al.* 1990; Tchoundjeu 1997) have generated encouraging results for *Dacryodes edulis* H.J. Lam, *Irvingia gabonensis* Baill., *Ricinodendron heudelotii* Pierie ex Pax, *Prunus africana* Kalkm. and *Pausinystalia johimbe* (Schumann) Bielle (Tchoundjeu *et al.* 1999; Tchoundjeu *et al.* 2002, Mialoundama *et al.* 2002;

Avana *et al.* 2004). In addition, air layering, a method of propagating mature material that may fruit at an early age, has been successfully applied, even though this yielded rather low rates of rooting and survival for some priority species (Leakey and Tchoundjeu 2001).

With a view to test and adapt the technologies to the conditions prevailing in rural areas, a participatory approach to agroforestry tree domestication has been developed since 1998. The programme seeks to involve NGOs and local communities in the development and evaluation of tree domestication strategies, and more specifically in the establishment of nurseries for vegetative propagation (Tchoundjeu *et al.* 1999; Leakey *et al.* 2003).

Tree domestication, however, is not about tree propagation alone, but also about integrating trees in the landscape. According to Simons *et al.* (2000) the largest scope for future tree planting in the tropics will be on agricultural land. Whereas in the past agroforestry was defined as "land-use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land-management unit", it now sees the increasing integration of trees, or agroforestry practices, into land-use systems over time, as akin to a natural succession, moving towards a mature agroforest of increasing ecological integrity (Leakey 1996). ICRAF-African Humid Tropics' Regional Programme therefore has started developing methods and approaches of creating and diversifying multi-strata systems, building on existing cocoa agroforests and compound gardens (ICRAF-AHT 2003; ICRAF-AHT 2004a).

To be successful, tree domestication has to be associated with efforts to seek and expand market opportunities for saleable products, and to determine if they have commercially important characteristics, which should be included in the programme of genetic selection. Accordingly, in addition to identifying producer, trader and consumer preferences, tree domestication includes the development of improved post-harvest technologies and of cottage industries for processing tree products (Garrity 2004). It also involves encouraging farmer group marketing of tree products and empowering farmers with marketing information and with entrepreneurial skills (ICRAF-AHT 2003; ICRAF-AHT 2004a). In this respect, Russell and Franzel (2004) suggest the creation of investment promotion centres, which would provide services as one-stop licensing, market research and feasibility studies, and a national reference library for sector studies and marketing information.

3.2 The Rationale behind Farmer Participation in Agroforestry Technology Development

'People's participation' is one of the critical components of success in agricultural development and a wide range of organisations have attempted to involve people in some aspect of planning and implementation of projects. Yet, there are many ways in which the term participation is interpreted and used. Britha (1995), Pretty (1996), Martin and Salman (1997) and Ashby and Sperling (1998) classify participation in several types, ranging from passive participation, where people are involved merely by being told what is happening, to self-mobilisation, where people act as research partners, take initiatives independent of external institutions and see their skills enhanced. From Table 3-2 it is clear that the term participation can mean many things and should not be used without appropriate qualification.

Table 3-2: A typology of participation

Typology	Characteristics of each type
Passive participation	People participate by being told what is going to happen or what has already happened. It is a unilateral announcement by an administration or project management without taking into account people's responses. The information being shared belongs only to external professionals.
Participation in information giving	People participate by answering questions posed by extractive researchers using questionnaire surveys or similar approaches. People do not have the opportunity to influence proceedings, as the finding are neither shared nor checked for accuracy.
Participation by consultation	People participate by being consulted and external agents listen to views. These external agents define both the problems and solutions, and may modify these in the light of people's responses. Such a consultative process does not concede any share in decision-making and professionals are under no obligation to take on board people's views.
Participation for material incentives	People participate by providing resources, for example labour, in return for food, cash or other material incentives. Much on-farm research falls in this category, as farmers provide the fields but are not involved in the planning of experimentation or in the process of learning. It is common to see this called participation, yet people have no stake in prolonging activities when the incentives end.
Functional participation	People participate by forming groups to meet predetermined objectives related to the project, which can involve the development or promotion of an externally initiated social organization. Such involvement does not tend to be at early stages of project cycles or planning, but rather after major decisions have been made. These institutions tend to be dependent on external initiators and facilitators, but may eventually become self-dependent.
Interactive participation	People participate in joint problem analysis, which leads to action plans and formation of new local institutions or strengthening of existing ones. It tends to involve interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes. These groups take control over local decisions and so people have a stake in maintaining structures or practices.
Self-mobilisation	People participate by taking initiatives independent of external institutions to change systems. They develop contacts with external institutions for resources and technical advice they need, but retain control over how resources are used. Such self-initiated mobilisation and collective action may or may not challenge existing inequitable distributions of wealth and power.

Source: Pretty 1996 (p173)

The common criteria to distinguish between categories used in all classifications are the degree of people's involvement and the stages (i.e. at planning, implementation, evaluation, etc.) of the set of activities in which people participate. In development projects, the evidence to date would suggest that in broad terms people's participation develops along a continuum (Van Rooyen *et al.* n.d.). It invariably begins with passive participation where beneficiaries basically welcome the project proposals and support them, but are generally cautious in relation to becoming involved in project management. This will result in increasing involvement where beneficiaries begin to develop more trust in the project and more contact with its activities and staff; they may also begin to take on some responsibilities. The next step is the active participation where beneficiaries play the role of active partners in the project's planning, implementation and evaluation and assume increasing responsibility. The final stage is ownership and empowerment where beneficiaries are both willing and able to sustain and further develop the initiatives begun by the project. On-farm experimentation should promote nothing less than functional participation and should attempt to reach interactive participation and ideally self-mobilisation, because the process of technology development requires that farmers and researchers work as partners. Involving farmers in this process increases the probability that the practice will be adopted, and the earlier the involvement the better (Franzel *et al.* 2002).

Farmer participation has been seen as especially critical in *agroforestry* technology development. This is due to the poor understanding of farmers' agroforestry strategies, lack of empirical information about on-farm agroforestry practices, agroforestry system complexity and variability (in terms of objectives, components, management and ecological interactions), the longer technology cycle and period required for farmer and researcher assessment and the lack of scientifically validated technologies (Scherr 1991).

3.3 Approaches and Methods to Farmer Participation

Assessments of adoption potential are key elements of a participatory, farmer-centred model of research and development. They improve efficiency of the technology development and dissemination process, help document progress made in disseminating new practices, demonstrate the impact of investing in technology development, provide farmer feedback for improving research and extension programmes, and help to identify policy and other factors contributing to successful technology development programmes as well as the constraints limiting the achievements, as illustrated in Figure 3-1 (Franzel *et al.* 2001).

According to Franzel *et al.* (2002), "*assessing the adoption potential of a technology is multifaceted, requiring an understanding of biophysical performance under farmers' conditions, profitability from the farmers' perspective and its acceptability to farmers (in terms of both their assessment of its value and their willingness and capacity to access the information and resources necessary to manage it well)*". Conventional approaches to technology generation used in the 1960s and 1970s, focusing almost exclusively on biophysical variables, were not effective in promoting adoption (Byerlee and Collinson 1980). Rather, comprehensive assessment of the adoption potential combines elements of various on-farm research approaches in an effort to answer key questions, as outlined in Table 3-3.

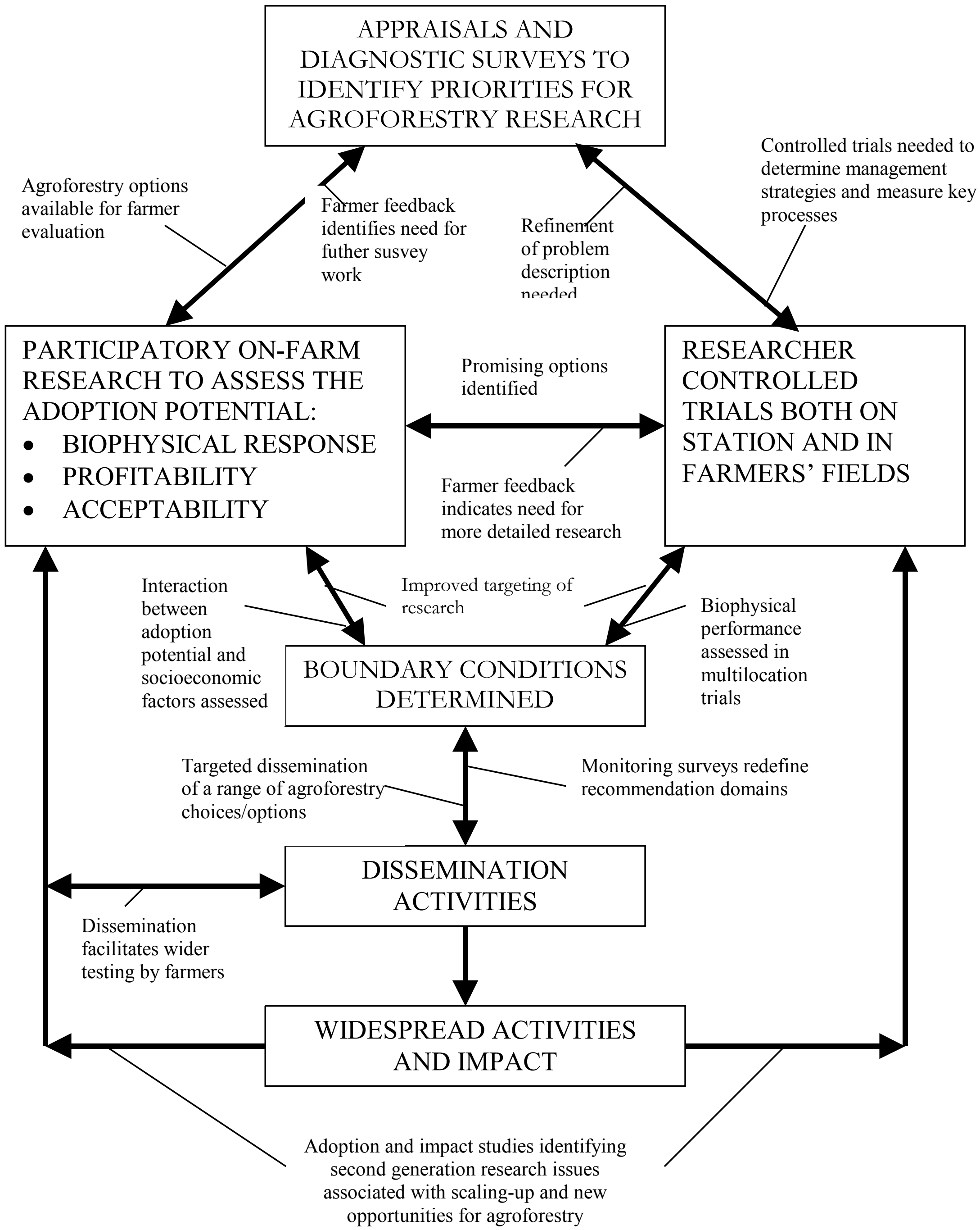


Figure 3-1: Flow diagram of decisions and activities in farmer-centred agroforestry research and extension
Source: Franzel *et al.* (2001), p 40

Table 3-3: Framework for assessing the adoption potential of agroforestry practices

Factors	Key questions
Biophysical performance	Does the practice result in higher yields, lower variability in yields and provide the anticipated (i.e. by research and/or farmers) environmental services? Are these biophysically sustainable?
Profitability	Is the practice profitable to the farmer as compared with alternative practices? How variable are returns, and how sensitive are they to changes in key parameters?
Feasibility and acceptability	Do farmers have the required information and resources to implement the technology, and are they willing and able to establish and manage the practice and cope with problems that eventually will occur? Do farmers perceive significant advantages of using the technology?
Boundary conditions	Under what circumstances (e.g. biophysical, household and community characteristics, market conditions) is the practice likely to be profitable, feasible and acceptable to farmers?
Lessons for effective dissemination: - Extension - Policy	What does farmer feedback suggest will help raise interest of farmers in the practice? What type of extension support do they need most? What types of changes in institutional and legal arrangements, public investments or market conditions would enhance the adoption potential of the practice?
Feedback to research and extension	How do farmers modify the practice? What does farmer experience suggest are research priorities for further modification and development of the practice?

Source: Franzel *et al.* 2002, p 13

In the following sections, we describe the methods used to evaluate the adoption potential of two agroforestry practices, i.e. soil fertility management through improved tree and shrub fallows, and domestication of indigenous fruit and medicinal trees. Methodologies are presented in their geographical and chronological context in Table 3-4 and the location of the research sites is shown in Figure 3-2. First, we sketch the farmer livelihoods approach used to understand the broader context in which farmers operate. Then, we describe the methods used in on-farm soil fertility improvement research: types of on-farm trials, socio-economic surveys and group discussions, financial analysis, pilot dissemination projects and impact assessment. Finally, we portray the methods employed in our participatory tree domestication research: farmers testing, evaluating and adapting vegetative propagation techniques in village nurseries, and the use of demonstration plots and integration trials.

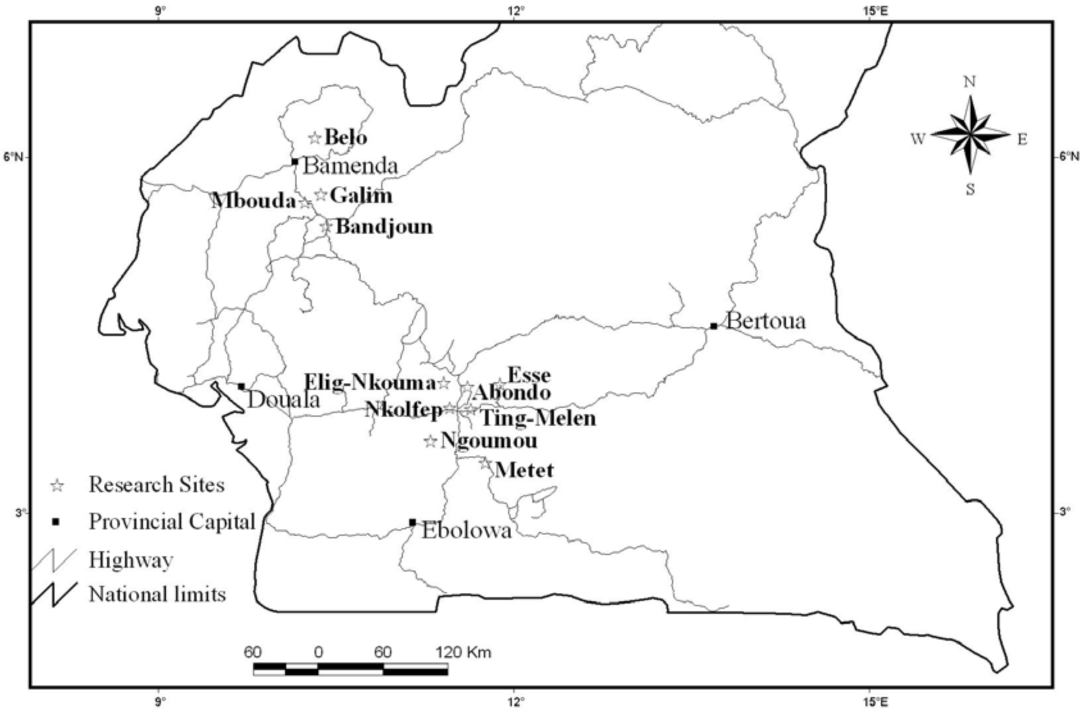


Figure 3-2a: Location of research sites, humid forest and moist savannah zones of Cameroon *(Drawn by Makak 2005)*

Nkom-Efoufoum is bordering Elig-Nkouma and is not shown on the map
Bamboutos is an administrative unit, covering the area around Mbouda and Galim

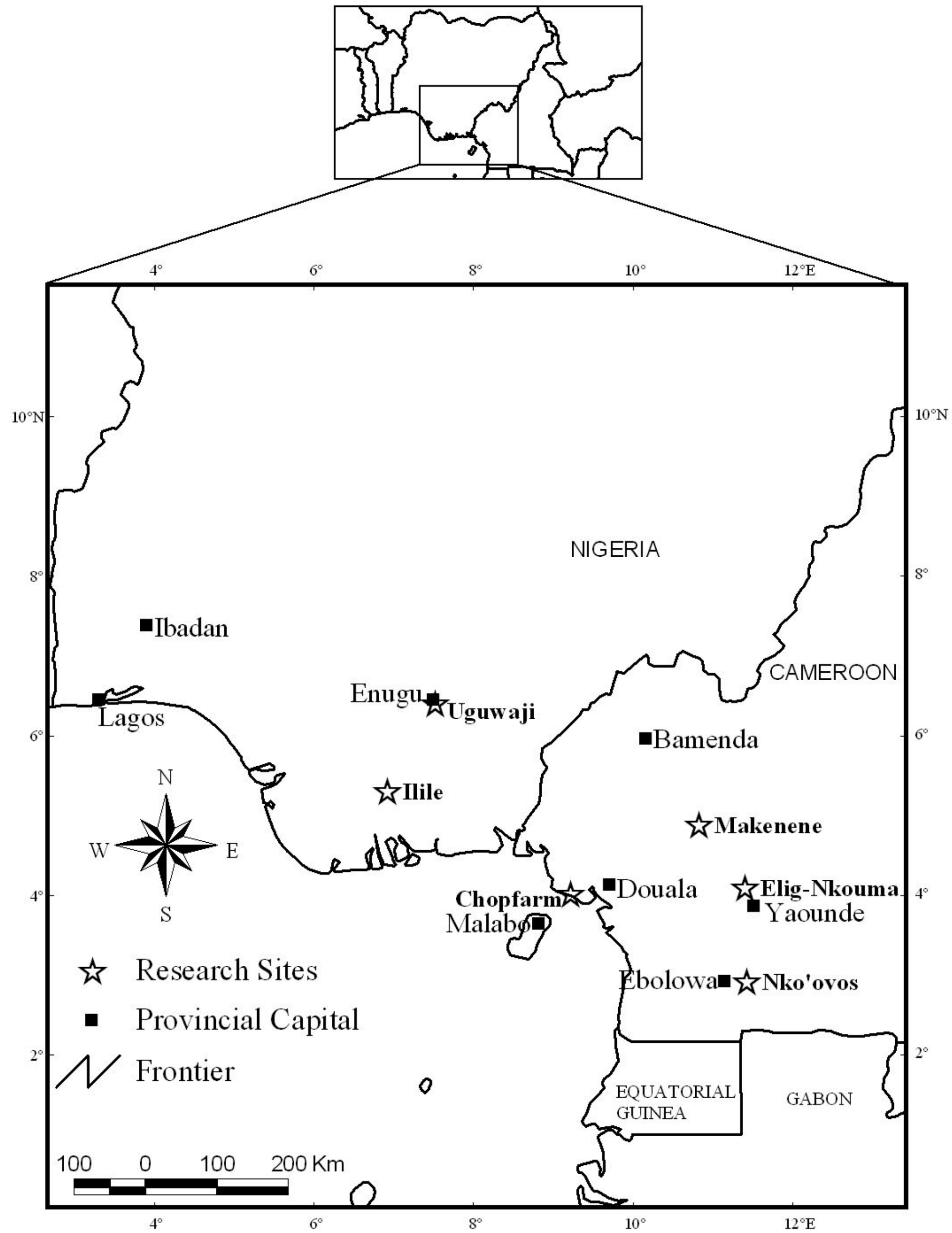


Figure 3-2b: Location of tree inventory research sites, humid forest zone of Cameroon *(Drawn by Makak 2005)*

The sites are: Chopfarm, Nko'ovos, Elig-Nkouma and Makenene

Table 3-4: Timing and location of improved fallow management and tree domestication research from 1994 to 2004 in the humid forest and savannah zone of Cameroon

Technology / Research domain	Research Methods	Year											Research sites													
													Humid Forest										Moist savannah			
		89-94	95	96	97	98	99	00	01	02	03	04	Abondo	Nkolfep	Nkom-Efoufoum	Elig-Nkouma	Esse	Metet	Ting-Melen	Ngoumou	Chopfarm	Nko'ovos	Makenene	Bamboutos	Bandjoun	Belo
Improved Tree and Shrub Fallow	On-farm trials type I & II																									
	On-farm trials type III																									
	Farmer evaluation																									
	Women participation																									
	Financial analysis																									
	Studying spread																									
	Impact assessment																									
	Continued use & expansion																									
Participatory Tree Domestication	Testing of vegetative propagation																									
	Understanding tree nursery performance																									
	Financial analysis																									
	Studying spread																									
	Impact assessment																									
Understanding farmers' livelihoods	Household inventory																									
	Sustainable livelihoods framework																									
	Tree inventory																									

3.3.1 Understanding Farmers' Livelihoods

"*Rural households operate complex farming systems, allocating their limited resources among many enterprises in a manner determined by their priorities, preferences and their biophysical and socio-economic circumstances and constraints*". (Franzel *et al.* 2002) In assessing the adoption potential of agroforestry technologies therefore, a systems approach is required. To unravel the complexities in which farmers operate and make choices, we used the sustainable livelihood analysis method as developed by DFID (1999). This method recognises that households pursue a range of livelihood strategies based on the assets (natural, financial, social, human and physical capital) they have to draw on and the livelihood outcomes they wish to achieve, be it enhancing household income, food security, health, social networks and savings (DFID 1999). In its simplest form, the framework views people as operating in a context of vulnerability. Within this context, they have access to certain assets or poverty reducing factors. These gain their meaning and value through the prevailing social, institutional and organisational environment. This environment also influences the livelihood strategies – ways of combining and using assets – that are open to people in pursuit of beneficial livelihood outcomes that meet their own livelihood objectives (DFID 1999).

Although the sustainable livelihoods framework was used to synthesise findings, the analysis itself incorporated a variety of tools, as presented in Table 3-5. We used a combination of quantitative and qualitative data collection methods (IISD 1995; FAO 2003). We also opted to involve the communities as much as possible in the gathering and analysis of information by using participatory survey tools, carried out with focus groups, such as village mapping, historical profile and Venn diagram. The study was carried out in 8 sites (ICRAF's pilot villages: Abondo, Bandjoun, Belo, Elig-Nkouma, Ngoumou, Nkolfep, Nkom-Efoufoum and Ting-Melen; Fig 3-2) in 2002-03.

Research on livelihoods started with a complete household inventory in the 8 study sites (Table 3-4 and Fig 3-2). We recorded for each household in the community: age and sex of the head of household, household composition (number and age of spouse(s) and children), wealth level and type of livelihood strategy.

In the light of this study and based on previous work, we identified livelihood categories that reflect the household's main sources of income in ICRAF's pilot villages:

1. *cocoa or coffee dominant*. Households that generate their revenues mainly from the "traditional" cash crops, mainly cocoa in the forest zone and coffee in the savannah zone.
2. *cocoa or coffee + food crops*. Households that generate an important part of their revenues from cocoa or coffee, but complement this income with food crops.
3. *cocoa or coffee + market gardening*. Households that generate an important part of their revenues from cocoa or coffee, but complement this income with market gardening (e.g. tomatoes, okra, green maize, green vegetables).

4. *food crops dominant*. Households that generate revenues mainly from food crops
5. *market gardening*. Households that generate revenues mainly from market gardening
6. *other perennials*. Households that generate their revenues mainly from perennial crops other than cocoa and coffee; these may include oil palm, fruit trees, etc.
7. *non-agricultural*. Households that generate their revenues mainly from non-agricultural activities, such as petty trade, pension, casual labour, etc.

Table 3-5: Participatory methods and their uses (inspired by IISD 1995; FAO 2003)

Method	Brief description	Used to collect data on:
Timeline	Historical profile of longer-term events or trends	Vulnerability context; changes in land use and agricultural activities; importance of trees
Resource maps	Maps identifying natural and other resources	Natural capital; land use systems; existence of and access to services and infrastructure
Venn diagrams	Diagrammatic representation of key institutional features and their interactions	Social capital; relations between social groups, institutional and policy environment
Wealth ranking	Assigning households to wealth categories	Socio-economic characterisation of pilot sites; strategies and assets needed to exit from poverty, relations between social groups
Agricultural calendars	Graphical depiction of agricultural activities	Knowledge on farming system; strategies; vulnerability context (peak and lean periods in labour); human capital
Household income & expenditure	Graphical depiction of income and expenditure	Vulnerability context (dearth periods); presence of financial capital

Households were also classified into well-being categories. The criteria and categories used were gathered during earlier participatory wealth-ranking exercises in the zone (Degrande *et al*. in press). First, in each community a list of all households was established. Then, four key informants from the village, two men and two women, ranked households into well-being categories with were grouped to give categories per village using standard wealth-ranking techniques, described in Pretty *et al.* (1995). For the present study, this information was used by enumerators to classify households into well-being categories. It is important to note that these categories are subjective and that comparison of households is only relevant within one village and not across villages.

1. *Very poor*. Households that lack land; generally do not own cocoa or coffee; households headed by very young, very old, disabled persons or immigrants; do not manage their money well (drink too much, lazy, …). These households are not able to send their children to school or to ensure adequate healthcare; the state of their house also indicates the difficulties they must have to make ends meet.
2. *Poor* or *well-being below average*. Households that lack land and/or have a large family, generally don't have cash crops.
3. *Average level of well-being*. Households that generate sufficient income from cocoa, market gardening and/or food cropping, but have a large family and a lot of expenses.
4. *Well-being above average*. Middle-aged households with well-managed cocoa plantations, few children or grown up children or young households doing market gardening; hard working. This category can meet the needs of their household and have no problems with sending their children to school.
5. *Rich* or *well-off*. Households that generate income from non-agricultural activities such as pension, trade, wage labour, households with large cocoa plantations and good management of their money. These households can be identified through their clothing, food, health care, some assets (vehicle, house, …). These people often lend money to others.

From the list of households, we sampled 1 household per combination (livelihood strategy x wealth level) per village and studied their main activities, revenue and expenditure profile. By doing so, a total of 112 households were interviewed[3].

Information more specifically related to numbers and diversity of fruit trees on farms was obtained from a tree inventory in 4 communities in Cameroon (Table 3-4 and Fig 3-2), carried out under a research project funded by the United Kingdom Department for International Development (DFID; R7190 Forestry Research Programme) in 1999 (Degrande *et al.* in press). Here also, a stratified sampling procedure based on the well-being of households was used (Mbosso 1999; Schreckenberg *et al.* 2002; Degrande *et al.* in press). First, in each community a list of all households was established. Then, four key informants from the village, two men and two women, ranked households into well-being categories which were grouped to give five categories per village using standard wealth-ranking techniques described in Pretty *et al.* (1995). From each category, four households were chosen at random for the on-farm inventory. In total, 72 households were interviewed. The researcher and each respective farmer visited all the farmer's plots, whether owned or rented/borrowed. Each plot was categorised by land use (home gardens, food crop fields,

[3] The total number of household interviewed was less than the theoretical number, i.e. (7 livelihood strategies * 5 wealth categories * 8 villages) = 280, because not all combinations were found in each village.

fallow land, cocoa and coffee plantations, oil palm fields and small orchards) and a record made of its tenure status, size (based on farmer and researcher estimate), distance from the homestead, age and land use history. The researcher and farmer systematically walked through each plot and recorded all exotic and indigenous fruit trees, whether planted or not. For each tree, a record was made of species and approximate age (from size), the reason for planting (e.g. for sale, consumption or shade), who planted and where the planting material had been obtained. The inventory data was recorded in an Access database and analysed in Excel and SPSS version 9 (Degrande *et al.* in press).

3.3.2 Methods Used in On-Farm Soil Fertility Improvement Assessment

On-Farm Trials

To evaluate the performance of tree and shrub fallow technologies developed through on-station research under a wide range of conditions, collaborative adaptive research was carried out in farmers' fields with their participation. To ensure partnership between farmers and researchers and better capture their innovative ideas, reactions to the technologies and modifications of the trial set-up and management, three types of trials were established, ranging from researcher-designed and researcher-managed trials to farmers' own experiments. This so-called "type I, II and III trial" approach is used by ICRAF and is well documented (IRA/ICRAF 1996, Franzel *et al.* 1999; Franzel *et al.* 2002). Box 3-1 summarises the specificities of each type and their suitability for meeting specific objectives.

The criteria used in farmer selection for the on-farm trials were availability of a suitable piece of land and willingness to participate. Type II and type III trials had the same treatments as type I trials, but in type III, other layouts and management were possible. The treatments for tree and shrub fallow management research are described in Boxes 3-2 and 3-3 respectively. The farms were regularly visited and information was collected on modifications farmers made in set-up and management, compared to the technologies proposed in type I. In addition to biophysical and socio-economic data collection on tree biomass, crop yield and labour use in type I and type II plots, innovative changes in type III trials were monitored through informal discussions, group meetings and direct observations in the field. Periodic surveys with experimenting farmers were conducted to document their assessment of the technology, such as the management problems they experienced and modifications they introduced.

Box 3-1: Types of on-farm trials

Type I: researcher-designed and researcher-managed. These trials are simple on-station trials transferred to farmers' fields. They are useful for evaluating biophysical performance under farmers' conditions and require the same design rigour as on-station research.
Type II: researcher-designed and farmer-managed. Here, farmers and researchers collaborate in the design and implementation of the trial. Farmers are responsible for conducting all of the operations in the trial. Here it is possible to obtain reliable biophysical data over a broad range of farm types and circumstances and realistic data on costs and returns. The trials are also useful for assessing farmers' reactions to the technology and its management requirement.
Type III: farmer-designed and farmer-managed. Here, farmers are allowed to select an appropriate technology and experiment with it as they wish. This type of trials is particularly useful in identifying farmer innovations and in determining boundary conditions.

Source: adapted from Franzel *et al.* 2002, p15-16

Box 3-2: On-farm trial design for tree fallow management research by ICRAF and partners in the humid forest zone of Cameroon

The trial prototype for assessing tree fallows consisted of planting seedlings of leguminous trees (*Gliricidia sepium, Leucaena leucocephala* and/or *Calliandra calothyrsus*) at the start of the rainy season (early April) at 4 m by 0.25 m and cutting back of the trees after one year at 0.30 m. Prunings were applied as mulch and maize was planted in the alleys. To minimise aboveground competition, trees were pruned before planting and then twice during the cropping phase, respectively 4 and 8 weeks after maize planting.

There were two main treatments:
T1 = a plot with trees planted in rows, with a minimum area of 16 m x 10 m; and
T2 = a control plot without trees with a minimum area of 25 m^2.

Each farm represented a replicate. The tree fallow could either be composed of one of the species, or a combination of 2 species. There were 10 type I trials, 3 with a combination of *Gliricidia* and *Leucaena* hedges and 7 with hedges of *Calliandra*. The aim was to compare tree fallow with natural fallow.

Source: ICRAF 1997

Box 3-3: On-farm trial design for shrub fallow management research by ICRAF and partners in the humid forest zone of Cameroon

The trial prototype for shrub fallows consisted of planting leguminous shrubs (*Cajanus cajan* and *Sesbania pachycarpa*) by direct seeding in rows of 1 m x 0.40 m intercropped with maize, also planted in rows of 1 m x 0.40 m (season 1). After maize harvest, shrubs were left in the field for another growing season (season 2). Then at the next cropping season (season 3), shrubs were slashed, residues were burnt after which maize and groundnut were planted at 40,000 and 200,000 plants ha^{-1} respectively. After this cropping phase, the cycle recommenced with shrub establishment, intercropped with maize, etc.

There were 3 treatments; each plot measured 10 m x 10 m and each farm represented a replicate:
T1 = a plot planted with *Cajanus cajan*;
T2 = a plot planted with *Sesbania pachycarpa*; and
T3 = a control plot with natural vegetation during fallow.

It was, however, observed that during the dry season *S. pachycarpa* shed its leaves and shrub biomass at harvest was accordingly low (IRA/ICRAF 1996). It was therefore decided to eliminate *S. pachycarpa* from further investigations, leaving only two treatments per farmer, i.e. (1) Cajanus fallow and (2) natural fallow.

A total of 10 type I-trials and 32 type II-trials spread over 2 villages were monitored extensively. By the end of 1998, over 250 farmers were experimenting with the Cajanus technology in more than 10 villages, most of them belonging to type III. The objective here was to monitor innovations and management options introduced by the farmers. At the same time, the process of diffusion and expansion of the technology was studied.

Source: Degrande 2001

Socio-Economic Surveys

The feasibility of a technology can be assessed through the ability of farmers to manage this technology, i.e. for example they can establish successfully, cutback and timely prune the trees (Franzel *et al.* 2002). Therefore, feedback about constraints in the establishment and maintenance of the improved practice was formally collected and analysed. Furthermore, farmers' perceptions of the advantages, disadvantages and the extent of the spread of the technology in their environment were assessed.

Farmers' Evaluation of the Technologies
In 1995-6, a survey of 44 households involved in testing the tree fallow technology (type I and type II) in Abondo, Nkolfep, Nkom-Efoufoum and Elig-Nkouma (Fig 3-2) was undertaken. The study aimed to provide baseline data on socio-economic conditions of the households and to test the following hypotheses on key characteristics that are likely to influence adoption of rotational hedgerow intercropping, as stated in the literature (see chapter 2).

- Rotational hedgerow intercropping[4] is more likely to be adopted where farmers perceive a need for soil fertility improvement and for various tree products.
- Security of land and tree tenure is necessary for farmers to establish hedgerows.
- Hedgerow intercropping is a labour-intensive technology and is highly inflexible in the timing of its labour requirements. It is thus unlikely to be adopted where labour is a limiting factor.
- One of the main benefits of hedgerows is soil and water conservation. This is particularly significant in moderately to severely sloping land.
- Rotational hedgerow intercropping is known to suppress weeds effectively during the fallow phase (IRA/ICRAF 1996). Adoption would thus be enhanced where farmers perceive weeds as a problem to cropping.
- Hedgerow intercropping has the disadvantage of providing limited early returns on investment. Unless short-term benefits such as fodder, fuel and stake provisions are of high value, farmers are unlikely to be willing to adopt it.
- Rotational hedgerow intercropping is more likely to be adopted in areas of high land pressure.

After the cropping season in 1998, a formal survey was conducted in the same villages (Abondo, Nkolfep, Nkom-Efoufoum and Elig-Nkouma) with 28 farmers, managing type II shrub fallow trials, to document their assessment of the shrub fallow technology.

Do Women Benefit?

So far, little attention had been paid to women's specific capacities and needs related to improved fallows. In 1997, only 7 out of a total of 95 experimenting farmers (type I, II and III) were women. This low participation (7%) in the development of new agroforestry technologies is regrettable because women play a major role in household food production and natural resource management. To learn more about the reasons behind the low participation of women in the on-farm testing of improved fallows, an ex-ante analysis on the adoption of these technologies by women was carried out as part of this evaluation in 1997 (Ntone 1997). The specific objectives of the study were to identify constraints to and factors favouring the adoption of improved fallows by women in the humid lowlands of Cameroon.

In Ntone's study (Ntone 1997) it was hypothesised that 3 categories of factors limit the adoption of agroforestry technologies by women:

1. factors related to women and their position in society: lack of land and tree tenure rights, less access to information, lower level of education, higher workload;
2. factors related to agroforestry technologies: requiring a high level of technicality, less appropriate to meet women's needs and capacities; and
3. factors related to extension: "gender-bias" in transferring/extending technologies.

These hypotheses were verified using semi-structured interviews and Participatory Rural Appraisal tools, including gender resource mapping, seasonal calendars, Venn diagram and

[4] Rotational hedgerow intercropping (RHI) is an improved fallow system where fertilizer trees are planted at 4 m by 0.25 m, cut back for the first time two years after establishment at 0.05 m above the ground. Subsequently, a 1-2 years intercropping phase is alternated with a 1-2 years fallow phase.

ranking of agricultural activities in 2 research villages, Abondo (40 km north of Yaoundé) and Nkolmetet (100 km southeast of Yaoundé). Most of the interviews were carried out with women groups, formed spontaneously by volunteers willing to participate in the study, and completed with individual discussions with both men and women.

Assessing Impact

When in 1998, ICRAF management in consultation with partners, decided to phase out fallow management research in Cameroon, the need to document the impact of improved fallows arose. Therefore, on 24 August 1999, ICRAF ran an impact workshop. Forty-five farmers, among which 10 female, were selected from all sites where improved fallow activities had been introduced (Table 3-4). All farmers had first-hand experience with tree or shrub fallows on their farms. Other workshop participants included researchers (10) and extensionists (18), representing the collaborating non-governmental organisations and the national agricultural extension service.

The main objectives of the workshop were to:

- obtain farmers' views on the expected impact of improved fallows on their fields, in their households, in their villages (assuming more farmers will adopt and expand) and how to measure this impact (indicators by which impact can be measured);
- elicit farmer expectations of magnitudes of impact and constraints in achieving these levels;
- identify key target groups for future recommendation of improved fallows;
- identify factors affecting diffusion and adoption, and obtain suggestions for an action plan for dissemination of improved fallows.

Participants discussed the above topics in mixed groups (farmers, researchers and extensionists) and presented results in plenary.

Continued Use and Expansion

In August 2003, 5 years after the reorientation of ICRAF's research from improved fallow management to tree domestication and thus the end of active fallow dissemination by ICRAF, a survey was carried out to assess farmers' perceptions on tree and shrub fallows and to identify bottlenecks for continued use and/or expansion of the technologies (Essomba 2003). The survey covered the villages of Abondo, Nkolfep, Nkom-Efoufoum and Elig-Nkouma (Table 4-3; Fig 3-2). A total of 58 farmers (of which 10 female) were interviewed from a list of 83 farmers who had participated in ICRAF's on-farm trials (type I, II and III) between 1988 and 1998. Twenty-five farmers could not be interviewed due to absence from the village during the survey, definitive departure, death or non-availability of local guides. The questionnaire covered the following aspects: continued use of tree and shrub fallows, reasons for continuation or abandon, results of improved fallows, modifications made in spatial arrangement and/or management of trees and shrubs, farmers' efforts to diffuse the technologies, and preference between shrub and tree fallows. The data were entered and analysed in SPSS.

Financial Analysis

To determine the profitability of tree and shrub fallows, net financial benefits were calculated, using the enterprise budget approach described by Alima and Manyong (2000). To do that, results on treatments plots were compared with those on control plots, which represented farmers' current practices of fallowing.

Tree and shrub biomass and crop yields were collected from type I-trials. Data and labour inputs for planting and managing the trees and shrubs were collected by monitoring work rates through observation on-station and in type I-trials. Prices for labour, seeds and agricultural produce were collected from local markets. Then, budgets were drawn up using average yield data from type-I trials. Net present values per hectare to assess returns to land (in which household labour is valued) and net returns per workday to assess returns to labour were calculated, following Franzel *et al.* (2002). The time horizon of the analysis for shrub fallows was six years whereas for tree fallows it was 12 years. The time horizon considered for tree fallows was longer than for shrub fallows because it is expected that trees will take longer to have a visible effect on soil fertility than shrubs. In both analyses, a discount rate of 20 % was used, as suggested by Izac (2003). For the individual farmer's budgets, average data for costs, but farm-specific crop yield data were used. This latter method was used to acquire a better understanding of the variation in returns across farms, and thus the risk of the practice. Sensitivity analysis (Alimi and Manyong, 2000; Izac 2003) was conducted to show the effects of changes in key parameters on returns.

Studying Spread: the Role of Pilot Dissemination Projects

Test and evaluation of tree and shrub fallows in farmer's fields, with strong researcher involvement, had been going on from 1987 to 1996 in ICRAF's pilot sites of Abondo, Nkolfep, Nkom-Efoufoum and Elig-Nkouma in the Centre province of Cameroon (Fig 3-2). In 1996, a technology transfer project funded by USAID permitted researchers to team up with a number of non-governmental organisations (NGOs) and extend on-farm validation of technologies over a wider range of biophysical and socio-economic conditions and a greater number of farmers (ICRAF 1997). In 1998, about 300 farmers spread over Centre (Abondo, Nkolfep, Nkom-Efoufoum, Elig-Nkouma, Metet and Esse) and West (Bamboutos) Provinces (Fig 3-2) experimented thus with technologies for soil fertility improvement; the majority with assistance from NGOs and the National Programme for Agricultural Extension and Research (PNVRA). This type of on-farm research has been proven to be extremely useful to document the process of adapting and adopting technologies by farmers (Franzel *et al.* 2002). At the same time, the process of diffusion and expansion of the technology is studied. This provides lessons for effective dissemination of shrub and tree fallows and suggestions for future research priorities.

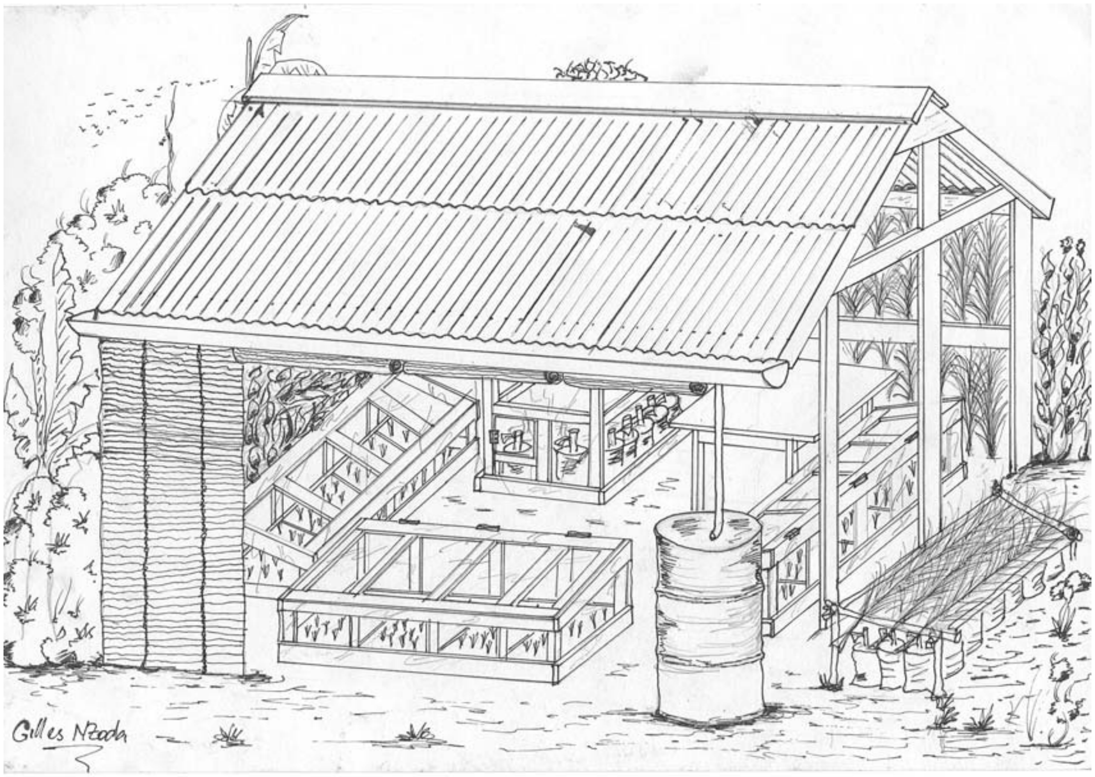


Figure 3-3: Prototype of a vegetative propagation unit, as developed by ICRAF and partners in Cameroon

Figure 3-4: Non-mist propagator, as developed by ICRAF and partners in Cameroon

3.3.3 Methods Used in Participatory Tree Domestication Research

On-Farm Experimentation

With a view to testing and adapting tree propagation techniques with farmers, vegetative multiplication units, as described in Box 3-4 were put in place in pilot villages (Leakey *et al.* 2003; ICRAF-AHT 2003). Pilot nurseries were established on the principle of sharing responsibilities, costs and results. Partner-NGOs played a leading role in the process of identification of farmer groups, organisation and monitoring of day-to-day nursery activities. The farmers provided the land for the nursery, built the nursery shed with local material (in some cases ICRAF supplied zinc roof) and provided timber, sand, gravel and sawdust for the construction of propagators. They further supplied all the labour in the nursery. ICRAF offered nursery tools (watering can, secateur, knapsack sprayer, …) and inputs (polybags, plastic sheets, fertilizer, insecticide) not readily available in rural environment.

Box 3-4: Prototype of a farmer-managed vegetative propagation unit, as developed by ICRAF and partners in Cameroon

Rooting of stem cuttings consists of cutting a portion of a stem with a leaf and axillary bud from the parent plant and then set it in an environment where humidity is high (Tchoundjeu *et al.* 1997). A simple practical tool for this is the non-mist propagator described by Leakey *et al.* (1990) and fine-tuned by Mbile *et al.* (2003). A non-mist propagator (Fig 3-4) is a simple practical tool used in the process of rooting of cuttings. It is made using a wooden frame completely covered with a clear polythene sheet in a view to make it air- and water-tight. The rooting medium lies over two layers of small stones and gravel filled with water, resulting in a permanently humid environment and moist substrate. This technology is well-adapted to rural areas of developing countries. It does not require running water supply or electricity, and it can be constructed locally. Layering, on the other hand, is the development of roots on a stem while it is still attached to the parent plant. The rooted stem is then detached to become a separate plant growing from its own roots. (Tchoundjeu *et al.* 1997). Both techniques have been tested and fine-tuned on a number of indigenous tree species by ICRAF in West Africa and have been under farmer evaluation since 1998.

The prototype of a farmer-managed vegetative propagation unit, as schematised in Figure 3-3, consists of two non-mist propagators and a stock plant area that can accommodate 200 plants for rooting of cuttings. If the farmers also engage in air layering, a humidity chamber for the weaning of rooted marcotts is added. The propagators are covered with a roof to keep out rainfall. The shed for acclimatisation of rooted plantlets awaiting transplantation in the field or sales is covered with palm tree leaves. A fence made of wooden pegs and bamboo to avoid intrusion by animals completes the nursery set-up. Other nursery tools and inputs include watering can, knapsack sprayer, cutlass, spade, secateur, scissors, sharp knife or surgical scalpel, bucket, polybags of different sizes, plastic sheets and fine strings for marcotting, organic or mineral fertilizers and pesticides.

Once these nurseries were operational, a series of farmer trainings on vegetative propagation techniques and the use of a non-mist propagator (Box 3-4) were organised (building and use of propagator, setting of cuttings, evaluation of rooting and weaning of cuttings, general nursery techniques). These training sessions were led by researchers and took place in the villages with the farmer nursery group. Then, one farmer was nominated by the group to ensure daily maintenance in the nursery and the group decided to come together once a week to carry out the more labour-demanding activities such as maintenance of stock plants, setting, evaluation and potting of cuttings, etc.

Six pilot farmer nurseries were established between 1998 and 1999: Abondo, Nkolfep, Ngoumou and Ting-Melen in the humid forest zone; Belo and Bandjoun in the humid savannah zone of Cameroon (Fig 3-2). The knowledge-intensive nature of the approach required that, in first instance, researchers concentrated their efforts in a small number of villages. In this situation, the sites were chosen to represent a variety of socio-economic and agro-ecological characteristics (Table 3-6) as it was hypothesised that understanding the impact of a number of these factors on the success of tree propagation units would help in identifying the most appropriate sites for tree domestication and subsequent dissemination.

In addition to the initial training sessions, technical assistance was provided through follow-up visits by the agroforestry research and extension team at least once a month over the 1999-2003 period. Monitoring and evaluation was done through informal discussions with farmers and yearly evaluation and planning meetings (Degrande 2001b; ICRAF-AHT 2002; Sado 2003; Sado and Tsobeng 2004); regular feedback was obtained from collaborating NGO staff. Records on number of plants produced and integrated in farmers' fields were registered once a year (ICRAF-AHT 2004b).

Financial Analysis

For the financial analysis, the vegetative propagation unit in one of the pilot villages – Abondo (Fig 3-2) - was chosen as a case study because it had been the first to become operational under the ICRAF participatory tree domestication programme. A nursery enterprise budget (Alima and Manyong 2000) was developed in 2002 using potential though realistic production figures instead of actual production. By doing so, the study can be seen as an '*ex-ante*' analysis of the profitability of a vegetative propagation unit. This choice was made taking into consideration the experimental nature of the nursery at this stage. It should be underscored that the establishment of the propagation unit in Abondo was initially aimed at evaluating and adapting vegetative propagation techniques with farmers. Hence, the focus was primarily on understanding the factors underpinning farmers' capability and willingness to propagate trees vegetatively, and not on optimising production or economic performance as such.

Table 3-6: Socio-economic and biophysical characteristics of 6 community nurseries, established by ICRAF and partners in Cameroon in 1998-1999

Community	Agro-ecological zone	Tree diversity	Ethnic group	Population density	NGO involvement	Experience in and attitude towards collective action	Experience with tree nurseries
Abondo	Transition zone forest-savannah	Low	Eton	Average (50 hbt/km^2)	None	Weak	Individual cocoa and fertiliser trees
Nkolfep	Degraded humid forest	Medium	Eton	Medium	None	Weak	Individual cocoa and fertiliser trees
Ting-Melen	Humid forest	High	Ewondo	Medium	CRATAD	Weak	Individual cocoa
Ngoumou	Humid forest	High	Ewondo	Medium	ATD	Weak	Individual cocoa
Bandjoun	Sub-humid savannah	Medium	Bamileké	High (500 hbt/km^2)	CIPCRE	Strong	Individual coffee and fruit trees
Belo	Sub-humid savannah highlands	Medium	Kom	High	CIPCRE	Strong	Group nursery fruit trees and medicinal plants

Cost of infrastructure, equipment, nursery tools and inputs were calculated using local market prices. Labour costs were estimated by evaluating together with farmers the time spent on different activities, using the recall method described by Upton (1987) cited in Franzel *et al.* (2001). The time horizon of the analysis was 5 years, being the estimated lifespan of most of the infrastructure and basic equipment. We supposed that all investment is made in the first year and revenues are obtained from the second year on. A discount rate of 20% was used, as is commonly practiced in the region (Izac 2003). In Cameroon as elsewhere in the region, the techniques of rooting of cuttings and air layering for fruit trees are new; therefore market prices for vegetatively produced plantlets are not yet available. For the purpose of this study and comparing with prices of fruit seedlings and grafts in urban tree nurseries (Mfoumou 2001), sales prices of cuttings were estimated at 1000 FCFA (1.5 €) and marcotts at 1500 FCFA (2.3 €). Sensitivity analysis (Alima and Manyong 2000; Izac 2003) was conducted to show the effects of changes in key parameters on the returns.

In 2004 a similar financial analysis, but using actual production data, was carried out in Lekie-Assi (Djontu 2005[5]). Lekie-Assi nursery has a shed covered with raphia mats and supported by 12 poles. There are 2 non-mist propagators and 1 humidity chamber and a fence made of local material. The stock plant area has 221 plants of different species (e.g. *Dacryodes edulis*, *Irvingia gabonensis*, *Ricinodendron heudelotii*, etc.). Actual production of cuttings, marcotts and grafts were recorded for 2002 and 2003; production for 2004 and 2005 was estimated assuming a 10 % increase per year.

Studying Spread

After the establishment of the 6 community nurseries for experimentation and training purposes, 9 more nurseries were initiated between 1999 and 2002. A number of factors were studied to explain the reasons behind the spread of nurseries:

- Size of nursery groups;
- Distance between the nursery site and the living quarters of the group members;
- Authority structure and cohesion in a nursery group;
- Innovativeness and creativity of group members.

Participation of Vulnerable Groups

As part of our evaluation on adoption potential of tree domestication, we studied participation of vulnerable groups in tree domestication activities in 2004. The main objective was to identify constraints and enabling factors affecting adoption of tree domestication by women, youth and the poorest farmers with a view of designing appropriate dissemination strategies to enhance their participation. To this effect and with the assistance of a B.Sc.-student (Essomba 2004), we held focus group discussions with women, youth and the poorest households in the community in 6 villages where farmers

[5] This study was carried out as part of participatory evaluation of tree domestication by a student Germain DJONTU, under supervision of Ann Degrande in 2004.

have been experimenting with tree domestication techniques since 1999 (Belo, Elig-Nkouma, Nkolfep, Ting-Melen, Nkom-Efoufoum, Bandjoun, Ngoumou and Abondo; Fig 3-2). In each village, focus groups were composed as follows (Table 3-7).

- For the women's group, representatives of women's associations were identified with the help of the leader of the pilot group that is experimenting with tree domestication and the village head. These representatives then invited some of their members to attend the focus group discussions. All female members of the tree domestication pilot group also participated in the discussions.
- To compose the youth's group, all members of the pilot group younger than 35 years, if any, were convened. They were asked to bring their friends along. Invitations were also distributed among the youth at sports events and places where young people normally gather during holiday evenings.
- The poorest categories were identified using participatory wealth ranking, described in Pretty *et al.* (1995) and Schreckenberg *et al.* (2002). In each community, four key informants, two men and two women, identified households from the complete list of households (established during a household inventory; see 3.3.1) that, according to them, belonged to the poorest categories in the community. The interviewer then invited these households personally to attend the focus group discussion. Because poverty is a sensitive issue, the interviewer explained that key persons in the community chose them because they might have some specific information on trees and tree cultivation.

Table 3-7: Number of participants in focus group discussions, per category and per village, for survey on participation of vulnerable groups in tree domestication, June-August 2004, Cameroon

Village	Women		Youth		Poorest category	
	Number	Age range (yr)	Number	Age range (yr)	Number	Age range (yr)
Belo	43	[19-61]	24	[17-29]	4	> 47 yrs
Elig-Nkouma	21	[30-60]	10	[26-34]	3	> 50 yrs
Nkolfep	16	[35-60]	13	[24-33]	Not possible to group persons identified because of their age	
Ting-Melen	Not possible to group women at time of survey		8	[13-25]	Resource persons did not identify this category in this village	
Nkom-Efoufoum	14	[30-69]	19	[17-36]	3	[58-66]
Bandjoun	10	[38-58]	4	[25-36]	3	[58-69]
Ngoumou	28	[26-68]	17	[13-37]	3	[29-58]
Abondo	8	[35-61]	5	[28-34]	2	[56-60]

Source: Essomba (2004)

Using a checklist, the focus groups addressed the following issues:

- knowledge and perception of tree domestication techniques, benefits, disadvantages and requirements;
- reasons for participation in tree domestication and/or constraints to participation;
- problems faced in practicing tree domestication techniques, specific to their category or not;
- strategies to overcome obstacles and suggestions for research and extension;
- diffusion and adoption of other innovations in the community;
- sources of information about innovations;
- experiences working collectively and sharing benefits within the household, in associations/groups and in the community.

In addition to the focus group discussions, we interviewed individually all members of our nursery groups who fell in each of the categories on their knowledge and perception of tree domestication (Table 3-8). A sample of non-participants was also interviewed to find out why they were not involved in tree domestication (Table 3-8). However, as members of the poorest category had never experimented with tree domestication techniques, only non-participants from this category could be interviewed. Topics covered in the questionnaire were almost the same as those discussed in the focus groups, mentioned above.

Table 3-8: Number of interviewees per category and per village for individual interview on participation of vulnerable groups in tree domestication, June-August 2004, Cameroon

	Women		Youth		Poorest category[6]	Total
Village	Participant in tree domest.	Non-participant	Participant in tree domest.	Non-participant		
Belo	4	2	2	1	2	11
Elig-Nkouma	2	2	1	2	2	9
Nkolfep	0	4	0	1	1	6
Ting-Melen	1	1	2	0	0	4
Nkom-Efoufoum	0	1	0	2	2	5
Bandjoun	0	1	0	2	3	6
Ngoumou	1	1	0	1	1	4
Abondo	2	1	1	2	1	7
Total	10	13	6	11	12	**52**

Source: Essomba (2004)

[6] only non-participants in sample because the poorest category was not represented in the pilot domestication groups

Assessing Impact

In November 2004, 6 years after the start of ICRAF's tree domestication programme in Cameroon, two village workshops on the impact of tree domestication on farmers' livelihood were organised. The rationale for holding village workshops was that farmers are likely to identify types of impacts that researchers may be unaware of, whereas impacts important to farmers would be the most critical ones to monitor and evaluate (Kristjanson *et al.* 2002).

The main objectives of the workshop were:

1. to obtain farmers' views on the impact indicators (economic, socio-cultural and ecological) that are important to them and to share with them our ideas on impact;
2. to elicit farmers' expectations of magnitudes of impact and constraints in achieving these levels; and
3. to identify factors affecting adoption of tree domestication in the area.

Two locations were chosen for the workshop: (1) Lekie-Assi, situated at about 70 km northwest from Yaoundé in the humid forest zone and (2) Belo, located in the savannah highlands of Cameroon (Fig 3-2). It was expected that differences in agro-ecology would lead to differences in types and magnitudes of impacts, especially at the economic level.

The majority of participants were farmers who had at least 3 years of first-hand experience with tree domestication techniques. Other participants included extensionists and ICRAF staff. Lekie-Assi hosted 45 farmers, 7 extensionists and 8 ICRAF staff (total of 13 women and 46 men). In Belo, 35 farmers, 1 extension agent and 5 ICRAF staff attended the workshop (total of 16 women and 24 men). Efforts were also made to have a good balance between old and young farmers.

Four simultaneous working groups were convened and they addressed the following topics: impact of tree domestication on: (1) production, productivity and product quality; (2) household economy; (3) farmers' social and cultural well-being; and (4) environment. In the afternoon session, all groups focused on the identification of constraints to the adoption of tree domestication. The organisers opted for one topic per working group to focus the discussion and avoid confusion of impacts at different levels. Key collaborators were chosen to facilitate the group sessions. However, group members designated note takers. After each group session, results were presented in plenary and time was allocated for some general questions or remarks from other participants.

The Missé family from Lekie-Assi in Centre Province
of Cameroon, proudly showing *Dacryodes edulis* fruits

CHAPTER FOUR

FARMER LIVELIHOODS IN THE HUMID FOREST AND MOIST SAVANNAH ZONES OF CAMEROON

Ann Degrande, Kate Schreckenberg, Charlie Mbosso and Chimene Mfoumou

'Not everything that counts can be counted,
and not everything that can be counted counts'
Albert Einstein

4.1 Introduction

The way in which rural households earn their living is becoming increasingly complex. Understanding the diversity of livelihood portfolios and the options rural people develop by integrating new opportunities in order to grow out of poverty is equally complex. Furthermore, farmers in the tropics make decisions regarding a given field or a given practice, such as soil fertility management and agroforestry within the context of the whole farm and of the totality of resources and assets available to them, and not in isolation (Izac 2003). This chapter therefore focuses on understanding issues at the level of households and villages, and on understanding the broader context in which farmers earn their living.

4.2 Presentation of the Humid Forest and Moist Savannah Zones of Cameroon

4.2.1 Socio-economic Context

Population and Social Organisation (www.iss.co.za)

Cameroon is situated in western Africa, bordering the Bight of Biafra (6º00' N, 12º00' E). Neighbouring countries are Equatorial Guinea, Gabon and the Republic of the Congo (Congo-Brazaville) in the south, Central African Republic in the east, Chad in the northeast and Nigeria in the northwest and west (Figure 4-1). Cameroon has a total area of 475,440 km^2 and is inhabited by various ethnic groups. The largest group are the Cameroon highlanders who comprise 31% of the population. Other major groups are the Equatorial Bantu (19 %), Kirdi (11 %), Fulani (10 %) and Northwestern Bantu (9 %). Total population was estimated at 16.2 million in July 2002 with an annual growth rate of 2.36 %. Forty-two percent of the population falls in the age category 0-14 years. Linguistically diverse with more than 200 local languages classified in 24 major African language groups, Cameroon has both English and French as official languages. While the people of the south and west have been profoundly influenced by Christianity, the people of the north are either Muslim or animist and have largely retained their traditional modes of life. One other major contrast in the social geography of Cameroon is between Anglophone northwest and southwest Cameroon, and the much larger, more populous Francophone area of former East Cameroon. The contrasting influences of British and French rule remain evident in many aspects of life.

Economy (www.isss.co.za)

Cameroon has a rich and diversified commodity-based economy. Agriculture was the sole engine of growth and foreign-exchange earning until the late 1970s when oil became the primary source of income. Food and export crops, livestock, fishing and forestry are the mainstay of the economy, accounting for about 29 % of GDP, employing some 50 % of the active population and generating more than half of total export earnings. The petroleum and manufacturing sectors represent 20 % of GDP. The secondary sector contributes 31 % of GDP and employs 15 % of the population. Cameroon is the most important market in the *Communauté Economique et Monétaire de l'Afrique Centrale* (CEMAC).

Most agricultural production comes from smallholders, with the exception of rubber and oil palm, which are run under a plantation system. Millet, sorghum, rice, yam, cassava and plantain are produced for both domestic consumption and for exports to countries within the central African region. The main cash crops, which provide about 40 % of Cameroon's exports, are cocoa (Cameroon is the world's sixth-largest producer; FAOSTAT 2003), coffee and cotton.

With forests and woodland covering nearly 78 % of the country, the forestry sector is the country's second largest export earner after oil, generating around 20 % of export revenues and employing some 55,000 people. There is, however, a great untapped potential in the forestry sector – Cameroon could be one of the major exporters of timber and other wood products but is constrained by the lack of basic transport infrastructure, especially in the tropical rainforest region of the country. Five species, Ayous (*Triplochiton scleroxylon*), Azobe (*Lophira alata*), Iroko (*Milicia excelsa*), Sapelli (*Entandrophragma cylindricum*), and Sipo (*Entandrophorma utile*), traditionally accounted for more than 75 % of Cameroon's timber exports (Ndoye and Kaimowitz 2000). Logging is quite selective and rarely involves clearing of forests. Nevertheless, it significantly disturbs the forests affected, often reduces the availability of commercial timber species, and sometimes encourages hunting and agricultural activities in nearby areas.

Land Tenure

Cameroon's postcolonial land policy, established through the 1974 reform and currently still in force, has instituted the principle of the national land domain. "*The State shall be the keeper of all the lands. In that capacity, it can intervene in order to ensure a rational use or in order to take into account the imperatives defence of economic options of the nation*" (law 74-1 of 6 July 1974). The land law institutes only one judicial form, i.e. absolute and exclusive private property, and one procedure, i.e. the registration. The land title is the official testimony of land property. It can be obtained in many ways: purchase by mutual agreement, donation *inter vivos*, legacy or State's attribution with an obligation to land development. However, in spite of the compulsory aspect of land registration, the majority of farming lands remains under customary occupation (Bigombe and Bikie 1998). In 1987, less than 30,000 of the 1,145,700 rural farms in Cameroon were registered lands (Cameroon Agricultural Census 1987). Customary land rights are usually based on lineage (Stienbarger 1990). Original rights to land were gained through settlement or clearing. Settlers on formerly unclaimed land "founded lineages", which would exercise control over the land in the area. Access to land and generational transfer of property rights are determined by the type of descent groups. In most areas of Cameroon, property rights are passed from father to son. If a man has more than one wife, each wife with sons may be allotted an equal share of the father's land to be distributed among the sons, although the wife may continue to work on the lands she worked while her husband lived. If a man dies without male heirs, his eldest brother will usually get control over the land. It is critical to realise that women are rarely allocators of land rights. Their right to use land generally comes through men, either from a husband as part of his holdings or from other male family members.

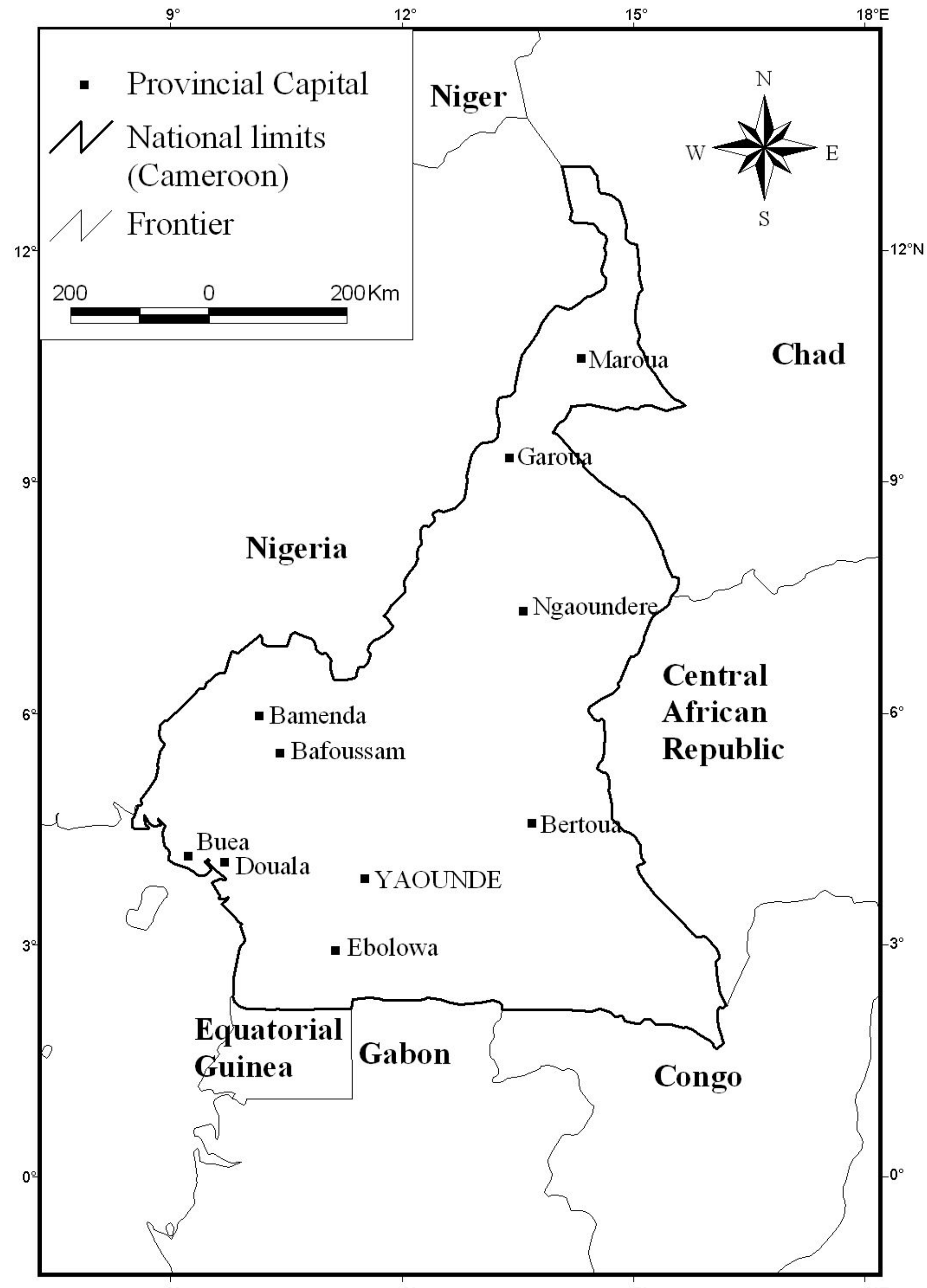


Figure 4-1: Map of Cameroon (*Drawn by Makak 2005*)

Poverty

Similar to most countries in the region, Cameroon has significant natural resources but many poor people. From 1977 to 1985, Cameroon enjoyed an export-led boom based on petroleum, coffee and cocoa (ASB 2003). This boom came to an end in the second half of the 1980s, as the country's oil ran out and international prices of its main export commodities slumped. The fall in export revenues forced the government to stop subsidizing agricultural inputs and to cut the prices of coffee and cocoa offered to farmers. This was followed, in the early 1990s by serious cuts in public-sector employment and wages. Finally, Cameroon's currency, the franc CFA, was devalued in 1994 (ASB 2003). Cash crops, which had earned 123 billion FCFA for rural households in 1984-85, only generated 6.3 billion FCFA in 1992-93 (Amin and Dubois 1999). Food crop production also fell in value from 417 billion CFA in 1984-85 to 378 billion in 1992-93 (Amin and Dubois 1999). Average consumption fell by 30 % from 1983/84 to 1996 (Cida 2000). Education was hard hit by financial constraints faced by the government in the early 1990s. School participation fell from full attendance in 1990 to 81 % by 1996 (Cida 2000). As a result, 29 % of young men and 46 % of young women in rural areas did not finish primary school. Poorly maintained health infrastructure and services – also a consequence of budget cuts since the early 1990s – have led to sharp increases in infant and child mortality rates and a decline in life expectancy.

The macro-economic context has improved since 1995: annual economic growth is stabilized around 5.0 %, inflation was reduced from 5.2 % to 2.8 % per annuum, and the external deficit is maintained at about 2.4 % of GDP (Amin and Dubois 1999). Nevertheless, Cameroon is still beset with an unsustainably high level of foreign debt - an estimated USD 10.9 billion in 2000 (www.iss.co.za). In January 2001, the Paris Club creditors agreed to restructure Cameroon's public external debt under the enhanced Heavily Indebted Poor Countries (HIPC) initiative bringing a reduction in total debt services. The overall improvement of Cameroon's economy remains fragile because it is facing strong competition from outside, fluctuations of world prices for exports, and weak confidence on the part of investors, both national and foreign, in the country's future. The weak confidence is in large part due to the country's extremely poor ratings on indices of corruption, human rights, and democracy. Despite increases in GDP and private consumption per capita, poverty still remains significant. Today, measures of relative and absolute poverty thresholds show not only increasing poverty but also increasing inequality. About 5.6 million of Cameroon's 6.5 million poor live in rural areas, with the most intense poverty occurring in the plateau and forest zones (Cida 2000). In the forest areas, this proportion rises to 66 % of total forest population (Cida 2000). While GDP per capita was USD 559 in 2001, UNDP (2003) recorded that 33.4 % of Cameroon's population was living below the poverty line of USD 1 a day. Table 4-1 summarises some development indicators for Cameroon.

Table 4-1: Some development indicators for Cameroon

Population, total (millions) in 2003	16.1
Population growth (annual %) in 2003	2.0
Rural population (% of total)	51
Forest area (sq. km)	2,386,000
Annual deforestation (% of change, 1990-2000)	0.9

Source: The World Bank, World Development Indicators database, 2003

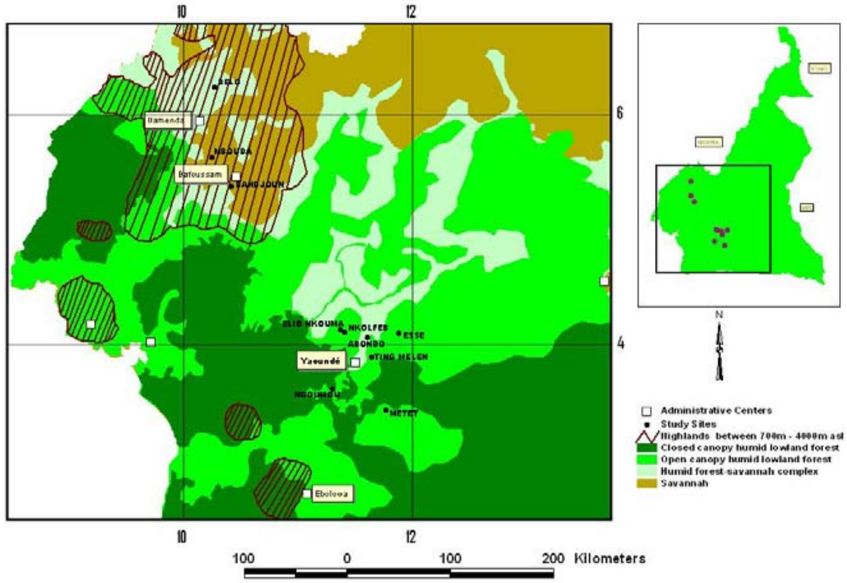


Figure 4-2: Overview of research sites following main vegetation types in Cameroon *(drawn by Mbile 2005)*

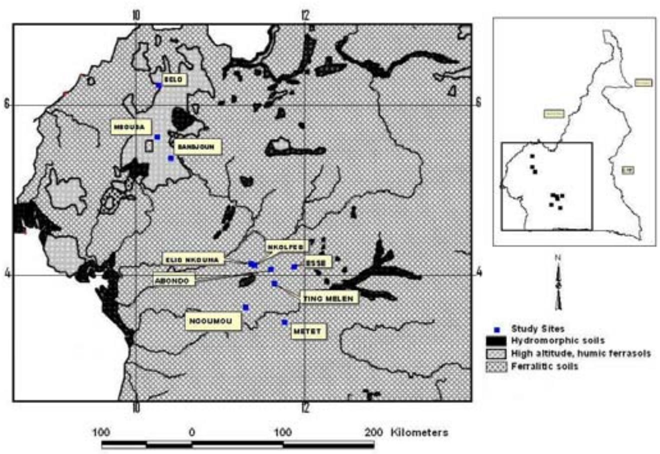


Figure 4-3: Overview of research sites following main soil types in Cameroon *(drawn by Mbile 2005)*

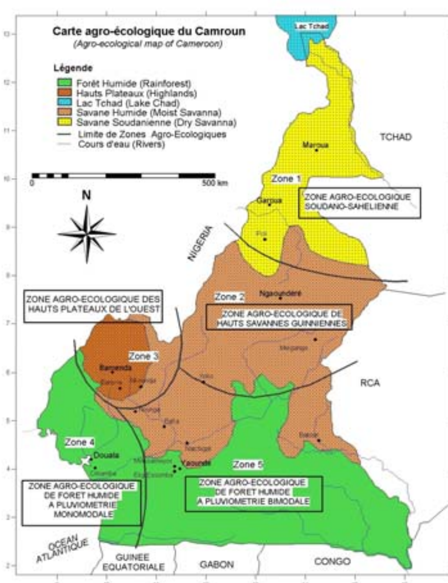


Figure 4-4: Main agro-ecological zones in Cameroon *(IRAD 2004)*

4.2.2 Biophysical Context

Humid Forest

Cameroon's forests are of vital importance to the country's economy, and perform ecosystem functions of immense regional and global importance. The rainforest in Cameroon covers 175,000 km^2 representing about 37 % of the national territory (Gartlan, 1992). The climate of the humid forest is equatorial with two rainy seasons corresponding to two cropping seasons: March to June and August to November. Average annual rainfall is 1692 mm with bimodal distribution (Fig 4-4). Mean daily temperature ranges from 19.2 to 28.6 ^{0}C. The soils are generally classified as Ultisols (Fig 4-3), characterised by low base saturation and a low cation exchange capacity. The climax vegetation is moist closed canopy tropical forest (Fig 4-2) now replaced by a patchwork mosaic of rotational fallow slash and burn agricultural systems and perennial crop systems (Gockowski *et al.* 2004).

The farming system is classified by IFAD (2001b) as a tree-based system, which is providing the majority of agricultural export revenues thanks to cash crops such as cocoa, coffee, oil palm and rubber. Fluctuation of world market prices for these cash crops is causing high vulnerability of such systems, often resulting in serious macro-economic effects for the country. Farming is essentially based on shifting cultivation and mixed cropping. Livestock is of minor importance. Major food crops grown in the area include groundnut (*Arachis hypogaea*), cassava (*Manihot esculenta),* maize (*Zea mays*), yam (*Dioscorea* spp.), plantain (*Musa acuminata*) and cocoyam (*Colocasia esculenta*); major tree crops are cocoa (*Theobroma cacao*), coffee (*Coffea arabica* and *Coffea robusta*), oil palm (*Elaeis guineensis*) and rubber (*Hevea brasiliensis*). Food crops are intercropped with several other legumes and vegetables on relatively small plots (< 0.5 ha). Tree crops are usually cultivated as plantations mixed with other fruit trees, medicinal plants and high-value timber trees. In this type of farming system, short annual cropping periods of 1 to 3 years alternate with 2 to 15 years of fallow. The fallow period is normally required to restore soil fertility, suppress weeds, and reduce pests and diseases through self-regenerating natural vegetation. In recent years however, population densities have increased causing reduction in fallow period length in some areas to 2 or 3 years, leading to enormous degradation of the natural resource base.

Moist Savannah

The moist savannah part of our study zone is situated in the West and Northwest provinces of Cameroon and occupies an area of 31,290 km^2. The climate is characterized by a long rainy season (April to November) and a short dry season (December to March) with annual rainfall varying between 1600 mm and 1750 mm. Maximum temperatures average 22 ^oC and minimum temperatures 17 ^oC (Tchouamo *et al.* 2000). The relief comprises of three parts (FAO-UNDP 1979): plains and valleys below 800 m, highlands with altitudes between 800 m and 1500 m and mountains. The soils of the highlands are classified as Ferralitic, whereas the rest are old volcanic soils. Originally, the whole area was covered with forests, but due to human activities, such as agriculture, pasture, and bush fire, the area is now covered with different types of moist savannah vegetation (FAO-UNDP 1979). The only witnesses of the original forest vegetation, at present, are sacred groves and gallery forests along rivers. However, the population has re-afforested the area with timber (*Eucalyptus*) and fruit trees (*Cola acuminata, Dacryodes edulis, Persea americana, Mangifera indica, Canarium schweinfurthii*).

In 1987, its population was estimated at 2,577,129 habitants with an average density of 82 habitants km^{-2} (Tchouamo *et al.* 2000). This population puts a lot of pressure on the land, resulting in 2 cropping seasons per year with fallow periods of less than 6 months. Main food crops include maize, plantain, beans, yam and cocoyam, often cultivated in association. The principal cash crop is coffee, which is cultivated in an agroforestry system with fruit trees in the upper layer and shade-tolerant crops in the under-storey.

4.3 Farmer Livelihoods

4.3.1 The Sustainable Livelihoods Framework Approach

The concept of livelihoods has moved analysis away from narrow parameters of production, employment and income to a much more holistic view which embraces social and economic dimensions, reduced vulnerability and environmental sustainability, all within the context of building on local strengths and priorities (Shackleton *et al.* 2000). This approach recognises that households pursue a range of livelihood strategies based on the assets (natural, financial, social, human and physical capital) they have to draw on and the livelihood outcomes they wish to achieve. The ability to access various combinations of assets helps to determine how vulnerable or robust a livelihood may be. The livelihoods of the poor are complex and dynamic, typified by a diverse portfolio of activities that not only enhance household income but also food security, health, social networks and savings.

The sustainable livelihoods framework (Figure 4-5; DFID 1999) is a tool to help understand and analyse these so-called livelihoods, particularly of the poor. Like all schematic representations, it is a simplification of the diversity and richness of livelihoods. The framework views people as operating in a context of vulnerability. Within this context they have access to certain assets or poverty-reducing factors. These gain their meaning and value through the prevailing social, institutional and organisational environment. This environment also influences the livelihood strategies – ways of combining and using assets – that are open to people in pursuit of beneficial livelihood outcomes that meet their own livelihood objectives. The livelihoods framework aims to help stakeholders to identify the many factors that affect livelihoods, their relative importance and the way in which they interact. This, in turn, should help in the identification of appropriate entry points for support of livelihoods.

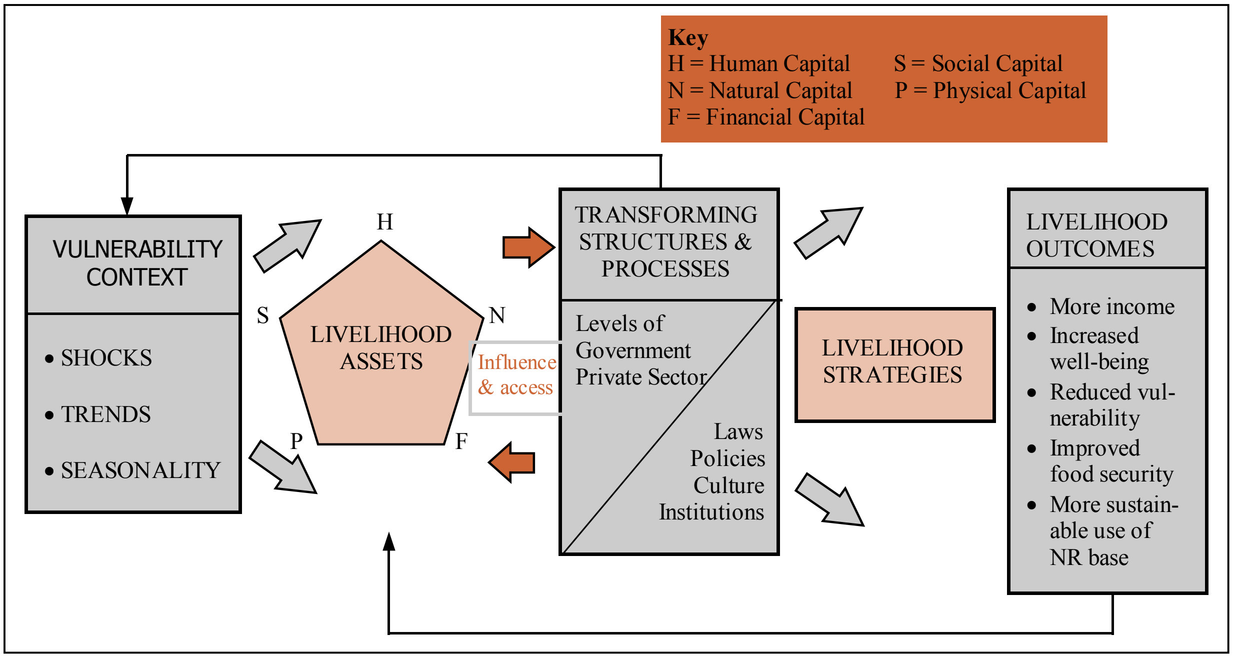


Figure 4-5: **Sustainable livelihoods framework (DFID 1999)**

The **core concepts** of the sustainable livelihoods framework (DFID 1999) are as follows.

- *People-centred*: fully involves people and respects their views in order to support them to achieve their own livelihood goals.
- *Holistic*: attempts to identify the most pressing constraints faced by, and promising opportunities open to, people regardless of where these occur; helps to organise factors which constrain or provide opportunities, and to show how these relate to each other.
- *Dynamic*: seeks to understand and learn from change.
- *Building on strengths*: implies the recognition of everyone's inherent potential, whether this derives from their strong social networks, their access to physical resources and infrastructure, their ability to influence core institutions or any other factor that has poverty-reducing potential.
- *Macro-micro links*: emphasises the importance of macro-level policy and institutions to the livelihood options of communities and individuals.
- *Sustainability*: stresses the importance of livelihoods that are resilient in the face of external shocks and stresses, are not dependent upon external support, maintain the long-term productivity of the natural resources and do not undermine the livelihoods of, or compromise the livelihood options open to, others.

4.3.2 Vulnerability Context

The *Vulnerability Context* (DFID 1999) frames the external environment in which people exist. People's livelihoods are fundamentally affected by critical trends (population, resource, economic, governance, technological) as well as shocks (human health, natural, economic, conflict, crop/livestock health) and seasonality (of prices, production, health or employment opportunities) – over which they have limited or no control. Analysing the vulnerability context comprises of identifying those trends, shocks and aspects of seasonality that are of particular importance to livelihoods.

Historical Trends

Table 4-2 demonstrates the historical profile of one of the study sites. Overall in Cameroon, 4 main historical periods have shaped the economies of rural households as they are today.

1) 1880-1930: German colonisation, settling of population
Most of the villages in the Centre province (forest zone) were created late nineteenth century, when people from the 'Sanaga area' migrated in. The area was still under dense forest and people opened up small plots for subsistence farming. Hunting was also an important activity at that time. With German colonialism and the creation of roads, the population was asked to settle along these axes; the current pattern of houses in most villages is still witness of this movement. Agriculture was not diversified and consisted principally of the traditional groundnut field (*afup owondo*), associated with maize, plantain and cassava for home consumption. However, the Germans introduced some fruit trees like mango, citrus and banana, as well as cocoa and coffee.

2) 1930-1960: French colonisation; intensification of cash cropping and monetisation
Under the French mandate, cocoa farming was intensified as a means of levying taxes. Farmers, faced with the possibility of generating cash, now entered the market economy. The end of forced labour (to build the railway) in the '50s resulted in a rapid expansion of the population in rural areas. Young people stayed in the village and formed families. This phenomenon, together with growing demand for food in urban areas, generated the creation of periodic markets in rural areas. Consequently, food cropping was intensified with the objective of commercialisation.

3) 1960-1990: Independence and economic prosperity
Independence took place rather smoothly and did not much affect rural populations in the forest zone. Agriculture and especially cash crops benefited from government support. The creation of SODECAO (*Société de Développement de la Cacaoculture*) and the emergence of cooperatives boosted prosperity in the villages. It was also during that period that a lot of primary schools were built in the rural areas. This changed life in the villages completely because children could go to school close to home, leaving time free to help the parents in their farms and significantly increasing the number of children attending school.

4) 1990-to date: economic crisis and liberalisation

Things started to become hard for farmers from the mid-80s. The oil crisis and the launching of the structural adjustment programmes increased urban unemployment. A lot of young people came back to the villages and had no other option than to farm. This increased pressure on the land and some farmers had to look for new farmland elsewhere. In addition, cocoa and coffee prices fell drastically and government support stopped abruptly resulting in liberalisation of the sector. Farmers had difficulties in buying chemicals and fertilisers, and in negotiating prices for their cocoa and coffee with the multitude of traders. In 1992, the government (law 92/006) encouraged farmers to group themselves in "Common Initiative Groups" (CIG). The creation of CIGs however was often used with the sole intention of obtaining assistance from NGOs or government services, rather than as a motor to development (Oyono and Temple 2001). As a result of the problems in the cash crop sector, farmers progressively intensified food cropping. This change also affected the traditional distribution of tasks. Men no longer only concentrated on cash crops, but likewise engaged in food cropping for commercial purposes. To date, this intensification of agriculture still continues, although cocoa prices have gone up again in recent years. This is unlike the situation for coffee, which continues to fetch very low prices in world markets. According to IFAD (2001), the demographic growth rate in urban areas of Cameroon has reached 6 % annually between 1960 and 1990. While the growth rate will probably not remain as high as 6 %, urbanisation will continue in the years ahead. To feed urban populations, farmers will have to intensify their food production, employing new techniques.

This historical perspective clearly shows that households adjust to changes in their environment by changing their livelihood strategies. First, farmers increased their food production to cope with population growth. In colonial times, farmers adopted the introduced cash crops (cocoa and coffee) to mark their land and to enter the market economy. Then, responding to ever increasing demand for food in urban areas, households started selling production surpluses and later engaged in commercial food cropping. Confronted with slumping prices of cash crops in the late 1980s, farmers were forced to diversify their activities in order to make ends meet and to keep their living standards. Farmers also formed common initiative groups with an aim of attracting technical or financial support for group or community projects. However, these efforts have often been in vain because of lack of focus in group objectives, lack of group cohesion and inefficient management.

Table 4-2: Historical profile of Belo, moist savannah zone in Cameroon

Period	Event	Impact
1865-1912	Kom people killed 2 Germans	Because of the resistance and courage of the Kom people, the Germans promised to help the Kom people in the future
1919-1926	Arrival of first missionaries	Conflict between Fon and missionaries
1937	Introduction of coffee	Important source of income for farmers
1926-1954	Kom extended their settlement towards Njinikejem, chasing the Babangki; Harmony between tradition and administration; Tree planting was introduced (eucalyptus and tephrosia)	Population growth More farms Windbreaks, fuel wood, timber Soil fertility improvement
1954-1966	Women's riot; Hon. Jua won elections and contour farming was introduced	Ridges along contours to control erosion
1966-1974	Marked development in Kom land; development of churches, schools, technical services of government (ex. MIDENAO)	Social status was raised; facilities in education (secondary school, higher education)
1974-1982	50% of Njinikejem land was given to an individual for ranging	Considerable decrease in available farmland, while population increased; Cattle destroyed crops
1982-1985	Serious exploitation of forest (more farms and unsustainable exploitation of prunus)	Drought => hunger
1987	Electricity	Increase in commercial and socio-economic activities (bars, shops, …)
Late 1980s	Community development organisations formed	Enhanced development: water, health, farm-to-market roads, primary schools, community halls
1992	Sensitisation on forest protection by Birdlife International and introduction of sustainable livelihoods activities	Rate of exploitation decreased Introduction of beekeeping, tree planting
1993	Start nursery initiatives, beekeeping, gardening	Increased tree planting Increased family income
1995	Union of farming groups was formed	Increased tree planting Increased family income
1995	Main road Bamenda – Fundong was tarred	Transport facilitated => increased marketing opportunities
1995-2000	More traders come to the area	Commercialisation increased by about 70%; increased production and increase in family income
1999-2000	Formation of community forest management institutions	Decreased access to forest resources; increased awareness and incentives for tree planting

Source: baseline study 2003

Seasonality Aspects

Farming in the forest and humid savannah zones of Cameroon is characterised by peaks and slacks in labour demand. Tasks such as weeding and harvesting of food crops are very labour-demanding and generally do not allow for much flexibility. Therefore, the months of April-May-June are the busiest for farm households.

In terms of food supply, most (81 %) farmer households in the forest zone are self-sufficient all year round (baseline survey 2003). Those who are not, generally buy tubers and cereals in the months of March and April. In the savannah zone on the other hand, half (50 %) of the rural households were not food self-sufficient all year round (baseline survey 2003). Periods of food scarcity are the same as in the forest zone. These periods correspond to the inter-harvest, when food from the previous cropping season is finished and crops from the current season are not yet ready to be harvested. It should be noted that, unless the household has extra-agricultural activities (salary or pension, temporary jobs, trade), the period of food scarcity generally coincides with the period of income scarcity, hereby increasing household's vulnerability. As shown in an example from Makenene, southern Cameroon (Figure 4-6; Schreckenberg *et al.* 2002), income and expenditure of rural households also follow seasonal trends. The seasonal pattern of income flows, however, differs fundamentally between men and women. Men primarily rely on income from their cocoa and coffee crops, which are harvested around November. Women tend to have a range of activities including food crops (particularly tubers and bananas) that bring them a steady stream of income throughout the year (Guyer 1989). Fruit trees, although often not fully exploited because of conflicting farming activities when fruit harvesting is due, also play an important role in household income generation. Often their total absolute contribution to household income is not very high, but the income is generated at a period where other revenues are rare and/or expenses are high. For example, the period of greatest expense in the year in Cameroon is generally considered to be September/October when school fees and related costs are due. For men this is a particularly difficult period as they rely primarily on income from their cocoa and coffee crops, which are harvested around November. The timing of income from *Dacryodes edulis* (Schreckenberg *et al.* 2002) is such that it covers the cost of school fees when few other income sources are available. Figure 4-7 shows the fruiting period for a number of fruit trees in forest zone in Southern Cameroon. In most cases, fruit trees play a more important role within the women's portfolio than for the men because it is women who take fruit to market for sale. The resulting income is used to pay for the family's daily needs including soap, salt and kerosene.

Fig 4-6a: Main monthly expenditure of women in Makenene Est, Cameroon (*Source*: Schreckenberg *et al*. 2002)

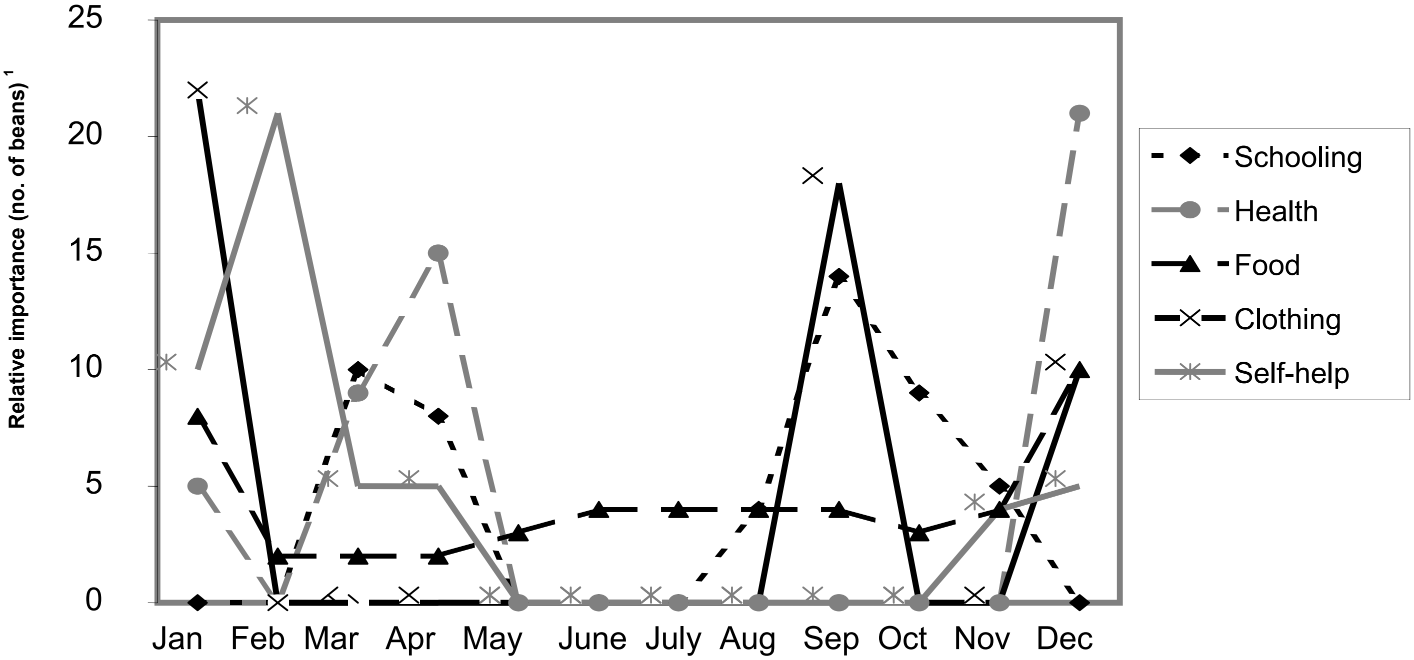
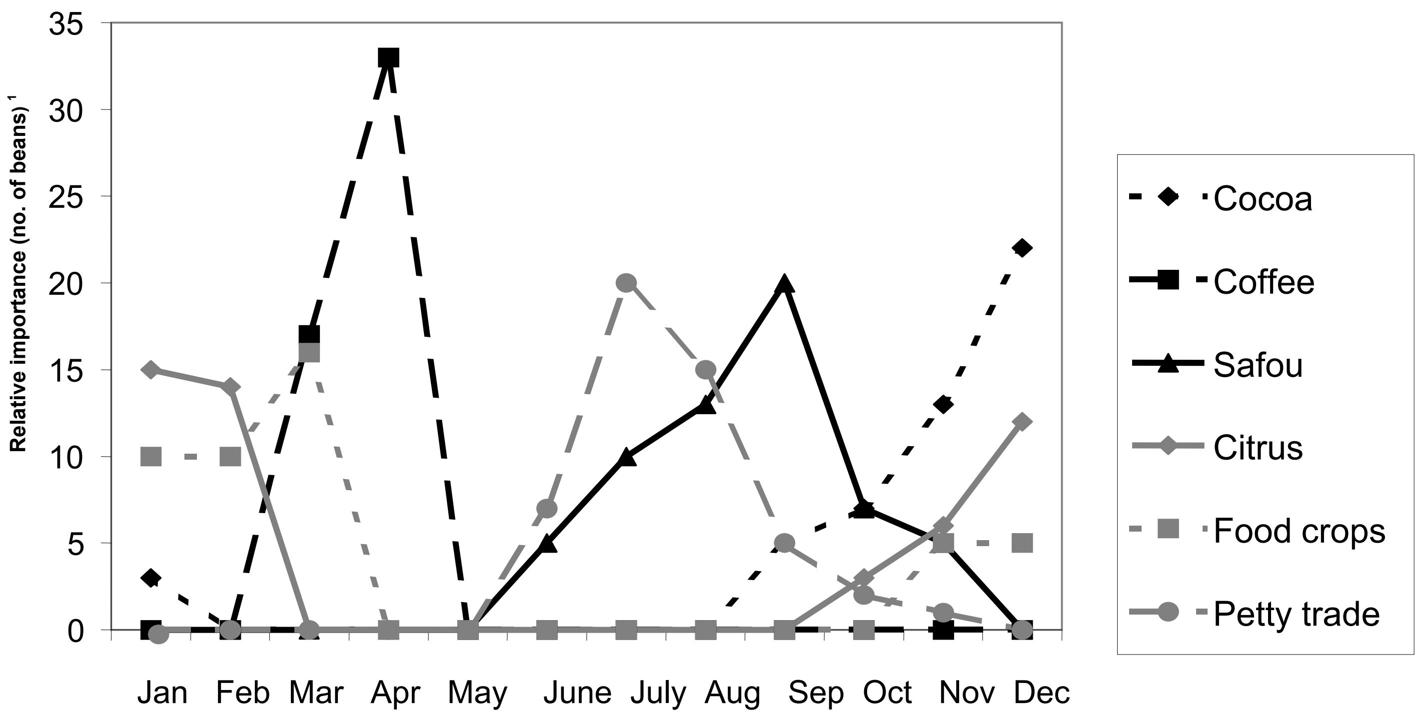


Fig 4-6b Main sources of revenue for women in Makenene Est, Cameroon (Source: Schreckenberg *et al*. 2002)



[1] Participants in focus group discussions estimated relative importance of income and expenditure by distributing a fixed number of beans over their different activities and over the year. The higher the number of beans, the more money is spent on that particular item (Fig 4-3a) or the more important the activity for income-generation (Fig 4-3b)

Except for daily household needs and health, households adjust their expenses to their income flow. Because of lack of saving and credit facilities, major expenses (such as clothing, building and family celebrations) usually are scheduled immediately after cocoa or coffee sales.

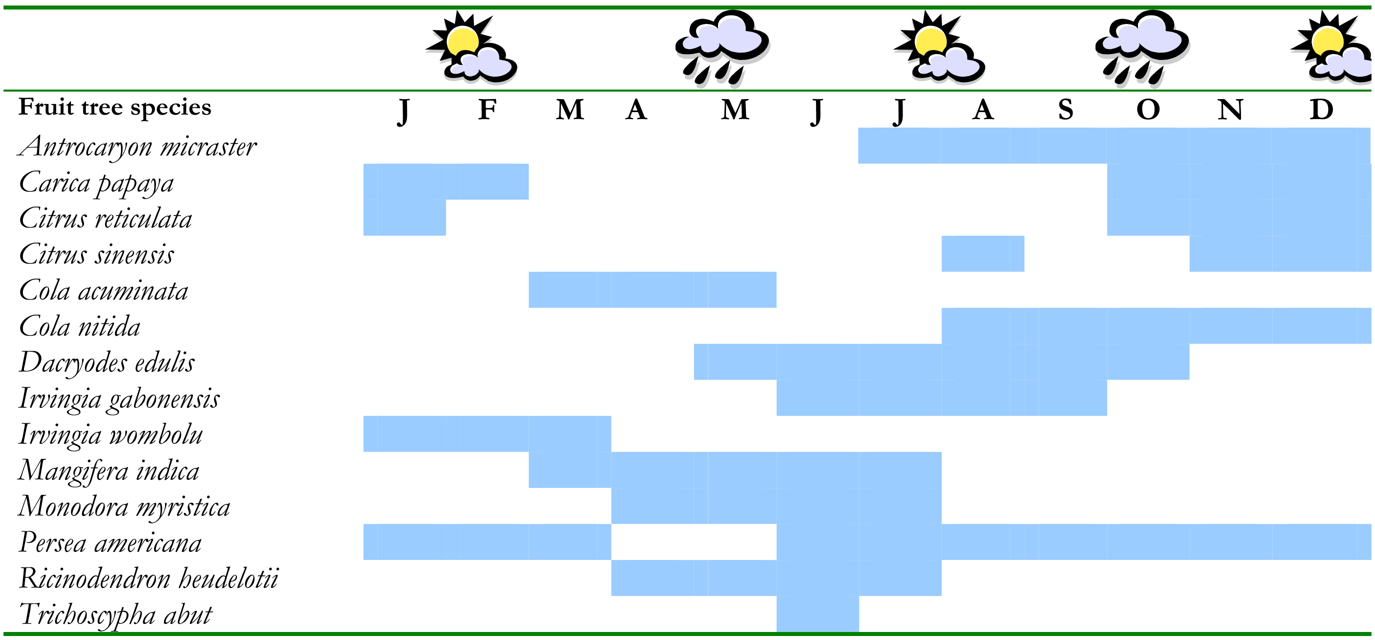


Figure 4-7: Fruiting calendar of some fruit tree species in the forest zone of Cameroon
(*Source:* Adapted from Tassi 2001; Vivien and Faure 1985; Vivien and Faure 1996)

4.3.3 Livelihood Assets

People require a range of *Livelihood Assets* to achieve positive livelihood outcomes. Taken on its own, no single category of assets is sufficient to yield the many and varied livelihood outcomes that people seek. As a result, they have to seek ways of nurturing and combining what assets they do have in innovative ways to ensure survival. Besides, lack of assets is an effect as well as a cause of poverty in terms of income, opportunities, consumption and capability building of people and the institutions they belong to.

a) Human Assets

Human Capital represents the skills, knowledge, ability to labour and good health. At household level, human capital depends on the amount and quality of labour available; this varies according to household size, skill levels, leadership potential, health status, etc. (DFID 1999)

Human development indicators for Cameroon (Table 4-3) are comparable to those of other countries in the central African region. The situation is of course worse for the Democratic Republic of Congo, coming out of five years of conflict, while it may be better for oil-rich countries such as Gabon and Equatorial Guinea, at least in urban areas. Growing poverty, decreasing public investments and escalating corruptive practices in education and health, however, are reasons for concern and may affect human capital negatively in years ahead. Unemployment in Cameroon is one of the highest in Africa: 24.6 % of the urban population is unemployed. Unlike in other developing countries, the higher the education level the higher the unemployment rate in urban areas. One third of the active population with a university qualification are seeking employment, while just 6.4 % of those without education are unemployed (Amin and Dubois 1999).

Table 4-3: Some human development indicators of Cameroon

Male life expectancy at birth, 2002	45.6 years
Female life expectancy at birth, 2002	48.1 years
Total fertility rate, 2000-2005	4.6 per woman
Infant mortality rate, 2002	95 per 1,000 live births
Under-five mortality rate, 2002	166 per 1,000 live births
Physicians, 1990-2003	7 per 100,000 people
Undernourished people, 1999-2001	27 % of total population
Children underweight for age, 1995-2002	21 % under age 5
Malaria-related mortality rate, all ages, 2000	108 per 100,000
Public health expenditure, 2001	1.2 % of GDP
Male adult literacy rate, 2002	77.0 % age 15 and above
Female adult literacy rate, 2002	59.8 % age 15 and above
Population with sustainable access to an improved water source, 2000	58 %
GDP per capita, 2002	575 USD
Population living below USD 1 a day, 1990-2002	17.1 %
Share of income or consumption, poorest 10%	2.3 %
Share of income or consumption, richest 10%	35.4%
Human Development Index Rank	141

Source: UNDP Human development report 2003 (http://www.hdr.undp.org/statistics/data/cty_f_CMR.html)

Another epidemic likely to affect workforce in rural areas is HIV/AIDS. UN statistics (UNAIDS 2004) reported an adult HIV infection rate of 6.9 % in 2003, while unofficial sources estimate HIV prevalence rate to be closer to 11 %. This rate is one of the highest in Central Africa. In 2003, 49,000 people died of AIDS according to UNAIDS (2004).

During our baseline survey (details in 3.3.1) in 8 villages, we enumerated a total of 789 households of which 162 (20%) were female-headed. Details on population, and human and natural capital assets per village are presented in Tables 4-4 and 4-5.

Table 4-4: Population in study villages, humid forest and savannah zones of Cameroon

	Total number of households	% female-headed households	Total population
Abondo	104	16	700
Nkolfep	92	35	490
Nkom-Efoufoum	153	11	866
Elig-Nkouma	60	13	334
Ngoumou	106	32	661
Ting-Melen	58	24	199
Bandjoun	68	44	533
Belo	148	8	418

Source: Baseline study, 2003

Most households in the study sites seem to have at least 1 male and 1 female adult, and between 2 to 5 children under 15 years, living permanently in the household (Table 4-5). From this, it seems that farm work and off-farm activities, on average, rely on the head of the household and his wife, with the help of 1 other adult, often being the father or mother or a son or daughter, aged 15 or older. During weekends and holidays, younger children may help a hand, especially during land preparation, weeding and harvesting, which are traditionally peak periods for labour demand.

Our baseline survey showed that, on average, heads of households in the study sites are middle-aged and the majority has had primary education, suggesting that they are able to understand extension messages without problems. Moreover, a study in Esse area in the centre province of Cameroon (Bikoue 2004) revealed that more than 90 % of the interviewed farmers spoke French in addition to their local languages.

The study did not record number of years of experience in farming, but Bikoue (2004) showed that farmers in Esse, centre province of Cameroon, had on average 19 years of experience in agriculture. This suggests that most households are familiar with their environment and have developed adapted farming skills.

Table 4-5: Human and natural capital assets in study villages, humid forest and savannah zones of Cameroon

Mean figures	Forest study villages						Savannah study villages	
	Abondo	Nkom-Efoufoum	Ting-Melen	Elig-Nkouma	Ngoumou	Nkolfep	Bandjoun	Belo
No of households interviewed	16	12	11	16	17	10	15	15
Household size	7.44	7.33	4.55	5.88	5.06	6.00	8.27	5.93
No of adult males	1.69	1.50	1.27	1.69	1.18	0.90	1.27	1.47
No of adult females	1.56	1.33	1.36	1.25	1.41	1.30	1.87	1.67
No of male children	2.50	2.58	0.91	1.63	1.76	2.60	2.73	1.60
No of female children	1.69	1.92	1.00	1.31	0.71	1.20	2.40	1.20
Age of household head	44.38	46.50	56.27	42.56	51.59	51.60	59.80	53.07
% of household heads with education level of CEPE (primary school) or above	31.2	58.3	54.5	75	76.5	80	33.3	64.3
Total farm size[1] (ha)	11.13	2.87	8.16	8.92	6.20	4.94	1.74	4.72
- Area under perennial crops	3.03	1.09	1.68	2.58	1.62	1.06	0.13	2.02
- Area under food crops	3.63	0.82	1.25	2.05	0.93	1.31	1.01	1.53
- Area under fallow	4.47	0.96	5.23	4.07	3.65	2.58	0.60	1.17
Average fallow period (years)	3.13	2.17	4.55	3.86	4.06	2.78	0.33	0.94
% of households that have purchased or rented land	12.5	0	0	6.3	11.8	10.0	35.4	14.3
% of households that are food self-sufficient all year round	93.8	75.0	100.0	68.8	64.7	80.0	53.3	46.7

Source: baseline study 2003

[1] Farm size was estimated by the farmer with help of the enumerator. For each farming system, dimensions of all the fields were estimated and summed to obtain total area under perennial crops, area under food crops and area under fallow.

b) Social Assets

Social Capital (DFID 1999) means the social resources upon which people draw in pursuit of their livelihood objectives. These are developed through networks and connectedness, membership of more formalised groups and relationships of trust, reciprocity and exchanges.

According to Amin and Dubois (1999), social capital, or relational goods, may be understood to mean "*a combination of cultures, relations, interconnections, and synergy that enables average social productivity to be higher than that obtainable by individuals with the same level of human and physical capital operating in isolation or in a different relational system*". Social capital can have a great effect on poverty and consequently cannot be dissociated from poverty alleviation policies.

Amin and Dubois (1999) recognise that at the micro-economic level, social capital involves the various links among family members; whereas at the meso-economic level, it covers the action of various groups of people—such as NGOs, for example;

Micro-Economic Level
In relations within the family, social capital is expressed by a series of obligations that generate financial transfers through giving gifts, participating in funerals, fostering and educating children, and so forth. These obligations also generate rights in the community, such as decision-making role and participation status, and allocation of land. Amin and Dubois (1999) found that during the economic crisis of 1986–94 in Cameroon, these family links helped households overcome the crisis's financial impact. Then, with the deepening of the crisis, these links began to loosen, generating various situations of social debt. After currency's devaluation and growth revival, the first objective was to reimburse this social debt and reinforce these social links.

In our baseline survey of 2003, we found that the proportion of household revenue from remittances only constituted 0.1 % in the forest and 7.2 % in the savannah zone. However, female-headed households usually relied more on remittances than male-headed households. Female-headed households in the savannah and forest zone respectively drew 44% and 0.4% of total revenue from remittances. The proportion of total household expenditure used for gifts and social assistance made up 4.7 % in the forest and 8.9 % in the savannah zone. There was no remarkable difference between male and female-headed households. From the above, it seems that people in the savannah zone have slightly stronger social bounds than in the forest zone.

Meso-Economic Level
The following groups or associations exist in all ICRAF pilot villages: farming groups, mutual aid groups, cultural groups and church associations. Many of the groups are mixed, although some are exclusively for women and others for men. In addition, political parties often have representations at the community level. The groups that are mostly in contact with NGOs, extension services and projects from outside the community are farming groups, often with a legal status of Common Initiative Groups (CIG), according to the Cameroonian law 92/006 of 1992 on CIGs and cooperatives (Oyono and Temple 2001). They may have a variety of activities from agriculture, bee keeping, fish and poultry farming

to cooperative commercialisation of agricultural products and cocoa/coffee. Mutual aid groups are formed to foster solidarity in the community; the members contribute regularly a certain amount of money that feeds into a solidarity fund, which is used to assist members during happy and sad events (weddings, birth, burials, …). Moreover, these groups also function as informal saving and credit organisations ("*tontines*"). These groups are extremely important for rural households since they constitute a safety net in times of hardship. Church groups come together to pray, to maintain church buildings and cemeteries and to help the priest in his duties (parish committee). Each parish also has its choir(s). As an illustration, Figure 4-8 shows the different organisations operating in Belo and the interactions between them.

It seems that groups of all kinds play an important role in the life of rural households. It is difficult to find somebody who does not belong to a group. In the study sites, 80 % of the heads of households and 79 % of their spouses belong to at least one association. Most people even belong to different groups at the same time. Therefore, it is quite surprising that the interaction and collaboration between different groups in the village is generally weak or even non-existent. This lack of interaction between groups also poses problems for external organisations, wanting to reach a great number of people in the community by introducing new technologies to specific groups. The underlying rationale for this is that the innovation would spread from one group to another; and that this would be quite easy as people belong to different groups at the same time. However, this assumption is rarely confirmed in the field. Moreover, experience has shown that innovations do not diffuse automatically through that channel. When asked about major sources of information on agricultural and health issues (Essomba 2004), people ranked "groups" only fifth, after family, neighbours, research organisations and NGOs. Also, women tend to receive more information from groups then men and youth.

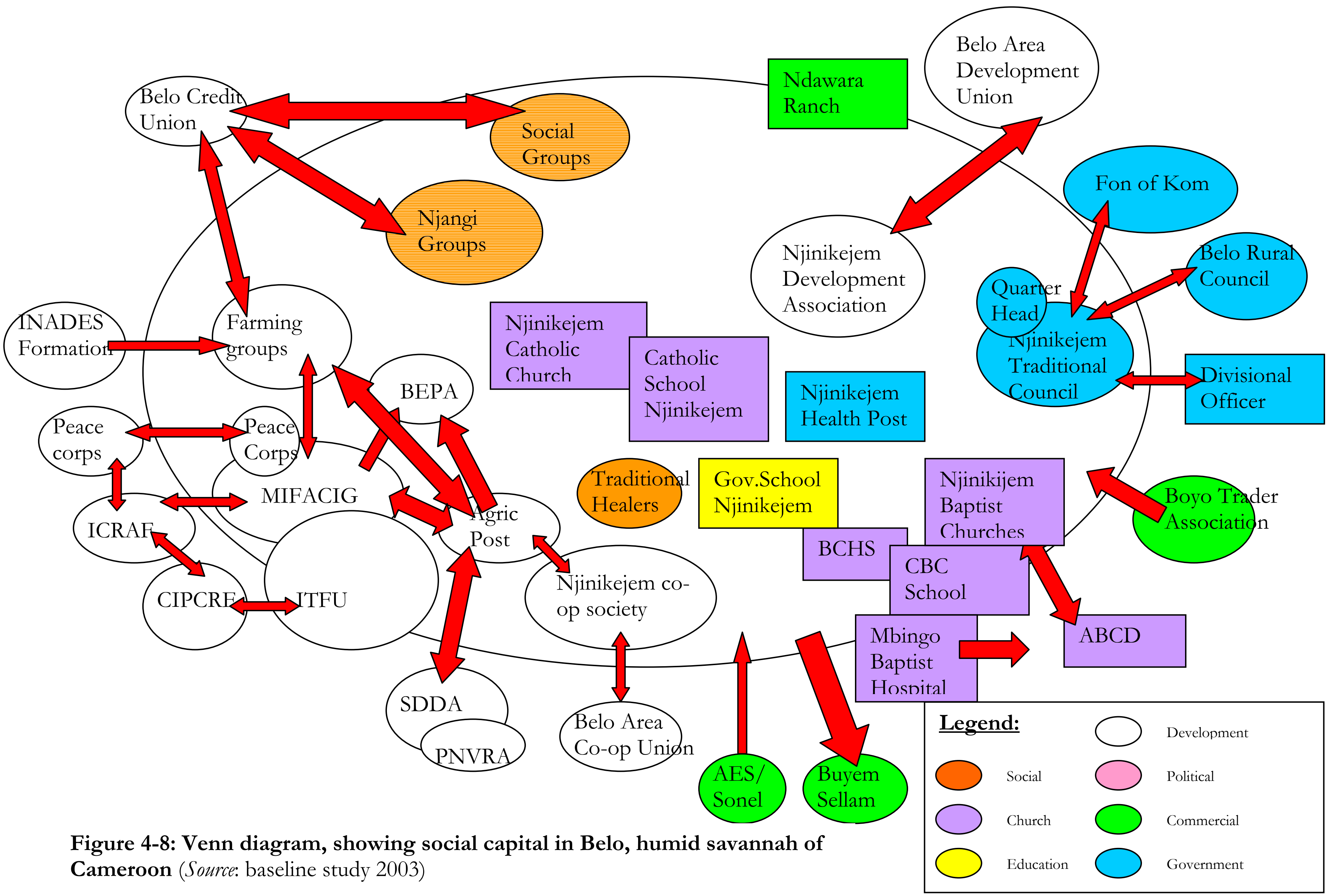


Figure 4-8: Venn diagram, showing social capital in Belo, humid savannah of Cameroon (*Source*: baseline study 2003)

c) Natural Assets

> **Natural Capital** is the term used for natural resource stocks from which resource flows and services are derived; examples are: land, forests, natural resources, water, erosion protection, biodiversity degree and rate of change (DFID 1999).

In agrarian societies, natural resources are key assets. Therefore, wealth is intricately linked to property rights over natural resources. Abondo, Nkolfep, Nkom-Efoufoum, Elig-Nkouma, Ngoumou and Ting-Melen are located in the forest zone of Cameroon, characterised by semi-deciduous forest vegetation, orthic ferralsols and a bimodal rainfall pattern (April-July and September-November) allowing cultivation of a diversity of crops twice a year (Figure 4-9). Natural forests have disappeared almost completely in these villages, although some patches of secondary forest or old fallows still subsist (Figure 4-11). Almost all the land in these villages is under private ownership, this means that land is owned by households or families and is inherited from father to son. Tree ownership is closely linked to land ownership. Where land is rented, farmers usually do not have the right to plant perennial crops except in agreement with the landlord. Generally, if land is sold, the purchaser obtains all rights to trees on that land. Land-use systems comprise of homegardens, cocoa plantations, food crop fields and fallows. The main cash crop in the study sites in the forest zone is cocoa. Farming is characterised by mixed food cropping based on groundnut, cassava, plantain and more intensive monocropping of horticultural crops and maize, especially where market access is good. Dry season cropping (mainly of vegetables and maize) is practiced in the swampy areas along streams. Despite increasing population pressure, short fallows (2-4 years) are still commonly practiced and form practically the only means of soil fertility management in these areas.

Most fruit trees are found in cocoa fields and in homegardens. A full-farm fruit tree inventory (Degrande *et al.* in press) in 4 communities (3 in the forest and 1 in the forest-savannah transition zone of Cameroon) identified 34 fruit tree species, of which 22 were indigenous. Table 4-6 shows the most common species, i.e. safou (*Dacryodes edulis*), mango (*Mangifera indica*), avocado (*Persea americana*), *Citrus* spp. and guava (*Psidium guajava*). Cocoa-coffee plots, cocoa plots, homegardens and coffee plots had the highest number of fruit tree species. Taken together, this group of land-uses had a mean number of species of 7.09 ± 0.23, which is significantly different (one-way ANOVA: $F = 94.715$; $p = 0.000$) from the other major grouping of land-uses (food crop, fallows, oil palms and orchards), which taken together had a mean number of species of 3.8 ± 0.25. Reasons for integrating trees in cocoa agroforests is that they provide the necessary shade for a good development of cocoa trees and also because here they receive a better protection against fire then they would in food crop fields.

Table 4-6: Most common fruit tree species in 4 communities in Cameroon

Rank	Species	% of all fruit trees in farmers' fields
1	*Dacryodes edulis*	42
2	*Persea americana*	16
3	*Citrus* spp.	13
4	*Mangifera indica*	11
5	*Psidium guajava*	3.4

Source: Degrande *et al.* (in press)

Bandjoun and Belo are situated in the humid savannah zone of Cameroon. There, agriculture is dominated by intensive cropping, using ridges and furrows where crop residues and grasses are incorporated into the soil to improve fertility. Natural fallows have shortened to 3-6 months. Acquisition of land happens through inheritance from father to son (in the matrilineal systems of Belo from uncle (mother's side) to nephew) or through buying. Annual precipitation follows a unimodal pattern (April-October) and allows for 2 cropping cycles (Figure 4-10). Main food crops include maize, plantain, beans, yam and cocoyam, often cultivated in association. The principal cash crop is coffee, which is cultivated in an agroforestry system with fruit trees in the upper layer and shade-tolerant crops in the under storey. Many of the farms are situated on steep slopes and are prone to severe soil erosion. The most common place to plant trees is the homegarden, but some families may have an extra piece of land where they can create an orchard. Some land on the hillsides is marginal and improper for cropping; here trees such as *Prunus africana,* can be planted to protect the soils against erosion. In Bandjoun area, trees are not tolerated in food crop fields. This can be explained by the small plot size (average of 0.33 ha) due to demographic pressure. In Bandjoun, the only remaining forest patches are the sacred forests around the "chefferies", where exploitation of any kind is strictly prohibited. Long fallows do no longer exist, nor does the village have any common land. Women often collect firewood and men tap palm wine in the raphia palm galleries along the streams. However, access to these swamps is not free but regulated by family. On the other hand, the landscape in Belo is characterised by patches of natural forest. Access to these natural forests is open for people within the tribe for hunting, harvesting of forest products, but the place cannot be opened for farmland. The nearby Kilum-Ijim Forest Reserve, however, used to be open to everybody but with the new regulations on community forestry, access is now restricted and requires authorisation from the local communities managing these forests.

Crops	J	F	M	A	M	J	J	A	S	O	N	D
Maize	□□□ ♀♂		--- ♀♂	— ♀♂		+++ ♀♂	□□□		---	——	+++	+
Cassava	□□□ ♀		--- ~~ ♀	— ~~	— ♀	□□□		--- ♀		~~~ ♀		
Cocoyam/yam	□□□ ♀	□□	--- ♀	----	— ♀	——						~~~ ♀
Sweet potato	□□□ ♀	□□		---- ♀	— ♀	——	+++ ♀	+++				
Groundnut	□□□ ♀♂	□□□	-- ♀	----	– ♀	— +	+++ ♀	□□□	---	——	+	+++
Hot Pepper	---- ♀♂	—— ♀		++ ♀			+++			+++		□□□ ♂
Eggplant	---- ♀♂	—— ♀		++ ♀		+++		+++				□□□ ♂
Tomato	□□□ ♂H	----- ♀♂	---	— ♀♂	—	+++ ♀♂	□□□	----	—	+++		
Okra	□□□ ♀♂H	---- ♀♂	— ♀♂	++ ♀♂		□□□	-----	——	++			
Green vegetables	—— ♂	——	++ ♀♂							□□□ ♂		----- ♂
Cocoa	□□□ ♂	□□□		— ♂	—	——	——	——	++ ♀♂		+++ ♀♂H	+++
Banana/plantain	□□□ ♂	□□□ ~♀♂	--♂ ~~	---- ~~	~~	~~~	—♂ ~~~	—— ~~~	~~~	~~~		□□□
Sugarcane	□□□	□□		----		——	——					+++

key :		
	□□□	clearing and land preparation
	-----	planting
	——	maintenance (weeding, etc.)
	+++	harvesting
	~~	periodic or staggered harvesting
	♀	female task
	♂	male task
	H	hired labour

Figure 4-9: Agricultural calendar for forest zone of southern Cameroon
Source: baseline study 2003

Crops	J	F	M	A	M	J	J	A	S	O	N	D
Maize		□□□ ♂	□-- ♀	---	— ♀	——	+++ ♀	□□□	---	——		+++
Cocoyam		□□□ ♀	--- ♀	— ♀			— ♀					+++ ♀
Yam	□□□ ♀	□□	--- ♀							++ ♀	+++	
Sweet potato		□□□ ♂	---- ♀			+++ ♀		□□ ♂	----			+++ ♀
Irish potato		□□□ ♂	--- ♀		— ♀	— +	+++ ♀					
Banana/plantain	~~	□□♂ ~♀♂	--♂ ~~	-- ~~	~~	~~~	~~~	~~~	~~~	~~	~~~	~~~
Groundnut		□□□ ♀	--- ♀		— ♀	—		+++ ♀				
Beans		□□□ ♀	--- ♀		— ♀	+++ ♀		□□□ ♀	--- ♀	— ♀	+++ ♀	++
Cabbage/Tomato	+++ ♂									□□□ ♂	----- ♂	—— ♂
Green vegetables			□□ ♀	--- ♀		~~~ ♀	~~~	~~~				
Coffee	++	□□□ ♂H	□□	— ♂		□□□ H			□□□ H		+++ ♂	+++
Kola nut				++ ♂	++							

key :

□□□ clearing and land preparation
----- planting
—— maintenance (weeding, etc.)
+++ harvesting
~~~ periodic or staggered harvesting

♀ female task
♂ male task
H hired labour

Figure 4-10: Agricultural calendar for humid savannah zone of Cameroon
Source: baseline study 2003
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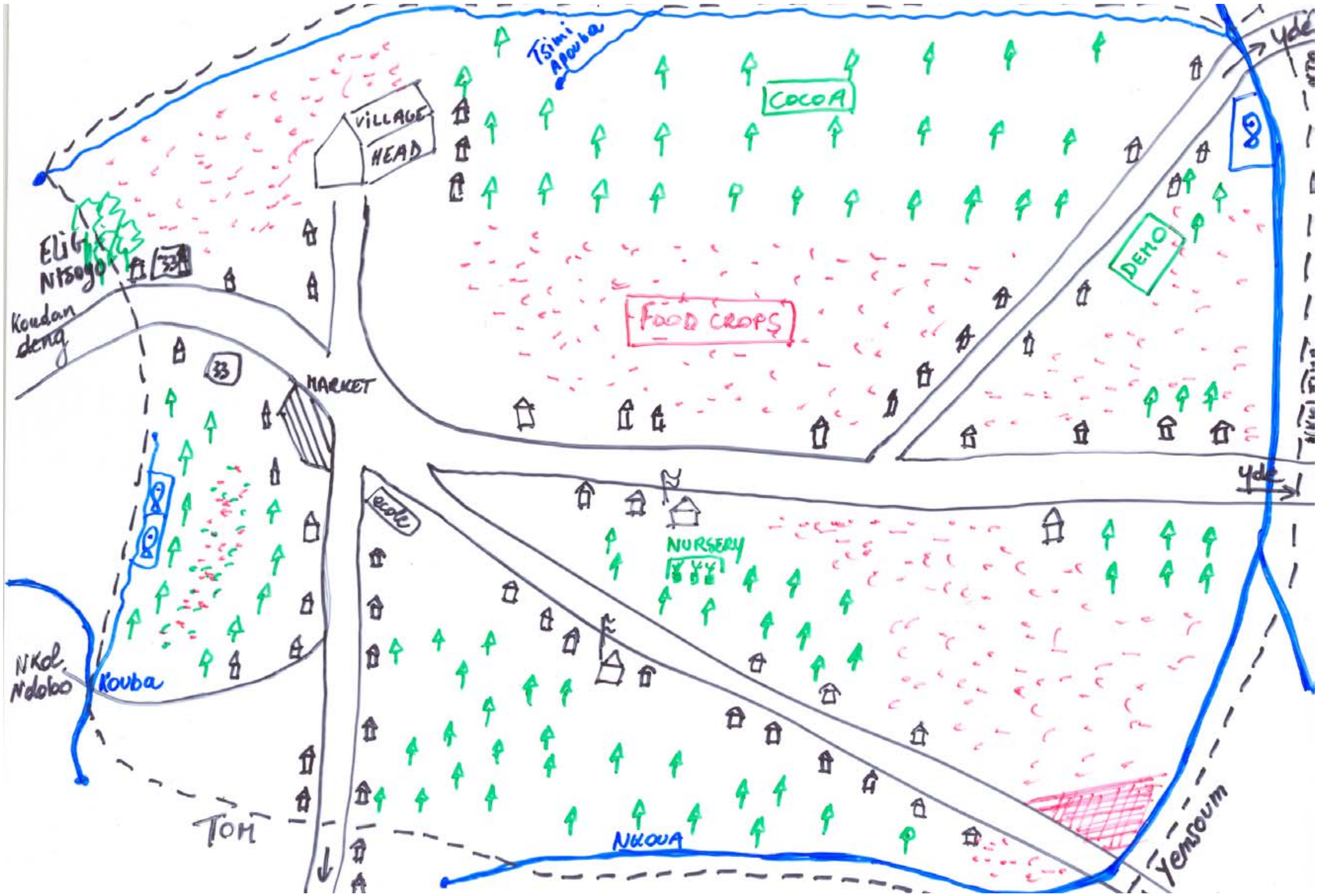


Figure 4-11: Participatory map of land-use in Nkolfep, forest zone of Cameroon

d) Physical Assets

Physical Capital comprises the basic infrastructure (roads, rails, communication, shelter, water supply, energy) and producer goods (tools and equipment) needed to support livelihoods (DFID 1999).

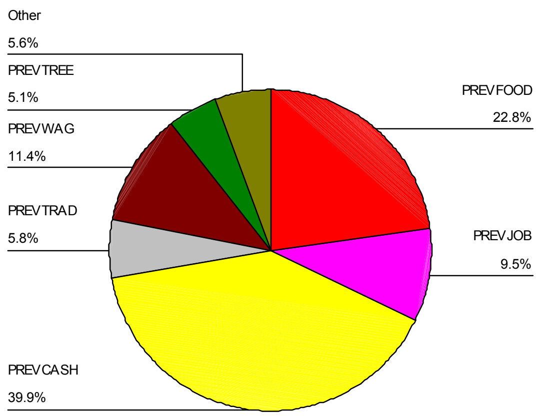
Most villages studied have basic infrastructure such as primary schools, churches and a commercial place (either weekly market, bars or small shops), although health centres and sound water points are often lacking. Electricity still is not widespread in rural areas, especially in the forest zone. Table 4-7 gives an overview of existing infrastructure and services in the different villages. The house often comprises the poor's main physical asset by value. Houses in the study sites were generally made of a wooden frame filled with mud (plastered or not) and covered with a zinc roof. Palm frond thatches are becoming rare and usually typify the poorest households in the village. On the other hand, houses built with cement blocks, as well as the presence of stuffed chairs, indicate higher levels of wealth.

Table 4-7: Infrastructure in study sites, Cameroon

Village	Primary school	Sound water source	Health centre	Church	Shop, market	Electricity
Abondo		✓		✓	✓	
Nkolfep					✓	✓
Nkom-Efoufoum	✓	✓		✓		
Elig-Nkouma	✓			✓	✓	
Ngoumou		✓		✓	✓	✓
Ting-Melen				✓	✓	
Bandjoun	✓	✓	✓	✓	✓	✓
Belo	✓	✓	✓	✓	✓	✓

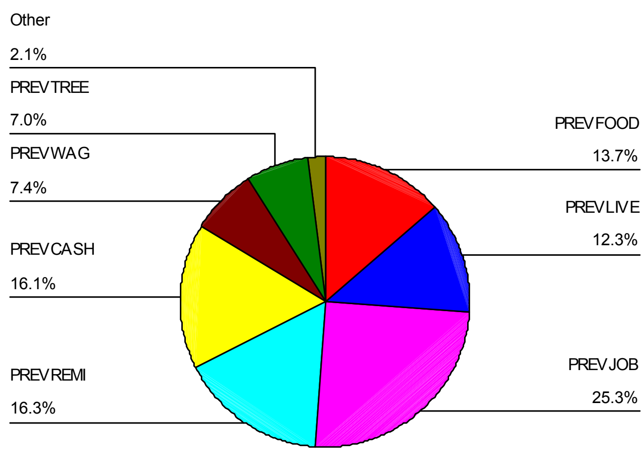
Source: baseline study 2003

Assets found in almost all households included a set of pans, dishes and a transistor radio. Television, bicycles, hand-push carts and motorcycles were limited to a few privileged households. These results follow the same trend as found by Amin and Dubois (1999), where 43.3 % of rural households in Cameroon owned a radio, 15.2 % a bicycle and only 7.0 % had a television. As agricultural implements, the majority of households interviewed owned a machete and a hoe. Tools such as axes, wheelbarrows and motor saws were less common. Farmers involved in cocoa and market gardening often owned knapsack sprayers to treat against pests and diseases, although sometimes these were shared between neighbours.

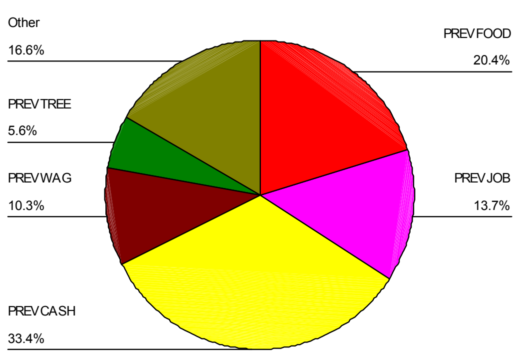


Legend:
PREVFOOD = revenue from food crops
PREVJOB = revenue from temporary jobs
PREVCASH = revenue from cash crops
REVLIVE = revenue from livestock
REVREMI = revenue from remittances
PREVTREE = revenue from fruit trees
PREVWAGE = revenue from salary or pension
PREVTRAD = revenue from commercial activities

Sites in forest zone



Sites in moist savannah zone



All sites

Figure 4-12: Contribution of different sources of revenue to household income (all sites together, forest and savannah zone of Cameroon, respectively)
Source: baseline study 2003

e) Financial Assets

> **Financial Capital** (DFID 1999) denotes the financial resources that people use to achieve their livelihood objectives; it captures the availability of cash. There are two main sources of financial capital: available stocks (savings: cash, bank deposits, livestock, jewellery, credit) and regular/reliable inflows of money (pensions, remittances).

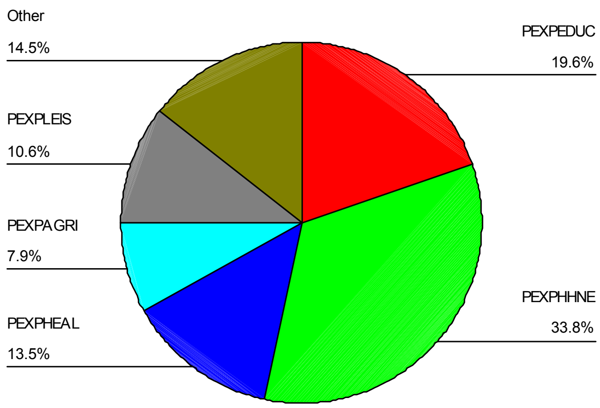
The baseline study in ICRAF's pilot villages (2003) elaborated budgets with 112 households, estimating household revenue and expenditure over the year. Many farmers were not able to give amounts on a monthly basis, so that itemised revenue and expenditure is presented on a yearly basis.

Income

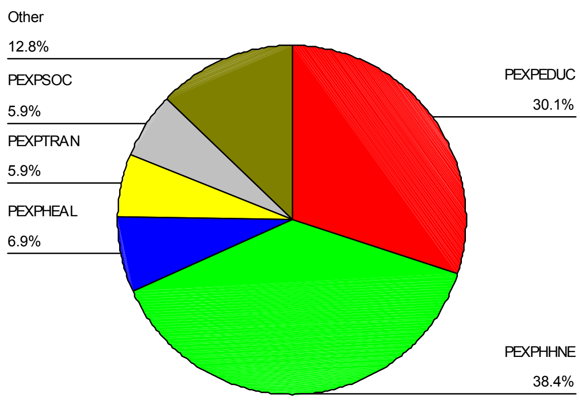
The following sources of income were distinguished: revenue from cash crop (cocoa in the forest zone and coffee in the savannah zone), wages (regular salary or pension), food crops, temporary jobs (e.g. carpentry, chain sawing, mechanics, etc.), petty trade, livestock, trees and remittances. Taking all villages together (Figure 4-12), traditional cash crops (cocoa and coffee) contributed proportionally the most to household income (33.4 %), followed food crops (20.4 %), temporary jobs (13.7 %) and wages (10.3 %). However, in the savannah zone, the major cash crop, which is coffee, only contributed 16.1 %, while in the forest zone, cocoa still counted for 39.9 % of household revenue. To compensate, households in the savannah zone relied more on temporary jobs (25.3 % of household income) and remittances (16.3 %). In general, male-headed households seemed to have more opportunities to do jobs then their female counterparts. Female-headed households relied more on remittances, in addition to doing petty trade.

In absolute terms, yearly household income averaged 847,355 FCFA (= 1294 €), but varied enormously from household to household [min: 0 FCFA, max: 5,280,000 FCFA]. Mean annual revenue from other trees (not including coffee and cocoa) was estimated at 47,562 FCFA (= 72 €), representing about 5.6 % of total household revenue. However, this was variable from village to village: households in Elig-Nkouma, Belo, Ting-Melen and Ngoumou seemed to derive a greater share (respectively 11.6, 8.0, 5.7 and 5.1 %) of their revenue from trees than in the other pilot villages. Overall, revenue derived from wages occupied an important place in rural household's income. In absolute terms, salaries and pension contributed annually for 238,937 FCFA (= 365 €), being 10.3 % of the household's total income.

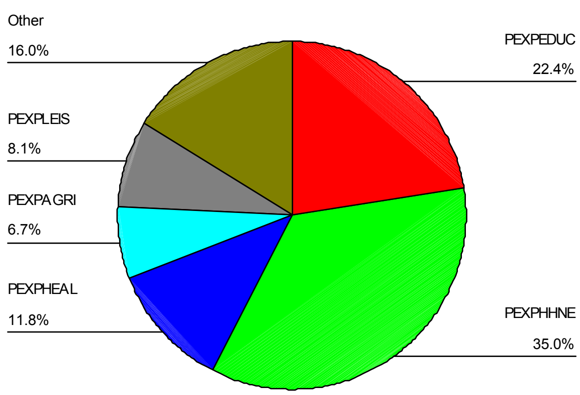
Legend:
PEXEDUC = expenditure for education
PEXHHNE = expenditure for daily household needs (soap, kerosene, salt, …)
PEXPAGRI = expenditure for agricultural inputs (fertiliser, pesticides, farm tools, etc.)
PEXPHEAL = expenditure for health
PEXPLEIS = expenditure for leisure (drinks, cigarette, …)
PEXSOC = expenditure for social obligations (funerals, weddings, birth, …)
PEXPTRAN = expenditure for transport (visits to family, market, school, etc.)



Sites in forest zone



Sites in moist savannah zone



All sites

Figure 4-13: Share of different expenses in household expenditure (all sites together, forest and savannah zone of Cameroon, respectively)
Source: baseline study 2003

Expenditure

Household expenditure was divided up in expenses for daily household needs (soap, kerosene, salt, etc.), education, health, agricultural inputs, livestock inputs, transport, social events, leisure, clothes and building. As shown in Figure 4-13, households spent proportionally most money on daily household needs (35.0 %), followed by educational expenses (22.4 %), health care (11.8 %), agricultural inputs (6.7 %) and leisure (8.1 %). This expenditure pattern was not remarkably different in the forest compared to the savannah zone, even though households in the savannah zone appeared to spend more on education and social matters and slightly less on health and agricultural inputs. As opposed to income patterns, expenditure patterns of male and female-headed households were quite similar. In absolute terms, households spent on average 622,288 FCFA (= 950 €) per year, which is approximately three quarters of their income, though this varied much from household to household.

From the baseline study (2003), it was not clear whether interviewed households effectively had surplus and how they saved or invested this money, although literature (IFAD 2001a) shows that households around the world have always saved: as insurance against emergencies, to meet religious and social obligations and for investment and future consumption. The importance of savings in Cameroon is also demonstrated by the proliferation of local rotating savings and credit associations (*tontines* or *njangi*). On the other hand, Essomba (2004) asked farmers from the same study area what they would do in case their income doubled. Building or improving their house was first on the list (40 %), followed by paying better education for the children (21.1 %), investing in a small business (11.5 %) and buying land (7.7 %). Saving money was only mentioned by 5.8 % of the interviewed households. This indicates that less than 20 % of the households thought of making productive investments (small business, land purchase), although investment in education can also be seen as a productive investment in the long term, provided it leads to employment. This can be explained by the fact that the saving mechanisms currently at the disposal of poor people often fail to meet their needs in a convenient, cost-effective and secure way. There exists evidence that if a poor household is given a safe, accessible opportunity, its capacity to save and the amounts it manages to save are remarkable (IFAD 2001a), opening a window of opportunities to smoothen consumption and later acquire assets.

4.3.4 Transforming Structures and Processes

> *Transforming Structures and Processes* (DFID 1999) within the livelihoods framework are the institutions, organisations, policies and legislation that shape livelihoods. They operate at all levels, from the household to the international arena, and in all spheres, from the most private to the most public. They effectively determine access to various types of capital; terms of exchange between different types of capital; and returns to any given livelihood strategy. Because culture is included in this area they also account for other 'unexplained' differences in the 'way things are done' in different societies.

Participation allows the poor to have a voice, and through transfer of responsibilities gives them the power to discover and determine ways to improve their lives. Empowering the poor is the foundation of rural poverty alleviation. IFAD (2001) suggests three institutional approaches to empowering the rural poor in their quest for poverty reduction:

(1) a blend of devolution and collective action for natural resource management;
(2) delivery of financial services to the poor to enable them to access and secure financial assets; and
(3) developing linkages with NGOs and the private sector as partners for service delivery.

Devolution of Responsibilities

According to Oyono (2003), devolution or 'democratic decentralisation' implies that authorities or entities representing local populations are elected and - because of their easier access to local information and greater sensitivity to local needs - are more accountable to the local community. However, the claim that local institutions are accountable to the poor is controversial, as decentralised institutions may be controlled by powerful elites that reduce community programmes' efficiency.

Decentralisation efforts in Cameroon have to be viewed in the light of its double colonial heritage. At independence in 1960, a federal structure of government was adopted, but this had changed into a highly centralized, one-party state by 1972. These institutional developments did not allow sufficient participation by the poor, and consequently their energy was not catalysed enough to increase their opportunities for self-fulfilment. With the economic crisis, the tension and fragmentation - brought about by the previous institutional development - degenerated into much social violence through the "dead cities" operations. This forced the government to accommodate the rising political opposition and the law instituted political pluralism in November 1990. This was still not enough, as was shown by the civil unrest that followed in 1991–92; violent protest against the political regime and its 'governance practices' including corruption, nepotism and social injustice. Further reforms were then put in place to allow more freedom and liberalization—for example, the 1990 law on association, the 1993 law on cooperatives, measures concerning the media, and so forth (Amin and Dubois 1999). By doing so, the government declared its interest in the strengthening of local governments. Yet, the central state continued to control them and worked towards their authoritarian deconstruction (Oyono 2003).

One example of decentralisation in Cameroon is the forestry code reform in 1994 that transfers powers to peripheral actors for the management of forestry fees in order to foster community development, Council Forests and Community Forests (Oyono 2003). The introduction of Community Forests was hailed by all local communities in Cameroon's dense forest zone as the beginning of an era of equity in intra-generational access to natural resources. Unfortunately, the results are not as tangible as all that and local communities still seem vulnerable and captive. For example, Oyono (2003) views the slowness of the administration in treating applications for Community Forests as indicative of the central state's wish to keep full control over the process or to even block it and maintain the status quo. Furthermore, senior civil servants and politicians, in their capacity of 'local elites', tend to hijack the management committees and hence contribute to the decline of the decentralisation process and the retention of powers at the centre.

Based on the above analysis of forest management decentralisation, two facts emerge (Oyono 2003). First, regional-level administrative authorities and national-level bureaucrats tend to withdraw powers and resources devolved to elected bodies and to other local actors. Second, the organisational infrastructure set up at village level to support devolutions seems immature, and incapable of promoting and controlling a collective effort like that required for local management. It certainly means that the way leading to democratic decentralisation in Cameroon needs effective change in policy and practice.

Delivering Financial Services

While it is increasingly recognised that microfinance alone is not a magic bullet for poverty reduction, finance for investment helps the poor if basic consumption can be assured and technology (or market access) enables them to earn a decent return on assets (IFAD 2001). Yet, investment by the rural poor is often constrained because they cannot borrow.

As a whole, access to credit in Cameroon is very difficult, especially for those in the informal sector. The poor financial situation of the Cameroon banks accounts for the difficult credit conditions imposed on customers, and these conditions are generally not favourable to the poor, especially those in agriculture or the informal sector. These difficulties have pushed people, particularly women, to create solidarity funds with which they can start income-generating activities to satisfy monetary needs or solve financial problems. *Njangis* provide start-up capital for activities started by their members. The present role of a few non-governmental organizations in the fight to increase credit accessibility for the poor and the more vulnerable cannot be overlooked. To help solve this issue of credit inaccessibility in rural areas, the government, with the help of the World Bank, put in place a specific institution: *Fond d'Investissements pour les Micro-réalisations Agricoles et Communaitaires* (FIMAC), to disburse investment funds for micro-projects. FIMAC provides financial assistance in the form of collective loans (Amin and Dubois 1999).

With the law No 90/05 of December 19th, 1990, on the liberalization of associations in Cameroon, many community-based associations, *common initiative groups* (CIGs) and, more generally, NGOs came to life. Besides many other things, they help develop human capacities. As of 1998, about 7,000 CIGs had been registered and some 3,000 applications were still pending approval. Recent experiences in the poverty-reduction program show that these NGOs have a comparative advantage over other development partners (Amin and Dubois 1999). This advantage comes from their proximity, flexibility in approach, technical competence, and, often, international backing. Even though there is not enough evidence to show the extent of their aid to the poor, there is a general belief that their predominant location in rural areas brings them nearer to the poor. Oyono and Temple (2001), however, questioned the capacity of CIGs to play a role in agricultural development because of their diversity and the blurred motivation of their promoters (governmental and non-governmental organisations).

4.3.5 Livelihood Strategies

Livelihood Strategies (DFID 1999) is the overarching term used to denote the range and combination of activities and choices that people make/undertake in order to achieve their livelihood goals (including productive activities, investment strategies, reproductive choices, etc.).

In the light of the baseline study in ICRAF's pilot villages (2003) and based on previous work in the area, we identified livelihood categories that reflect the household's main sources of income in ICRAF's pilot villages.

1. *Cocoa/coffee dominant*. Households that generate their revenues mainly from "traditional" cash crops, i.e. cocoa in the forest zone (Abondo, Nkolfep, Nkom-Efoufoum, Elig-Nkouma, Ngoumou and Ting-Melen) and coffee in the savannah zone (Bandjoun and Belo).
2. *Cocoa/coffee + food crops*. Households that generate an important part of their revenues from cocoa or coffee, but complement this income with food crops.
3. *Cocoa/coffee + market gardening*. Households that generate an important part of their revenues from cocoa or coffee, but complement this income with market gardening (i.e. tomatoes, okra, green maize, green vegetables).
4. *Food crops dominant*: households that generate revenues mainly from food crops.
5. *Market gardening*. Households that generate revenues mainly from market gardening.
6. *Other perennials*. Households that generate their revenues mainly from perennial crops other than cocoa and coffee, these may include oil palm, fruit trees, etc.
7. *Non-agricultural*. Households that generate their revenues mainly from non-agricultural activities, such as petty trade, pension, casual labour, etc.

Taking the sites of the forest zone together (Figure 4-14), the most important livelihood strategy was the system that combines cocoa with food crops, which concerned 28 % of all households. The second most important category (24 %) was made up of households that generate the majority of their income from cocoa alone. Food cropping constituted the main income generating activity for 23 % of forest households overall, but is the main source of income for 56 % of female-headed households. Thirteen percent of all households obtained their main income from non-agricultural activities. Except for Abondo (10 %) and Ngoumou (6 %), market gardening had not yet taken off in the forest pilot villages. Overall, only 1.5 % of households used this system to generate most of their income.

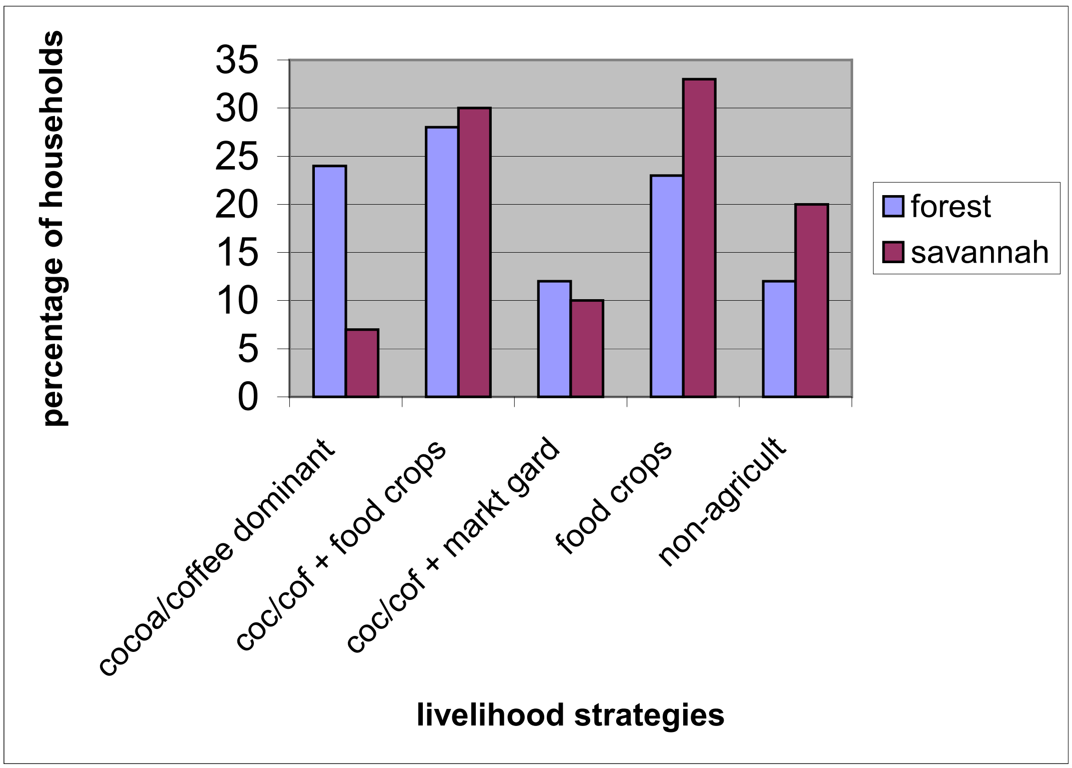


Figure 4-14: Livelihood strategies in humid forest and moist savannah zone of Cameroon, respectively
Source: baseline study 2003

Coffee, which is the traditional cash crop of the savannah zone, has lost much of its importance as an income generator. Only 7 % of households in Bandjoun and Belo relied exclusively on coffee for income generation (Figure 4-14). On the other hand, almost one-third of the households (30 %) used a combination of coffee and food crops to make a living. Thirty-three percent generated the majority of their income from food crops alone. This proportion was even higher in Bandjoun where 59 % of households relied on food crops for their income. It must be noted that, in Bandjoun, 44 % of households were female-headed which might explain the dominance of food cropping in the household economy.

Looking at the contribution of different sources of income per livelihood strategy (Figure 4-15), we noticed that cash crops remained an important source of revenue in all strategies, ranging from 9.7 to 42.3 % of total revenue. Food crops contributed between 12.9 and 17.3 % to household revenue, except for non-agricultural households. Wages, i.e. regular income in the form of a salary or pension, appeared to be a very important source of income for rural households, regardless their livelihood strategy. Temporary jobs, on the other hand, contributed differently to income, but seemed most important for non-agricultural households and for those combining cash crops and market gardening. Trees, overall, contributed to a lesser degree to farmers' income. This proportion was highest for households engaged in food cropping (10.8 %).

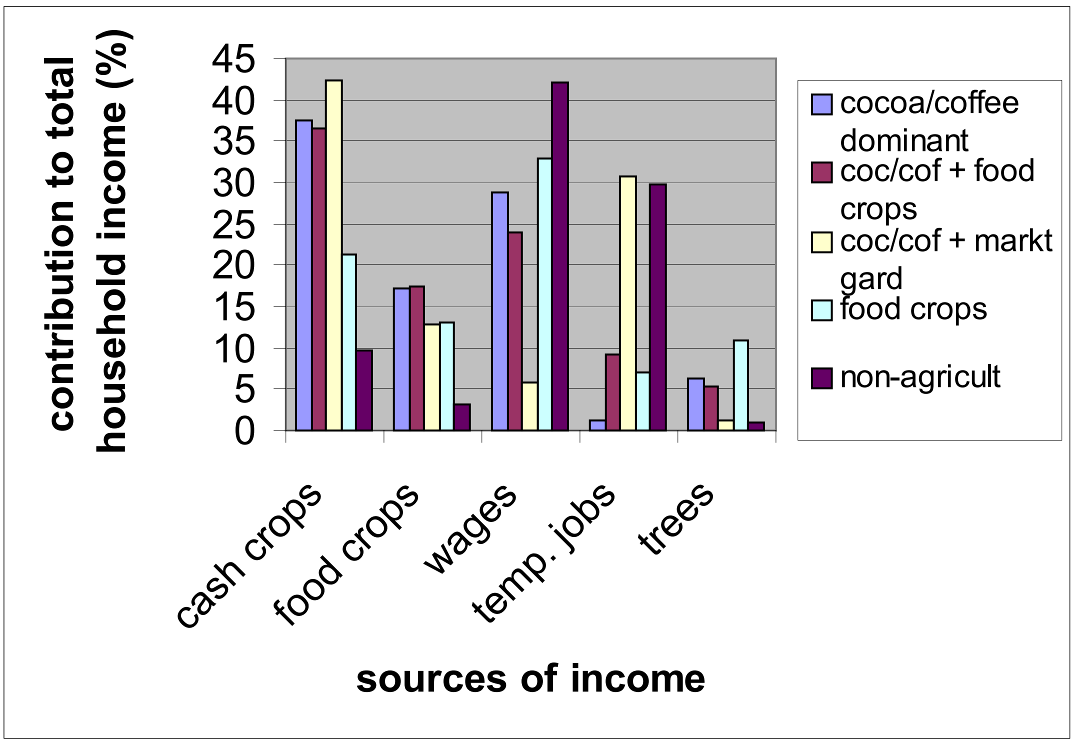


Figure 4-15: Contribution of different sources of income per livelihood strategy, humid forest and moist savannah zone of Cameroon
Source: baseline study 2003

Livelihood strategies are expected to be determined by availability of land and labour, and might change with ageing of the household. Therefore, we looked at relationships between livelihood strategies and farm size, household size and age of the household head (Table 4-8). No clear relationship was found between livelihood strategy on the one hand and household size and age of the household head on the other hand. It was true that households engaged in market gardening had the youngest heads (average age = 45.3), but the difference with other livelihood strategies was not significant. While overall, households combining cash crops and food cropping had big families (average household size = 7.2), non-agriculture households had even more people (7.9). Households focusing on cash crops for income generation overall had the smallest household size (4.5) and this was equally true for both forest and savannah zones. Nonetheless, differences in household size between different livelihood strategies were not significant. Land availability however seemed to affect livelihood strategy more. Overall, farm size was largest for households combining cash crops and food crops (9.3 ha) and smallest for non-agricultural households (2.8 ha). The impact of farm size was more explicit in the forest zone than in the savannah zone. In the latter, largest farm sizes were found with households combining coffee and market gardening.

Table 4-8: Relationship between livelihood strategy on the one hand and farm size, household size and age of the household head on the other hand, forest and savannah zone of Cameroon (*Source*: baseline study 2003)

Livelihood strategy	Farm size (ha)			Household size			Age of household head (years)		
	Overall	Forest	Savannah	Overall	Forest	Savannah	Overall	Forest	Savannah
Cash crop dominant	5.1	5.5	0.36	4.5	4.9	1.0	48.6	46.7	67.5
Cash crop + food crop	9.3	11.0	5.0	7.2	7.2	7.3	54.3	50.7	63.4
Cash crop + market gardening	5.8	5.2	7.9	6.3	6.5	5.7	45.3	43.7	50.7
Food crops dominant	5.5	7.4	1.8	5.9	5.2	7.1	52.6	54.0	49.9
Non-agriculture dominant	2.8	3.7	1.5	7.9	6.9	9.5	45.7	39.5	56.0
	N=112	N=82	N=30	N=112	N=82	N=30	N=112	N=82	N=30
	F=3.412	F=3.261	F=2.071	F=1.788	F=1.557	F=0.690	F=1.336	F=2.016	F=0.975
	p=0.012	p=0.016	p=0.115	p=0.137	p=0.194	p=0.606	p=0.261	p=0.100	p=0.439

4.3.6 Livelihood Outcomes

Livelihood Outcomes (DFID 1999) are the achievements or outputs of livelihood strategies and include the following categories: more income, increased well-being, reduced vulnerability, improved food security, and more sustainable use of the natural resource base.

In 4.3.5 we observed that the way in which households combine their assets to make a living differs, not only depending on the assets at their disposal, but it is also influenced by age, gender, market access, etc. However, the choices they make in designing their livelihood strategies determine the outcome. The perception of livelihood outcomes in itself may differ among people. As defined by DFID (1999), categories of livelihood outcomes include more income, increased well-being, reduced vulnerability, improved security and more sustainable use of the natural base. Box 4-1 gives a diverse collection of Cameroonian farmers' views on livelihood outcomes.

Box 4-1: Farmers' views on livelihood outcomes

"I want my children to pursue their education to a high level. I want to invest in farms for my children; I don't want to keep my money in the bank, I'd rather want to invest it well, for example by planting trees."

Emmanuel Kuh, Belo

"Poverty is when there is not enough food in the house. When my children have enough to eat every day, all year round, I am happy."

Eunice Tosi, Belo

"Poverty is a state in which your resources do not allow you to solve all your problems; it's when you can't fulfil all your obligations. It's like me now, I don't have enough money to send my children to college. My cocoa farm is not producing anything, because I lack money to pay fungicides. I am not happy because I cannot take care of my family."

Ferdinand Ohandja, Abondo

"I don't want my children to live the same life as I do. I wish they could go to school, become important people, succeed in life. Then, I could also have a solid house made of cement blocks."

Valentine Tsogo, Abondo

In our baseline study (2003), sample households were classified into well-being categories, using local indicators that reflect different perceptions of livelihood outcome (income, food security, well-being). Based on experience with participatory wealth-ranking exercises in our study zone (Schreckenberg *et al.* 2002; Degrande *et al.* submitted), 5 categories were retained. Enumerators classified households into well-being categories using the criteria below. It is important to note that these categories are subjective and that comparison of households is only relevant within one village and not across villages.

1. *Very poor*. Households that lack land and generally do not own cocoa or coffee. Households headed by very young, very old, disabled persons or immigrants. Household that do not manage their money well (drink too much, lazy, …). These households are not able to send their children to school or to ensure adequate healthcare. The state of their house also indicates the difficulties they must have to make ends meet.
2. *Poor/well-being below average*. Households that lack land and/or have a large family. They generally do not have cash crops.
3. *Average level of well-being*. Households that generate sufficient income from cocoa, market gardening and/or food cropping, but have a large family and a lot of expenses.
4. *Well-being above average*. Middle-aged households with well-managed cocoa plantations, few children or grown up children, or hard working young households doing market gardening. This category can meet the needs of their household and have no problems with sending their children to school.
5. *Rich or well-off*. Households that generate income from non-agricultural activities such as trade or wage labour, or that benefit from a pension. Households with large cocoa plantations and good management of their money. These households can be identified through their clothing, food, health care, some assets (vehicle, house, …). These people often lend money to others.

In most villages, the well-being pattern followed a normal distribution curve with few people in the extreme categories of '*very poor*' on one side or '*rich*' on the other side, and close to half of households in the category of '*average well-being*' (Figure 4-16). Nevertheless, some differences were found between villages. Abondo and Elig-Nkouma, for example, had a larger proportion of '*very poor*' households, respectively 18 % and 15 %, while Ting-Melen and Nkolfep apparently had no households in the poorest category. The latter have good access to Yaoundé, which favours interactions with relatives working in town and offers job opportunities. In Bandjoun, 37 % of households were classified as '*very poor*' and 35 % as '*poor*'. In Ting-Melen 41 % of households were categorised as '*well-off*', which was significantly higher than for the rest of the villages (17 % overall).

The sampling procedure used in the study did not allow us to determine whether there was a link between livelihood strategy and level of well-being (too small sample size). However, looking at sources of revenue per well-being category (Figure 4-17) may give us insights in strategies that permit households to move out of poverty. We noticed that the poorest categories had fewer sources of revenue than better-off categories. Households with average well-being disposed of the most diversified income portfolio with 6 different sources of revenue (only sources contributing more then 5 % were counted) against only 3 for the poorest categories and 4 for the richest categories. Generally, we noticed an increase in the proportion of revenue coming from wages (0 % in the poorest category and 62.3 % for the wealthiest category). At the same time, the contribution of food crops and jobs (temporary work) decreased respectively from 26.3 % to 7.4 % and from 25 % to 9 %. Interestingly, the share of trees in income generation was much larger for households in the average wealth category (15.3 %) than in any other category.

These results are in agreement with literature on rural livelihood diversity and agriculture. Ellis and Mdoe (2003) found that income from non-farm sources in Tanzania was higher for upper income groups than for the lowest income quartile. A study of 11 countries in Latin America (Reardon *et al.* 2001) indicated that non-farm income constituted approximately 40 % of rural incomes. Surprisingly, the highest levels were found in the zones where agriculture was successful, suggesting that rising farm productivity is a driver of the rural non-farm economy with linkages both from production (processing and agro-industries) and consumption (increased demand for manufactured products and inputs) (Chapman and Tripp 2004).

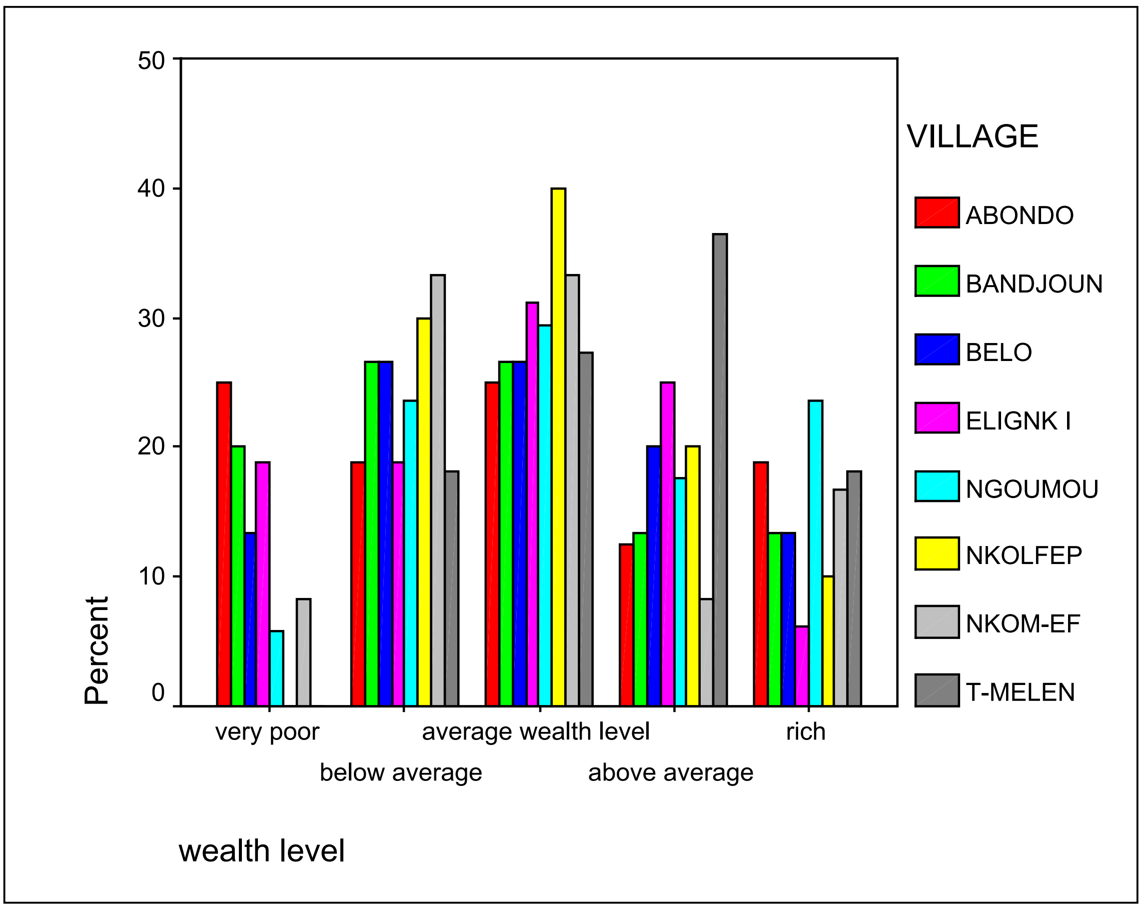


Figure 4-16: Distribution of households by well-being category and by village, forest and savannah zone (Bandjoun and Belo) of Cameroon
Source: Baseline study 2003

We also examined the balance between household revenue and household expenditure and tried to find relationships with livelihood strategies on the one hand and well-being categories on the other hand. Differences in yearly balance between livelihood strategies were not significant. Although there was a clear trend of increasing yearly balance as one moved from poorest category (40,285 FCFA), over average wealth category (74,924 FCFA) to richest (794,252 FCFA), the difference was only significant between the richest category and all other categories.

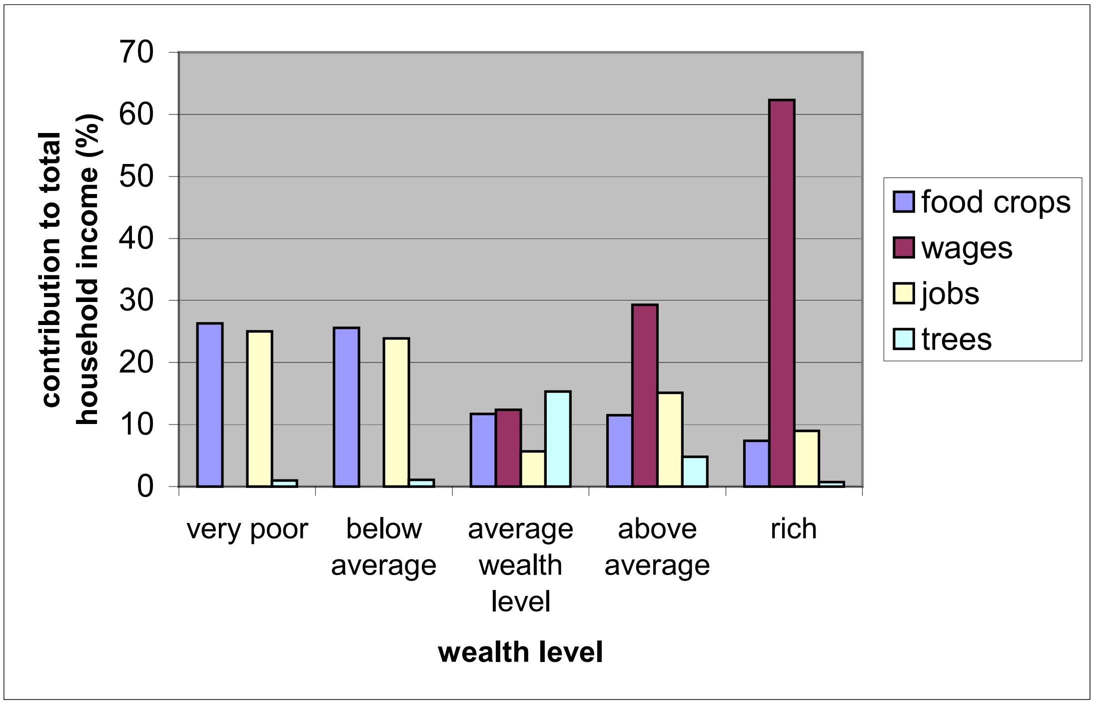


Figure 4-17: Proportion of revenue coming from wages, food crops, jobs and trees per well-being category, forest and savannah zone of Cameroon
Source: Baseline study 2003

4.4 Conclusion

In a context of vulnerability, households pursue a range of livelihood strategies based on assets (natural, financial, social, human and physical capital) they have to draw on and livelihood outcomes they wish to achieve.

Context

Despite its richness in natural resources, Cameroon still has many poor people. Its economy has been hard hit in the late 1980s - early 1990s due to drastic fall in export revenues and the consequences of structural adjustment programmes. Since 1995, Cameroon experiences a macro-economic improvement, but poverty is still high and inequality is increasing. Cameroon has one of the highest unemployment rates of the region. In the area of health care, despite reduced mortality rate and increased life expectancy, Cameroon's evolution in access to health care services in general is still discouraging. Decreasing public investments and escalating corruptive practices in all domains are reasons for concern.

Tree crop or forest-based farming systems in the forest and moist savannah zones were, until recently, highly dependent on industrial cash crops, namely cocoa and coffee. This made farmers extremely vulnerable to fluctuations in world market prices. However, alternatives for income generation were scarce, especially outside the agriculture sector. Therefore, farmers turned their attention to food cropping, thereby opening new forest land where possible, and intensifying cropping patterns elsewhere by reducing fallow periods. This inevitably led to physical degradation of soil, depletion of soil nutrients and increasing incidence of weeds, pests and diseases. In addition to problems with soil fertility, rural households still suffer from seasonality effects. Many households go through periods of food shortage prior to harvest. This shortage in food generally is accompanied by periods of financial distress when the household has no other sources of income than food crops. Moreover, many of the food crops fetch relatively low prices in the market because of their lack of added value. There is thus a need for alternative income-generating activities and, if possible, activities which build on and make effective use of existing assets.

Assets

- Improving human capital increases the skills and capabilities of people, enabling them to overcome various shocks in life and escape from poverty gaps. Education also speeds adoption of new rewarding technologies, eases access to new information, facilitates access to others with information (health professionals and extension agents) and improves ability to make sense of new information. In our study sites, households are comprised of 1 male and 1 female adult and 2-5 children, on average. Most heads of households have had primary education and have substantial experience in agriculture. Although we have no information on health status of households in our study sites, general data for Cameroon raise reasons for concern. Health care coverage as a whole has been poor, especially because a number of health care facilities are poorly equipped or absent. On average, the distance to the nearest health care facility is still long, and services are still poor because of lack of drugs and low motivation of personnel. Only 2 out of 8 study sites had a health centre and 3 had no potable water source at all.

- Strong social organization makes it possible for the poor to gain access to resources and knowledge within their communities and to develop links with external partners. In our study site, groups of all kinds (farming groups, cultural groups, mutual aid groups, savings and credit associations, church associations) occupy an important place in daily life. Credit and savings associations (*tontines or njangi*) are almost the only financial services accessible to rural households in Cameroon and often provide start-up capital for income generating activities or to buy agricultural inputs or tools. However, their capacity to finance investment for small-scale business is rather low, because of the small amounts involved. Common Initiative Groups (CIGs), because of their legal character, have most contact with NGOs, extension services and projects, but their contribution to development depends a lot on group objectives and cohesion, and dynamism of their leader. Our study revealed very little interaction and collaboration between groups within villages, neither did the households indicate groups as an important source of information about agricultural innovations. Remittances, gifts and transfers are also indications for social bounds. In our study sites, remittances constituted only a small proportion of household income. Overall, the contribution of remittances was higher for female-headed households. We therefore conclude that social capital in our study sites is potentially strong. To be able to become real motors of development however, groups will need training and assistance to mature.

- Natural capital is an extremely important asset for agricultural households. This is demonstrated by the fact that it is an important criterion in participatory wealth ranking. It is also the most important reason for conflicts in the village. Most land in the study sites is privately owned. The general rule is that property rights are passed from father to son. Women's access to land generally comes through men. Primary forests have disappeared in all study sites, although patches of secondary forests or old fallows exist. The latter are owned by families. This implies that, in most villages, open access to natural resources does no longer exist. The predominant farming type is mixed food cropping based on groundnut, cassava, maize and plantain in the forest zone and a combination of beans and maize in the moist savannah area. Perennial cropping systems are dominated by cocoa in the forest and coffee in the moist savannah zone. Most fruit trees are found in these perennial systems. A tree inventory in the study area (Degrande *et al.* in press) identified *Dacryodes edulis*, *Mangifera indica*, *Persea americana*, *Citrus* spp. and *Psidium guajava* as most common fruit tree species. The results also confirmed that farmers do compensate for loss of access to trees in the wild by planting more trees on their farms. Their tree planting pattern also responds to market incentives.

- It is known that rural areas in developing countries often lack basic infrastructure, such as health centers, schools, markets, roads, electricity, etc., even though better access to this type of physical capital allows the poor to benefit more from innovations. In our study, only half of the sites had a primary school, 2 out of 8 disposed of a health centre and 5 had potable water. Household furniture and equipment was scanty and agricultural tools in most households were limited to hoes and machetes. Three out of the 8 sites were located near a tarred road, while access to the other villages is difficult in the rainy season. Bad roads make the gap between farm and market prices high. This problem is especially acute for roots and tubers, which are quite bulky and perishable. Households in remote places can therefore benefit less from improved incentives and liberalization. Also, apart from easier trips to schools, clinics, extension and so on, better transport facilities can relieve drudgery and save time.

- Financial assets comprise of savings and inflows of money. In our study sites, traditional cash crops (cocoa and coffee) contributed proportionally the most to household income (33.4 %), followed by food crops (20.4 %), temporary jobs (13.7 %) and wages (10.3 %). Household's average yearly income was 847,355 FCFA (1294 €) with big variations from household to household. Average annual revenue from trees was estimated at 47,562 FCFA per household, being 5.6 % of total revenue. Nonetheless, this proportion was as much as 11.6 % in one of the sites. Irrespective of livelihood strategy or wealth category, temporary jobs contributed an important share to household revenue, being the first and third source of income in the savannah and forest zones respectively. The study also found that about three quarters of the income was spent, which represents an average yearly expenditure of 622,288 FCFA. Households spent proportionally most money on daily household needs (35.0 %), followed by educational expenses (22.4 %), health care (11.8 %), leisure (8.1 %) and agricultural inputs (6.7 %).

Transforming Structures and Processes

The study also looked at how policies and processes contribute to development at local level. Three approaches to empowering people in their quest to reduce poverty were highlighted.

(1) Devolution and collective action for natural resource management. In Cameroon, reforms to strengthen participation of people at the community level, illustrated by decentralization of forest management, are at serious risk because administrative authorities and bureaucrats tend to take back powers and resources devolved to elected bodies and to other local actors. Another constraint is that the organisational infrastructure set up at village level to support these devolutions seems immature, and incapable of promoting and controlling a collective effort like that required for local management.
(2) Delivery of financial services. In general, access to credit in Cameroon is difficult. This situation of poor financial services has led to formation of local rotative savings and credit associations that provide start-up capital for activities of their members, but they generally generate rather small amounts of money, lack flexibility and convenience.
(3) Developing linkages with NGOs and private sector. After the 1992 law on liberalization of associations, there has been a boom of NGOs and CBOs that got actively involved in development and poverty reduction. Because of their proximity

to the poor, they are expected to respond better to local needs. However, their diversity and lack of funds impedes many of them to contribute effectively to development of the poor.

Livelihood Strategies

Rural households in southern Cameroon undertake a combination of activities and make choices in order to achieve their livelihood goals. These livelihood strategies are categorised based on the household's main source of income. In the forest zone, 37 % of the households combine cocoa and food crops to earn a living, whereas 24 % rely on cocoa and 18 % on food crops alone for the majority of their income. Fifteen percent of the households obtain their main income from non-agricultural activities. In the moist savannah, coffee, which is the traditional cash crop, has lost much of its importance; only 2 % of the households still consider it as their main source of income. Almost half of all households combine coffee and food crops, while food crops alone constitute the biggest share of revenues for 35 % of households. A larger proportion of female-headed households generate their revenues mainly from food crops. The results confirm the diversification of farmers in southern Cameroon into food cropping as from the mid-1990s. Whereas cocoa and coffee remain important income generators, many households combine them with food crops to increase revenues.

From the study, it appears that land availability mostly affects livelihood strategies. Households that combine cash crops with food crops had largest farm sizes, while those with non-agricultural activities as main income generator were characterised by smaller farms. Age of the household head and family size - a proxy for labour availability - does not seem to affect livelihood strategies significantly, although younger household heads opted more for market gardening, big households were more into cash crops combined with food crops, whereas small households were more involved in cash crops alone.

Livelihood Outcomes

Using local indicators of well-being, sample households were categorised from very poor to well-off. The sample size was too small to permit us to determine a relationship between well-being and livelihood strategies, but looking at main sources of revenue we noticed that poorest categories had fewer sources of revenue than better-off categories. Households with average well-being disposed of most diversified income portfolios with 6 different sources of revenue. We also remarked a steady increase in proportion of revenue coming from wages as one moves from the poorest category to the wealthiest, while the contrary was true for the contribution of food crops and jobs. The share of trees in income was much larger for households in the average wealth category than in any other category.

Implications for Poverty Reduction Strategies

Poverty reduction strategies need to be situated in the context of the Central African region in general, and southern Cameroon in particular. These include: a weak human capital base;

inappropriate or insufficiently pro-poor policies and institutions; low agricultural productivity combined with degradation of the natural resource base; insufficient and poorly maintained rural infrastructure; and the need to operate more effectively in the global market place.

First of all, the capacity of the rural poor and their organizations to develop adequate livelihood strategies needs to be strengthened. Although in Cameroon, social, human and physical capital are improving, respectively through more NGO networks and social links, better health and education policies and improvements in the banking sector, the rural poor need to have greater access to a variety of interdependent assets – human and social, natural, infrastructural and financial. Our study revealed that development policies and institutions, despite decentralization processes, have not been able to meet the needs of the poor. Therefore, emphasis must be put on building the technical, organizational, and administrative capacity of local governments, communities and civil-society organizations to take on roles previously held by central authorities in this domain.

Another priority for development is to raise agricultural and natural resource productivity and to improve access to technology. Intensification and diversification of agriculture call for the generation and dissemination of improved agricultural and natural resource technologies. These technologies should concentrate on areas where population pressure has increased incentives for intensification, and on promotion of community-based natural resource management activities. As IFAD (2001b) suggests, there should be a specific focus on technologies that: (i) use locally available inputs; (ii) build upon indigenous knowledge and practices; (iii) take into account existing systems and their gradual evolution, as well as present constraints in terms of labour, gender division of labour and decision-making, access to finance, access to support services, markets and policies; (iv) are sustainable and environmentally friendly with locally reproducible resources; and (v) can be disseminated through cost-effective client-driven institutions.

Diversification of income sources should address two constraints in particular: (1) current high dependence on few crops that are prone to price fluctuations on the world market, and (2) seasonal fluctuations in income and consumption. This can be achieved either through production and marketing of non-traditional crops or by more fully exploiting off-farm opportunities. Indeed, rural non-farm activities may provide steadier streams of cash income than agriculture alone (which is highly seasonal) and are already part and parcel of rural livelihoods (Chapman and Tripp 2004). From our study it also appears that households with non-agricultural activities seem to be better off. However, among the most important rural non-farm activities are those directly linked to agricultural outputs (food processing and marketing) and inputs (blacksmith construction and repair of agricultural implements). Indeed, it is often overlooked that a dynamic smallholder agricultural economy forms the backbone of a vibrant rural non-farm sector. Due to multiplier effects, developing smallholder agriculture is more likely to stimulate off-farm employment than either large-scale agricultural development or industrial development.

Nevertheless, rural poor have special problems in exploiting non-farm employment opportunities, because of their limited human and social capital, insufficient access to markets, and lack of credit for working and investment capital. It appears that while the poorest diversify to supplement income and the poor to mitigate risk, only the rich are able to further increase income through diversification (Chapman and Tripp 2004). In the case of non-timber forest products (NTFPs) for example, Ruiz-Perez *et al.* (2004), based on 61 case studies from Asia, Africa and Latin America, demonstrate that NTFP-specialised households, i.e. cash-oriented households that rely on a forest product as their main source of income, tend to have higher household incomes than the local average. On the other hand, where NTFPs provide income to households that earn the bulk of their income from agriculture or off-farm sources, income equals the local average. Hence, income potential of commercial NTFP production is linked to the existence of infrastructure, access to skills and services, and other enabling conditions that are often lacking in rural Africa. Moreover, because of reasons of food supply, farmers often prefer a mix of activities including both agriculture and micro-enterprises. This was illustrated by Orr and Orr (2002) showing that amongst farmers in Malawi, faced with options to either further specialise in commercial agricultural niches or diversify into other micro-enterprises, a key factor was not to disrupt household food supply. Therefore, targeting the rural poor for diversification and micro-enterprise development requires specialized institutions.

Calliandra calothyrsus: a fast growing and N-fixing fallow tree species

Chapter Five

Adoption potential of improved tree and shrub fallows[1]

Ann Degrande, Jacques Kanmegne, Steven Franzel and Patrick Van Damme

'One must learn by doing the thing,
for though you think you know it,
you have no certainty until you try'

Sophocles, 400 B.C.

5.1 Introduction

Declining soil fertility in the humid tropics of Cameroon was identified during a diagnosis by researchers and developers as a problem area that agroforestry practices could address (Duguma *et al.* 1990). Between 1988 and 1998, ICRAF's research activities focused on developing improved fallow systems that would increase food crop production and make it sustainable, and in addition help mitigate declining soil fertility. In this context, suitable agroforestry trees and shrubs were identified that could be used to develop improved fallow systems and efficient fallow management techniques. Fast-growing species such as *Calliandra calothyrsus*, *Inga edulis* and *Cajanus cajan* were evaluated on-station for their long-term ability to replenish the fertility and structure of the region's acid soils and best performing provenances were identified. On the other hand, the on-farm research work initially focused on assessing the biophysical performance of improved fallow systems under a wider range of soil, climate and management conditions. However, as from 1994, more emphasis was put on evaluating profitability, feasibility and acceptability of the improved fallow technologies in order to assess their adoption potential.

In this chapter we first discuss the adoption potential of rotational tree fallows, looking at their biophysical performance, profitability, feasibility and acceptability. Then, a similar approach is followed to assess the adoption potential of shrub fallows. In the last section we look at how farmers integrate planted fallows in their livelihoods. In this respect, we examine constraints to and factors favouring adoption by women and present farmers' views on the impact of improved fallows on their field, in their household and in their village.

[1] Parts of this chapter have been presented in the following papers: Degrande and Duguma (2000); Degrande (2001a); Kanmegne and Degrande (2002); Degrande *et al.* (2004).

5.2 Rotational Tree Fallows

5.2.1 Biophysical Performance

Long-term on-station trials in Yaoundé (ICRAF 1996) demonstrated that rotational hedgerow intercropping has the potential to maintain high levels of maize production without degrading the soil resource base. A detailed diagram of the treatments of this trial can be found in Annex 1. As shown in Table 5-1, rotational hedgerow intercropping with 2 years of fallow (T3 and T4) resulted in consistently high and significantly greater maize yields than cropping once a year without trees (T1a) and 2 years cropping followed by natural fallow without trees (T1b). In the topsoil, important soil fertility indicators (organic C, available P, pH and exchangeable Mg, Ca, K) under the rotational hedgerow intercropping system (allowing 2 years of fallow) were significantly higher than under the annual cropping and seasonal fallow system without trees. In spite of the excellent on-station performance, on-farm evaluation of hedgerow intercropping revealed much lower biophysical performance of the technology under farmer management (Table 5-2). Yield improvements of maximum 40% were reported on-farm against 100% on-station; this may not be enough to convince farmers to adopt the technology without additional benefits (Table 5-3).

Table 5-1: Tree fallow cropping cycles and maize grain yields (t ha^{-1}), on-station Yaoundé

Treat ment	1990		1991		1992		1993		1994		1995		1996		Tot
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
T1a	1.52	NF	2.98	NF	3.54	NF	2.54	NF	2.17	NF	2.33	NF	2.69	NF	17.77
T1b	1.52	NF	2.98	NF	3.54	NF	2.54	NF	NF	NF	NF	NF	3.58	NF	14.16
T2	2.13	TF	3.70	TF	4.79	TF	5.09	TF	4.55	TF	3.33	TF	3.68	TF	27.27
T3	TF	TF	TF	TF	6.28	TF	6.09	TF	TF	TF	TF	TF	6.51	TF	18.88
T4	2.72	TF	4.48	TF	TF	TF	TF	TF	5.27	TF	4.82	TF	TF	TF	17.29
SED	0.38	-	0.28	-	0.14	-	0.44	-	0.14	-	0.36	-	0.35	-	

Source: ICRAF Annual Report 1996, p 127

NF = natural bush fallow

TF = tree fallow of *Leucaena leucocephala* and *Gliricidia sepium* mixture

T1 Control treatment of continuous maize cropping with 1 season of maize (in the first rainy season April-June) and 1 season natural fallow (in the second rainy season September-November) each year; in 1994 plots were split to allow the comparison with a 2-year natural fallow (T1b) in addition to continuous cropping (T1a)

T2 Continuous maize cropping with 1 season of maize grown between the rows of trees (regularly pruned back as hedgerows) and 1 season of tree fallow during which the hedges were allowed to grow unchecked

T3 2 years of tree fallow followed by 2 years of cropping, as in treatment 2

T4 same as treatment 3, but starting with the cropping cycle

For more details, the reader is referred to Annex 1

Table 5-2: Effect of tree fallow on maize yield in researcher-designed/researcher-managed trials in farmers' fields in Abondo and Nkolfep, Cameroon

Village	Farm	Maize dry grain yield (t ha^{-1})	
		tree fallow	natural fallow
NKOLFEP	Farm 1	3.63	2.38
	Farm 2	4.75	3.16
	Farm 3	5.26	2.88
	Farm 4	2.87	2.00
	Farm 5	2.23	1.71
	Farm 6	3.29	2.43
ABONDO	Farm 7	3.61	3.20
	Farm 8	3.29	2.76
	MEAN	**3.62**	**2.57**
	SED	0.24* (significant at $p<0.05$)	
	CV%	15	

Source: IRA/ICRAF 1997

Table 5-3: **Benefits and disadvantages of tree fallows, in order of importance, as stated during an evaluation session on a farmers' field day, Abondo, June 1997**

Benefits	Disadvantages
1. Enhanced fertility/improved yield	1. Labour requirement in nursery
2. Weed suppression	2. Labour requirement for tree cutting
3. Secondary products: stakes, honey production	3. Presence of roots
4. Reduced fallow period	4. Yield response only after several years
5. Save on fertilisers	

Source: IRA/ICRAF 1997

5.2.2 Profitability

To determine the profitability of tree fallows, net financial benefits were calculated using enterprise budgeting (CIMMYT 1988; Alimi and Manyong 2000). Hereto, tree biomass and crop yields were collected from researcher-designed, researcher-managed trials. However, as complete yield data under farmer conditions were only available for very few farms and few years, enterprise budgets were developed using yield data from a ten-year-old on-station trial (Table 5-1). The data were adjusted (yield adjustment factor of 0.8) to on-farm conditions, as recommended by CIMMYT (1988). Data and labour inputs for planting and managing the trees were collected by monitoring work rates through observation on on-station and researcher-designed/researcher-managed on-farm trials, and using farmers' recall after one season in researcher-designed/farmer-managed on-farm trials. Prices were collected from local markets. For more details on the methodology, the reader is referred to chapter 3.3.2 in this document.

Cost-benefit analysis of rotational hedgerow intercropping over a period of 12 years showed that the proposed technology is not profitable (Annex 2; Table 5-4). This can be explained by the high upfront investment costs for tree establishment (633,500 FCFA $ha^{-1} \approx 967$ € ha^{-1}) and the labour requirements for cutting back and pruning hedges. Total labour increase in a rotational hedgerow intercropping system compared to natural fallows was estimated at 37% over a 12-years period. Over these 12 years, cropping in the natural fallow system required 1055 workdays ha^{-1}, whereas cropping using RHI technology required 1430 workdays ha^{-1}. The increase in labour apparently is not compensated by increased outputs, as the returns to labour of RHI (1322 CFA $workday^{-1} \approx 2$ € $workday^{-1}$) were much lower than those of natural fallows (1899 CFA $workday^{-1} \approx 2.9$ € $workday^{-1}$).

One way of bringing establishment costs down is by reducing the price for tree seedlings. Sensitivity analysis demonstrated that returns to land for RHI increased from negative to 272,289 CFA ha^{-1} ($\approx$ 416 € ha^{-1}) when costs of tree seedlings were divided by two (Table 5-4). Prices for tree seedlings used in the cost-benefit analysis came from a study carried out in 1997 (IRA/ICRAF 1997), which calculated prices for potted calliandra seedlings. Faced with labour shortages for tree establishment, farmers tested different methods such as transplanting of wildings, direct seeding, bare rooted seedlings, size reduction of polythene bags in order to reduce time for filling and to facilitate transport of the seedlings from the nursery to the field. Another strategy to reduce labour costs suggested by farmers was starting the nursery in the rainy season to reduce watering, which counts for more than 50% of total costs (IRAD/ICRAF 1997; IRAD/ICRAF 1999). Unfortunately, no systematic evaluation of the various methods of tree establishment has taken place in Cameroon. However, experiences have shown that survival rates of calliandra, established through direct seeding and bare-rooted seedlings, were low under humid forest conditions, although this method worked quite well in other places, such as Central Kenya (Franzel *et al.* 2003) and Uganda (Nyeko *et al.* 2004).

Another possibility of reducing tree establishment costs and possibly subsequent labour costs for cutting back and pruning is reducing tree density. Asaah *et al.* (2003) found that calliandra trees planted at 1 m x 2 m (5000 trees ha^{-1}) and at 2 m x 2 m (2500 trees ha^{-1}) produced greater or similar amounts of leaf biomass than trees planted in hedges at 4 m x 0.25 m (10,000 trees ha^{-1}), suggesting that the same soil fertility improvement can be obtained with considerably fewer trees than recommended in the original design. These tree arrangements, however, were not evaluated with farmers under ICRAF's fallow management programme. A study by the International Institute of Tropical Agriculture (IITA) on farmers' preferences for different fallow tree arrangements in the humid forest zone of Cameroon (Lekeulem 1999) indicated that farmers preferred hedgerow to equidistant and cluster arrangements because of the ease of working in the alleys. Experimenters claimed that tree roots in equidistant arrangements hinder land preparation, weeding and even harvesting. Another constraint highlighted by farmers was the competition between crops and trees, which seems to be more important in equidistant arrangements. Therefore, it is rather unlikely that farmers would go for 1 m x 2 m or 2 m x 2 m, despite the fact that these arrangements require fewer trees, reduce establishment costs and turn the tree fallow technology into a more profitable activity than natural fallows (Table 5-4). The break-even point of RHI with 2500 trees ha^{-1} is year 4, which means that investment costs are recovered in year 4 and profits can be made as from year 5.

Table 5-4: Sensitivity analysis showing the effects of changes in key parameters on the profitability of rotational hedgerow intercropping compared to natural fallow, humid forest zone of Cameroon

	Natural Fallow	Rotational Hedgerow Intercropping with beekeeping	Rotational Hedgerow Intercropping without beekeeping
Base analysis			
Returns to land (CFA ha^{-1}) r = 20%	282,181	70,831	- 47,046
Break-even point	Year 1	Year 11	Not before year 12
Total labour (workdays/ha)	1055	1446	1430
Returns to labour (CFA/workday) r = 20%	1899	1322	1117
Change in key parameters			
Returns to land (CFA ha^{-1}) r = 10%	441,650	476,175	253,987
Returns to land (CFA ha^{-1}) r = 25%	234,129	(- 35,442)	(- 123,868)
Calliandra seedling price – 50%			
NPV (r = 20%)	282,181	272,289	154,413
Break-even point	Year 1	Year 7	Year 7
Tree density/4 (2500 trees ha^{-1})			
NPV (r = 20%)	282,181	373,018	255,142
Break-even point	Year 1	Year 4	Year 4

r = interest rate
Source: on-station and on-farm experimental data

Literature (Buresh and Cooper 1999; Adesina *et al.* 2000) suggests that farmers' interest in tree fallows increases when trees also provide other benefits than soil fertility improvement alone, such as fodder, fuelwood, staking material, etc. One of such additional benefits of RHI with calliandra is that the trees flower almost all year round and are suitable for bee-forage (Duguma and Mollet 1997). After a bee-keeping training workshop organised in 1997 for farmers experimenting with calliandra fallows in the humid forest and savannah zones of Cameroon, participants started integrating beehives in their calliandra plots. Hence, we included beekeeping in the cost-benefit analysis of RHI (Annex 2; Table 5-4), assuming that the activity can only take place during the fallow phase. Associating honey production to the RHI budget, made the Net Present Value positive, though still much lower than that of natural fallows.

Time is an important factor in soil fertility improving technologies. Benefits are cumulative over time and tend to be relatively low during the initial years following adoption. The time lag between costs and benefits of adoption for farmers, coupled with the fact that small-scale resource-poor farmers have short-planning horizons and high discount rates, implies that planted fallows can be very unattractive to farmers (Izac 2003). Table 5-4 demonstrates that by changing the discount factor from 20 % to 10 %, RHI with beekeeping becomes more profitable than natural fallow system.

5.2.3 Feasibility and Acceptability

(based on Degrande and Duguma 2000; Kanmegne and Degrande 2002)

Between 1994 and 1998, periodic surveys were conducted with experimenting farmers to document their assessment of rotational hedgerow intercropping, to determine the problems they were having with management and to monitor modifications introduced (Degrande and Duguma 2000). In 1995/1996, a survey of 44 households involved in testing the technology was undertaken. The study provided baseline data on socio-economic conditions of trial households and revealed key characteristics that are likely to influence adoption of rotational hedgerow intercropping (Degrande and Duguma 2000).

Rotational hedgerow intercropping is a labour-intensive technology and is unlikely to be adopted where labour is a limiting factor. Monitoring of on-farm trials showed that the first pruning, approximately 4 weeks after planting was carried out in 80 % of the tree plots, however it was often done too late. On the other hand, the second pruning was neglected in 67 % of the cases. Farmers said that they were very busy with crop weeding at that time and many thought that tree coppices could not harm the crops anymore. Fifty-seven percent of the respondents explicitly complained about time required for tree cutting.

The incentive to adopt hedgerow intercropping for the purpose of erosion control in the study villages appears to be low. Survey results suggest that farmers do not consider erosion in the study area as a major problem. Seventy-five percent indicated that less than 1/4 of their fields are on steep slopes whereas only 4 % reported that more than 3/4 of their fields are on steep slopes (steep, as defined by each farmer).

According to Carter (1995a; 1995b), hedgerow intercropping is more likely to be adopted in areas with high land pressure. In the study area however, 64 % of households reported that they have enough land to meet the needs of the family. Seventy-three percent indicated that it is still possible to get more land in the village, provided one has the means to buy or rent. Only 16 % reported that they had no possibility of acquiring additional land. However, there is evidence that forest land is becoming scarce, especially near Yaoundé. Only 2 out of 44 households had cleared land from the forest after 1990, whereas 66 % reported that the last time they had cleared forest land was before 1980. The average fallow period in Yaoundé area is estimated at 4 years (IITA 1996).

By-products are known to be an additional incentive for farmers to adopt tree fallows. In spite of evidence that firewood is still abundant in the study area, 67 % of the trial farmers said that they collect firewood from the pruned hedgerows. Furthermore, the production of stakes for yam and tomatoes is well appreciated by experimenting farmers. Eighty percent of them used wood from hedges for staking whereas it was mentioned as the main benefit by 47 % of respondents.

Feedback to Research

In the conventional hedgerow system (tested from 1988 to 1993), trees were planted in rows with distances of 4 m between rows and 0.25 m within rows. A year later, hedgerow trees were cut back at 0.5 m above ground level and the tree prunings were incorporated in the soil as mulch (Kang and Wilson 1987). These management options were observed to have several shortcomings (IRA/ICRAF 1996), including:

(1) Poor hedgerow tree growth, thus low biomass yield due to premature cut back (only 1 year after planting) and too frequent pruning (two to three times per cropping cycle);
(2) High labour demand and low flexibility in time of tree pruning. The resprouts of trees pruned at 0.5 m rapidly overshadow adjacent crops, causing yield suppression. To avoid this, farmers need to prune hedgerow trees as soon as resprouts start hindering crop growth. Research results recommend pruning of hedgerow trees respectively before planting (during land preparation), 4 weeks (during first crop weeding) and 8 weeks (during second crop weeding) after planting.
(3) Low impact on weed control and nutrient cycling due to absence of a tree fallow phase. Fast growing trees, such as calliandra and leucaena, planted in rows of 4 m close canopy after 1 year of fallow, allowing to shade out weeds efficiently.

To address the above problems, the management of the conventional hedgerow system was modified in 1993. Some of the modifications were greatly inspired by observations in farmers' fields and informal discussions with pilot farmers. The modifications deal with aspects of pruning height and frequency, cropping intensity and combination of crops, residue management, and agroforestry tree species used (Kanmegne and Degrande 2002).

a) Pruning Height and Frequency

Recommended pruning height was initially at 0.50 m above ground level; hedges were pruned three times during each cropping phase: before crop planting, then 4 and 8 weeks later. The plots were cropped twice a year, resulting in 6 prunings per year. Farmers complained that they lacked appropriate tools to prune trees well. They also reported that respecting the pruning height of 0.50 m took too much time compared to the traditional system where slashing is done at ground level. With these remarks, it was suggested to prune hedges at ground level (or 0.05 m). All interviewed farmers appreciated the change in cutting height, which also reduced pruning frequency. Subsequent surveys showed that the first pruning - approximately 4 weeks after planting - was carried out in 80 % of the farms, but the second pruning - about 8 weeks after planting - was done only in 33 % of the farms. Farmers considered hedgerow regrowth not to be harmful to the adjacent maize crop at that stage because the maize had already reached a height, allowing it to compete with hedgerow tree resprouts. This was considered as an added advantage of pruning at ground level.

Tree establishment: calliandra is planted alongside maize

After harvest of maize, calliandra is left to grow for about 2 years

During the fallow period, beehives are placed in the calliandra tree plot

After the fallow phase, calliandra is cut back

The best branches of calliandra are removed and used for staking of yams, tomatoes, etc.

After the cut-back of calliandra trees, crops are planted in the alleys

b) Cropping Intensity and Crop Combination

While during on-station and in researcher-designed/researcher-managed (type I) on-farm trials maize was the sole test crop, most of the farmers preferred associating groundnut and cassava with maize. This mixture of crops affected the management of hedgerows considerably. First, unlike maize (harvested after 3 months), cassava is a crop that takes between 6 and 18 months to mature, depending on the variety used. Second, cassava is harvested progressively over time. In fact, since storage of harvested tubers in the humid tropics is difficult, farmers prefer "storage in the soil" and harvest cassava tubers when need arises. Thirdly, after cassava harvest, farmers usually allow the plot to enter a fallow phase of at least one year before a new crop is planted. This is because cassava exhausts soil nutrients quickly. As a result of associating cassava, hedgerow plots were thus entering a fallow phase, allowing leguminous trees to grow. Consequently, initial alley cropping or hedgerow intercropping shifted to a rotational tree fallow (Annex 3). This rotational tree fallow system favoured recycling of nutrients with the possibility of obtaining higher crop yields. The majority of farmers using this technology (93 %) mentioned an improvement in soil fertility whereas 71 % reported increased yield in the tree plots compared to the control plot. The fact that during the fallow phase hedgerow trees were allowed to grow longer also offered opportunities to obtain by-products of the trees, such as stakes, fuelwood and honey, mentioned by 67 % of interviewed farmers.

After having observed these added benefits of introducing a fallow phase, rotational tree fallow was now recommended to farmers, independently of the kind of crops planted in the alleys.

c) Residue Management

In the original design of hedgerow intercropping, the leafy materials of the prunings were applied as mulch while the wood was removed from the plots. With the introduction of a fallow phase, however, wood biomass increased considerably because the trees were now allowed to grow longer. Leucaena wood biomass for example increased from 4.5 t ha^{-1} to 10.1 t ha^{-1} and with gliricidia from 1.9 t ha^{-1} to 3.4 t ha^{-1} after two years of fallow. This increase in tree biomass makes management of the residues a time-consuming and labour-intensive activity, in addition to the fact that a lot of nutrients contained in the wood are exported from the field. Farmers modified residue management in rotational tree fallows after having observed what happened in a tree plot that was incidentally burnt. The best branches were removed and used as stakes (mentioned by 80 % of interviewed farmers) or taken home for use as fuelwood in the kitchen (67 %), whereas the remaining wood was burnt in the field. In this type of burning, also referred to as 'spot burning', tree leaves are removed from the branches and woody residues are piled in the middle of the alley, where they are burnt. During land preparation, ash is spread over the alley and incorporated in the soil together with the mulch. The fact that leaves are separated from the branches avoids burning of leaves, so that they can rather decompose. Nevertheless, 60 % of farmers admitted that some leafy material is usually burnt. Spot burning is reported to increase phosphate and cation levels of the surface soil through addition of ash. It cleans the land of great masses of residues, reduces weed seeds in the soil and increases soil pH (Kang and Saggapongse 1980, Tonye *et al.* 1997).

d) Agroforestry Species

Leucaena leucocephala and *Gliricidia sepium* were initially introduced as best suited agroforestry species for the humid forest zone of Cameroon (Tonye *et al.* 1994). After experimenting a number of years, farmers complained that leucaena was too invasive and that the biomass yield of gliricidia stands decreased significantly over the years. In response, researchers introduced *Calliandra calothyrsus*, which was previously screened on-station. This species produces few seeds, so is not invasive, and performs as well as leucaena for soil fertility restoration in the humid lowlands of Cameroon (Duguma and Tonye 1994; Duguma *et al.* 1994; Duguma 1995; Duguma and Mollet 1995). Calliandra also has the added advantage of providing fodder and producing flowers throughout the year, making it an excellent melliferous plant (Duguma and Mollet 1997). With increasing interest of farmers in Cameroon for bee farming, calliandra was the most suitable tree species and farmers shifted from gliricidia and leucaena to calliandra fallow.

With this added flexibility in technology design, a growing interest from farmers to plant hedgerows was observed between 1996 and 1998. The total number of farmers with hedgerows increased from 57 in 1996 to 236 in 1998, whereas more NGOs and farmer associations were asking for tree seeds. Eighty-six percent of experimenting farmers said to be satisfied with the technology and 42 % spontaneously expanded their tree plot. The increased spread of tree fallows in the humid lowlands of Cameroon was mainly due to efforts from NGOs, which actively promoted the technology by distributing tree seeds to interested farmers and providing them with technical assistance.

5.3 Shrub fallows

5.3.1 Introduction

While offering a multitude of opportunities, tree fallows have characteristics that hamper their adoption by certain farmer categories.

- First, farmers who do not have long-term tenure rights will not establish tree fallows because the trees occupy the land permanently or at least for long periods of time (Stienbarger 1990; Buresh and Cooper 1999). Either those farmers do not have the right to plant trees there or they will not be able to reap the long-term benefits of the trees planted as they will have to move before the benefits appear.
- Second, certain cropping systems and crop species are incompatible with tree fallow management. For example in Southern Cameroon, the traditional mixed groundnut fields (*afup owondo*), mainly managed by women, are completely cleared from trees because groundnut does not tolerate shade. The presence of trees in these fields is considered as an obstacle to groundnut cropping.
- Finally, soil fertility improvement induced by trees is only observed after a number of years because trees need time to pump nutrients from deeper soil layers and restore them to top soil through litter fall and root decomposition. Because of this time lag between investment and benefit flows, resource-poor farmers are less likely to adopt tree fallows (Buresh and Cooper 1999).

In response to the above constraints, a shrub fallow technology was designed. In the first year, *Cajanus cajan* is intercropped with maize at 1 m x 0.40 m. After maize harvest, pigeon pea shrubs are left in the field until the next year, when they are slashed and residues are either burnt or incorporated during subsequent land preparation, after which crops are planted. The shrub fallow technology cycle is schematised in Annex 4.

Shrub fallows are expected to have the following advantages over tree fallows. First, annual and bi-annual shrubs do not occupy land for a long period, so long-term land tenure is not necessary. Second, the non-permanent nature of shrubs facilitates their use in a range of cropping systems, even those that do not tolerate trees. This is possible through the principle of a relay system. Here, crops benefit from improved soil fertility induced by shrubs, after the shrubs have been removed from the field. Third, soil fertility improvement induced by shrubs seems quicker than with trees.

5.3.2 Biophysical Performance (*based on IRA/ICRAF 1997; Degrande 2001*)

In on-farm trials, *Cajanus cajan* is reported to produce up to 8.5 t ha^{-1} of total dry biomass one year after planting (Fig 5-1; IRA/ICRAF, 1997).

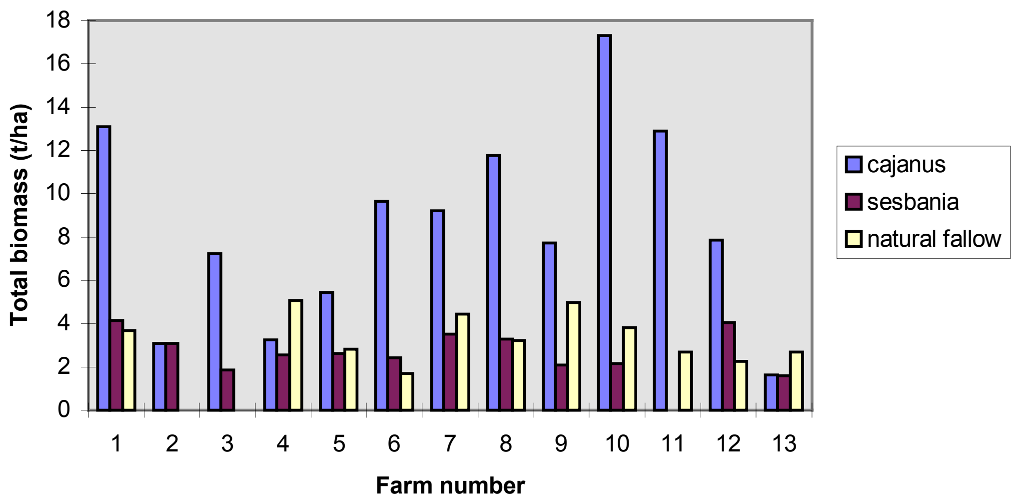


Figure 5-1: Dry biomass of total vegetation of 1-year fallows of cajanus and sesbania; on-farm type I trials in forest zone of Cameroon
(*Source*: IRA/ICRAF 1997)

Table 5-5 shows **crop yield** data for 5 researcher-designed, researcher-managed (type-1) trials over a 3 years period. The results were highly variable from farm to farm, limiting conclusions that can be drawn.

(1) In the first year, cajanus shrubs were established in association with maize. The control plot had only maize. Intercropping of cajanus with maize during shrub establishment had no discernable effect on crop yields. The difference in grain yield from maize associated with cajanus (2.99 t ha^{-1}) was not significantly different (SED = 0.364) from maize grown without cajanus (3.46 t ha^{-1}).

(2) In year 2, cajanus shrubs and natural vegetation were slashed and both plots were cropped with a mixture of maize and groundnut. Crop yields in the plot where cajanus had been slashed were higher than in the control plot, where only natural vegetation had been cut. An average yield increase of 80 % for maize and 97 % for groundnut was observed but because the data were so variable, neither increase was found to be significant. In fact, maize yields following cajanus fallow were higher than those following natural fallow on only 3 of the 5 farms.

(3) In the third year, the cycle recommenced. The first plot was planted with cajanus in association with maize and the control plot received only maize. A residual effect of cajanus on maize yields was observed and cajanus plots had higher maize yields than natural fallow plots on 4 of the 5 farms. Maize yield in cajanus plots (1.81 t ha^{-1}) was 60 % higher than in plots without cajanus (1.12 t ha^{-1}). Although statistically not significant, some farmers visibly noticed this increase in crop yields.

Table 5-5: Effect of shrub fallow on crop yields in farmers' fields, Abondo and Nkolfep, forest zone of Cameroon (*Source*: Degrande 2001)

	Maize grain yield (groundnut grain yield) in t ha^{-1}					
Farm nr	**Year 1**		**Year 2**		**Year 3**	
	cajanus	**natural**	**cajanus**	**natural**	**cajanus**	**natural**
1	2.31	2.86	0.10 (0.55)	0.90 (0.30)	0.44	0.94
2	2.30	1.91	0.93 (1.07)	1.85 (0.47)	1.46	1.27
3	3.89	3.87	1.78 (0.98)	0.63 (0.46)	2.10	1.54
4	2.56	4.32	2.85 (0.33)	0.00 (0.13)	3.43	1.54
5	3.88	4.35	1.34 (0.70)	0.52 (0.52)	1.60	0.31
Mean	**2.99**	**3.46**	**1.40 (0.73)**	**0.78 (0.37)**	**1.81**	**1.12**
SED	0.364 NS		0.696 NS	(0.087*)	0.417 NS	
CV%	17.8		100.9	(25.1)	45.1	

NS not significant
* significant at $p<0.05$

5.3.3 Profitability *(based on Degrande 2001)*

To determine the profitability of shrub fallows, net financial benefits were calculated. To do this, results on treatment plots were compared to those on control plots, which represented farmers' current fallow practices (Table 5-6). After calculating the enterprise budget, net present values per hectare and per workday were determined. The time horizon of the analysis for shrub fallows was six years and a discount rate of 20 % was used (Izac 2003). For more details on the methodology, the reader is referred to chapter 3.3.2.

Economic analysis of cajanus fallows compared to natural fallows projected over 6 years demonstrates the profitability of the technology in the humid lowlands of Cameroon. Detailed budgets for cajanus and natural fallows are shown in Annex 5 whereas results of the economic analysis are summarised in Table 5-7.

Table 5-6: Data used to calculate cajanus fallow enterprise budget (*Source*: Degrande 2001)

Practice	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Data used from year	1996	1997	1996	1997	1996	1997
Natural Fallow	M	M/G	F	F	F	F
Cajanus Fallow	C/M	M/G	C/M	M/G	C/M	M/G

Cajanus Fallow = cajanus intercropped with maize (C/M) in the first year, followed by maize/groundnut (M/G) in the second year. This cycle is repeated three times.
Natural Fallow = maize (M) cropped in the first year, maize/groundnut (M/G) in the second year, followed by 4 years of natural fallow (F). This system is based on the traditional practice in the area, where a field is cropped for a couple of years and then left fallow for approximately 3 to 4 years.

The shrub fallow allowed yearly cropping and increased total maize production per hectare over the six-year period by 200 % and groundnut by 350 % relative to natural fallow. Relay cropping the shrubs into maize greatly reduced the extra establishment and weeding requirements of the shrubs. Labour for land preparation, weeding and even planting in the cajanus-maize plot was not much different from that in the control plot (maize only). In fact, in the shrub plot, a line of shrubs replaces every other line of maize, keeping total labour for maintenance in the cajanus-maize plot similar to that in the control plot. Labour for cutting shrubs, estimated at 28 workdays ha^{-1}, was higher than the clearing labour for 1-season natural fallow (18 workdays ha^{-1}), but was considerably lower than when one has to clear a 4-year old natural fallow (40 workdays ha^{-1}). Total labour requirement in cajanus fallows was three times higher than that in natural fallows, because shrub fallow plots were cropped every year. Aside from labour, extra costs of cajanus fallows were only for shrub seeds.

Table 5-7: Labour requirements, maize production and returns to land and labour of cajanus fallow compared to natural fallow over a 6-year period

	Cajanus fallow	Natural fallow
Total maize produced (t ha^{-1})	15.18	4.98
Total groundnut produced (t ha^{-1})	1.83	0.40
Total number of workdays	1435	483
Present value of:		
Returns to land (CFA ha^{-1})	912,000	307,000
Returns to labour (CFA day^{-1})	2,180	1,860

Source: Degrande 2001

Net present values per hectare, a measure of returns to land, for shrub fallows were 3 times higher than for natural fallows. Because labour is relatively scarcer than land in the humid lowlands of Cameroon, we also assessed returns to labour. Comparing the two fallow systems using returns to labour, improved fallows outperformed natural fallows, but only by 17 %. Returns to land for shrub fallow were higher than for natural fallow on all farms.

Returns to labour in shrub fallows outperformed those in natural fallow on 5 of the 7 researcher-designed, researcher-managed farms (Table 5-8).

In summary, cajanus fallows are a profitable alternative to natural fallows for households that do not have enough land to practise long natural fallows, which are required to restore soil fertility.

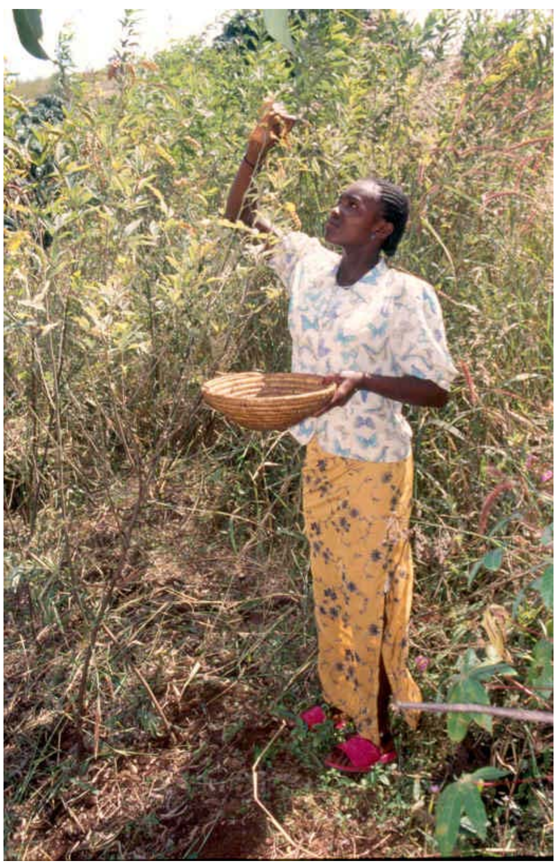
Table 5-8: Diversity in returns to land and to labour of cajanus fallows compared to natural fallows for 7 individual farms in Abondo and Nkolfep, Centre Province of Cameroon (*Source*: Degrande 2001)

Farm	Returns to land (CFA ha^{-1})		Returns to labour (CFA workday^{-1})	
	Cajanus fallow	Natural fallow	Cajanus fallow	Natural fallow
1	1,150,000	474,000	2500	2300
2	1,513,000	726,000	3000	3100
3	292,000	130,000	1400	1400
4	1,036,000	202,000	2300	1600
5	1,455,000	295,000	2900	1800
6	466,000	- 50,000	1600	900
7	568,000	115,000	1700	1300

The performance of cajanus fallows relative to natural fallow was fairly stable under a range of possible changes in key parameters (Table 5-9). Cajanus fallows were found to perform better than natural fallows under most conditions both in terms of returns to land and to labour. For example, shrub fallows had returns to land and to labour which were at least 2.5 and 1.17 times higher than those of natural fallows under most conservative scenarios, for example a 50 % decline in maize price, a 50 % increase in shrub seed price or discount rates of 10 % or 30 %. If maize prices dropped to 50 % of the actual price, returns to land for cajanus fallows would be 6 times higher than for natural fallows, against only 3 times at current maize prices. This means that improved shrub fallows reduce the risk of falling prices to farmers. On the other hand, changes in shrub seed prices hardly affected returns to land and to labour. This can be explained by the fact that shrub seeds only account for 5 % of the total cost of cajanus fallows. A discount rate of 30 % instead of 20 % had very little impact on the profitability of cajanus fallows versus natural fallows. In fact, higher discount rates would reduce profitability of options whose payoffs are longer term. However, this is not the case of cajanus fallows where initial investment is low and yield response rather quick.

Cajanus cajan: N-fixing shrub used in improved fallows

Cajanus cajan fallow, one year after planting



In areas where fuelwood is scarce, the woody residues of cajanus are removed from the field and taken home

Table 5-9: Sensitivity analysis showing the effects of changes in key parameters on returns to land and to labour of cajanus fallow, compared to natural fallow
(*Source*: Degrande 2001)

	Returns to land (CFA ha^{-1})		Returns to labour (CFA day^{-1})	
	Cajanus fallow	**Natural fallow**	**Cajanus fallow**	**Natural fallow**
Base analysis	912,000	307,000	2200	1900
Maize price – 50 %	364,000	56,000	1500	1200
Maize price + 50 %	1,459,000	558,000	2900	2600
Shrub seed price + 50 %	903,000	307,000	2200	1900
Discount rate 10 % instead of 20 %	1,194,000	339,000	2200	1800
Discount rate 30 % instead of 20 %	724,000	281,000	2200	1900

5.3.4 Feasibility and Acceptability *(based on Degrande 2001)*

The feasibility of a technology can be assessed through the ability of farmers to manage this technology. Therefore, feedback about constraints in the establishment and maintenance of the improved practice is important. Furthermore, farmers' perceptions of the advantages, disadvantages, requirements and benefits of the technology will eventually determine adoption.

Benefits

After the 1998 cropping season, a formal survey was conducted in the sites of Abondo and Nkolfep with 28 farmers who had been conducting researcher-designed/farmer-managed (type II) shrub fallow trials (see also 3.3.2). Half of the respondents mentioned increased yields as a reason for expanding cajanus fallows and 35% reported it as main benefit of shrub fallows. In fact, 92 % of the farmers who tried the technology noted a positive impact of cajanus fallow on crop yields, while only two farmers did not see a change in yield. Farmers' second most important reason for expansion was soil fertility improvement, mentioned by 39 % of the farmers. In the same line of thinking, more than half of the experimenting farmers deliberately planted cajanus on their poorest soils. They said they did so because, after hearing about the benefits of cajanus, they wanted to test its potential to improve soil fertility there where they needed it most. The third main benefit, considered by 32 % of the respondents was the potential of cajanus to suppress weeds during the fallow period. Ngobo et al. (2004) identified the following species as dominant on soils with high clay, N and C contents: *Chromolaena odorata, Cyathyla prostrata, Mariscus alternifolius, Mikania cordata, Musanga cecropioides* and *Trema orientalis*, whereas *Ageratum conyzoides, Cyperus sp., Haumania danckelmaniana, Paspalum conjugatum, Pouzolzia guineensis, Richardia brasiliensis, Sida rhombifolia, Stachytarpheta cayennensis, Talinum trainulare* and *Triumfetta cordifolia* were preponderant on sandier soils with high pH, P and Mg content. A survey in southern Cameroon (ASB 1996) indicated that grass and broadleaf weeds were reported as the major constraint to agricultural production by 70 % and 55 % of the respondents, respectively. The same survey revealed weed incidence as a major reason for fallowing. Thirty percent of farmers interviewed heard about the potential use of cajanus grains as food, but no one had actually eaten cajanus grains so far because their shrubs had not yet produced seed. Eighteen percent noted the shortening of the fallow period and the ease of clearing and ploughing following the fallow period as benefit. The fact that only 1 farmer mentioned the use of cajanus for firewood could be explained by the availability of other sources in the humid forest zone.

Problems

Thirty-five percent of farmers interviewed did not experience any problems in planting and managing cajanus fallow. Storing cajanus seeds was cited as a problem by 23 % of trial farmers. However, the biggest problem reported by adopters was that cajanus did not produce seeds, thereby limiting expansion of the technology. The cajanus variety promoted by ICRAF produces a lot of biomass, thereby enabling good nutrient recycling for soil fertility improvement, but does not flower nor seed well. On the other hand, farmers in the western highlands of Cameroon use varieties that seed profusely. A good balance between biomass and seed production should be sought since provision of good quality seed in adequate quantities is crucial for the promotion of shrub fallows on a large scale.

Expansion

The monitoring and evaluation results of cajanus fallows after four years indicate a strong interest in the technology shown by farmers. The number of shrub fallows increased from 40 in 1996 to 95 in 1997 and 282 in 1998. There was also considerable expansion within farms. In ICRAF's pilot villages (Nkolfep and Abondo), 56 % of the farmers expanded their shrub fallows in 1998. In 71 % of the cases, the second shrub field farmers established was larger than the first one. When asked what proportion of their farm land they would like to plant with shrubs, 64 % reported to be willing to plant more than half of their crop fields with cajanus. Two major modifications in shrub management were recorded. First, a few farmers preferred broadcasting cajanus instead of planting it in lines. Second, some farmers extended the cajanus fallow for two or three years for better soil coverage and hoping for seed production.

Interest of Women

Thirty percent of the farmers testing shrub fallows were female. The interest of women in cajanus fallows can be explained by the following reasons.

1. Clearing of a cajanus fallow is much easier compared to natural fallow. This is an important factor, given recent changes in division of tasks between men and women in rural areas of Southern Cameroon. Traditionally, men were responsible for clearing of fields, but with the intensification and commercialisation of food cropping, men also got involved in food cropping, especially in areas with relative good market access (Kumar 1987; Guyer 1989). Therefore, women can no longer rely on male family labour to do land clearing. Hiring of labour would be another option, but would increase costs substantially.
2. After slashing cajanus shrubs and spot burning of woody residues, the field is clean and can easily be ploughed for groundnut planting. Groundnut is the main crop in the mixed food crop fields and is generally managed by women.
3. Cajanus is established through direct seeding, a less labour-intensive technique than nursing and transplanting seedlings, as is the case for trees such as calliandra. Given the high demand for women labour in rural areas, there exist incentives to adopt low labour-intensive technologies.
4. Yield response to shrub fallows is relatively quick compared to tree fallows. This is an important incentive for poor households that cannot afford to wait several years for their investment to yield benefits.

Incorporation of Shrub Fallows in Farming Systems

Farmers' main intention in using cajanus fallows is to increase yield, improve soil fertility and suppress weeds, but it is not clear how they will actually incorporate the technology into their farming system. For example, in the farmer survey of 1998, 64 % reported to be willing to plant more than half of their cropland with cajanus. But so far, trial farmers preferred rotating the improved fallows around their farms. There is a need to find out what percentage of their land farmers are willing and able to cover with shrub fallows.

5.4 Integration of Improved Fallows in Farmers' Livelihoods

5.4.1 Do women benefit from improved fallows? *(based on Ntone 1997[2])*

On-farm testing of improved fallow technologies in the humid lowlands of Cameroon, carried out by ICRAF from 1987 to 1998, has paid little attention to women's specific capacities and needs. In 1997, only 7 out of 95 experimenting farmers were women. This low participation (7 %) in the development of new agroforestry technologies is regrettable because women play a major role in food production and natural resource management.

[2] This study was carried out as part of participatory evaluation of improved fallow technologies by a student Nelly NTONE, under the supervision of Ann Degrande in 1997.

Lack of involvement of women in technology testing may slow down their future adoption or even lead to inappropriate recommendations for female farmers.

To learn more about the reasons behind the low participation of women in the on-farm testing of improved fallows, constraints to and factors favouring the practice of improved fallows by women in the humid lowlands of Cameroon were identified. In accordance with Rogers (1995; see Chapter 2 of this study), we examined first the factors that were immediately related to women themselves, i.e. lack of land and tree tenure security, low education level, low access to information on innovations. Then we investigate factors inherent to the technology (complexity and appropriateness), followed by factors related to the mode of technology transfer.

a) Factors related to women themselves

- Land tenure is known to play a significant role in the process of adoption of tree-based technologies, such as improved fallows (Buresh and Cooper 1999). In most traditional inheritance systems of Africa, women cannot own land and the latter is often considered as a limiting factor for adoption of tree-based technologies (Rocheleau 1987; Scherr 1995). In the forest zone of Cameroon, ownership rights to land and trees are largely determined by customary tenure rules (Bigombe and Bikie 1998). Following the principle of patrilineal descent, sons are the heirs of their father's property whereas daughters cannot inherit. This does not mean, however, that women are excluded from ownership because 'ownership' starts with the principle of 'having the right to use' (usufruct right). According to Diaw (1997), women's user rights on farming lands are guaranteed as long as they remain married. Secondly, widows can inherit from their deceased husband. Thirdly, sons' inheritance, in polygamous families, is transmitted through their mothers and divided equally according to the number of wives and not the number of sons. Fourthly, unmarried daughters can inherit in case they do not have brothers or when the brothers consent. As tree planting is considered an act of land appropriation, women are often limited in tree planting because they do not own the land (Atta-Krah 1992; David 1992; Stienbarger 1990; Renolds 1994). However, in our study sites (*Beti* culture) women are allowed to plant and actually plant trees in their fields, although not as much as men do. One reason is that women do not want shade in their food crop fields, as opposed to men who usually retain and plant trees in their cocoa and coffee plantations, which actually need shade. Furthermore, planting trees for soil fertility has the disadvantage of immobilising land for food cropping, which limits the husband in his choice to allocate this land to other enterprises. Prior consent of the husband is thus a prerequisite. These results make us believe with Adesina *et al.* (1997) that land and tree tenure do not negatively affect the adoption of improved fallow technologies by women in the humid forest zone of Cameroon. Indeed, a study in Ghana and Sumatra (Quisumbing and Otsuka 2001) demonstrated that tree planting on insecure land was in fact stimulated by the expectation of strengthened individual land rights. The authors argued that commercial trees had been planted under the communal ownership system as widely and actively as under the private ownership system. In the matrilineal system in Ghana, plots planted with trees, which confer strong individual rights, were often transferred to wives and children as gifts and as a reward for their efforts in helping the husband of father to plant cocoa trees.

- Women's lower level of education is often mentioned to explain their lower participation in on-farm trials and development projects in general. While it is true that rural women in Africa are less instructed than their male counterparts, most women (66.7 %) in our study site got some primary education, enabling them to easily understand any message brought to them in a simple way.

- Women are also said to be conservative and averse to innovations. However, examples of innovations adopted by women in the study zone prove that women are susceptible to try out new things provided that they dispose of the necessary information. Amakiri and Igben (1992) found that good knowledge about the technology and the benefits that result from that technology are the two main factors leading to adoption. However, information meetings are generally attended by men only and in most cases the information is not passed on to their wives or daughters. After 10 years of on-farm research in their village, very few female farmers in Abondo knew about agroforestry. Adesina *et al.* (1997) found that in the Centre Province of Cameroon, 52 % of the interviewed women had heard about agroforestry. This number is considerably lower than the 83 % found for men in the same province. Essomba (2003) also mentioned the absence or decease of the husband as an important reason for discontinuing or for non-expansion of improved fallows. This shows that the man's knowledge of and experience with improved fallows was not transferred to other members of the household.

b) Factors related to the technology

- Hedgerow intercropping would be too labour-intensive, especially for cutting back and pruning of hedges. Considering the already heavy workload of rural women, this might limit the adoption of the technology. Women have the possibility of hiring labour for certain tasks, but this would raise the costs of implementing the technology considerably. On the other hand, time of tree pruning coincides with the period of weeding, which is principally a woman's task. Swinkels and Franzel (1997) also found that in Kenya, despite their participation in on-farm trials, women in male-headed households, unlike their counterparts from female-headed households, did not prune hedges in an alley cropping system claiming that pruning is a man's responsibility.

- Improved fallows would be incompatible with women's farming practices. Indeed, while fallowing is a common agricultural practise in the forest zone of Cameroon, some characteristics of improved fallows do not match women's current cropping system. For example, women's "groundnut fields" (*afup owondo*) are completely cleared from trees before a mixture of crops is planted. Those crops (groundnut, cassava, maize) do not tolerate shade, contrary to men's cash crops such as cocoa and coffee, which actually need it. Regarding the management of tree fallows, women face problems in tree cutting, traditionally a male task. Women also have little experience in managing tree nurseries, although they often participate in the maintenance and watering of seedlings when nurseries are male-run. However, women in our study zones confirmed that it is possible to establish and maintain tree fallows provided that difficult tasks are carried out in group or with the assistance of a male member of the household. Shrub fallows seem more suitable to women then tree fallows because shrubs are established by direct seeding and are easier to cut back. Moreover, *Cajanus cajan* has edible grains, which could be an additional benefit of this specific shrub fallow technology that is appreciated by women, even though they have yet to experience it.

- Improved fallows would not respond to women's immediate needs of providing food for the family and generating income to take care of day-to-day household needs. However, whereas the main objective of improved fallows is soil fertility improvement, tree fallows do offer much more advantages than increased soil fertility alone. For example, they suppress weeds considerably, in addition to providing fuel wood and stakes. Tree fallows also offer the possibility to engage in bee keeping for income generation. Women in particular might be interested in the potential of improved fallows to reduce weeds, as they are dedicating a great deal of their time to weeding. Fuel wood provision could be equally important in the promotion of improved fallows for women. Because, even where wood is still abundant, women spend about an hour a day to collect firewood and often have to cover increasing distances to look for it. According to Degrande and Duguma (2000), 67 % of the trial farmers bring firewood from their tree fallow home.

c) Factors influencing adoption related to extension

- From the above, it is clear that lack of information is hampering the adoption of improved fallows by women. The insufficiency of information can be due to lack of gender focus in research and extension projects. According to Adesina *et al.* (1997) the most important sources of information for agroforestry in the Centre Province are researchers (40 %) and extension agents (27 %). This does not coincide with the most common sources of information for women, i.e. their associations, called "*tontines*", farming groups and the household (Essomba 2004). In addition, most of the extension staff are men and generally no effort is made to take women's availability into consideration in the planning of meetings and work schedules. Women's participation in sensitisation and information meetings and farmer training might increase by ensuring that the time and place of such encounters suit women's schedule and by integrating female staff in research and extension. Female participants in on-farm trials in our study zone admitted that the presence of a female researcher in the team had increased their interest in agroforestry.

- To increase adoption of improved fallows by women, extension messages should stress more the advantages that are of particular relevance to women. As mentioned above, improved fallows have a number of benefits that may interest women particularly, such as reduction of weeds, provision of fuelwood and stakes, saving labour and production of edible cajanus grains.

5.4.2 Impact of Improved Fallows

An impact assessment workshop grouping farmers, extensionists and researchers was organised on 24 August 1999 in one of ICRAF's pilot villages Abondo (see also 3.3.2). The main objectives of the workshop were to: (1) obtain farmers' views on the impact of improved fallows on their field, in their household, in their village and how to measure this impact; (2) elicit farmer expectations of magnitudes of impact and constraints in achieving these levels; (3) identify recommendation domains for improved fallows; and (4) identify factors affecting diffusion and adoption, and obtain suggestions for an action plan for dissemination of improved fallows.

The impacts of improved fallows were examined at three levels: farmers' fields, their households and the village as a whole. Farmers generally found it easier to assess the impact of improved fallows on their fields than at household and village level. For example, in the working groups on impact at village level, participants often referred to the field level.

Impacts at Field Level

The results from the field level discussions are found in Tables 5-10 and 5-11. Farmers especially stressed effects of cajanus and calliandra on soil fertility and crop yields. Calliandra was said to increase the quantity and quality (healthier, bigger) of maize and cassava, provided that trees are well established, tree spacing is adequate and pruning regime respects research recommendations. Cajanus has moderately positive effects on maize, cassava and tomato and to a lesser extent on groundnut. Yield increases are monitored by number of bags or buckets harvested. The group working on impact of cajanus emphasised the need for a control plot to measure changes in soil fertility or crop yields. However, in case comparison with a control plot is not possible, other indicators for soil fertility are the amount of litter under the trees, the colour of the soil (soils under improved fallow are black) and increased activity of soil fauna such as earthworms.

Both calliandra and cajanus fallows reduce the amount of weeds in the field. The magnitude of this impact depends on the ability of the trees and shrubs to cover the soil rapidly and the amount of mulch produced. Nevertheless, participants expected no change from cajanus on frequency of weeding, but a moderate reduction of weed density, which facilitates the weeding task. The participants appreciated reduction of soil erosion by tree hedges, but it was considered less important because most of the farmers in the group crop on rather flat land. Another field level impact of cajanus is decrease in crop pests and diseases, which was attributed to a richer, thus healthier soil.

Impacts at Household Level

Many impacts were noted at household level**,** but they all more or less related to increased crop yields. Increased crop yields generate physical surpluses in addition to what is needed for home consumption. These surpluses can be sold and generate income. Moreover, calliandra trees, in addition to improving soil fertility, are used for stakes, fuelwood, bee keeping and fodder, thereby diversifying farmers' income-generating activities and thus, household income. The revenues coming from crop surpluses and other activities are used for health care and enable farmers to send their children to school, improving the general well-being of the household.

Calliandra fallows reduce the traditional fallow period considerably, which is interesting to older farmers who no longer have the strength to cut secondary forest or long fallow vegetation (> 10 years). The main constraint farmers face in the use of calliandra fallows and the development of related enterprises is organising these activities in time and space. Farmers already have many different activities and the integration of new ones requires a certain re-allocation of inputs (labour and other resources) at the household level.

The impact of the use of cajanus at the household level is also felt in higher yields, leading to increased income. Ripe cajanus seeds can substitute for groundnut whereas green seeds and pods can be eaten as a vegetable in many different forms (Duke, 1983). Seeds also constitute a direct source of income as they can be sold in local markets. According to the participants, a great advantage of cajanus is that it helps rural households to maintain continuous and sustained crop yields. The impact of cajanus fallows on labour demand (especially for slashing the cajanus shrubs after fallow) differs according to the ecological zone and prevalent cropping system. In fact, in the forest zone, cajanus fallows are an alternative to the traditionally practiced 4-year natural fallow, which consists of a lot of biomass. It is thus understandable that here farmers prefer cajanus to natural fallow because it is easier to cut. On the other hand, natural fallows in the humid savannah generally do not exceed 6 months and are mainly composed of grasses. Cutting cajanus in this environment is harder than clearing the natural grass fallow. According to the farmers however, integration of cajanus in the cropping cycle does not change the distribution of tasks within the household.

Impact at Village Level

In general, participants agreed that the use of improved fallows can enhance the well-being in the village, through increased crop yields, shorter fallow periods, less erosion and fewer weeds, provided there is a market for the crops grown. On the other hand, the introduction of calliandra in the village also raised some conflicts between farmers who adopted the technology and those who did not. For example, if calliandra is left to flower and seed without attention, calliandra seeds can spread to neighbouring farms. But participants noted that pruning trees close to neighbouring farms before they seed and/or collecting seeds before the pods open can avoid this type of problem. Many participants also thought that, through sensitisation and information, the whole village could understand the advantages of the innovation and become involved in improved fallows.

It was anticipated that the participatory approach of research and development of improved fallows in pilot villages would have strengthened the collaboration between farmers. However, ideas on this topic were divided. While some participants believed that collaboration between farmers within the village and between villages had improved, others expressed the feeling that the work had become more individual. The latter explained that soil fertility improving technologies could only be implemented on individual farms. As a result of the introduction of improved fallows, members of the group abandoned their community fields, because nobody was willing to invest in the fertility of land that belonged to the group.

There was a general concern about future seed provision, because participants anticipated increased demand for seeds of calliandra and cajanus. The same may be true for technical assistance and extension, as somebody mentioned that there were many farmers for very few technicians.

5.4.3 Target zones, target groups and dissemination strategy

Table 5-12 summarises the outcome of a group discussion at the impact workshop on the identification of key target zones and groups. In general, participants agreed that improved fallows are most appropriate in areas with high population density, poor soils, shortening fallows and weed problems. Adoption is accelerated when there are problems of erosion and a need for fuelwood or fodder. Any farmer can adopt improved fallows, provided he or she is innovative and interested in the technology. Households that are more likely to adopt improved fallows lack land or have to grow crops on poor soils and look for ways to diversify their income. Participants in the workshop believed that households with limited financial resources are able to adopt the technology and are even more likely to adopt it than richer households because they cannot afford to buy chemical fertilisers. The only prerequisite to the adoption of calliandra would be the availability of (especially male) labour to plant and cut the trees. On the contrary, cajanus would be more appropriate for female farmers, because its management requires less labour and integrates well in the women's cropping activities, whereas seeds can be used in the kitchen. Moreover, cajanus does not occupy the land for a long time (women do not own land).

There seems to be no age restriction to adopt the technology, although farmers of different age may have different objectives in introducing tree and shrub fallows. For younger farmers, the main objective is increasing yields, while the older people are more interested in saving time and energy for clearing. Many participants mentioned good market access for their food crops (road infrastructure, transport facilities) as a favouring factor for adoption of improved fallows, but one group reported that farmers near major roads generally get involved in more intensive commercial farming (e.g. green vegetables, tomatoes) and may therefore be less interested in improved fallows.

Regarding preferences for one or the other technology, lower initial investment costs and labour requirements, and quicker yield response explain the success of shrub fallows compared to tree fallows. However, there is some evidence that both technologies catch the interest of farmers. In 1998, 88 % of trial households had both tree and shrub fallows whereas 60 % could not express a particular preference for one or the other. Similar results were obtained in our study on continued use of improved fallows (Essomba 2003). Forty-five percent of interviewed farmers had no specific preference for either shrub or tree fallows. According to these farmers, the two technologies have essentially the same advantages.

Table 5-10: Results from the farmer workshop on impact of calliandra at field level
(*Source*: ICRAF-AHT. 1999. Village workshop on impact of improved fallows. Internal Report)

Indicator	How to measure	Magnitude	Factors increasing impact	Factors decreasing impact
1. Effect on soil fertility	- quantity of organic matter - crop yields (quantity produced) - activity of soil fauna (quantity of earthworms, insects)		Good establishment of calliandra Good management of calliandra Good soil moisture in dry season Initial fertility state of the soil	Diseases on calliandra Neglect of field by farmer Bad establishment of calliandra
2. Effect on erosion	Accumulation of soil at the base of the tree hedges		Fields with steep slopes	Flat fields
3. Effect on crop yields	Quantity produced (bags, buckets, weight)		Appropriate establishment of calliandra; Good management of trees; Respect fallow period	Destruction of crops by domestic animals or insects; Bad field management; Climatic factors
4. Effect on quality of crops	Size of cobs, tubers, grains Vigour of plants		Appropriate tree spacing for different crops Respect time of planting Appropriate pruning regime	Farmer neglecting field Rigid tree spacing
5. Effect on weeds	Reduction or increase in weeds		Rapid coverage of soil by trees Large production of biomass by trees	Open space due to dead trees Inappropriate spacing of trees
6. Importance of the plot	Area under calliandra Restoration of the field Supply of by-products (diversity of products)	Will depend on the initial cropping status of the field (under fallow, abandoned, cropped)	Availability of land; Availability of seed; Willingness of farmer Objectives of the farmer Good establishment of trees Existence of other uses of tree products in the village Lack of stakes for certain crops	Lack of land Lack of plants Lack of labour Lack of interest by farmer Absence of crops that need stakes Presence of other material to provide stakes in the village

Table 5-11: Results from the farmer workshop on impact of cajanus at field level
(*Source*: ICRAF-AHT. 1999. Village workshop on impact of improved fallows. Internal Report)

Indicator	**How to measure**	**Magnitude**	**Factors increasing impact**	**Factors decreasing impact**
1. Effect on soil fertility	- control plot - colour of the soil - soil moisture - less parasites	visible effect visible effect large effect large effect	Depending on type and density of crops	Not recorded
2. Effect on crop yields	- Control plot	Large positive impact on maize yields Moderate impact on groundnut yields Positive for cassava and tomatoes Good vegetative development of cocoa	Not recorded	Not recorded
3. Effect on weeds	- Frequency of weeding - Density of weeds - difficulty of weeding	No impact Moderate impact Large impact	Not recorded	Not recorded
4. Effect on quality of crops	- size of cobs, tubers, fruits, grains - vigour of plants	Moderate impact	Not recorded	Not recorded
5. Effect on diseases	- control plot	Large effect on nematodes	Good rotation of crops	Not recorded
6. Effect on erosion	- control plot - infiltration of rains - speed of drainage	Moderate effect	Fields with steep slopes Cropping during second season (heavy rains)	Not recorded

The last topic of the workshop on impact assessment was the development of a strategy for the dissemination of improved fallows in Cameroon. The groups had different ideas, but three common points could be extracted: information, organisation and seed production. The participants were convinced that the first step towards wide-scale adoption is raising awareness about improved fallows and familiarising farmers with the technologies. Therefore, the link between research and extension should be strengthened and demonstration plots should be established in pilot villages. Field days, farmer-to-farmer visits and the organisation of training sessions for extensionists and farmers should support this approach. Up-to-date technical manuals and simple leaflets should be developed and made available. Demonstration plots should also serve the purpose of adapting the technology to local conditions and to crops, grown in that area, and should enable researchers to answer some of the so far unsolved questions. Second, the organisation of farmer groups becomes essential, because it is practically impossible for the extension service to reach all farmers individually, even if the number of extensionists would increase. More emphasis should be given to training of farmer-leaders, who can later take over the role of extensionists in their community. Here, the involvement of traditional, political and religious leaders is crucial. Third, it is widely accepted now that the key to successful adoption of agroforestry technologies depends on the availability of good quality seeds in sufficient quantities. It is thus essential to develop seed production units at different levels: in research stations, through NGOs and with farmers in the village.

Table 5-12: Key target zones and groups for promotion of improved fallows in the humid forest and savannah zone of Cameroon
(*Source*: ICRAF-AHT. 1999. Village workshop on impact of improved fallows. Internal Report)

Objective of improved fallow	Target zones	Target groups
Improve soil fertility	Areas with high population density (West and Centre Province)	
Diversify production	South and Centre Province	Everybody (young, old, men, women)
Decrease labour requirements	Forest zone	Older farmers, women
Shorten fallows	All areas	
Control erosion	Slopy areas with high rainfall (West and South)	
Produce stakes and firewood	Areas where farmers crop tomatoes and yam (Centre and South)	Younger farmers, Women
	Deforested areas (West)	Women
Increase revenues	Isolated areas (those closer to main roads, get involved in commercial intensive farming)	

5.5 Conclusion

In this chapter, the adoption potential of two soil fertility management technologies, i.e. rotational tree fallows with *Calliandra calothyrsus* and shrub fallows with *Cajanus cajan*, in the humid forest and moist savannah zones of Cameroon were assessed. This evaluation was based on approximately 10 years (1987-1998) of on-station and on-farm research. Major opportunities for and constraints to the adoption of these two innovations by small-scale farmers are highlighted below.

For a technology to be adopted, it has to respond to farmers' perceived needs and must be compatible with existing farming systems and local norms and values. Moreover, the innovation has to be profitable and have a relative advantage over its alternatives. Also the technology should be simple in terms of management and number of components and the benefits should be easily observable. Finally, policy support can have a large impact on adoption of innovations. Based on the above, tree and shrub fallows have a number of properties, which would favour their adoption by small-scale farmers in the humid forest and moist savannah zones of Cameroon.

Tree Fallows

- On-station and on-farm trials have demonstrated the potential of hedgerow intercropping to reduce weeds considerably (IRA/ICRAF 1996). On-farm trial results indicated that weed biomass after two years of tree fallow (2.07 t ha^{-1}) was significantly lower than after two years of natural fallow (11.54 t ha^{-1}). In 1996, 47 % of experimenting farmers mentioned weed suppression as the main advantage of hedgerow intercropping. This is an important fact knowing that in the area weeds are listed as number one constraint in agricultural production, far ahead of 'poor soils' (ASB 1996). A small number of experimenting farmers mentioned easiness of field operations as an additional advantage. This implies a serious reduction in time for clearing alleys and a softer soil that facilitates ploughing and weeding.

- Many authors have stressed the importance of short-term benefits, such as production of firewood and staking material in facilitating adoption of tree fallows (Carter 1995; Buresh and Cooper 1999; Adesina *et al*. 2000). The fact that farmers usually do not mention fuel wood as a benefit from hedgerow intercropping suggests that firewood is still abundant in the study area. Nevertheless, 67 % of the trial farmers (Degrande and Duguma 2000) said they collect firewood from pruned hedgerows. Other by-products of tree fallows are stakes for yams or tomatoes. Eigthy percent of trial farmers used wood from the hedges for staking in 1996 (Degrande and Duguma 2000). A few farmers even started selling calliandra wood for staking at 10 FCFA per unit.

- In the study zone, bee keeping is well known and honey has a great potential as a cash enterprise. As it is, 1 l of honey sells for 3000-4000 F CFA (4.6-6.1 €) in Yaoundé market whereas 1 hive yields approximately 7.3 l per year (Mboufack 2003). Calliandra is known to be an excellent source of nectar, and it has been tested for honey production (16.9 µl of nectar per flower per night) in Southeast Asia (ICRAF 1996). In 1996, ICRAF in collaboration with two NGOs introduced bee keeping as a side activity in improved tree fallows. To this end, farmers were trained in construction of top-bar hives and in bee keeping techniques (Mboufack 2003). Results of the survey on continued use of improved fallows (Essomba 2003) show that the main reason for farmers to extend calliandra fallows was the wish to increase honey production. Mboufack (2003) found that farmers in the Centre province of Cameroon generated on average 64,240 FCFA (98 €) [min = 42,240 FCFA; max = 85,860 FCFA] per year from hives in their calliandra fields.

Shrub Fallows

- In on-farm trials, *Cajanus cajan* is reported to produce a total of 8.5 t ha^{-1} of dry biomass (IRAD/ICRAF 1997). Crop yield results suggest the following. (1) Intercropping of maize with cajanus during establishment does not decrease maize crop yields. At establishment, the difference in maize grain yield in cajanus fallows (2.99 t ha^{-1}) was not significantly different (SED=0.364) from the one without cajanus (3.46 t ha^{-1}), even though the latter was higher. (2) Crop yields after cajanus fallow are higher than after natural fallow. An average yield increase of 80 % for maize and 97 % for groundnut was observed but due to high variability in the data, the increases were not found to be significant. (3) A residual effect of cajanus on yields is observed in the third year. Maize yield in cajanus plots (1.81 t ha^{-1}) is 60 % higher than in natural fallows (1.12 t ha^{-1}). Although statistically not significant, farmers acknowledged this increase in crop yields.

- Half of the 28 farmers interviewed mentioned increased yields as a reason for expanding cajanus fallows and 35 % reported it as main benefit of shrub fallows. In fact, 92% of the farmers who tried the technology noted a positive impact of cajanus fallow on crop yields, while only two farmers had not seen a change in yield. Farmers' second most important reason for expansion was soil fertility improvement, mentioned by 39 % of the farmers. The third main benefit, considered by 32 % of the respondents was the potential of cajanus to suppress weeds during the fallow period. Potential use of cajanus grains as food was reported by 30 % of farmers interviewed, while 18 % noted the shortening of the fallow period and the ease of clearing and ploughing following the fallow as benefits.

- There is a clear interest of women in cajanus fallows because of the following. (1) Clearing of a cajanus fallow is much easier compared to natural fallow. (2) After clearing cajanus and spot burning of woody residues, the field is clean and can easily be ploughed for groundnut planting. Groundnut is the main crop in the women's mixed food crop fields. (3) Cajanus is established through direct seeding; this is a less labour intensive technique than nursing and transplanting tree seedlings. Given the high demand for women labour, there is an interest to adopt low labour-intensive technologies. (4) Yield response to shrub fallows is relatively quick compared to tree fallows, which can be considered to be an incentive for poor households with very high discount rates.

- Economic analysis of cajanus fallows compared to natural fallows projected over 6 years demonstrates the profitability of the technology in the humid lowlands of

Cameroon (Degrande 2001). Cajanus shrub fallow increases total maize production per hectare over the six-year period by 200 % and that of groundnut by 350 % relative to natural fallow. Relay cropping maize into shrubs greatly reduces the extra establishment and weeding requirements of the shrubs. In fact, during the establishment phase, land preparation, weeding and even planting labour demand does not change from the cajanus to the natural fallow plot. Total labour requirement in cajanus fallows, however, is three times higher than that in natural fallows, because shrub fallow plots are cropped every year. Aside from labour, extra costs of cajanus fallows are only for shrub seeds. Net present values per hectare for shrub fallows are 3 times higher than for natural fallows. Comparing returns to labour, improved fallows outperform natural fallows, but only by 17 %.

On the other hand, some of the requirements for effective technology adoption are not fulfilled.

The proposed technology should respond to farmers' perceived needs. Originally, hedgerow intercropping was designed to solve three main problems: low soil fertility, risk of soil erosion and low availability of fodder for livestock. Although these problems were diagnosed as priority research areas at the start of ICRAF's agroforestry research programme (Djimde and Raintree 1988; Duguma *et al.* 1990), surveys in 1995 (Degrande and Duguma 2000) revealed that none of these problems were of major concern to farmers in our study sites.

- Farmers in the study area do not perceive the need for soil fertility improvement. Fifty-two percent of the households involved in tree fallow testing in 1996 assessed that more than half of their fields had good fertility whereas only four percent thought that the fertility status of more than half of their fields was low (Degrande and Duguma 2000). In reality, in most cases there was still a possibility to leave land to natural fallow for a reasonable long period; 73 % of the trial households indicated that they had enough land to meet their household needs (Degrande and Duguma 2000).

- In the study zone, livestock husbandry is a secondary activity for most households; goats, sheep and pigs are free-roaming during the dry season and tethered during the rainy season. Generally here farmers did not show interest in supplying fodder to their animals (Degrande and Duguma 2000).

- Theoretically, the adoption of hedgerow intercropping is expected to be higher on sloping land. In most villages of the study area, however, farmers did not consider erosion as a major problem. Degrande and Duguma (2000) reported that 75 % of the trial farmers indicated that they have less than one-quarter of their fields on steep slopes and only 4 % reported that more than three-quarters of their fields are on steep slopes (steep as defined by each farmer). In evaluating the technology, farmers did not mention erosion control as a benefit (Essomba 2003).

For an innovation to be adopted, it has to be profitable and have a relative advantage over its alternatives. Although offering interesting advantages, such as weed suppression, and marketable by-products (honey, stakes, firewood), our study shows that rotational tree fallows are less profitable than natural fallows and require much more labour. Labour demand in tree fallows is problematic at two levels. First, there is the establishment and maintenance of the tree nursery, raised by 57 % of the interviewees. Tree pruning comes second and is reported by 57 % of the farmers. We noticed that the first pruning after planting is carried out in 80 % of the tree plots, though sometimes too late, but that the second pruning is neglected in 67 % of cases. Farmers are very busy with weeding at that time and many think that resprouts do not harm the crops anymore. However, failure to apply the recommended pruning regime is known to result in severe yield losses due to competition of the trees for light and nutrients (Kang *et al*. 1999). In the survey on continued use (Essomba 2003), 17 % of farmers cited 'too labour demanding' as the reason for non-expansion and 8 % as a reason for abandoning. Those farmers who continued to use the tree fallows indicated 'competition and shade' (17 %) as an important problem, followed by 'timing of pruning' (5 %) and 'too labour demanding' (2.4 %). Half of the respondents mentioned that calliandra trees are very difficult to cut.

Adoption of new technologies is facilitated when benefits are easily observable. In the case of soil fertility improvement, benefits are generally long term and often difficult to see, although some techniques yield faster results than others. The first effects of rotational tree fallows on crop yields may take more than 4 years, whereas crop yield improvement can be noticed from the first year after Cajanus planting. However, increased crop yield alone may not provide sufficient incentives for farmers to adopt improved fallows. One also needs to consider markets for agricultural commodities, since the sale of their surplus production depends on these markets (Izac 2003). For example, in the lowlands of Cameroon, farmers complained that yield increases brought about by soil fertility improvement did not result in increased income because of lack of adequate market opportunities. Indeed, in most on-station and on-farm trials maize had been used as test crop. However, farmers in the study zone had difficulties selling maize surpluses, partly because of storage problems (insect attacks) and partly because of inadequate marketing strategies or possibilities (individual selling of small quantities). Then, trial farmers were encouraged to use high-value crops in the improved fallow technology. For example, in areas with good market access farmers started using the technology to improve yields of vegetables and to produce stakes for their yams and tomatoes (ICRAF 1996).

Using the framework suggested by Franzel *et al.* (2002) and described in Chapter 3.3, the biophysical performance, profitability, feasibility and acceptability of respectively rotational tree and shrub fallows in Cameroon are summarised in tables 5-13 and 5-14.

A number of research questions remain to be solved in order to encourage farmers to adopt tree and shrub fallows. Cost-benefit analysis, in addition to participatory evaluation with farmers, have highlighted that a major bottleneck in adopting tree fallows is tree establishment. Research and extension should investigate alternative establishment methods that would be cheaper and require less labour. Pilot farmers have started experimenting with bare-rooted seedlings, postponing tree seedling nursing to the rainy season in order to avoid watering in the dry season, reducing the size of polythene bags to minimise costs and time to fill bags, etc. These methods, however, have to be systematically evaluated for efficiency before they can be proposed as extension messages. On-station experiments on the effect of tree densities and spacing suggest that reducing the number of trees does not necessarily lead to a reduction in soil fertility improvement. If similar results on soil fertility can be obtained with half or one quarter of the trees, establishment costs will be significantly reduced. However, more profound on-station and on-farm observations are required to confirm these results and get farmers' assessment of tree spacing.

In the case of shrub fallows, the major problem is the availability of cajanus seeds. In fact, depending on the variety and agro-ecology, cajanus shrubs develop either more leaf biomass or more seeds. While abundant leaf biomass is appreciated for soil fertility improvement, lack of seed setting poses problems for the widespread adoption of the technology. Moreover, storage of cajanus seeds is hindered by weevil and fungi attacks under warm and humid conditions. The development of adequate strategies for improved fallow seed production, storage and dissemination, preferably at community-level is thus required.

From the study, it has become clear that farmers' interest in tree fallows goes beyond soil fertility improvement. Therefore, extension should focus on short-term benefits of hedgerow intercropping, such as the potential to reduce weeds, provision of fuel wood and stakes and bee keeping for honey production. Participatory evaluation has also shown the importance of targeting, both at geographical and household level. Promotion of rotational hedgerow intercropping should thus target sites where fallows are still practised but pressure on land is increasing, where farmers perceive soil fertility as a major problem and where market opportunities favour an intensification of the cropping system. Cajanus fallows in turn have proven to be less labour demanding, to yield benefits more quickly whereas the production of edible grains is particularly attractive to women.

Table 5-13: Summary of the adoption potential of rotational tree fallows in Cameroon

Factors	**Key results**
Biophysical performance	On-station trials showed that rotational tree fallows give significantly higher maize yields than continuous cropping without trees and natural fallows. However, performance of tree fallows under farmer management was consistently lower, with yield increases of maximum 40 %.
Profitability	Cost-benefit analysis over a 12-years period showed that rotational tree fallows with Calliandra are not profitable, because of: - high upfront tree establishment costs (when costs for tree seedlings are halved, returns to land increase from negative to 154,413 F CFA ha^{-1}); - high labour requirement for cutting back and pruning of coppices (labour increase of 37 % compared to natural fallows). Profitability of rotational tree fallows increases when trees provide other benefits, e.g. honey production. Association of beekeeping makes NPV of tree fallows positive, but still lower than NPV of natural fallows. However, when the discount rate is reduced from 20 % to 10 %, tree fallows with beekeeping become more profitable than natural fallows.
Feasibility and Acceptability	Farmers experimenting with rotational tree fallows appreciate the technology for its ability to: - increase crop yields; - suppress weeds during the fallow phase; and - provide by-products: stakes, firewood, honey production, fodder. However, major constraints to the adoption of tree fallows include: - high costs for tree establishment, leading to low profitability; - high labour requirements for planting and cutting of trees; - farmers' perception that soil fertility is not yet a priority problem; - availability in some areas of enough land to practice long natural fallows; - low value of some by-products in certain areas (esp. fodder and firewood). Specifically women face a number of constraints in practicing tree fallows: - labour (especially male labour) requirements for tree establishment and cutting back; - incompatibility with women's cropping systems (esp. groundnut fields); - permanent nature of trees, which occupy the land for long periods; - women generally have less access to information.

Boundary conditions	Rotational tree fallows seem to be most appropriate in areas with: - high population density and shortening fallows (the so-called intermediate phase of intensification; Franzel 1999); - poor soils and weed problems. Adoption potential of rotational tree fallows is likely to increase where there is soil erosion, a need for firewood and fodder and good market access for farmers' crops (Adesina *et al*. 2000). Households that are more likely to adopt rotational tree fallows are those that lack land and have sufficient (male) labour to plant and cut the trees. According to farmers, there would be no significant links between the likelihood of adopting tree fallows and respectively age, gender or wealth.
Lessons for effective dissemination	Effective dissemination of tree fallows should consist of three components. - Farmers' awareness on the potential of tree fallows should be raised through demonstration plots, field days, farmer-to-farmer visits, technical manuals, leaflets and training. - Organisation of farmer groups to facilitate extension of technologies from farmer to farmer, using trained farmer leaders. - Development of seedproduction units at different levels: research stations, through NGOs and at community level.
Feedback to research and extension	A number of modifications to the suggested technology were inspired by observations in farmers' fields and informal discussions with pilot farmers. - Change in pruning height from 0.50 m to 0.05 m, resulting in more flexibility in time and frequency of pruning. - Introduction of a fallow phase, increasing tree biomass production and thus soil fertility restoration potential of the trees. - In addition to maize, which was the sole crop used in on-station trials, tree fallows were tested for groundnut and cassava cropping in farmers' fields. - The introduction of a fallow phase doubled tree biomass production, requiring different residue management. After slashing and drying of the trees, leaves drop and best branches are removed for use as stakes or firewood. The remaining branches are piled and burnt. Ash is spread over the whole field and incorporated during land preparation. - After having observed problems with leucaena and gliricidia, *Calliandra calothyrsus* was introduced as a highly performing N-fixing tree.

Table 5-14: Summary of the adoption potential of shrub fallows in Cameroon

Factors	**Key results**
Biophysical performance	On-station and on-farm trials have shown that maize yields after Cajanus fallow are higher on average than after natural fallow but results are variable. Moreover, intercropping Cajanus with maize in the shrub establishment phase does not suppress maize yields. Cajanus is successfully established through direct seeding at the same time as maize or 2-3 weeks after maize planting.
Profitability	Cajanus fallows are a profitable alternative for households that do not have enough land to practice long natural fallows. Cajanus fallows have been shown to allow yearly cropping and increase total crop production per ha over a 6 years period. Returns to land for cajanus fallows were three times those for natural fallows, whereas returns to labour were 17 % higher in cajanus fallows compared to those obtained from natural fallows. Cajanus fallows outperform natural fallows under most conditions, even when maize prices drop by 50 %, shrub seed prices increase by 50 % or using a discount rate of 30 % instead of 20 %.
Feasibility and acceptability	Farmers experimenting with cajanus fallows appreciate the technology for its: - increased yields; - soil fertility improvement; - suppression of weeds. Actually, 56 % of experimenting farmers expanded their use of cajanus after initial testing. Major problems faced in adopting cajanus fallows, mentioned by farmers: - weevil attacks during storage of cajanus; - lack of seed production and availability in certain areas. Cajanus is particularly of interest to women, because of: - easy clearing; - compatibility of cajanus with women's fields/crop combinations; - easy and cheap establishment through direct seeding; - relative quick yield response (from the second year onwards).
Boundary conditions	Cajanus fallows seem most suitable to: - households lacking land or with insecure land tenure; - women; - areas characterised by short fallow periods (< 6 months);
Lessons for effective dissemination	Dissemination of cajanus fallows should first of all target households or areas mentioned above. To allow widespread adoption of cajanus fallows, seed supply should be ensured.
Feedback to research and extension	Weevil attacks on cajanus grains during storage is a major problem that should be addressed by research. Different varieties of cajanus should be tested in different agro-ecological zones to determine their potential to produce respectively leaf biomass and seeds. Cajanus grains are nutritious and could become a good supply of protein to rural households, but their use is not well known to farmers. Promotion of cajanus for soil fertility should therefore also stress the importance in household nutrition. The potential of cajanus fallows to maintain crop yields has been tested for a number of years, but little is known about the sustainability of this practice.

CHAPTER SIX

ADOPTION POTENTIAL OF TREE DOMESTICATION[1]

Ann Degrande, Zac Tchoundjeu, Peter Mbile and Patrick Van Damme

'Tell me and I may forget, show me and I may try it,
but involve me and I will take ownership of it '
Anonymous

6.1 Introduction

Throughout the tropics, there has been considerable degradation of tropical moist forests for agriculture, especially over the last decades. In Cameroon, forest clearance for food production intensified during the economic crisis of the 1990s when cocoa and coffee prices were depressed and devaluation of the CFA franc and structural adjustment enhanced reverse migration from urban to rural areas (ASB 2003). Farmers looked for ways to diversify their sources of income and increasingly began to integrate indigenous trees producing marketable fruits and nuts into more permanent systems of agroforestry land use. These indigenous fruit trees now make a variety of contributions to farmers' livelihoods. Direct consumption of the fruit has nutritional benefits while fruit sales are an important source of income, particularly for women. The trees themselves provide a range of environmental benefits and, through the development of multi-strata cocoa-coffee agroforests, they mimic the original forest structure.

[1] Parts of this chapter have been presented in Degrande *et al.* "Feasibility of farmer managed vegetative propagation nurseries" (in press) and Mbile *et al.* (2004)

However, the potential of these indigenous trees has not been fully exploited because of a number of constraints.

- Farmers face problems in tree propagation. Many indigenous trees have irregular and/or low seed production, or else seeds are characterised by low germination rates.
- Indigenous fruit trees generally take a long time to start bearing, creating a considerable time gap between investment and income flows. This discourages farmers from investing in indigenous trees.
- Farmers also lack knowledge on tree planting and management. Inappropriate tree densities and tree/crop combinations, in addition to poor tree management practices often lead to sub-optimal tree performance, hence low production.
- Farmers often are unable to meet specific market demands. Markets generally offer better prices for fruits with specific taste and size characteristics and reward out-of-season products, but tree growers cannot meet nor respond to these demands.
- Tree growers in rural areas face high marketing costs. This is so because of underdeveloped market and transport infrastructure, such as bad roads, abusive road-checks, etc.
- Rural households also lack capacity to add value to their tree products, resulting in high post-harvest losses and inability to enter new markets.

Tree domestication, defined as an *accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven or market-led process* (Simons 1997), is expected to bring solutions to the above problems. Therefore since 1998, ICRAF and its partners are developing a new and more participatory approach to the domestication of high-value agroforestry tree species in Cameroon. This approach comprises of a number of steps in which farmers are actively involved: tree species priority setting, germplasm collection, low-technology vegetative propagation of identified superior individuals, genetic characterisation of the marketable products for consumption and processing, integration of the trees into agroforests managed by subsistence farmers and expansion of markets for agroforestry tree products (Sanchez and Leakey 1997; Leakey and Simons 1998; Tchoundjeu *et al.* 1999).

Although this chapter will look at factors affecting adoption of tree domestication as a whole, particular emphasis will be placed on the participatory development, evaluation and adaptation of tree propagation techniques as one of the first and indispensable steps in the tree domestication process.

The research focus has been on a few priority species for the humid forest region of West and Central Africa, such as *Irvingia gabonensis*, *Dacryodes edulis*, and *Ricinodendron heudelotii* (Box 6-1). The priority setting identified species for which domestication research and development would likely have the highest impact, including increasing incomes and welfare, improving health and preserving the environment. While in the past, criteria in setting priorities were guided by researchers' and developers' own interests and views, the methods used encouraged participation and integrated the views of various stakeholders involved in the process. The procedure that was developed by Franzel *et al.* (1996), builds on widely and easily available information to make initial screenings and which gradually collects and develops more specific information to make the final decisions. The procedure aims to approximate the expected value of research on agroforestry tree species, but does so only for a limited number of species that have passed through the initial screenings. The preliminary list of farmers' needs is assembled on the basis of secondary information: characterisation, diagnostic, ethnobotanical and other studies describing farming systems and agroforestry systems in the ecozone. For each user group, information is collected on their main problems and the tree products needed to alleviate the problems, as well as on species that can provide the products. The products that farmers need and use are a good starting point for drawing up the list, but the list should also include products that researchers believe could benefit farmers. Tree products and services are then ranked in order of their potential importance for solving the present and future problems of the clients. Here we are going beyond what farmers prefer because we may have information about trends, market opportunities, and future needs that farmers may not be aware of. Thus two analyses that are needed for ranking products are a *market survey* and an *assessment of new tree-based technologies that may become important in the future*. Based on the results of preference surveys in three countries of the African Humid Tropics (Cameroon, Gabon and Ghana), fruits and food stood out for their present and expected future importance. At the same time, researchability for fruits and food was considered high. Improvement strategies such as lengthening the harvest period, reducing seasonality or improving fruit quality could provide significant results in a reasonable period of time. The other products were either considered to be less important (medicine, live fences, fodder) or less amenable to improvement research (stakes and poles, firewood, timber, soil erosion control and fertility management). Consequently, the remainder of the priority setting exercise focused on tree species that provide fruits and food. *Irvingia gabonensis* and *Dacryodes edulis* had the highest ratings on value and researchability. The two also received about equal ratings on speed of adoption; whereas dacryodes fruits earlier than irvingia, irvingia is important in more areas throughout the ecozone. Irvingia provides more benefits to females than dacryodes, hence its higher rating on modifiers. There was a considerable distance between these two species and the remaining three (*Ricinodendron heudelotii*, *Chrysophyllum albidum* and *Garcinia kola*), which had significantly lower ratings on value, researchability, and expected adoption.

In 1998, experiments were set up in ICRAF's research nursery to identify factors (rooting media, leaf area of cuttings, hormonal type and concentration used in promotion of rooting, cutting length and node position) affecting rooting success under non-mist propagator conditions of a wide range of species (Mialoundama *et al.* 2002; Tchoundjeu *et al.* 2002a; Tchoundjeu *et al.* 2002b; Avana *et al.* 2004). Simultaneously, 6 pilot nurseries, 4 in the humid forest zone (Abondo, Nkolfep, Ting-Melen and Ngoumou) and 2 in the savannah zone (Bandjoun and Belo), were established in collaboration with NGOs and local communities. From the onset, all participating farmer groups were trained in the different techniques and their propagation skills were continuously upgraded through technical assistance and follow-up from research and extension services (Leakey *et al.* 2003). Monitoring and evaluation was done through informal discussions with farmers. Numbers of plants produced and sold were recorded once a year (ICRAF-AHT 2004b). This approach allowed us to assess tree propagation success, in terms of rate of rooting and survival, in village nurseries. It also permitted us to identify biophysical and socio-economic factors explaining the differences in plant production despite equal levels of farmers' training and similar levels of infrastructure in the village nurseries.



Irvingia gabonensis tree, fruits and kernels



Dacryodes edulis tree with fruits, fruits in market and roasted fruits


Ricinodendron heudelotii trees, fruits on tree and dried kernels

Box 6-1: Priority species information

Scientific Name	Local Name	Uses	Traditional mode of propagating	Advantages of vegetative propagation
Dacryodes edulis H.J. Lam	Safoutier, prunier, African plum; African pear	Fruits are eaten boiled or roasted. Bark and leaves used for treating yellow fever, diarrhoea and anaemia. Fuelwood, poles and stakes.	Planting of seedlings from pre-germinated seeds; transplanting of wildings	Control over fruit and tree characteristics (improve fruit taste, increase fruit size, higher yields); early fruiting
Irvingia gabonensis Baill.	Manguier sauvage, andok, bush mango	Kernel is used as thickening agent in sauces. Bark used for treatment of hernia, yellow fever, dysentery and diarrhoea. Fuelwood, timber, poles, stakes.	Retainment; transplanting of wildings; planting by seeds.	Control over fruit and tree characteristics (increase fruit and kernel size, improve taste of fruit, increase yield and regularity); early fruiting.
Ricinodendron heudelotii Piere ex Pax.	Esezang, njansang	Kernel is used as a thickening ingredient in sauces and stews, has high oil content. Leaves, roots and bark used to treat skin diseases, anaemia, malaria and stomach pain. Dried seeds are used for a popular game called “songho”.	Retainment	Avoid problems of obtaining male trees that do not bear fruits; early fruiting.

6.2 Biophysical Performance

Experiments carried out on-station have assessed factors for best rooting results of a number of species under non-mist propagator conditions. Table 6-1 summarises the treatments that provided the highest rooting percentage, the highest mean number of roots per rooted cutting and the lowest percentage of dead cuttings for two priority species (Avana *et al.* 2004).

Table 6-1: Factors assessed for best rooting results of *Prunus africana* and *Dacryodes edulis* under non-mist propagator conditions, Yaoundé, Cameroon

	Factors					
Species	**Rooting medium**	**Leaf area (cm^2)**	**Hormone type**	**Hormonal concentration (µg/cutting)**	**Cutting length (cm)**	**Node position**
D. edulis	Decomposed sawdust	100	Indole-3-Butyric Acid (IBA)	300	4	N3-N4
P. africana	Decomposed sawdust	20	IBA	100	4-6	N2-N5

Source: Avana *et al.* (2004)

Tables 6-2 and 6-3 give a summary of rates of rooting and survival of cuttings and marcotts for 3 indigenous tree species, obtained in ICRAF's research nursery in Yaoundé. Investigations are under way to deal with low survival rate of *Irvingia gabonensis* and *Ricinodendron heudelotii* marcotts after they are severed from the trees, including the assessment of mycorrhizal status and the effect of post-planting mycorrhizae inoculation on growth and survival of *Irvingia gabonensis* marcotts (Tsobeng 2003).

Table 6-2: Rates of rooting and survival of cuttings, number of cuttings that can be set in a non-mist propagator and time required to obtain maximum rooting for 3 indigenous fruit tree species, Yaoundé, Cameroon

Species	Number of cuttings per compartment[1]	Rooting %	Time required to obtain maximum rooting (weeks)	Number of rooting cycles per year	% survival after weaning
Dacryodes edulis	70	90	10	4	80
Irvingia gabonensis	100	80	20	2	65
Ricinodendron heudelotii	70	90	7	6	80

Source: Mialoundama *et al.* 2002; Avana *et al.* 2004

[1] The nursery in Abondo has 3 non-mist propagators: 2 for rooting and 1 for weaning of cuttings. Each non-mist propagator of 3 m x 1 m has 3 compartments of 1 m x 1 m. In the base analysis, the assumption is that each of the 3 tree species occupies 1 compartment per propagator, or a total of 2 compartments for rooting.

Results of on-station experiments are communicated to farmers using simple language. For example, regarding optimum leaf area in cuttings, recommendations are formulated as number of leaves and what proportion (½ or 1/3) of the leaves to keep when preparing the cuttings, depending on the species. Also, farmers are not encouraged to use hormones, because, even though application of hormones was found to accelerate the rooting process for most species, it did not significantly affect the final rooting percentage.

Table 6-3: Rates of rooting and survival of marcotts, number of marcotts that can be weaned in a humidity chamber and time required to obtain maximum rooting for 3 indigenous fruit tree species, Yaoundé, Cameroon

Species	Number of marcotts per humidity chamber	Rooting %	Time required to obtain maximum rooting (months)	Number of rooting cycles per year[3]	% survival after weaning
Dacryodes edulis	100	60	4	1	85
Irvingia gabonensis	100	45	6	1	40
Ricinodendron heudelotii	100	50-70	2	1	15-20

Source: Miandoulama *et al.* 2002, Tsobeng (pers. comm. July 2005), Ngo-Mpeck (pers. comm. July 2005)

Table 6-4 shows that, despite equal levels of farmers' training and backstopping, the number of *Dacryodes edulis* cuttings produced over a 3 months' period in 2002 varied enormously among 13 nurseries in Cameroon (Avana *et al.* 2004). This difference in production should be attributed to differing nursery infrastructure, farmers' preferences in propagating particular species, biophysical characteristics affecting rooting of cuttings (e.g. air temperature and humidity), nursery group dynamics and mastery of the technology by the farmers. However, in almost all cases, actual production was below potential capacity and most often below profitability levels, as will be illustrated in 6.3. It is thus imperative to find out bottlenecks that limit production in village nurseries. This will be dealt with in 6.4.

[3] Given the fact that setting of marcotts is best done at the beginning of the rainy season (May-June) and taking into account the time it takes to form roots (between 2 and 6 months), only one rooting cycle per year is feasible.

Table 6-4: Production of *D. edulis* through cuttings in different farmer nurseries in humid forest zone of Cameroon

Farmer group	Number of *D. edulis* cuttings produced over a 3-month period (per propagator)
Abondo I	102
Abondo II	12
Abondo III	81
Elig Nkouma	60
Lekie-Assi I	111
Lekie-Assi II	42
Nlobissong	24
Belo	93
Nkom Efoufoum I	24
Nkom Efoufoum II	6
Nkolfep	99
Ngoumou	63
Ting Melen	117

Source: Avana *et al.* (2004)

6.3 Profitability

Profitability being one of the key factors affecting adoption of innovations, the potential of small-scale multiplication units to provide improved germplasm at low costs and to constitute an alternative source of income to farmers in rural areas of Cameroon was assessed. The specific objective of this part of the study - of which the detailed methodology is described in 3.3.3 - was to investigate the profitability of farmer-managed nurseries by determination of their production capacity and analysis of their financial situation.

Ex-ante Profitability in Abondo Nursery

We started in 2002 with determining profitability of farmer-managed nurseries under favourable conditions (see assumptions in table 6-5). Therefore, the vegetative propagation unit in one of the pilot villages, Abondo, was chosen because it had been the first pilot nursery to become operational under ICRAF's tree domestication programme in 1998, and has served as a model to other nurseries. By doing so, this study can be seen as an '*ex-ante*' analysis of the profitability of a vegetative propagation unit.

Financial analysis of the vegetative propagation unit in Abondo projected over 5 years demonstrates the profitability of the technology in the forest zone of Cameroon. All prices are in francs CFA (1€ = 655 FCFA). The assumptions for the base analysis are summarized in Table 6-5, whereas the cost-benefit matrix is shown in Table 6-6 (details are shown in Annex 6). No sales are recorded in the first year considering that the period required for rooting of cuttings varies between 7 to 20 weeks, depending on the species, and weaning takes about 4 months. Thus, cuttings set in February would be ready for transplanting in the field around September. In theory, cuttings could be sold in the second half of the first year. Unfortunately, at that time demand is low because farmers prefer to plant trees in the first rainy season (April-July) to allow them to establish well before the long dry season arrives (mid-November). The Net Present Value under the assumption that the infrastructure is used to its full capacity to produce cuttings of 3 different species and marcotts of *Dacryodes edulis,* and using a discount rate of 20% over 5 years is 1,229,336 FCFA (2204 €; Table 6-6). The Internal Rate of Return under the same assumptions is 72%, which shows that the technology is highly profitable. However, surveys in urban fruit tree nurseries in Yaoundé (Nkana 2002[4]) have shown that most of the time only about 75% of total production can actually be commercialised. From Table 6-7, however, we can conclude that even under the hypothesis that only 75% of the plants are sold, the nursery remains a profitable business.

Table 6-5: Data and assumptions for base analysis of vegetative propagation unit budget, case of Abondo, Center Province of Cameroon

Annual production	**Number of plants after weaning:**
Cuttings : *Dacryodes edulis* (4 rooting cycles/year)	403 (for 560 cuttings set)[5]
Irvingia gabonensis (2 rooting cycles/year)	210 (for 400 cuttings set)
Ricinodendron heudelotii (6 rooting cycles/year)	605 (for 840 cuttings set)
Marcotts: *Dacryodes edulis* (1 rooting cycle/year)	85 (for 167 marcotts set)
Discount rate	20 %
Selling price cuttings	1000 FCFA/unit
marcotts	1500 FCFA/unit
Labour costs	1200 FCFA/day
Number of workdays per year	145
Valuation (% valued = % sold or used in own farm)	100 %

Source: experimental data in ICRAF's on-station nursery, Yaoundé and in on-farm vegetative propagation units, Abondo

Looking at the cost distribution of the vegetative propagation unit over a 5–year period (Fig 6-1) we note that the infrastructure takes up 39 % of total costs. Almost half of these costs however are for materials that are readily available in rural areas, such as stones, sand, poles, etc. The other major cost item is labour, adding up to 33 % of total costs. About 48 workdays are required for the establishment of the nursery and nursery management was estimated to take about 145 workdays per year. Under this assumption, the returns to labour represent 2299 FCFA (3.5 €) per day, which is highly acceptable in rural areas where employment opportunities are scarce and national minimum monthly salary is fixed at 23,514 FCFA (35.9 €; www.cleiss.fr/doc/pf/cameroun.html). This means that nursery activities, if taken seriously and if markets are available, can be a viable livelihood option in

4 A survey that identified yearly production, species, and prices in urban fruit tree nurseries was carried out in 2002 as part of an evaluation of vegetative propagation by an undergraduate student, Nkana Benjamin, under the supervision of Ann Degrande.

5 In the base analysis, the assumptions for *Dacryodes edulis* are: 70 cuttings can be set per compartment, 2 rooting propagators are available, there are 4 rooting cycles per year, rooting success rate is 90 % and survival rate after weaning is 80 %. Therefore, number of cuttings obtained after one year equals (70 x 2 x 4 x 0.9 x 0.8) = 403.

rural areas. However, more detailed studies to determine demand for vegetatively propagated indigenous fruit trees are required.

Sensitivity analysis (Table 6-7) shows that profitability is most affected by changes in number of plants produced and in selling prices. The net present value is reduced by 87 % when the number of fruit species (e.g. only *D. edulis* and *I. gabonensis*) and frequency of setting cuttings are reduced (e.g. only 3 rooting cycles per year instead of 4 for *D. edulis*), as is the case in assumption 2. Nevertheless, different combinations of species and cycles can give different levels of profit, hence the necessity to optimise production, but also to produce what the client demands in order to maximise the chances to sell. Reducing the unit price of cuttings to 500 FCFA (0.76 €) and that of marcotts to 1000 FCFA (1.53 €) brings the nursery below breakeven point, with a negative NPV and an IRR of 11 %. Under these selling prices, the nursery operator necessarily needs to reduce production costs to be able to make profits.

Table 6-6: Cost/Benefit analysis of a vegetative propagation unit, case of Abondo in humid forest zone of Cameroon (in FCFA*)

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs					
Land	22,500				
Stock plant area	296,050				
Fence	77,000				
Shed	213,250				
Non-mist propagators (3)	253,270				
Humidity chamber (1)	27,250				
Nursery equipment/tools	189,500				
	1,078,820	**0**	**0**	**0**	**0**
Production costs	**257,456**	**257,456**	**257,456**	**257,456**	**257,456**
Sales					
D. edulis: 403 cut. @ 1000 F	0	403,000	403,000	403,000	403,000
I. gabonensis: 210 cut. @ 1000 F	0	210,000	210,000	210,000	210,000
R. heudelotii: 605 cut. @ 1000 F	0	605,000	605,000	605,000	605,000
D. edulis: 85 marc @ 1500 F	0	127,500	127,500	127,500	127,500
	0	**1,345,500**	**1,345,500**	**1,345,500**	**1,345,500**
Income flux	**(- 1,336,276)**	**1,086,044**	**1,086,044**	**1,086,044**	**1,086,044**
Net Present Value	1,229,336				
Internal Rate of Return	72%				

*1 F CFA = 0.0015 €

Source: experimental data in ICRAF's on-station nursery, Yaoundé and in on-farm vegetative propagation units, Abondo

Table 6-7: Effect of changes in key parameters on profitability of vegetative propagation unit, case of Abondo in humid forest zone of Cameroon (in F CFA*)

Change in key parameter	Net Present Value	Internal Rate of Return
Base Analysis (1)	1,299,336	72 %
Annual production (2) Cuttings: *D.edulis* (3 yr^{-1}, 2 comp): 302 *I.gabonensis* (2 yr^{-1}, 4 comp): 416 Marcotts: *D. edulis* : 85	170,999	28 %
Annual production (3) Cuttings: *D.edulis* (3 yr^{-1}, 4 comp): 605 *I.gabonensis* (2 yr^{-1}, 2 comp): 208 Marcotts: *D. edulis* : 85	373,991	37 %
Selling price cutting: 500 F CFA (4) marcott: 1000 F CFA	(- 190,894)	11 %
Valuation rate: 75% (5)	504,760	43 %
Labour cost + 20%	1,125,487	67 %
Labour cost – 20%	1,333,189	78 %
Discount rate at 30%	781,813	72 %
Discount rate at 10%	1,914,852	72 %
Investment cost – 20%	2,111,001	89 %

*1 F CFA = 0.0015 €

Source: experimental data in ICRAF's on-station nursery, Yaoundé and in on-farm vegetative propagation units, Abondo

Notes

(1) **Base analysis:** see table 6-5

(2) Decrease in annual production and limit rooting of cuttings to 2 species (more Irvingia than Dacryodes)

Annual production: *D. edulis* (3 rooting cycles per year, 2 compartments): 302 cuttings
I. gabonensis (2 rooting cycles per year, 4 compartments) : 416 cuttings
D. edulis : 85 marcotts

(3) Decrease in annual production and limit rooting of cuttings to 2 species (more Dacryodes than Irvingia)

Annual production: *D. edulis* (3 rooting cycles per year, 4 compartments): 605cuttings
I. gabonensis (2 rooting cycles per year, 2 compartments): 208 cuttings
D. edulis : 85 marcotts

(4) Decrease in selling price

The survey with potential clients has shown that the majority of customers are willing to pay 500 F CFA for a cutting and 1000 F CFA for a marcott

(5) Decrease in valuation rate: only 75% of plants produced are sold or planted in the farm (this is based on a survey in urban fruit tree nurseries where on average only 75% of the produce is effectively sold)

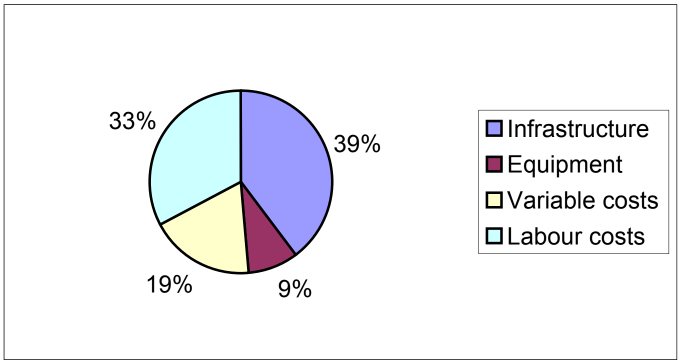


Figure 6-1: Distribution of the discounted costs in a vegetative propagation unit over a 5-years period
Source: experimental data in ICRAF's on-station nursery, Yaoundé and in on-farm vegetative propagation units, Abondo

Profitability Analysis of Lekie-Assi Nursery

In 2004, a similar financial analysis as the one in Abondo was done for the nursery in Lekie-Assi (Djontu 2005), which has the same biophysical and socio-economic characteristics. The difference is that for Lekie-Assi, we used actual production data for 2002 and 2003, and estimates for 2004 and 2005, based on a 10 % production increase per year (Table 6-8). In addition to propagation through cuttings and marcotts, farmers in Lekie-Assi also produce grafted plants of *Ricinodendron heudelotii* and *Cola acuminata*. Lekie-Assi nursery currently sells grafts at 1000 FCFA, cuttings at 1500 FCFA and marcotts at 2500 FCFA. Members of the nursery group plant all unsold propagules in their farms. Investment costs are about 73% of those in Abondo mainly because the shed roof is made of raphia thatches as opposed to corrugated zinc in Abondo.

Table 6-8: Production and production plan of Lekie-Assi nursery over 5 years

Species and propagule type	Year				
	2001	2002	2003	2004	2005
Marcotts					
Dacryodes edulis	0	357	120	132	145
Cuttings					
Dacryodes edulis	0	31	173	190	210
Irvingia gabonensis	0	19	68	75	82
Ricinodendron heudelotii	0	14	59	65	71
Grafts					
Ricinodendron heudelotii	0	41	32	35	39
Cola acuminata	0	0	23	25	28
TOTAL	**0**	**462**	**0**	**522**	**575**

Source: Djontu (2005)

The cost-benefit analysis of Lekie-Assi nursery for 2001-2005 (Table 6-9) shows a net present value of 323,566 FCFA (495 €) and an internal rate of return of 38 %, which makes vegetative propagation in Lekie-Assi profitable under the current conditions. However, the level of profitability is much lower than that under the more favourable conditions of Abondo. Chapter 6.4 looks at some of the reasons behind this discrepancy between ex-ante and actual profits in vegetative propagation units.

Table 6-9: Cost/benefit analysis of Lekie-Assi nursery (in FCFA*)

	Year				
	2001	**2002**	**2003**	**2004**	**2005**
Investment costs					
Stock plant area	145,600				
Fence	135,000				
Shed	75,000				
Non-mist propagators (2)	150,000				
Humidity chamber (2)	90,000				
Nursery equipment/tools	194,500	250	250	16,250	250
	790,100	**250**	**250**	**16,250**	**250**
Fixed costs (land rent and infrastructure maintenance)	**30,000**	**101,625**	**101,625**	**101,625**	**101,625**
Production costs	**278,752**	**278,752**	**227,627**	**234,000**	**253,330**
Sales					
Marcotts @ 2,500 FCFA	0	982,500	300,000	330,000	362,500
Cuttings @ 1,500 FCFA	0	96,000	450,000	495,000	544,500
Grafts @ 1,000 FCFA	0	41,000	55,000	60,000	67,000
	0	**1,029,500**	**805,000**	**885,000**	**974,000**
Income flux	**(-1,098,852)**	**648,873**	**475,873**	**533,125**	**618,795**
Net Present Value	323,566				
Internal Rate of Return	38 %				

*1 F CFA = 0.0015 €

6.4 Feasibility and Acceptability

Participatory evaluation of vegetative propagation from 1998 to 2003 showed that farmers, after a series of trainings and technical backstopping, mastered the propagation techniques and produced cuttings and marcotts for personal use and some even started selling. However, as also mentioned in 6.1, actual production figures were very much below capacity for most of the nurseries. For example, the nursery in Abondo with its current infrastructure has a capacity of producing 1218 cuttings and 85 marcotts per year, but produced only 265 cuttings and 4 marcotts in 2002.

After removing the bark over ± 10 cm, the rooting substrate is wrapped around the wound

Depending on the species, rooting of marcotts can take from 2 to 6 months

When the roots are visible through the transparent plastic, the marcott is removed from the mother tree

The wrapping is removed and the rooted marcott is potted

The potted marcotts are put in a humidity chamber for weaning

Transplanted marcott of dacryodes is fruiting 3 years after planting

To explain this discrepancy, one needs to understand the factors that determine the potential production capacity of a vegetative production unit. These factors are both biophysical and socio-economic, and include:

- rooting time of a species, i.e. the average time it takes a cutting to root and to develop new shoots. This will determine the frequency at which cuttings can be set (see Table 6-2 for some examples);
- rooting percentage and survival rate after weaning of a species, i.e. the percentage of plants that develop roots and the proportion of plants that survive and develop new shoots after weaning (see Table 6-2 for some examples);
- infrastructure and equipment at the disposal of the operator. The capacity to root cuttings will not only depend on the number and dimensions of the non-mist propagators, but also on vegetative material available in the stock plant area (quantity and quality);
- labour availability (amount and skills) to carry out nursery activities;
- existing demand for plants in rural and urban areas and access of nursery operator to clients.

Taking into consideration the above factors and through observations in on-farm vegetative propagation units and discussions with nursery operators, the following reasons could explain why production recorded in the pilot nurseries has been below potential capacity.

- *Insufficient availability of stock plant material*. To have enough juvenile material in the stock plant area all year round, rigorous management including adequate pruning, fertilisation, phytosanitary measures and watering in the dry season is required.

- *Poor water management*. One of the major difficulties farmers face in using the non-mist propagator is correct water management (Mbile *et al.* 2004). Whilst moisture is required for maintaining constant humidity levels in the non-mist propagator, too much water leads to inundation of the rooting medium, and thus favours rotting of cuttings. Farmers judge the water level in the propagators through a tube inserted into the substrate and correct it by adding or removing water to a mark on the tube. However, water may increase suddenly as a result of a thunderstorm, or leaking shed roof while the farmer is away. Frequent inundation also requires time-consuming removal of water using a sponge, in addition to causing damage to the cuttings.

- *Low rooting and survival percentages*. The rooting and survival percentages mentioned in Tables 6-2 and 6-3 have been obtained in researcher-managed trials (Mialoundama *et al.* 2002; Avana *et al.* 2004; Tsobeng (pers. comm. July 2005); Ngo-Mpeck (pers. comm. July 2005). While exact data on rooting and survival rates in village nurseries have not been systematically collected, it is to be expected that success rates will be lower under farmer management. Reasons are lower mastery of the techniques, lack of understanding of the underlying principles and less rigorous implementation of nursery requirements because of time, material or financial constraints. This fact is exacerbated if the nursery is managed by a group of farmers with different levels of skills and dedication. For example, records show that the average number of plants produced per group member decreases with increasing group sizes (ICRAF-AHT 2002).

A farmer-managed vegetative propagation unit, roofed with traditional thatches in Nkom-Efoufoum, humid forest zone, Cameroon

Building of a non-mist propagator

Cuttings from *Dacryodes edulis* and *Calliandra calothyrsus* in non-mist rooting propagator

Rooted single-node leafy cutting of *Pausinystalia johimbe* (a medicinal tree)

- *Long rooting cycles*. Table 6-2 shows average duration of a rooting cycle under researcher-controlled trials for 3 species (Mialoundama *et al*. 2002; Avana *et al*. 2004). In principle, 4 production cycles a year are possible for *Dacryodes edulis*, 2 for *Irvingia gabonensis* and 6 for *Ricinodendron heudelotii*. Obtaining these frequencies, however, requires good planning and organisational skills, and does not necessarily take farmers' other activities into account.

- *Lack of motivation or perspective*. Farmers sometimes deliberately keep production below capacity because they are unwilling to invest much effort if they perceive the benefits as long-term. Another cause of low production is their fear that they will be unable to sell their plants. They prefer to invest in activities that yield immediate benefits. Since the proposed propagation techniques are rather new to farmers, they often lack confidence in the results and adopt a wait-and-see attitude. Some may prefer to start off with a small nursery and gradually increase. Others may lose interest because their preferences in terms of species, techniques or tree traits are not adequately addressed, as was confirmed in the focus group discussions reported in 6.5. This notwithstanding, it is possible for farmers to adopt one or more of these vegetative propagation techniques at different points in time. One can start with adopting marcotting, since this technique requires less investment, is a seasonal activity, can be practiced on an individual basis and its benefits are rapidly observable. On the other hand, rooting of cuttings necessitates rather costly infrastructure (shed, non-mist propagators, nursery tools), which is difficult to obtain for resource-poor farmers individually. The daily maintenance requirement of non-mist propagators is another reason why farmers may want to carry out this activity in group.

- *Constraints related to group management*. From evaluation meetings with farmers (Degrande 2001b; ICRAF-AHT 2002; Sado 2003, Sado and Tsobeng 2004) it has become clear that group dynamics (attitude towards collective action, leadership, group composition and functioning) are determinant for the viability and sustainability of group nurseries. Essomba (2004)[6] found that 4 of the 9 nursery groups studied experienced serious drop-out from members, decreasing membership from 15-20 in 1999 to merely 1-2 in 2004. Discussions with members of nursery groups (Essomba 2004; Sado 2003, Sado and Tsobeng 2004) revealed that nurseries do not perform well when there is no charismatic leader, when group objectives are loosely defined and where there is lack of transparency in group management and benefit sharing. On the other hand, strong leadership, presence of rules and clear allocation of tasks and related benefits, are factors explaining success in nursery groups (Essomba 2004). On the other hand, strong leadership, presence of rules and clear allocation of tasks and related benefits, are factors explaining success in nursery groups (Essomba 2004). This is similar to results found by Böhringer *et al.* (2003) in Tanzania, Zambia and Malawi. They highlighted that group nurseries produced significantly fewer tree seedlings, leading to lower number of trees being transplanted. They explained this by the larger transaction costs for organisation and capacity building in group nurseries, compared to individual nurseries.

[6] A survey on participation of vulnerable groups in tree domestication was carried out in 2004, as part of participatory evaluation of tree domestication, by a B.Sc. student, Essomba Hermann, under the supervision of Ann Degrande.

However, the success of individual nurseries was depending again on human and social "start-up" capital being provided by group nurseries earlier, suggesting that both types of nurseries have a role to play in the dissemination of agroforestry.

Farmers' Innovations and Adaptations

One of the major innovations we observed in pilot nurseries was that, in addition to the priority species, farmers apply the vegetative propagation techniques to many other fruit tree species, both indigenous and exotic. This indicates that farmers master the techniques and have confidence in the results.

However, the main constraint that farmers currently face in adopting vegetative propagation techniques is the high up-front costs of the nursery. This is particularly true for rooting of cuttings, which requires building of non-mist propagators, a nursery shed with watertight roof, and specific nursery tools (secateur, surgery knife, knapsack sprayer, …). In all pilot villages, ICRAF and collaborating NGOs have been subsidising the set-up of such nurseries by providing material that is not easily found in the rural environment, e.g. plastic sheets, nails, some nursery tools, etc. Nevertheless, this has not hampered farmer modifications and innovations aimed to lower costs, including:

- traditional raphia thatches in stead of corrugated zinc to cover the nursery shed, reducing the cost by more than half;
- a simple but sharp kitchen knife in stead of a special grafting knife for marcotting and grafting, bringing down the cost from at least 15,000 FCFA to about 1,500 FCFA;
- razor blades, fixed on a wooden handle, to replace the costly and difficult to find surgery knife and blades;
- discarded wine cartons in stead of polythene bags;
- transparent plastic bags which are used to package sugar, salt, soap, etc. to wrap marcotts;
- old nylon shopping bags (big size) to pot marcotts; etc.

Spread of Vegetative Propagation Units

According to Franzel *et al.* (2002), acceptability of a technology is generally best ascertained by monitoring whether farmers continue to use and even expand their use of the innovation once the experimentation phase is finished. Therefore, we looked at the diffusion of vegetative propagation units over time. The 6 pilot nurseries (Abondo, Nkolfep, Ting-Melen and Ngoumou in humid forest zone and Bandjoun and Belo in sub-humid savannah area), established in 1998-99 with the main objective of testing and adapting with farmers vegetative propagation techniques, developed in ICRAF's research nursery, subsequently provided a possibility for training of neighbouring communities. This strategy envisioned a process-oriented differentiation of 'parent' group nurseries into smaller more production-oriented 'sibling' nurseries, managed by smaller groups or individuals. Figure 6-2 depicts the spread of vegetative propagation units within the humid forest area from 1999 to 2003. Three years after the establishment of the 4 'pilot' nurseries for initial experimentation and training purposes, 9 more nurseries had been created. For the most part, this spread of nurseries had occurred without extra dissemination efforts by either researchers or NGOs.

Various factors explained the creation of new nurseries. Amongst these, the most notable ones are listed below (ICRAF-AHT 2002).

1. Large size of initial nursery groups. The nursery group in Abondo counted more than 40 members before splitting up in three groups: Abondo I, Essong-Mintsang and Abondo II.
2. Considerable distance between the nursery site and the living quarters of group members who must trek sometimes as much as 10 km to and fro just to work in nurseries. This was the case for Nkom-Efoufoum and Elig-Nkouma where farmers came to attend training sessions and to work in the Nkolfep nursery before creating their own nurseries in 1999.
3. Strong differences in opinion between members of the same group over possible and/or perceived differential long-term benefits that may accrue to different members.
4. Enthusiasm and creativity of certain members who considered their initiative for experimentation stifled by belonging to a large group. This was specifically encouraged by researchers, with the intention of promoting innovation, experimentation and adaptation. Innovation will indeed take place if and when farmers are free to experiment individually in their own nursery. This has been the case for Lekie-Assi for example, where the group leader was first a member of the nursery group in Elig-Nkouma, but decided to create his own nursery two years later.

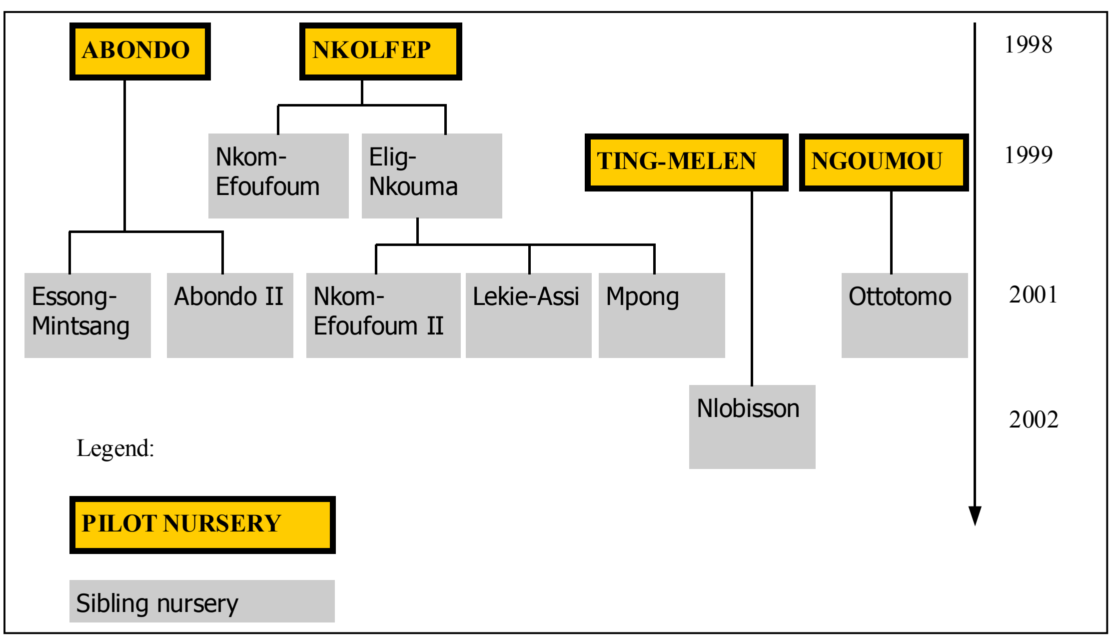


Figure 6-2: Spread of nurseries from 1998 to 2002, after establishment of 4 pilot nurseries in the forest zone of Cameroon (*Source*: ICRAF-AHT 2002)

Recommendations

The financial analysis, reported in 6.3, showed that the production of plants through vegetative propagation in rural areas could be profitable under a range of conditions. Since the net present value is most sensitive to volume and price of the plants produced, further research and extension efforts should focus on increasing productivity and genetic (choice of parent trees) and physical (a combination of height, diameter, plant nutrition, health, root size and shape) quality of vegetatively propagated plants in farmer nurseries (Wightman 1999). Summarising the different factors explaining low production rates in farmer nurseries, the following recommendations can be made in order to remove some of the obstacles faced by farmers. The first set of suggestions consists of modifying the technology/infrastructure to facilitate tasks for farmers. For example, a simple anti-inundation control mechanism can be installed to facilitate water level control in the non-mist propagator (Mbile *et al.*, 2003). A second set of actions is related to continuous upgrading of farmers' technical skills. This applies for example to stock plant management, where farmers need training on how to ensure continuous supply of vegetative material through adequate pruning, fertilisation, phytosanitary control and watering. In addition to technical assistance, nursery operators equally need training to upgrade their organisational and managerial skills. Better planning of nursery activities, for instance, can increase the number of cycles for rooting of cuttings whereas strengthening nursery groups may not only lead to increased production but can also catalyse other collective action.

Exploratory studies by Mfoumou (2002), as part of the financial analysis of vegetative propagation units, have indicated potential demand and need for improved germplasm in urban as well as in rural areas. Unfortunately, distribution pathways for seeds and seedlings in the forest zone of Cameroon are not well developed and farmers do not have the required information and skills to reach potential buyers. The price the majority of customers are willing to pay (500 for cuttings and 1000 for marcotts; Mfoumou 2002) brings the nursery activity, under current circumstances, near break-even point. However, about 20% of the potential customers said they were willing to pay a higher price for e.g. marcotts with desirable characteristics that fruit early, provided that the genetic and physical quality can be guaranteed. Hence, it is recommended that information and sensitisation campaigns as well as further research into the distribution and marketing of germplasm should accompany further extension of vegetative propagation techniques to enable farmers to fully benefit from the production and sale of their plants.

In spite of remarkable efforts, both by farmers and researchers, to reduce the financial burden of setting up vegetative propagation infrastructure, it is unlikely that resource-poor farmers or even farmer groups can carry the full costs. Considering the importance of domestication of indigenous trees in increasing and diversifying farmer households' income and in encouraging the development of sustainable agroforestry practices, two opportunities emerge.

- *Credit*. In chapter 6.3 we demonstrated the profitability of a farmer-managed vegetative propagation unit. Consequently, farmers willing to set up and run a nursery as a rural enterprise should be eligible for micro-finance. The financial institutions involved in such a programme could also provide assistance with entrepreneurial skill development (bookkeeping, staff management, …), quality control and marketing of nursery products.

- *Subsidies*. It is now acknowledged that domestication of indigenous trees contributes to rehabilitation of degraded farmland, sequestration of carbon and other greenhouse gases and enhancement of both biodiversity and the functioning of agro-ecosystems (Leakey *et al.* 2003). However, these environmental benefits cannot be achieved without large-scale adoption of tree domestication. In the past, many well-funded afforestation and tree planting projects failed because they were too centralised, not participatory enough or the tree species promoted did not respond to farmers' needs. Today, participatory tree domestication presents a promising alternative. Therefore, we suggest that the establishment of small-scale vegetative propagation units should be subsidised in areas where tree planting for environmental benefits is desirable, but people are too poor to bear the initial investment.

6.5 Integration of Tree Domestication in Farmer Livelihoods

6.5.1 Participation of Vulnerable Groups in Tree Domestication

(based on Essomba 2004[7])

Participation of vulnerable groups, i.e. women and youth, in tree domestication activities at village level varied a lot (Figure 6-3). In 2004, the proportion of women in pilot tree domestication groups ranged from 0 % to 53 % (mean: 23 %; median: 20 %) of the members, while that of youth varied from 0 % to 70 % (mean: 23 %; median: 13 %). However, 4 out of 9 groups had no female members at all, whereas 45 % of the groups had no members younger than 30 years. The very poor households in the village, as identified by participatory wealth ranking exercises with key informants (see 3.3.3), were represented in none of the pilot nursery groups.

While it was only normal that in the technology development stage the first participants would be people able to wait for benefits and to bear risks that the poorest or most vulnerable simply cannot afford to take on, greater attention to group composition in terms of age, gender, relationship with the group leaders, socio-economic status, access to assets, etc. will be required in the following phase of technology dissemination if large scale impact on farmer livelihoods is to be obtained. Also, in the case of tree domestication in Cameroon where the technology is still under development, it may be important to find out whether farmers, other than the early adopters, also have knowledge and accurate information about the technology, and if there are systematic biases that limit access to information by certain types of farmers, such as women, migrants and minority ethnic groups (Place and Swallow

[7] As part of the assessment of tree domestication adoption potential, a study on participation of vulnerable groups in tree domestication was carried out in 2004 by a B.Sc. student Hermann Essomba, supervised by Ann Degrande.

2002). Therefore, as part of assessing the adoption potential of tree domestication, a survey was carried out in 2004 by Essomba and supervised by Ann Degrande, to identify problems that vulnerable groups and the poorest categories face in practicing vegetative propagation, together with the reasons for not participating in pilot tree domestication groups (Essomba 2004; Figure 6-4). The study also examined how different categories, including women and youths, are likely to benefit, both directly and indirectly from tree domestication.

Youth

Eight focus group discussions and 17 individual interviews (6 with persons practising and 11 not practising tree domestication) with youth (less than 30 years old) in 8 pilot villages revealed that most young people had little or no information about tree domestication. Some mentioned that they were absent when tree domestication was first introduced in the village. Others said that information about tree domestication did not reach them, since they do not belong to any association. This category also complained about the leaders of pilot groups, whose attitude had not always been open to new members, especially to young people. Another factor limiting youths to participate in tree domestication was the lack of short-term benefits. Youths preferred activities that generate immediate cash, such as market gardening or charcoal making. In sites relatively close to urban centres, young people usually leave the village to search their fortune in town. Young men admitted to be hesitant to plant trees on land that is not yet under their control. However, it was rather the lack of 'success stories' in the village - showing tree domestication as a genuine income-generating enterprise - that limited their interest.

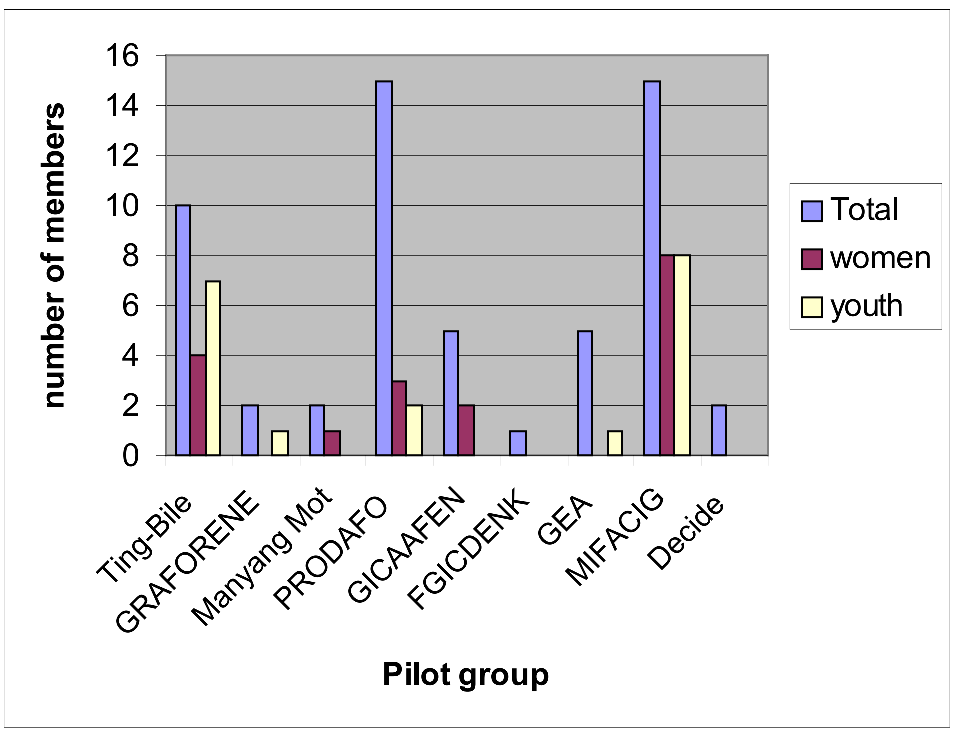


Figure 6-3: Membership of vulnerable groups in 9 pilot tree domestication groups in Cameroon, July 2004
Source: Essomba (2004)

Women

When women were asked in 8 focus group discussions and 13 individual interviews why they did not participate in tree domestication activities in the village, many mentioned that they had not been sufficiently informed about the innovation. Many knew that there was 'something' behind the house of the group leader, but they considered it his 'private business', so they hadn't asked for more details. Another factor causing women not to get involved in tree domestication was lack of time. Women feared that tree domestication activities would add more work to their already full work schedule of farm and household tasks. However, some of the women admitted that they had adopted innovations in the past, such as soap making, new varieties of maize, cassava, etc. It is thus likely that women did not take up tree domestication because traditionally they have not been much involved in tree planting.

From a cultural point of view, in all our study sites (whether *beti*, *bamilike* or *kom* culture) as is the case in many parts of Africa, trees remain the domain of men, and women do not have the right to plant trees because this would be considered as claiming control over the land (Place and Swallow 2002). If women want to plant trees they have to ask permission from the head of the household. The most acceptable niche for women to plant trees would be food crop fields, which are more or less under their control. Unfortunately, most food crops do not tolerate much shade and are therefore incompatible with trees.

Another reason why the women interviewed did not get involved in tree domestication was that they did not see how this activity could help them satisfy the day-to-day needs of their household. Women in southern Cameroon have the responsibility of feeding the family and acquiring basic household needs, such as kerosene, salt, soap, health care, etc. Most rural women manage their households thanks to food crops, such as cassava, groundnut, plantain, cocoyam, etc, which provide food for home consumption, whereas any surplus can be sold generating cash on a regular basis. Most female participants in the focus group discussions could see the benefits of tree domestication in the long run, but were sceptical about the potential of the innovation to generate income in the short term, and therefore hesitated to invest their time and resources.

Some female members of pilot groups cited problems regarding their integration in the groups and the attitude of the group leader. They complained about the lack of patience of the men when teaching the vegetative propagation techniques to women. Also they noticed some subjectivity from the part of the leader when plants produced in the nursery were shared among members. Female members received either less plants or plants of lower quality than their male counterparts. However, as the investment costs to start up a nursery are quite high, these women preferred to stay in the mixed groups and undergo this form of discrimination. Women practising vegetative propagation cited some technical difficulties as well. For example, because they cannot climb tall trees, they had to set marcotts on short trees, which were not always their preferred trees. Also, they experienced a certain discouragement following low rates of rooting of cuttings from certain species, such as *Irvingia gabonensis,* and problems of survival of the first marcotts planted in their farms.

It must be noted here that this study did not differentiate between unmarried, married, divorced women and widows, which is likely to affect women's participation in tree domestication activities. This certainly needs to be taken into account in future studies.

Very Poor Categories

As described in 3.3.3 and inspired by Pretty *et al.* (1995) and Schreckenberg *et al.* (2002), three to four key persons identified the category "very poor" in each community, using local criteria for wealth ranking. Although criteria differed from site to site, this category of people were generally characterised by bad housing conditions, small farm sizes, and few income generating activities or irresponsible use of revenues, in all communities. This category also comprised old persons, who had nobody to rely on and often lived very isolated.

Very few people in this category had been informed about tree domestication, as became clear in 6 focus group discussions and 12 individual interviews. This can be explained by their life style. The poorest of the poor rarely belong to associations and are, in general, marginalized in the community. They often develop an inferiority complex that makes it difficult for them to ask for information about a new technology. They are also pre-occupied with surviving and are not able to spend time and resources on experimenting new practices. According to the participants in the focus groups, their interest in tree planting is constrained by lack of land. Most often, farms managed by this category of people are hardly big enough to produce food for their home consumption.

Those who had heard about tree domestication claimed not to have participated because they doubted about the profitability of the innovation. Moreover, they were not sure the techniques would apply to all species of their choice. They also feared that if they wanted to join the pilot group, they would be asked money to contribute to the building of the shed house and propagators. Another constraint that limited participation of the poorest in tree domestication was their physical health. Many of them were old and sick and were no longer able to do any physical activity.

Beneficiaries of Tree Domestication

When asked who in the family would benefit from tree domestication, all focus group participants were unanimous. The first beneficiaries of tree domestication would be the children through better nutrition (more fruits), better health (more fruits and more income) and better education (more income). Next would be the person who practises tree domestication, woman or man without distinction, because he or she would have control over the trees and the benefit streams they produce. The interviewees agreed that after the children and the person involved in tree domestication, all other members of the household would benefit. In fact, participants perceived the benefits of tree domestication as satisfying the needs of all members in the household, even if the head of the household would still make the decision on the use of the income from the trees. Moreover, it seems that decisions on the use of income in many households nowadays are made jointly between husband and wife. Where there are adolescent children, they also get a say in family decisions.

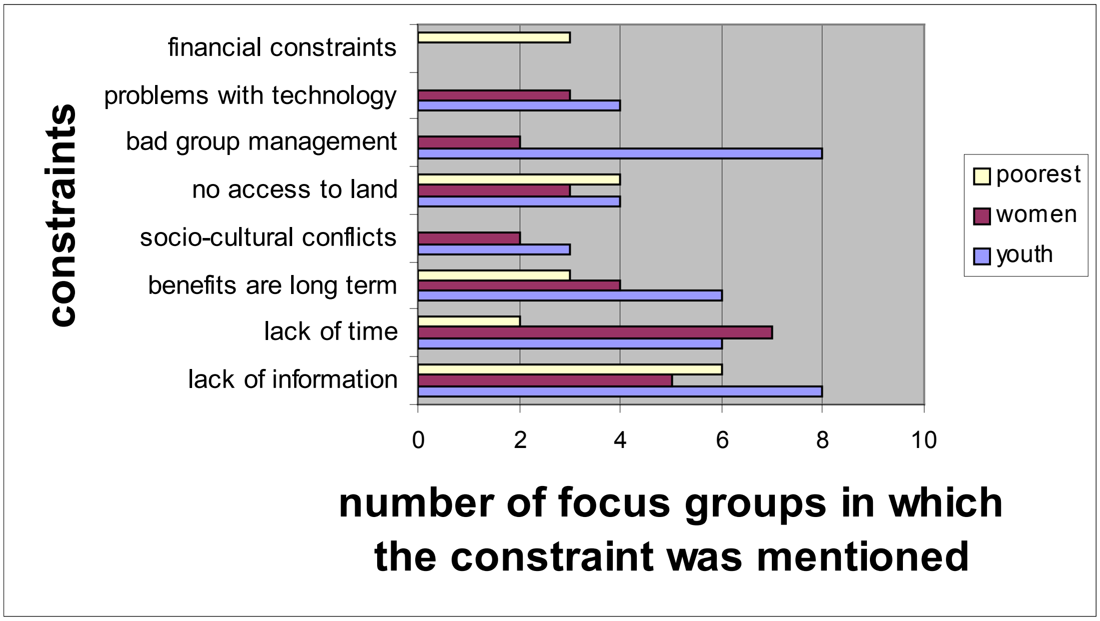


Figure 6-4: Major constraints expressed by vulnerable groups and poorest categories to participate in tree domestication
Source: Essomba (2004)

6.5.2 Impact of Agroforestry Tree Domestication

Collecting precise data on impact of agroforestry tree domestication at this stage, where farmers are still experimenting with the technology and have not yet decided whether to adopt or reject, is quite impossible. However, identifying expected impact on farmer livelihoods and choosing indicators to measure these effects is of great concern in assessing the *adoption potential* of tree domestication. Therefore, in 2004, two village workshops were organised with farmers and NGO partners on the impact of tree domestication on farmer livelihoods. The rationale behind these village workshops was that farmers are likely to identify types of impacts that researchers may be unaware of. Moreover, impacts important to farmers would be the most critical ones to monitor and evaluate. Finally, promoting the participation of farmers in monitoring-evaluation and impact assessment gives them a greater sense of ownership of project activities and increases empowerment of the beneficiaries (Waters-Bayer *et al.* 2001).

The majority of participants were farmers who had at least 3 years of first-hand experience with tree domestication techniques. Other participants included extensionists and ICRAF staff. Lekie-Assi, in the humid forest zone, hosted 45 farmers, 7 extensionists and 8 ICRAF staff (a total of 13 women and 46 men). In Belo, which is situated in the sub-humid savannah zone, 35 farmers, 1 extension agent and 5 ICRAF staff attended the workshop (a total of 16 women and 24 men). Overall, efforts were made to have a good balance between old and young farmers.

Impacts of tree domestication on farmer livelihoods (Table 6-10) were grouped into four categories: (1) impact on production, productivity and product quality; (2) impact on household economy; (3) impact on farmers' social and cultural well-being; and (4) impact on the environment.

1) *Impact of tree domestication on production, productivity and product quality*

According to the participants, tree domestication is expected to shorten the productive cycle, to increase fruit size and improve fruit taste of indigenous fruit trees, which households used to collect from the wild. Other expected results from tree domestication are yield increase and easy harvesting. Farmers are very much interested in the advantages of vegetative propagation because it induces early fruiting. The latter particularly encourages older people to plant trees. All impacts in this category were expected to occur in the medium term (in 4-10 years).

2) *Impact of tree domestication on household economy*

The impact on farmer's household economy was examined from 3 different angles: (a) income generation, (b) better nutrition and health, and (c) creation of jobs. Expected outcomes of tree domestication on nutrition were having a more balanced diet, while the impact on health was regarded in terms of decreased illness prevalence. However, these effects will depend largely on people's awareness of the potential benefits of fruits, as well as on the knowledge of medicinal plants and their uses. Tree domestication is also expected to increase household income, both in the short term through the sales of tree plantlets from the nursery, and in the long run through the sales of products from the trees planted. However, the impact is conditioned by the mastery of adequate marketing strategies. The perception of the magnitude of the expected impact on income, however, differed amongst participants. Some farmers saw tree domestication as a major activity, which could substitute their traditional cash crop – coffee – as main income generator, while others mentioned that tree domestication had a small share in their overall income, cocoa and cassava businesses being much more important income generators. The impact on job creation was estimated to be quite limited because farmers tend to integrate nursery and tree management activities in their usual farm work.

3) *Impact of tree domestication on the social and cultural well-being of the farmers*

For farmers to be involved in tree domestication was expected to have a positive impact on their social and cultural well-being in different ways. Farmers' technical knowledge on tree propagation, management and marketing would be improved. Being involved in tree domestication would also make them more enterprising in general and, through their newly acquired knowledge and relationships, would make them more respected in the community. These impacts were expected to be big, even though they could be jeopardized by jealousy and selfishness of some farmers.

Table 6-10: Results from the farmer workshop on impact of tree domestication on farmers' livelihood in humid forest and moist savannah zones of Cameroon (*Source*: ICRAF-AHT. 2004. Farmer workshop on tree domestication impact. Internal report.)

Impact	Indicator	Period	How to measure	Magnitude	Favouring Factors	Limiting factors
A) Impact of tree domestication on production, productivity and product quality						
Early fruiting	Year of first fruiting	Medium term	Farmers' records, observations, surveys	Medium	Favourable climatic conditions, propagation techniques	Poor soil
Increase fruit size	Size and weight of the fruit	Medium term	Ruler, rope, scale or hand	Big	Availability of improved varieties, fertile soil, more training	Lack of appropriate materials, lack of time
Easy harvesting	Tree height	Medium term	Bamboo stick	Medium	Propagation techniques, training	Destruction by stray animals and thieves
Good taste of fruit	More consumption	Medium term	Number of fruit consumed per day	Big	Climatic conditions and soil	Methods of preservation and preparation
Increased yield	Quantity of fruit per tree	Medium term	Weighing and farmer' s records	Medium	Land preparation, propagation techniques, soil fertility	Insects attack, pest and disease, bush fire, stray animals
Proximity	Distance between house and farm	Long term	Time to walk to the farm	Big	Cultural practices, adoption of the new technology	Lack of land, increased population density, government policy
More producers	Numbers of producers	Long term	Counting	Average	Availability of land, availability of planting materials, knowledge	Selfishness of pioneer farmers, low adoption rate

Impact	Indicator	Period	How to measure	Magnitude	Favouring Factors	Limiting factors
B) Impact of tree domestication on the economy of the household						
High purchasing power	Percentage of income generated by selling plants and products	Short term	Farmer's sale records, surveys	Small in Lékie Assi, big in Belo	Marketing strategies, quality and quantity of product	Poor storage facilities, lack of transportation infrastructure
Reduce illness prevalence	Number of sick farmers, frequency in using medicinal plants	Medium term	Surveys, interviews	Average	Poverty, knowledge on medicinal plant utilities	Ignorance, negligence
Good balance diet	Diversity and quantity of fruits consumed	Medium term	Surveys, observations, interviews	Big	Nutritional habits, processing facilities	Perishability of fruits, low quality fruits
Increased job opportunities	Self employment rate	Long term	Observations, interviews	Small	Training courses, extension programme	Lack of inputs (land, capital)
C) Impact of tree domestication on the social and cultural well-being of the farmers						
Increased knowledge	Number of farmers trained, number of workshops and seminars followed by the farmers per year	Medium term	Surveys, nursery attendance list	Big	Frequency of meetings and trainings	Lack of motivation and self-confidence
Improved education	Number of children sponsored	Medium term	Counting	Big	Access to market	Poor financial management
More enterprising	Numbers of activities carried out (Cutting, marcoting, grafting, bee keeping....)	Medium term	Surveys, list of different activities	Big	Meetings and trainings, access to information	Unsatisfying results, lack of production factors

New relationship	Number of people met	Short term	Counting, record keeping	Big	Meeting, training, transfer of knowledge	Lack of transport, conflict, jealousy, selfishness, lack of confidence
Increase awareness on importance of fruits	Number of households that regularly consume fruit	Short term	Surveys, record keeping	Big	More education and sensitisation	Lack of knowledge
Respect and popularity in the community	Number of people that come for assistance	Short term	Counting, record keeping	Big	Openness and welcoming, activeness	Lack of self-confidence, wrong political affiliation, jealousy
More unity	Collaboration among groups	Medium	Keeping records on group activities	Medium	Share of information and experience	Differences in objectives and approaches, conflicts, selfishness
Other impacts: Improved farming practices; Encouraged to plant trees; More time to do other things; Helps you to become more autonomous, reduces idleness, creates responsibility.						

Impact	Indicator	Period	How to measure	Magnitude	Favouring Factors	Limiting factors
D) Impact of tree domestication on the environment						
High species diversity	Numbers of species domesticated	Short term	Counting, planting records	Moderate	Economic, environmental and social values of the tree product, good tree propagation techniques	Uncontrolled bush fire, land tenure system, diseases, destruction by animals
Beautiful landscape	Shape and stratification of trees and canopies	Short term (calliandra, acacia) Medium term (fruit tree) Long term (prunus, timber)	Practical views, observation	Moderate	Farming system, planting techniques	Cost of tree, wind incident, theft
More shade, nutrients, fodder, foods for crops and animals	Fodder weighing, soil analysis shade measurement	Medium term	Scale, laboratory analysis...	Moderate	Using adapted species (leguminous, melliferous species)	Limit land for food crops
Improved soil fertility	Soil colour and texture, soil vegetation	Medium term	Observations, laboratory analysis	Moderate	Type of trees planted	Soil properties and nature of the mother rock
Other impacts: Less wind and water erosion, carbon dioxide reduction, weeds reduction						

4) Impact of tree domestication on the environment

Tree domestication was expected to create more tree species diversity on farms, thereby making the landscape more beautiful. More trees in the landscape would also create shade and reduce wind and water erosion. Planting of nitrogen-fixing trees, on the other hand, would render soils more fertile and would reduce weed incidence. These impacts were expected to occur in the short to medium term.

6.6 Conclusion

In this chapter, the adoption potential of tree domestication was assessed looking at both biophysical performance and socio-economic profitability, feasibility and acceptability. Studies were carried out to identify bottlenecks that constrain participation of vulnerable groups in tree domestication, whereas workshops with farmers, researchers and extensionists identified likely impacts of the newly acquired techniques on farmer livelihoods.

Several factors have contributed to the achievements obtained so far and speak in favour of the adoption of tree domestication in the humid tropics of Cameroon.

1) Tree domestication responds to farmers' perceived needs and is compatible with existing farming systems and local norms and values.

- The tree species promoted for tree domestication are of importance to farmers. This is so because farmers are involved in all steps of the tree domestication process, starting with asking farmers which trees they would like to cultivate on their farms (species prioritisation). The priority species provide fruits, condiments and medicines that have important nutritional and health benefits for poor households. The products have proven value on local and national markets, whereas some are even traded at a regional and international level.

- Farmers are interested in tree cultivation and wish to improve tree product quality because, in addition to products for home consumption, they need trees providing diversified and all-year round income streams to enable them to grow out of poverty. Fruit trees would be able to play this role, since a range of different species can provide income at different times of the year. Moreover, unlike the 'traditional' cash crops (cocoa and coffee), most of the indigenous tree products are sold on local or national markets and thus do not depend on world markets for price setting.

- There is a decline in the availability of traditionally important forest products from wild sources, whereas on the other hand, there is a growing population, especially in urban areas, that creates an expanding demand for these products (Leakey 1999).

- Tree cropping is not new to farmers of the region. Integration of these 'domesticated species' within existing farming systems (homegardens, cocoa and coffee plantations, etc.) will enhance the livelihoods of poor subsistence farmers while also providing environmental benefits (Leakey and Tchoundjeu 2001).

2) Vegetative tree propagation techniques are profitable and have relative advantage over their alternative (sexual propagation).

- The development of a low-cost propagation system that utilises non-mist propagators constructed out of cheap, readily and locally available materials and that does not need running water or electricity, has made propagation of trees through stem cuttings accessible to poor farmers. The advantage of rooting of cuttings compared to seed-based propagation is that it allows to rapidly select and multiply superior genotypes of tropical tree species, some of which have irregular flowering, and tiny or recalcitrant seeds.

- Air layering, a simple and cheap form of vegetative propagation, has the advantage of being applicable to mature trees that exhibit desired traits. It facilitates the selection and capturing of desirable traits from a wild population. Because marcotts are set on adult trees, early fruiting can be expected. Shortening the time to bearing is a very important feature for poor farmers, knowing that in the wild it may take as long as 10-15 years for many tropical tree species to start bearing.

- Cost-benefit analysis of farmer nurseries showed that vegetative propagation of indigenous trees is a profitable business provided that the nursery infrastructure is used to full capacity and that there is a market for the plants (Chapter 6.3). Therefore, vegetative propagation nurseries can evolve into small-scale enterprises, offering much needed employment opportunities in rural areas.

- For farmers to reap the benefits of tree domestication, markets have to recognise phenotypic variation in tree products. Studies (Leakey *et al.* 2003) have shown that although wholesalers did not take into account differences in fruit characteristics of a species like *Dacryodes edulis*, big fruits with lots of pulp fetched the highest prices in retail markets. It is to be hoped that, in future, farmers producing fruits of recognised and certified cultivars will be rewarded with higher prices.

3) Tree domestication is relatively simple in terms of management and number of components, because it is dividable. Moreover, the benefits are easily observable by farmers.

- Despite the fact that tree domestication is a complex innovation, it involves several steps and is composed of various components, which make it dividable. This implies that farmers can adopt the innovation gradually, following their own pace and according to their own resources. For example, farmers can begin their 'domestication project' with setting a couple of marcotts on trees of their choice, before applying other propagation techniques and integrating the propagules into the farming landscape. This will give farmers the time to experiment with the innovation and evaluate the benefits, costs and risks associated with it.

4) Policy makers start recognising the contribution of agroforestry and tree domestication to poverty reduction and sustainable development.

- Recently, interest for agroforestry as a low-input, low-risk, sustainable farming system, which can support rural livelihoods has increased. At international level, the first World Congress of Agroforestry, convened in Orlando in June 2003, declared that the adoption of agroforestry systems and technologies during the next decade will greatly enhance the achievement of the United Nations Millenium Development Goals (www.conference.ifas.ufl.edu/WCA/orlando.pdf). Agroforestry will (1) increase household income; (2) promote gender equity and empower women; (3) improve health and welfare of people, esp. mothers, children and HIV/AIDS sufferers; and (4) promote environmental sustainability. At national level, the Cameroon Poverty Reduction Strategy Paper (PRSP 2003) highlights the need to promote income-producing activities, particularly self-employment. In support of this, "*the Government intends to support initiatives of the poor in the most promising areas such as foodstuffs, processing of agro-foodstuff, small-scale livestock farming, and off-season crops. Small and medium-sized enterprises will be encouraged to position themselves in market segments with strong value added, such as industrial processing of natural resources*. Tree cropping and tree-based industries seem to be the type of activities that would benefit the poor.

On the other hand, a number of issues, if not addressed properly, are likely to limit the widespread use of tree domestication.

- Despite the fact that some of the vegetative propagation techniques shorten the time to bearing, tree planting remains a long-term project that will only generate benefits after a number of years, while still requiring substantial investment upfront. The gap between cost and benefit flows poses problems for resource-poor farmers with little or no capacity to bear these risks. While waiting for the trees to enter production, commercialisation of propagules could create short-term benefits for nursery operators. Yet, distribution pathways for tree plants are not well developed in Cameroon and farmers lack the information and skills required to reach potential clients.

- Some of the vegetative propagation techniques, especially the rooting of cuttings, require substantial investments, which are not always within reach of poor farmers. ICRAF has made a concerted effort to keep costs down and some farmers have reduced them further by using local materials (raphia, uncut poles, palm fronds) to build nursery sheds. A few were using discarded wine cartons as pot material, thereby saving on the cost of bags.

- The success of a domestication programme is very dependant on the presence and expansion potential of markets for the products. In general, there is a lack of capacity for value-adding. Many agroforestry products are very perishable and/or of "high volume for low value". For example, *Dacryodes edulis* fruit must be sold within 5 days after harvesting.

- At present, the majority of the established nurseries are operated by groups. However, many group leaders lack organisational and managerial skills, reducing the productivity and sustainability of the nurseries. Most often this leads to break up of the groups. Nevertheless, starting with groups is still effective because then individuals emerge who can manage the nursery enterprise. Moreover, it is probably not possible to identify these people except through the group approach.

Using the framework suggested by Franzel *et al.* (2002) and described in Chapter 3.3, the biophysical performance, profitability, feasibility and acceptability of agroforestry tree domestication in Cameroon is summarised in Table 6-11.

Based on the above, we suggest that research and dissemination would address the following challenges as a matter of priority.

- Domestication research should continue its efforts to identify factors affecting rooting and survival rates, leading to "improved" and recognised cultivars of an increased number of tree and shrub species for small-scale production.

- In order to increase productivity and efficiency of group nurseries, development organisations should strengthen farmer groups and enhance entrepreneurial skills among communities where farmers used to be subsistence-oriented.

- To allow farmers to generate income from their nurseries while waiting for future benefit streams from their trees, more research must be oriented towards studying the distribution and marketing of germplasm. At the same time, sensitisation campaigns should be launched by ICRAF and partners on a wide scale to inform potential clients about the advantages of vegetative propagation compared to seed-based multiplication.

- To make tree domestication accessible to all, including vulnerable and poor farmers, the costs of the technology must be further reduced. Since farmers themselves are the best experts in devising ways to lower costs, farmer experimentation and innovation should be encouraged. In addition, research and extension should identify and use appropriate communication channels to reach the most vulnerable groups. For example, major places where women get agricultural information are women associations, churches, markets and traditional celebrations. The youth can be targeted during holiday sport events, and by introducing tree domestication messages in rural radio programmes or in school curricula. The poorest categories in the community are rather difficult to reach because of their absence from most social gatherings. However, there are some indications that there exist strong solidarity and sharing mechanisms within extended families, making it possible for the poorest to benefit from the new technology. However, more research in this domain is still required and the possibility of encouraging the poorest in the community to embark on tree domestication by awarding special grants, e.g. in the form of nursery material must be examined.

Table 6-11: Summary of the adoption potential of agroforestry tree domestication in Cameroon

Factors	Key results
Biophysical performance	**Advantages** of vegetative propagation over seed-based multiplication: - vegetative propagation is suitable for tree species that have irregular flowering and fructification, and tiny and/or recalcitrant seeds; - vegetative propagation allows for rapid selection and multiplication of superior individual trees; at least for traits that are genetically controlled; - trees propagated by air layering or marcotting are usually shorter which facilitates harvesting, while they also fruit earlier; - rooting of stem cuttings allows for mass production (1 non-mist propagator can produce on average about 1000 cuttings annually); later on trees propagated through cuttings have proven to be more vigorous and faster growing than seedlings (ICRAF-AHT 2003). Limitations of and remaining challenges for vegetative propagation: - rooting percentage of some species, such as *Irvingia gabonensis*, is still low; - survival rate after weaning has to be improved; - vegetatively propagated trees, esp. marcotts, have a fragile rooting system and require appropriate management in the field.
Profitability	Vegetative propagation in farmer nurseries is profitable when nursery infrastructure is used to full capacity. Profitability is most sensitive to changes in production (species choice and quantity) and selling prices, showing the necessity to optimise production in response to what market demands and to develop appropriate marketing strategies for germplasm.
Feasibility and acceptability	After training and with subsequent technical assistance, farmers are able to apply vegetative propagation on a range of species of their choice. Most frequent problems are water management in non-mist propagator, susceptibility of propagator to termites and other woodborers, cost of some nursery materials, poor management of stock plants and integrating tree nursery activities with other livelihood activities. Research has suggested solutions to some of these problems: - an auto-regulatory system for water management in the propagators; - termite attacks can be prevented by treating the wood with used motor oil; - in extending the technology, costly nursery materials are as much as possible replaced by low-cost materials, readily available in rural areas;

	- it is also hoped that by strengthening the groups and developing enterprise skills among nursery operators, production can be optimised and profitability increased, so that farmers will consider tree nursery activities as serious business.
Boundary conditions	Gockowski *et al.* (1997) found that the importance of indigenous fruits in Cameroon was greatest in the areas of greatest deforestation, highest population density, largest market potential and greatest diversification and intensification of agriculture/horticulture. It was thus hypothesised that nursery performance would follow the same trend. However, our findings with respect to only 8 pilot nurseries did not allow us to verify this hypothesis, because of many other factors influencing nursery production, e.g. group dynamics. Nevertheless, nursery operators who were able to attract clients increased their production substantially, indicating that market access is an important success factor.
Lessons for effective dissemination	- Sensitisation and information on tree domestication should be done using mass media to reach a wide range of people: from nursery operators, tree cultivators, traders to processing industries and end-consumers. - Extension of tree domestication technology should use appropriate communication channels in targeting vulnerable groups and the poor. - Extensionists must be trained in agroforestry tree domestication techniques, since this is a new approach. - In addition to technical assistance, nursery groups require organisational and managerial skill development. - Policy makers need to recognise the potential of indigenous tree products in poverty alleviation and biodiversity conservation, and integrate tree domestication in their strategies.
Feedback to research and extension	Modifications made by experimenting farmers were mainly with the aim of reducing costs of nursery materials: i.e. using sharp knife or shaving blades instead of surgery knife to prepare the cuttings, use waste plastic bags as wrappings and vines to replace the rubber band for marcotting, etc. Most farmers also applied propagation techniques to other species, exotic as indigenous species alike. From on-farm evaluation, the following research priorities could be drawn: - success rate of certain species needs to be improved; - more attention must be given to field management of transplanted propagules, esp. marcotts; - nursery infrastructure and materials have to be scaled-down, i.e. needs to become cheaper, simpler and more accessible to all categories, including women, youth and the poorest; - research, extension and farmers together need to develop and test new business models for small-scale nursery management.

- Agroforestry tree domestication programmes must be implemented in parallel with studies on post-harvest storage and processing as an integral element of developing new crops for agricultural diversification. More investment is needed into initiatives to improve shelf life and process the tree products into new products like paste or oil. Development organisations should promote cottage industries related to indigenous fruit for the benefit of small farmers rather than large-scale entrepreneurs.

- To provide a favourable context for further development of participatory domestication of indigenous fruit trees, governments should publicise the important contribution of indigenous fruit trees to livelihoods and promote the adoption of agroforests as a more diversified, sustainable and environmentally friendly livelihood option than monocultures.

- To be able to keep the promise of tree domestication, wide-scale adoption is necessary. Therefore, mass media campaigns should spread information about the advantages and potential of tree domestication. Furthermore, training programmes for farmers in the simple techniques of vegetatively propagating trees should be extended widely. Establishment of vegetative propagation nurseries could be facilitated by the provision of credit and/or subsidies where desired.

Women in Ngali II, Center province of Cameroon, are setting their priorities for domestication of fruit trees, using matrix ranking

Chapter Seven

General Conclusions and

Recommendations for Future Research and Development Activities

Ann Degrande

"Vision without action is a daydream
Action without vision is a nightmare"

(Japanese proverb)

7.1 General Conclusions

Assessment of adoption potential of innovations is a key element of a participatory, farmer-centred model of research and development. It improves the efficiency of the technology development and dissemination process, helps document progress made in disseminating new practices, provides farmer feedback for improving research and extension programmes, and helps to identify policy and other factors contributing to successful technology development programmes as well as constraints limiting achievements (Franzel *et al*. 2001).

The main objective of this study was to assess adoption potential of two agroforestry technologies, that is: (1) improved tree and shrub fallows and (2) tree domestication of indigenous fruit and medicinal tree species, by farmers in the humid forest and moist savannah zones of Cameroon and to suggest means to ameliorate and accelerate adoption. Their biophysical performance and technical requirements, complexity, profitability, acceptability together with users' perception of benefits and advantages, relevance and compatibility were examined. In addition, we studied farmers' livelihoods to gain a more holistic view of the dynamics of farmer needs, objectives, personal characteristics and capital assets that are likely to affect adoption behaviour.

Strengths of the Study

Although other studies have looked at adoption of agroforestry technologies in the humid tropics of West and Central Africa (Adesina *et al.* 2000; Adesina *et al.* 1997; Kang *et al.* 1992; Kang et al. 1999); or at adoption of alley farming and hedgerow intercropping in other eco-regions (Carter 1995a, 1995b, 1995c; David 1992; David 1995; David and Swinkels 1994), this study presents some specific strengths, which makes it unique in its kind. First, because of ICRAF's long presence (1987 to date) in the sites where our studies were carried out, we were able to gain confidence and build up truthful relationships with experimenting farmers over time. Second, while previous studies focused on particular aspects of adoption, such as property rights (Adesina *et al.* 1997; Lawry *et al.* 1992) or socio-economic factors of adopters (Onu 1991; Carter 1995b; David and Swinkels 1994), whilst others employed specific methods like econometric analysis as in Adesina *et al.* (2002), the present study combined various research methods and tools, both quantitative and qualitative, to obtain a holistic view of the biophysical and socio-economic context in which farmers make the decision whether to adopt or reject the proposed agroforestry technologies. Another strength of this research work is that we examined adoption potential of two different agroforestry technologies that were tested and evaluated in the same research sites and often with the same farmers. The latter made it possible to assess specificities and/or complementarities of both technologies in solving farmers' problems.

Limitations of the Study

By definition, agroforestry technologies are complex innovations, featuring many components and often involving new knowledge and needing new management skills, as opposed to many agricultural innovations that consist of simply applying new inputs (e.g. fertilisers or new crop varieties) and adopting new tools. As a consequence, farmers often adopt agroforestry components in a step-wise manner. In such cases, the absence of a technology at a particular time may be unrelated to the farmer's plan to adopt the technology at a future time or does not mean that the farmer has never used the technology. Another factor increasing complexity of the present study is the location in which the study was carried out. The African Humid Tropics present a diverse socio-economic and ecological context, which is rapidly evolving under current pressure of market liberalisation and democratisation. It must also be noted that the study was carried out at a stage where the studied agroforestry technologies were still under development. Therefore, the study should be considered as an *ex-ante* analysis of adoption and *not* as an adoption study in itself. Moreover, the technologies were made available to farmers through adaptive research, which increased the difficulty to differentiate between a farmer who has adopted a technology from one who is still testing it (Place and Swallow 2002).

Adoption Potential of Tree and Shrub Fallows

Long-term on-station trials implemented by ICRAF from 1988 to 1997 in the humid forest zone of Cameroon showed that maize yields in rotational tree fallows were significantly higher than in continuous cropping (1 season per year) without trees and in natural fallows (ICRAF 1996). However, our studies showed that biophysical performance of rotational tree fallows under farmer conditions was much lower, with maize yield increases in tree fallow plots as compared to natural fallows not exceeding 40 % (Degrande and Duguma 2000). Cost-benefit analysis over a 12 years' period indicated that rotational tree fallows with *Calliandra calothyrsus* are not profitable under these conditions. Major reasons for this are the high upfront costs for tree establishment and high labour requirements for cutting back trees after the fallow period and pruning coppices in the cropping phase, which are not offset by increased yields. Farmers experimenting with the technology also mentioned the latter as bottlenecks to adoption of rotational tree fallows. The results suggest that the technology will probably not be adopted if the only long-term benefit is soil fertility improvement.

Nevertheless, farmers experimenting with rotational tree fallows said that they appreciated the technology for its ability to increase crop yields, even if they are only visible after several years, to suppress weeds during the fallow phase and to provide by-products such as stakes, honey and firewood. Indeed, when costs for tree seedlings are reduced or when bee-keeping activities are associated to the technology, the net present value of tree fallows becomes positive, even though it is still lower than that of natural fallows. Other incentives, that were found to encourage adoption of rotational hedgerow intercropping elsewhere, such as erosion control or providing fuelwood or fodder (Kang *et al.* 1999; Adesina *et al.* 1999), were not found to be very important to farmers in the study area. In fact, soil erosion is not so common here as most farms are on rather flat land; fuelwood is still abundant in farms and fallows; and the small livestock that farmers keep in the forest zone is free-roaming.

On-station and on-farm trials have shown that improved fallows with *Cajanus cajan* are significantly increasing crop yields as compared to natural fallows (IRA/ICRAF 1997). Cost-benefit analysis of cajanus fallows also demonstrated the profitability of the technology in the humid lowlands of Cameroon (Degrande 2001). The fact that cajanus shrubs can be established through direct seeding and intercropped with maize without depressing crop yields, considerably reduces establishment costs, which has been generally identified as the major bottleneck in adoption of improved tree and shrub fallows. The technology is particularly interesting to women who still are in charge of food cropping in Cameroon, as in most of Africa, because cajanus fits better into their cropping practices than tree fallows. Establishment is simple and clearing after cajanus fallow is easier than after natural fallow. Cajanus suppresses weeds and gives quicker yield responses (visible after one year) than tree fallows. Moreover, cajanus has the added advantage of producing edible grains, although their use is not yet well known to farmers in the forest zone of Cameroon. Therefore, we conclude that the adoption potential of shrub fallows with *Cajanus cajan* in the humid forest and savannah zones of Cameroon is high.

Adoption Potential of Agroforestry Tree Domestication

Research on agroforestry tree domestication has been going on in the humid forest and savannah zones of Cameroon since 1997. Being an approach comprising of different steps, i.e. tree species choice and priority setting, germplasm collection, propagation of superior tree individuals, integration and marketing of tree propagules and agroforestry tree products, until now, most research emphasis has been put on the identification, characterisation and collection of superior germplasm and the development of vegetative propagation techniques, as these represent the basis for tree improvement. Because of insufficient information on subsequent stages, this study had to limit assessment of the adoption potential of agroforestry tree domestication to the early stages of the domestication process. The value of this rather preliminary assessment lies in the fact that it will improve the efficiency of final technology development and dissemination process and provides farmer feedback for improving research and extension programmes.

Experiments in ICRAF's on-station nursery in Yaoundé and evaluation of vegetative propagation in farmer pilot nurseries in the humid forest and savannah zones of Cameroon have demonstrated that farmers are able to propagate a number of agroforestry species vegetatively, either through rooting of cuttings or marcotting (Avana *et al.* 2004; Mialoundama *et al.* 2004; ICRAF-AHT 2003). Vegetative propagation is recognised to have several advantages over seed-based multiplication. For example, vegetative propagation allows for rapid selection and multiplication of superior individual trees for traits that are genetically known and controlled. Trees propagated by air-layering are shorter and they also fruit earlier. Rooting of stem cuttings allows for mass production, whereas cuttings have proven to be more vigorous and faster growing than seedlings. All these make vegetative propagation attractive to farmers. In pilot farmer nurseries, farmers were able to apply vegetative propagation techniques to a range of species of their choice (Degrande *et al.* in press). However, wide-scale adoption is likely to be constrained by the cost of nursery infrastructure and materials, especially if farmers want to start the nursery on their own and not in groups, as has been the case so far. This notwithstanding, cost-benefit analysis showed that vegetative propagation in farmer nurseries is profitable when nursery capacity is used to full capacity and when there is sufficient demand for tree propagules. The majority of modifications made by experimenting farmers were in the domain of reducing costs of nursery materials, e.g. using sharp knife or shaving blades instead of surgery knife to prepare cuttings, use of waste plastic bags as wrappings and vines instead of rubber rope for marcotting. Nevertheless, in order to increase profitability better planning of nursery activities and pro-actively prospecting markets for improved tree propagules, is necessary. The latter might require new management and business skills for farmers and extensionists agents alike. Increasing nursery profitability is considered important in facilitating adoption of agroforestry tree domestication, because it allows farmers to generate income from their nurseries while waiting for future benefit streams from the "domesticated" trees they have planted in their farms.

We also investigated participation of vulnerable groups, i.e. women, youths and the poorest categories in the community, in tree domestication; identified problems these groups faced; and assessed how they are likely to benefit from tree domestication. Results suggested that the main problem constraining vulnerable and poor farmers to participate in tree domestication was the lack of information. Women and youths seem to have different communication channels and meeting points than men, which must be targeted if information on tree domestication is to reach them directly. The poorest categories in the community are difficult to contact because of their social isolation. Another obstacle mentioned by these vulnerable groups was the high start-up costs. Research into lowering nursery costs would thus also facilitate participation of vulnerable groups.

In focus group discussions, participants unanimously claimed that the first beneficiaries of tree domestication would be the children through better nutrition (more fruits), better health (more fruits and more income) and better education (more income). Other members of the family would also benefit directly or indirectly from tree domestication, because trees and tree products are expected to satisfy different needs for different household members, even if one person has control over the income from the trees. Worth mentioning is that, in addition to its impact on the household economy, pilot farmers expect tree domestication to have considerable impact on their social and cultural well-being (knowledge, self-esteem, prestige, …), as well as on the environment (shade, soil protection, on-farm tree species diversity, beautifying the landscape), and recognise that some of these effects will happen in the short and others in the long run.

Link to Farmers' Livelihoods

Despite its richness in natural resources, Cameroon still has many poor people. While GDP per capita was USD 559 in 2001, UNDP (2003) recorded that 33.4 % of Cameroon's population was living below the poverty line of USD 1 a day. In the forest areas, this proportion was as high as 66 % of the total forest population (Cida 2000). One of the explanations is that tree crop and forest-based farming systems in these areas are highly reliant on coffee and cocoa, for which international prices drastically fell in the late '80. Faced with this problem, most households had no other alternative than to increase their interest and activities in commercial food cropping, thereby opening new forest land where possible, and intensifying cropping elsewhere by reducing fallow periods. Today, not more than 1 quarter of the households in ICRAF's pilot villages in the humid forest zone continue to generate their main income from cocoa, whereas only 2 % in the savannah zone consider coffee as their major income generator. The majority of rural households, however, earn their living by combining cash crops with food crops.

Unfortunately, this shift to food cropping inevitably led to physical soil degradation, soil nutrient depletion and increasing incidence of weeds, pests and diseases. In addition to increased problems with soil fertility, rural households continue to suffer from seasonality effects. Many households go through periods of food shortage prior to harvest. This is particularly true in the moist savannah zone, where up to half of the interviewed households are not food self-sufficient. This shortage in food generally is accompanied by periods of financial distress for households that have no other sources of income than food crops.

In the light of the problems mentioned above, generation and dissemination of improved technologies should thus target two areas of intervention:

- increase crop yields through soil fertility improvement and decreased incidence of weeds, pests and diseases;
- diversify income sources in order to address two constraints: (1) current high dependence on only a few crops that are prone to price fluctuations on the world market; and (2) seasonal fluctuations in income and consumption.

The development of improved fallows and the research into agroforestry tree domestication seem to well address these priorities.

In developing technologies, however, one must take into account the context in which farmers operate and the resources they have at their disposal to undertake their livelihood strategies and achieve their livelihood outcomes.

Weak Human Capital

The situation of human capital – consisting of skills, knowledge, ability to labour and good health - in Cameroon was, until recently, estimated as one of the best compared to that of other countries in the central African region. In our study sites, household labour force is generally limited to 1 male and 1 female adult, and between 2 to 5 children under 15 years. Exchange of labour at peak periods, e.g. land preparation, groundnut planting and cocoa harvesting, is common. However, it is the availability of household labour that often limitss the area under cultivation. We found that heads of households on average finish primary school and more than 90 % of those in Centre Province speak French, suggesting that they should be able to understand extension messages without problems. On the other hand, current school curricula in Cameroon do not address the needs of future farmers that would consist of giving them the practical knowledge and skills that would enable them to analyse their changing environment and choose adequate farming options.

Moreover, growing poverty, decreasing public investments and escalating corruptive practices in education and health, coupled with increasing HIV/AIDS prevalence rates, are reasons for concern and may affect human capital negatively in the years ahead. Although we have no data on health status of households in our study site, the fact that only 2 out of 8 study sites had a health centre in the vicinity shows poor health care coverage in the country, leading to ill-health and high disease prevalence in many rural areas.

In situations where labour rather than land is the most limiting factor, soil fertility improving technologies that increase labour need substantially are unlikely to be adopted, unless the high demand for labour is compensated by increased outputs that cannot be obtained otherwise. The study shows that management of tree fallows requires 1.4 times more labour than natural fallows, while returns to labour are lower. This shows that crop yield increases and the value of by-products do not compensate the extra labour in tree fallows, which makes their adoption improbable at present. However, this is true as long as the alternative, i.e. natural fallows, are able to restore soil fertility sufficiently to continue to produce acceptable yields. On the other hand, cajanus fallows, as described in this study, have more chance to be adopted, not because they require less labour than natural fallows, but because their returns to labour are higher. Another advantage is that, although more labour demanding as a whole, specific tasks such as clearing and weeding become easier.

Financial analysis of a vegetative propagation unit demonstrated returns to labour to be higher than the minimum wages in Cameroon. Nevertheless, farmers identified “lack of time” as one of the constraints to adoption of a specific vegetative propagation activity. This can be explained by the timing and frequency, and not *per se* the total amount of labour required in a nursery. Nursery maintenance is a daily activity, necessitating a well-planned integration in other livelihood activities, whether on-farm or off-farm.

Degradation of Natural Resource Base

In the light of our study on adoption of agroforestry technologies, two components of the natural resource base are of importance: land availability and quality, and existing tree species diversity.

Land is an extremely important asset for rural households in the humid forest and savannah zone of Cameroon, since it is the basis for farming. As mentioned above, the only option farmers had to compensate for loss of income from cash crops in the late 1980s and early 1990s was to increase the area under food crops, with declining soil fertility and degradation of remaining forests as a consequence.

Whilst the majority of households in the study area still do not perceive declining soil fertility as a priority production constraint and claim to dispose of sufficient land to practice natural fallows (ASB 1996; Degrande and Duguma 2000), from a scientific point of view, soil fertility improving technologies are urgently needed to avoid further soil nutrient loss and degradation. Smaling and Braun (1996) argue that farmers' perception of soil fertility is biased by their short-time horizon. The majority of resource-poor rural households will most likely set its primary objectives and undertake actions using the time horizon dictated by one agricultural cycle (Vosti and Witcover 1996). A short-term horizon makes it more difficult for households to incorporate environmental maintenance or enhancement into their resource use strategy.

Longer-term processes that affect agricultural sustainability adversely, such as decreasing soil organic matter levels and nutrient stocks, are less visible and may seem less noteworthy. Raintree (1983) sees this as a design problem in which the agroforestry designer needs to find some way of linking the solution of imperceptible or low priority problems to the solution of perceived, high priority problems, i.e. he has to smuggle in the indiscernible conservation function as a by-product of the farmer's decision to adopt an agroforestry technology for its production benefits. In that case, the adoption of the undesired benefit is possible, after all, because it is packaged together with a desired benefit. For example, encouraging farmer investment in environmentally sound agroforestry systems with a multi-year lag before generating any return must include a component bringing earlier returns. An extension of this principle can also assist the agroforestry designer to address future production problems, by applying pre-adaptive designs whenever they can be linked to presently adoptable technologies (Raintree 1983). For example, farmers are unlikely to adopt the more land and labour-intensive technologies before population pressure compels them to do so, but we can conceive of technologies today which leave sufficient flexibility and scope to keep pace with future population growth.

In the case of the humid forest zone of Cameroon, one can easily identify areas where incentives for soil fertility management exist or are likely to occur in the near future, i.e. areas close to urban centres with increasing land-use pressure, which triggers land-use intensification, often resulting in soil fertility decline. There are also villages that have soil erosion problems and where fuelwood becomes scarce. According to Franzel *et al.* (2001; Figure 7-1), the degree of intensification of agriculture in southern Cameroon can be defined as intermediate, suggesting that the current adoption potential of improved fallows is medium, whereas it could be expected to increase rapidly with declining natural fallow periods.

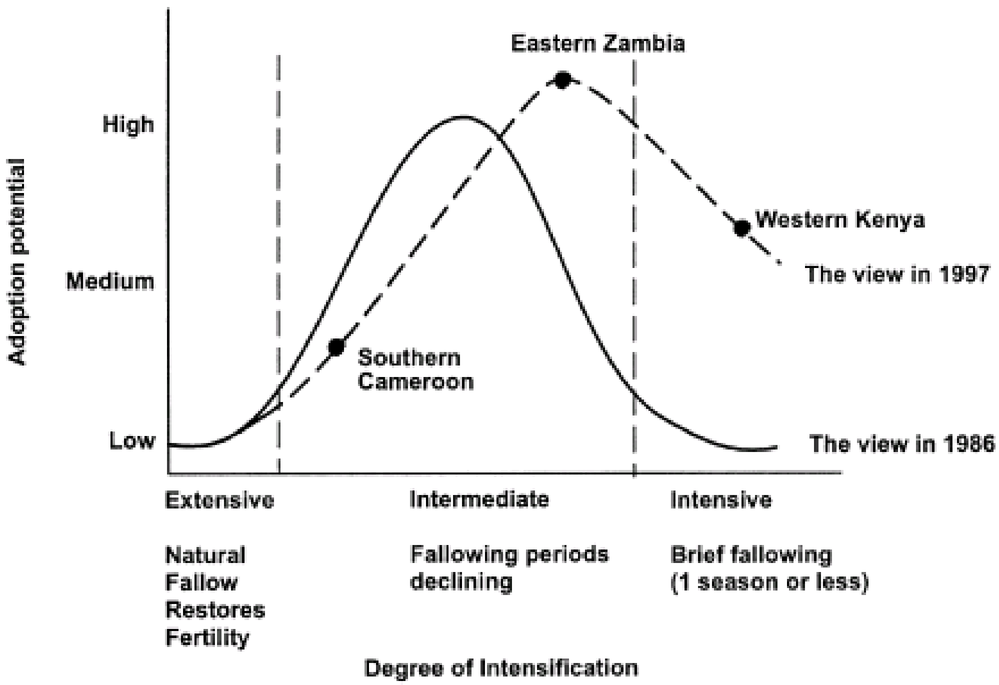


Figure 7-1: Adoption potential of improved fallows at different stages of intensification, comparing the view of 1986 with that of 1997
Source: Franzel *et al.* 2001

Declining tree diversity, both inter and intra-specific, is expected to have a double effect on tree domestication. First, tree domestication builds on existing variability in tree populations to select superior genotypes for multiplication (Simons and Leakey 2004; Leakey *et al.* 2003). The greater the variability, the greater the likelihood to find traits that will respond to farmers' needs and market demands. Declining diversity may thus affect tree domestication negatively. Most indigenous tree species are still widely found in forests as well as in farmers' fields all over southern Cameroon. For example, Leakey *et al.* (2001), Atangana *et al.* (2001, 2002) have shown great intra-specific variation in *Dacryodes edulis* and *Irvingia gabonensis*. The cocoa and coffee fields, typical land-use systems in southern Cameroon, have been privileged niches for fruit, medicinal and timber tree species and form an excellent basis for the development of economically interesting and ecologically sound agroforests.

On the other hand, it is recognised that diminishing access to wild tree populations, because forests recede or access is restricted for conservation purposes, may in fact be an excellent incentive for tree domestication (Russell and Franzel 2004). There is evidence worldwide that farmers plant more trees on farm to compensate for the loss of tree resources in the wild (Degrande *et al.* in press; Kindt *et al.* 2005; Schreckenberg *et al.* 2002; Warner and Raintree 1986). Moreover, human population growth and increasing urbanisation are expected to have positive effects on the demand for tree products.

Insufficient and Poorly Maintained Infrastructure

Poor road infrastructure, poorly functioning markets for agricultural and agroforestry commodities and the lack of access to communication facilities, electricity and post-harvest technologies, as is the case in the humid forest and moist savannah zones of Cameroon, are known to constitute major bottlenecks for smallholders to fully benefit from agricultural innovations (IFAD 2001b). In addition, Franzel *et al.* (2004) demonstrate that the presence of market options is one of the ten essential elements for successful dissemination of agroforestry innovations. Even if agroforestry technologies produce intermediate products or inputs, like soil fertility for crop production, their uptake will depend on the availability of markets for the final products. For example, in the case of improved fallows, increased crop yields alone do not provide enough incentives for farmers to adopt the technology, if their surplus production cannot be sold (Izac 2003). In southern Cameroon, farmers complained that maize yield increases brought about by improved tree and shrub fallows did not result in concomitant income increase because of lack of adequate market opportunities. In response, some of the trial farmers started experimenting the rotational tree fallow on higher-value crops such as tomato (ICRAF 1996), which were sold more easily. However, because of the perishability of such crops and in the absence of proper processing for longer shelf life, this is an option only for farmers living close to urban centres.

Russell and Franzel (2004) also argue that, if agroforestry systems and innovations are to contribute to the fight against poverty, market and value addition opportunities for smallholders must be explored, enabled, and expanded. They advocate concentrating on products that are important for local development, i.e. in energy, construction and locally valued food product sectors, rather than focusing on export markets, because smallholders' access to international markets is hampered by too many constraints. Domestication of indigenous fruit trees in southern Cameroon is an example of this approach. The tree species on which the participatory tree domestication programme is focusing, produce fruits and culinary products that are widely consumed and traded in the Congo Basin area. Despite this, farmers earn low returns from these products because of seasonal gluts, limiting and conflicting market knowledge and lack of networks and associations, etc. Therefore, the tree domestication programme is putting efforts not only on selection and propagation, but also and foremost on investigating markets and developing enterprise skills of smallholders.

Inappropriate or Insufficient Pro-poor Policies and Institutions

According to Amin and Dubois (1999), social capital – that is the networks, relations and membership of groups upon which people draw in pursuit of their livelihood objectives – can have a great effect on poverty and consequently cannot be dissociated from development action. People maintain and invest in kin-based relationships because they generate rights in the community, for example in terms of allocation of land, and provide safety nets in times of hardship.

Social capital in the forest and savannah areas of Cameroon can be classified as 'potentially strong'. In our study, we found evidence of building of social capital by households in the form of remittances received and expenditure for gifts and social assistance. Mutual aid groups which are formed to foster solidarity in the community through a solidarity fund are another example.

Strong social organisation makes it possible for the poor to gain access to resources and knowledge within the community and to develop links with external partners. One example of social organisation commonly found in the study area are the Common Initiative Groups (CIGs). These groups have a variety of activities from agriculture, bee keeping, fish and poultry farming to cooperative commercialisation of agricultural commodities but usually cover a limited geographical area (a quarter or a village). However, their capacity to play a prominent role in agricultural development is questioned because of their diversity and the often blurred motivation of their promoters. Another example of social organisation are the rotative credit and savings groups, which provide start-up capital for income-generating activities or solve financial problems of their members. Although they generally generate small amounts of money and sometimes lack flexibility and convenience, up to now they are just about the only financial service available to rural households.

Knowing the potentials and limitations of groups and associations to implement and disseminate innovations and understanding the ruling mechanisms is imperative. Agroforestry extension typically uses groups to experiment with and promote promising technologies and even helps build capacity in institutions that drive development. However, although groups may be effectively used in sensitisation and training on new technologies, their role in actively disseminating best practices is often limited. For example, Russell and Franzel (2004) and Böhringer *et al.* (2003) mention that group nurseries, typically used by agroforestry extension, produced significantly fewer seedlings than individual nurseries managed by farmers. Our study also highlighted group management as one of the key factors affecting nursery performance. This may be explained by the fact that collective adoption (such as for group nurseries), compared to innovation decisions taken at household level (like improved fallows), increases the social complexity of an innovation, often leading to conflicts related to distribution of responsibilities and benefits (Reed 2001). Likewise, marketing and enterprise development is more and more put in the hands of farmer organisations, which seem to be stuck between once government-promoted cooperative models that were inefficient, top-down, and often corrupt and new models that may not provide the necessary structure or information for farmers to deal with the private sector (Russell and Franzel 2004). Finding appropriate mechanisms to help farmers to share technologies, organise for production, garner market information, lobby and link with the private sector is one of the main challenges for agroforestry research and development.

Adoption of Improved Fallows and Tree Domestication as a Diversification Strategy

Diversification is the norm. Very few people collect all their income from any one source, hold all their wealth in the form of any single asset, or use their assets for just one activity. Our study showed that the majority of households in the humid forest and moist savannah zones of Cameroon combine more than one activity to earn their living. For example, 37 % of all households combined cash and food cropping. In agreement with existing literature (Barrett *et al.* 2001; Reardon *et al.* 2001), we also noticed that the poorest households had fewer sources of revenue than better-off households, suggesting that income diversification is critical for households to increase their well-being (Barrett *et al.* 2001). This has important implications for the development and dissemination of technologies. Franzel *et al.* (2004), among others, highlight the importance of offering a range of options to farmers rather than a specific recommendation because: (1) most farmers prefer to diversify in order to minimise production and market risks; (2) different farmers may have different preferences; and (3) different options are likely to perform differently as environments change. ICRAF's decision to turn its research focus to domestication of indigenous trees, after having developed technologies to restore soil fertility, falls in this line of thinking. Farmers recognised the value of tree and shrub fallows to improve soil fertility for food cropping, but were still looking for ways to enhance their capacity to generate cash (ICRAF 1997; Degrande and Duguma 2000). Tree domestication was expected to contribute to the diversification, increase and stabilisation of farmers' income (Leakey and Simons 1998; Tchoundjeu *et al.* 1999; Simons and Leakey 2004).

Improved fallows and tree domestication are two agroforestry technologies that solve different problems and have different objectives. Various adoption scenarios can thus be envisaged according to households' livelihood strategies and available assets.

a) Households having food cropping as principal livelihood strategy, formed 18 % of our overall sample, but as much as 56 % of female-headed households relied mainly on food cropping. These households would probably adopt improved fallows more easily because their main objective is to maintain soil fertility at a level that sustains satisfactory crop yields. However, the likelihood of adoption will predominantly depend on their land and labour availability, as well as on the opportunities to market their surplus production.

b) Households that combine cash and food cropping represented 37 % of our sample. Although none of the correlations were significant, this category of households also tends to have larger farm sizes, bigger families and older heads. They have already opted for diversification in income generation and seem to have reasons to adopt both agroforestry technologies that were presented to them. Since food cropping is important in providing food security but also as an income generator, these households are necessarily looking for ways to maintain soil fertility. At the same time, they have cocoa or coffee farms that could possibly be diversified and enriched, providing an incentive to adopt tree domestication. As Raintree and Warner (1986) indicated, high population densities (200 inhabitants km^{-2}), an overall land use intensity index of about 60, stable land tenure and proximity to a good market are all conducive factors in the transition to market-oriented tree crop production, as are higher returns to land and labour from the tree crop system.

c) Households that still earn the big share of their income from cash cropping, are expected to be quite similar in adoption behaviour as category (b) described above. The only difference is that here food cropping is subsistence-oriented, which may reduce the incentive to adopt improved fallows as long as crop yields satisfy household needs without the need for additional soil amendments. However, increased planting of tree cash crops will often take land out of subsistence food production. So with time, some form of field crop intensification, more specifically soil fertility improvement, will be necessary. Alternately, trees for cash and/or subsistence uses can be planted in interstitial locations around the farm, whereas contribution to subsistence can be increased through the intensification of homegardens (Raintree and Warner 1986).

d) Households that draw the majority of their income from non-agricultural activities are those who generally want to invest in low labour demanding activities that will provide future income streams, such as fruit trees. Indeed, tree domestication seems to especially attract civil servants, traders, etc. who consider it a good retirement plan.

7.2 Further Research Needs

In the Domain of Improved Fallows

A number of research questions remain to be solved in order to increase adoptability and eventually adoption of tree and shrub fallows by farmers.

First, the study demonstrates that the profitability of improved fallows largely depends on the costs of establishment. Lowering tree and shrub establishment costs should therefore be a priority for further research. Several suggestions in this respect have been formulated but there have been no systematic trials to test them. For example, we do not have hard data on survival rates of bare-rooted seedlings of calliandra or the success of direct seeding in the humid forest and moist savannah zones of Cameroon. Also, on-station experiments have shown the potential of decreasing tree densities from 10,000 to 2,500 trees ha^{-1}, but we have not assessed their long-term effect on soil fertility, nor have we evaluated this alternative tree spacing with farmers.

Second, in the case of cajanus, seed production has been problematic in the humid forest zone. Research should test cajanus provenances to select those that provide a good equilibrium between leaf biomass and seed production under the prevailing agro-ecological conditions.

Another issue that has not yet been addressed is how and to what extent farmers will integrate tree and shrub fallows in their farms. The present study revealed that many farmers are using shrub and tree fallows at the same time on different fields. However, we have no information on the criteria farmers use to allocate a specific technology to a particular field. Anecdotic information suggests that farmers may have several fields planted with cajanus, whereas others prefer to have only one shrub fallow in any one season. The latter then rather prefer to have one cajanus fallow on a particular parcel this season and establish another one on another parcel next season, and so on. "What is the proportion of the farm size that farmers wish to cover with improved fallows?" and "Why?" are still unsolved questions.

Then, many authors (Sanchez 1999; Szott *et al.* 1999; Nolte *et al.* 2003) have questioned the sustainability of improved fallows and their potential to restore highly degraded soils. Planted tree and shrub fallows are a way for *in-situ* accumulation of high quantities of N for provision to subsequent crops. However, the residual benefits of improved fallows on the productivity of subsequent crops usually only lasts for one or two cropping seasons. Moreover, harvesting of by-products such as grains and fuelwood, which is very attractive to farmers, will lead to considerable nutrient export (Nolte *et al.* 2003). Therefore, Szott *et al.* (1999) argue that the maximum cropping intensity (R) for sustained crop production on unfertilised N-deficient soils would be about 0.5. When other nutrients, such as Ca and P are limiting, the cropping intensity without fertilizer inputs could even be lower ($R < 0.33$) since fallows have a limited ability to restore P fertility. In sum, long-term sustainability will depend on the size of nutrient stocks present, the magnitudes of net nutrient losses during each crop-fallow cycle (Szott *et al.* 1999), and fallow management.

In the Domain of Agroforestry Tree Domestication

Based on the assessment of adoption potential of agroforestry tree domestication, we suggest that research should address the following issues as a matter of priority.

The uniqueness of participatory tree domestication lies in the fact that farmers participate in the choice of tree species to improve upon. This implies that research has to deal with a great number of tree species, increasing the difficulty to come up with appropriate recommendations for successful domestication of all these species. Nevertheless, research should continue ameliorating propagation techniques for priority species and identifying factors affecting rooting and survival of other species. More importantly, however, as Simons and Leakey (2004) recommended, ICRAF as an international research organisation, should focus on developing "domestication strategies" or "domestication decision frameworks", that describe the different steps and procedures in domesticating "model" species of different tree categories (based on product type, mode of propagation, generation interval). National research institutions and other clients/stakeholders could then easily apply these strategies to other species within each of the categories.

To make tree domestication accessible to all, including the vulnerable and poorest farmers, propagation techniques should be further simplified in order to reduce costs. One of the ways to go about this would be to evaluate effectiveness of alternative materials in areas where "standard" nursery material is not available or too costly. For example, recommended rooting substrate in non-mist propagators is composed of sand and sawdust, which is readily available in some areas but difficult to access in others. Here, research identifying alternative substrates should be a priority. Occasionally, farmers themselves make modifications to reduce costs, but often these innovations need to be crosschecked by research before disseminating them on a wider scale.

Commercialisation of nursery products is very important in the adoption of agroforestry tree domestication because it allows farmers to generate income from their nurseries while waiting for future benefit streams from the "domesticated" trees planted in their farms. However, profitability analysis showed that a vegetative propagation unit is profitable only when infrastructure is used to full capacity and at least 75 % of propagules are sold. Hence, increasing nursery productivity is of utmost importance. Our assessment of pilot nurseries revealed that, apart from some minor technical problems with vegetative propagation and the limited market scope, nursery output was also affected by the way in which responsibilities are attributed and benefits are shared within the group. Tree nurseries run by groups thus require significant skills in collective action, which are not always present in farming communities. Russell and Franzel (2004) found that small-scale individual tree nursery enterprises are more flexible and often better in meeting changing demands. On the other hand, individuals may not be able to run vegetative propagation units on their own because of high start-up costs and daily labour requirements. Another reason to work in group would be to have access to sufficient stock material, e.g. superior trees to set marcotts on. From the above it is thus clear that more research is needed to be able to design new organisational models and to determine the level and type of support (technical, financial, business development, etc.) or incentives required for sustainable nursery development and effective germplasm distribution in rural areas.

Our study has not looked into the integration of improved propagules in farming systems, because ICRAF's research results in Cameroon are still very preliminary. However, it is obvious that adoption of agroforestry tree domestication will depend on integration options offered to farmers, since the ultimate goal of tree domestication is to increase households' benefits from trees. Hence, research should focus on gaining understanding of current tree-based systems and identifying ways of enriching and diversifying these. Another component of integration research should look at below and above-ground interaction between trees and companion crops, because in most cases trees will be planted and managed along with other crops, at least for some time, in order to bridge the gap between investment costs and income generated from tree products.

As has been stressed on many occasions during this study, markets for trees and tree products must be expanded and value addition opportunities must be explored if agroforestry systems and innovations are to effectively contribute to the fight against poverty. Together with other stakeholders, ICRAF's Regional Programme for the African Humid Tropics is studying markets for agroforestry tree products and is developing approaches to increase marketing and entrepreneurial skills of smallholders. Going one step further and following Russell and Franzel (2004), we recommend that more efforts should be put on building and supporting rural industries, while creating and promoting market intelligence systems. Related to this, one big question subsists though: "What should be the key role for research organisations in this process?"

7.3 Recommendation for Development Activities and Policy

From the issues discussed in this thesis, there is evidently much work to be done in bringing agroforestry technologies to a large number of farmers.

Related to the Approach

First of all, agroforestry is an old practice but a new science. Many extension agencies do not have up-to-date information on agroforestry innovations. Until today, most agroforestry extension material in the humid forest and moist savannah area of Cameroon is dominated by the "*alley cropping concept*" of the 1980s, despite significant changes in definition and practices of agroforestry since then. This situation is exacerbated by the fact that agroforestry is a multidisciplinary approach and falls between the gaps of mandates of particular institutions and ministries (for example agriculture, forestry, livestock). Likewise, agroforestry as a discipline has often been neglected in curricula of colleges and universities. All these result in a situation where extension services are ill-prepared to disseminate agroforestry innovations to farmers.

Nevertheless, the participatory nature of agroforestry technology development, described in this thesis and used by ICRAF, has contributed to more active involvement of extensionists early on in the process, and consequently should facilitate dissemination on a larger scale later on. The role for extensionists and scientists in this process is illustrated in Figure 7-2. In this model (Reed 2001) dissemination of innovations is a key role for development agencies. Extensionists enhance the efficacy with which innovations are communicated, thereby reducing the perceived complexity, and enhancing their observability and adaptability. In some cases there may be an opportunity to improve the innovations that have been identified, before disseminating them more widely.

In the Domain of Improved Fallows

Effective dissemination of tree and shrub fallows should include the following components.

- Our assessment of adoption potential of improved fallows in the humid forest and savannah zone of Cameroon, in agreement with Adesina *et al.* (1999), has shown the importance of appropriate biophysical and social targeting. Promotion of rotational hedgerow intercropping should focus on: (1) areas in the so-called intermediate phase of intensification (Franzel 1999), i.e. increasing population densities and shortening fallow periods; (2) where soils are poor; and (3) where weed incidence is a serious problem. Its adoption potential is likely to increase in areas where, in addition to soil fertility, erosion and fuel wood are major problems for farmers. Households that are more likely to adopt rotation hedgerow intercropping are those that lack land and have sufficient (male) labour to plant and to cut fertiliser trees. On the other hand, shrub fallows with Cajanus are more suitable for households with insecure land tenure, for women and in areas that are characterised by short fallow periods (e.g. West Cameroon with < 6 months' fallow).

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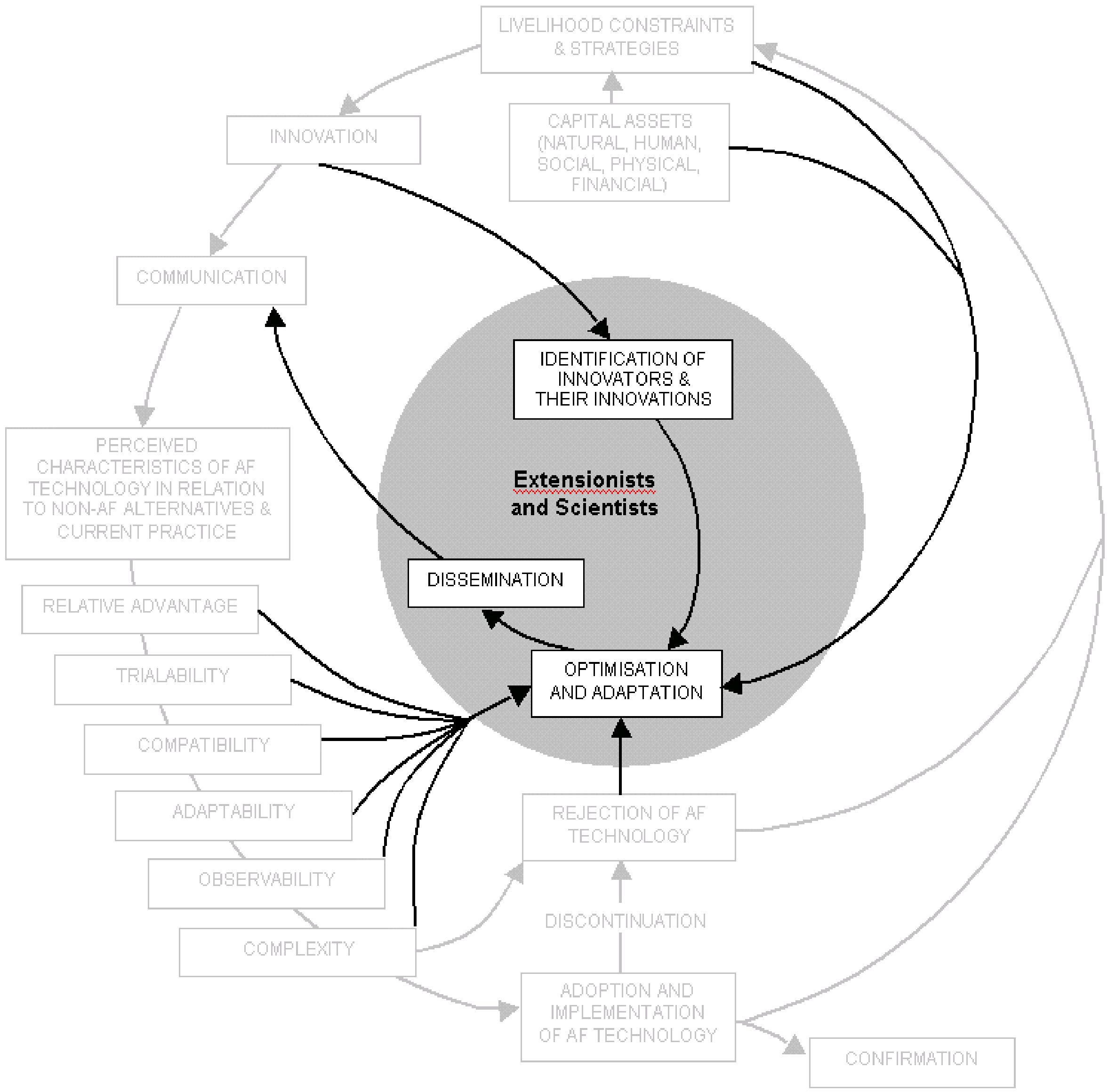

Figure 7-2: Role of research and extension in the agroforestry technology adoption cycle
Source: Reed (2001)

- In the priority areas mentioned above, farmers' awareness on the benefits of improved fallows should be raised through demonstration plots, field days, farmer-to-farmer visits, technical manuals, leaflets and training. We insist on the establishment of demonstration plots, because they are known to improve the observability of agroforestry systems and to have a direct impact on agroforestry adoption rates (Rogers 1995).

- Lack of planting material is repeatedly identified as one of the most important constraints to the wider adoption of agroforestry innovations (Franzel *et al.* 2004; Buresh and Cooper 1999). In the case of improved fallows in southern Cameroon this is not different. The spread of Cajanus fallows was hampered by insufficient seed production and problems during storage. Therefore, seed-production units should be developed at different levels. Ideally, seed supply should be in farmers' hands, so that it constitutes an income-generating business at the same time. However, this will require assistance with organisation and training of farmers in seed collection, handling and marketing.

Even if extension agencies were to disseminate improved fallows effectively, adoption would still be lower than what is desirable for society, given the potential of agroforestry in rehabilitating degraded land and in conserving land and water. Therefore, policy prescriptions and institutional changes that broaden farmers' latitude for choice among livelihood activities to improve welfare and natural resource management are necessary. Until this happens, Vosti and Witcover (1996), Izac (2003) and Garrity (2004) call upon research and development organisations to identify agroforestry innovations that do not only protect the resource base but also make money for smallholders. In this effect, it is important to enhance the market value of crops grown after improved fallows, as well as to increase the so-called auxiliary benefits of improved fallows, e.g. fuelwood, honey production, etc.

In the Domain of Agroforestry Tree Domestication

To facilitate the adoption of agroforestry tree domestication in general, and vegetative propagation techniques in particular, the following areas are crucial.

Wide-scale dissemination of agroforestry tree domestication should start with information campaigns on its importance in simultaneously resolving the poverty and environmental crises facing the developing world (Simons and Leakey 2004). This is expected to raise enough interest from local and international development agencies, conservation bodies and policy makers, so that they integrate agroforestry tree domestication in their strategies and provide a favourable context for its further development.

Participatory tree domestication is a holistic concept using indigenous knowledge, participatory priority setting and diagnosis, capacity building and enterprise development, extensionists need to be trained and backstopped in this new approach. Development agencies, projects and governments must be willing to invest in building their staff's capacity in tree domestication.

As the importance of agroforestry tree products is likely to be highest in areas of greatest deforestation, highest population density, largest market potential and greatest diversification of agriculture, areas responding to these criteria should first be targeted. Here, appropriate communication channels and tools should be used to reach different categories of farmers, especially the most vulnerable and the poorest.

In implementing agroforestry tree domestication with farmers, one must recognise the difference with other innovations, for example new varieties of maize. Agroforestry tree domestication is not a technology package that can be given out in one passage. Rather, it requires a stepwise approach, calling for a longer term engagement of the extension service. The approach is also information-intensive and necessitates skills development and real empowerment of farmers. This may call for changes in attitude and ways of operating of extensionists.

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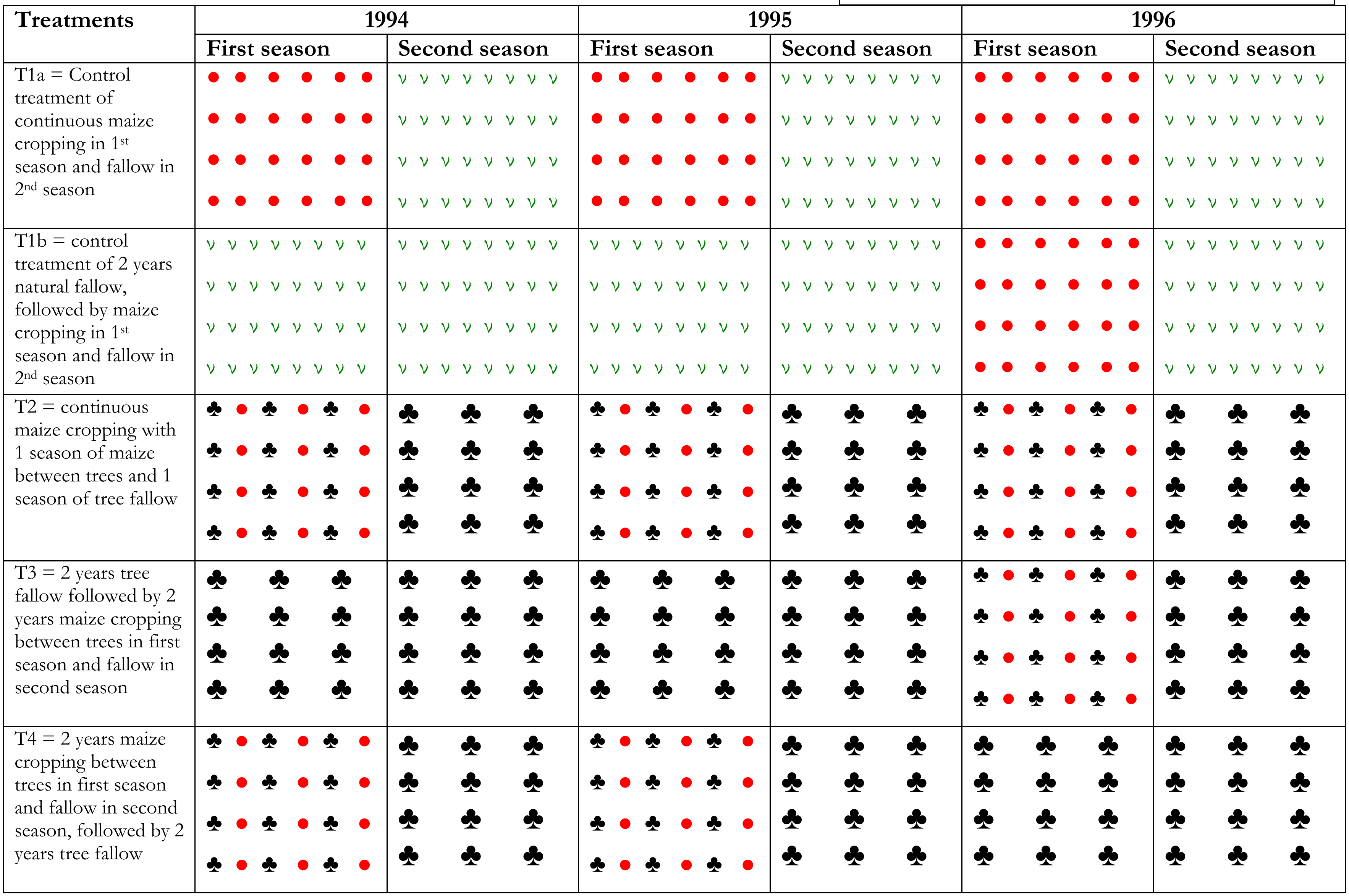
Annex 1: Diagram of treatments in a tree fallow on-station trial, Yaoundé, Cameroon

Key:
- ● maize crop
- ν natural fallow vegetation
- ♣ trees cut back during cropping phase
- ♣ trees allowed to grow during fallow



Annex 2: Cost-Benefit Analysis of Rotational Hedgerow Intercropping as Compared to Natural Fallow, Humid Forest Zone, Cameroon

Data used in cost-benefit analysis

Data type	Figure	Unit	Source
Labour			
workday	5.5	hours day^{-1}	Casual labourers workday 7.30-13.00h
Maize total labour	125	workdays ha^{-1}	Experimental data
Labour bee-keeping	4	workdays year^{-1}	Mboufack 2003
Wage rate	1200	F CFA day^{-1}	ICRAF pay casual labourers
Prices and quantities			
Maize hybrid seeds	600	F CFA kg^{-1}	Local market
Maize seed rate	16	kg ha^{-1}	Experimental data
Maize price (at harvest)	125	F CFA kg^{-1}	Local market
Calliandra seedling price	48.35	F CFA seedling^{-1}	Nursery budget
Tree density	10,000	ha^{-1}	Experimental data
Yield adjustment factor	0.8		CIMMYT 1988
Price of stakes	10	F CFA piece^{-1}	Local market
Price of honey	3000	F CFA l^{-1}	Local market
Cost Kenyan top-bar bee hive	10,000	F CFA piece^{-1}	Mboufack 2003
Equipment bee-keeping	30,500	F CFA	Mboufack 2003

Experimental data that vary between treatments

Data type	Unit	Natural Fallow	Rotational Hedgerow Intercropping
Tree density	ha^{-1}	0	10,000
Tree planting labour	workdays ha^{-1}	0	125
Clearing labour after 1 season fallow	workdays ha^{-1}	15	10
Clearing labour after 2 years fallow	workdays ha^{-1}	40	15
Cut back labour after 1 season fallow	workdays ha^{-1}	0	25
Cut back labour after 2 years fallow	workdays ha^{-1}	0	45
Pruning labour (2 prunings/yr)	workdays ha^{-1}	0	50
Maize density	plants ha^{-1}	50,000	40,000
Maize yield			
Year 1	t ha^{-1}	2.45	2.45
Year 3	t ha^{-1}	3.58	2.72
Year 4	t ha^{-1}	2.98	4.48
Year 7	t ha^{-1}	3.58	5.27
Year 8	t ha^{-1}	2.54	4.82
Year 11	t ha^{-1}	3.58	5.27
Year 12	t ha^{-1}	2.54	4.82

Costs and benefits (F CFA) of rotational hedgerow intercropping, compared to natural fallow

Year	Costs	Natural Fallow	Rotational Hedgerow Intercropping	Benefits	Natural Fallow	Rotational Hedgerow Intercropping
1	clearing	48,000	48,000	Maize	245,000	245,000
	Tree seedlings	0	483,500			
	Tree planting	0	150,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 1	**207,600**	**809,180**		**245,000**	**245,000**
2	Fallow					
	TOTAL 2	**0**	**0**		**0**	**0**
3	Clearing	18,000	18,000	Maize	358,000	272,000
	Cut back	0	30,000	Stakes	0	100,000
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 3	**177,600**	**235,680**		**358,000**	**372,000**
4	Clearing	18,000	12,000	Maize	298,000	448,000
	Cut back	0	30,000			
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 4	**177,600**	**229,680**		**298,000**	**448,000**
5	Bee-keeping equipment	0	60,500	honey	0	135,000
	Bee-keeping labour	0	4,800			
	TOTAL 5	**0**	**65,300**		**0**	**135,000**
6	Bee-keeping labour	0	4,800	honey	0	135,000
	TOTAL 6	**0**	**4,800**		**0**	**135,000**
7	Clearing	48,000	18,000	Maize	358,000	527,000
	Cut back	0	54,000	Stakes	0	100,000
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 7	**207,600**	**259,680**		**358,000**	**627,000**
8	Clearing	18,000	12,000	Maize	254,000	482,000
	Cut back	0	30,000			
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 8	**177,600**	**229,680**		**254,000**	**482,000**

Year	Costs	Natural Fallow	Rotational Hedgerow Intercropping	Benefits	Natural Fallow	Rotational Hedgerow Intercropping
9	Bee-keeping labour	0	4,800	honey	0	135,000
	TOTAL 9	**0**	**4,800**		**0**	**135,000**
10	Bee-keeping labour	0	4,800	honey	0	135,000
	TOTAL 10	**0**	**4,800**		**0**	**135,000**
11	Clearing	48,000	18,000	Maize	358,000	527,000
	Cut back	0	54,000	Stakes	0	100,000
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 11	**207,600**	**259,680**		**358,000**	**627,000**
12	Clearing	18,000	12,000	Maize	254,000	482,000
	Cut back	0	30,000			
	Pruning	0	60,000			
	Maize seed	9,600	7,680			
	Maize labour	150,000	120,000			
	TOTAL 12	**177,600**	**229,680**		**254,000**	**482,000**

Income flows and returns to land of rotational hedgerow intercropping (RHI), compared to natural fallow

Year	Net Benefits (F CFA ha^{-1})		
	Natural Fallow	RHI with bee-keeping	RHI without bee-keeping
1	37,400	- 564,180	- 564,180
2	0	0	0
3	180,400	136,320	136,320
4	120,400	218,320	218,320
5	0	69,700	0
6	0	130,200	0
7	150,400	367,320	367,320
8	76,400	252,320	252,320
9	0	130,200	0
10	0	130,200	0
11	150,400	376,320	367,320
12	76,400	252,320	252,320
Net Present Value (20%) Returns to Land	**282,181**	**70,381**	**- 47,046**
Net Present Value (10%)	441,650	476,175	253,987
Net Present Value (25%)	234,129	- 35,442	- 123,868

Income flows and returns to labour of rotational hedgerow intercropping (RHI) compared to natural fallow

Year	Net Benefits (F CFA) excluding labour costs		
	Natural Fallow	RHI <u>with</u> bee-keeping	RHI <u>without</u> bee-keeping
1	235,400	- 246,180	- 246,180
2	0	0	0
3	348,400	364,320	364,320
4	288,400	440,320	440,320
5	0	74,500	0
6	0	135,000	0
7	348,400	619,320	619,320
8	244,400	474,320	474,320
9	0	130,200	0
10	0	135,000	0
11	348,400	619,320	619,320
12	244,400	474,320	474,320
Net Present Value (20%) Excluding labour costs	765,242	759,921	637,733
Total labour (workdays)	1055	1446	1430
Returns to Labour (20%) F CFA workday^{-1}	**725**	**525**	**446**

Annex 3: Diagram of hedgerow intercropping cycle with and without cassava

Year	Season	Hedgerow intercropping		Rotational hedgerow intercropping (with cassava)	
1	1 Apr-July		Tree establishment and maize cropping		Tree establishment and maize cropping
	2 Sep-Dec		No cropping, trees are allowed to grow		No cropping, trees are allowed to grow
2	1 Apr-July		No cropping, trees are allowed to grow		No cropping, trees are allowed to grow
	2 Sep-Dec		No cropping, trees are allowed to grow		No cropping, trees are allowed to grow
3	1 Apr-July		Trees are cut back, followed by maize cropping		Trees are cut back, followed by maize and cassava cropping
	2 Sep-Dec		Maize is harvested and trees are allowed to grow		Maize is harvested; cassava is left in the field to grow. Trees are left to grow
4	1 Apr-July		Trees are cut back, maize is planted		Trees are left to grow; cassava is progressively harvested
	2 Sep-Dec		Maize is harvested and trees are allowed to grow		Trees are left to grow; cassava is progressively harvested
5	1 Apr-July		Trees are cut back, maize is planted		Trees are cut back, maize is planted
	2 Sep-Dec		Maize is harvested and trees are allowed to grow		Maize is harvested and trees are allowed to grow
6	1 Apr-July		Trees are cut back, maize is planted		Trees are cut back, followed by maize and cassava cropping
	2 Sep-Dec		Maize is harvested and trees are allowed to grow		Maize is harvested; cassava is left in the field to grow. Trees are left to grow

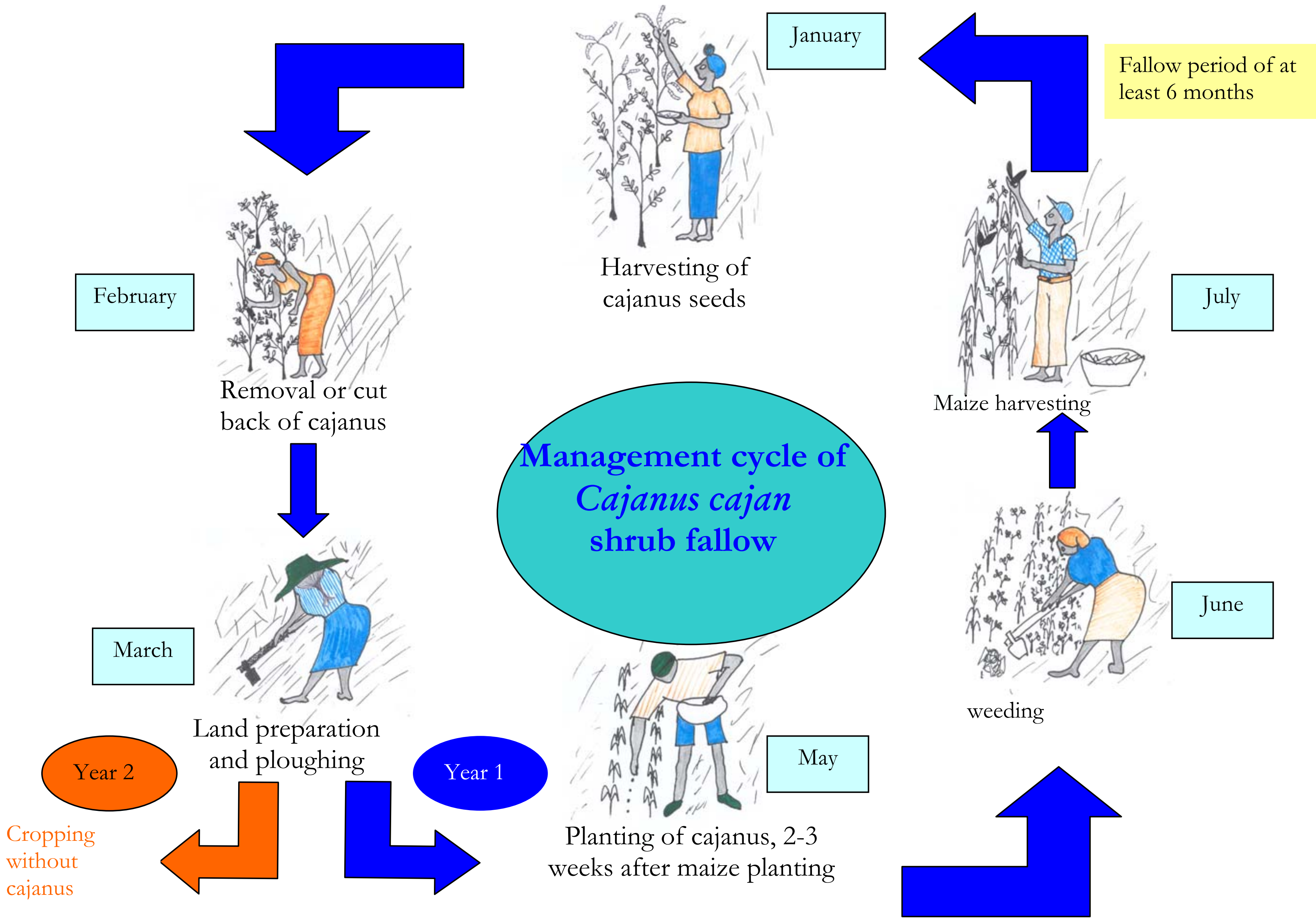
Fertiliser tree

maize

Trees after fallow

Cassava

Annex 4 : Shrub fallow cycle



Annex 5: Cost-Benefit Analysis of Cajanus shrub fallow compared to Natural Fallow, Humid Forest Zone, Cameroon

Data used in Cost-Benefit Analysis

Data type	Figure	Unit	Source
Labour			
workday	5.5	hours day^{-1}	Casual labourers' workday 7.30-13.00h
Shrub cutting labour	28	workdays ha^{-1}	Experimental data
Clearing labour in natural fallow of 1 season	18	workdays ha^{-1}	Experimental data
Clearing labour in natural fallow of 4 years	40	workdays ha^{-1}	Experimental data
Maize total labour	125	workdays ha^{-1}	Experimental data
Maize + groundnut labour			
Wage rate	1000	F CFA day^{-1}	ICRAF pay casual labourers, 1998
Prices and quantities			
Maize hybrid seeds	500	F CFA kg^{-1}	Local market, 1998
Groundnut seeds	14,000	F CFA bag^{-1}	Local market, 1998
Maize seed rate at 25,000 plants ha^{-1}	10	kg ha^{-1}	Experimental data
Maize seed rate at 50,000 plants ha^{-1}	20	kg ha^{-1}	Experimental data
Groundnut seed rate	3	bags ha^{-1}	Experimental data
Maize price (at harvest)	125	F CFA kg^{-1}	Local market
Groundnut price (at harvest)	750	F CFA kg^{-1}	Local market
Yield adjustment factor	1		On-farm data

Maize and Groundnut Yield Data

Year	Unit	Maize yield		Groundnut yield	
		Cajanus Fallow	Natural Fallow	Cajanus Fallow	Natural Fallow
Year 1	t ha^{-1}	3.67	3.98	0	0
Year 2	t ha	1.39	1.00	0.61	0.40
Year 3	t ha	3.67	0	0	0
Year 4	t ha	1.39	0	0.61	0
Year 5	t ha	3.67	0	0	0
Year 6	t ha	1.39	0	0.61	0

Costs and Benefits (F CFA) of Cajanus Fallow, Compared to Natural Fallow

Year	Costs	Cajanus Fallow	Natural Fallow	Benefits	Cajanus Fallow	Natural Fallow
1	Shrub seed	9,600	0	Maize		497,500
	Maize seed	5,000	10,000			
	Clearing	40,000	40,000			
	Maize labour	125,000	125,000			
	TOTAL 1	**179,600**	**175,000**		**458,750**	**497,500**
2	Clearing	28,000	18,000	Maize	173,750	125,000
	Maize seed	10,000	10,000	Groundnut	457,500	300,000
	Groundnut seed	42,000	42,000			
	Crop labour	300,000	300,000			
	TOTAL 2	**380,000**	**370,000**		**631,250**	**425,000**
3	Shrub seed	9,600	0	Maize	458,750	**0**
	Maize seed	10,000	0			
	Clearing	40,000	0			
	Maize labour	125,000	0			
	TOTAL 3	**179,600**	**0**		**458,750**	**0**
4	Clearing	28,000	0	Maize	173,750	125,000
	Maize seed	10,000	0			
	Groundnut seed	42,000	0	Groundnut	457,500	300,000
	Crop labour	300,000	0			
	TOTAL 4	**380,000**	**0**		**631,250**	**425,000**
5	Shrub seed	9,600	0	Maize	458,750	**0**
	Maize seed	10,000	0			
	Clearing	40,000	0			
	Maize labour	125,000	0			
	TOTAL 5	**179,600**	**0**		**458,750**	**0**
6	Clearing	28,000	0	Maize	173,750	125,000
	Maize seed	10,000	0			
	Groundnut seed	42,000	0	Groundnut	457,500	300,000
	Crop labour	300,000	0			
	TOTAL 6	**380,000**	**0**		**631,250**	**425,000**

Income Flow and Returns to Land of Cajanus Fallow, Compared to Natural Fallow

Year	Net Benefits (F CFA ha^{-1})	
	Cajanus Fallow	Natural Fallow
1	279,150	322,500
2	251,250	55,000
3	301,150	0
4	251,250	0
5	301,150	0
6	251,250	0
Net Present Value (20%) Returns to Land	**907,715**	**306,944**
Net Present Value (10%)	1,188,097	338,636
Net Present Value (30%)	721,604	280,621

Income Flow and Returns to Labour of Cajanus Fallow, Compared to Natural Fallow

Year	Net Benefits (F CFA) labour costs excluded	
	Cajanus Fallow	Natural Fallow
1	444,150	487,500
2	579,250	373,000
3	444,150	0
4	579,250	0
5	444,150	0
6	579,250	0
Total number of workdays	1435	483
Total number of workdays discounted (20%)	774	358
Net Present Value (20%) Returns to Labour (F CFA $workday^{-1}$)	**2,172**	**1,858**

Annex 6: Detailed Cost-Benefit Analysis of a Vegetative Propagation Unit

Infrastructure

Item	Unit	Unit Cost (F CFA)	Amount	Total Cost (F CFA)
1. Land				
Land	m^2		500	22,500
2. Stock plant area				
Rope	m	2000	30	2,000
Tape	piece	5000	1	5,000
Vegetative material	piece	750	379	284,250
Labour	workdays	1200	4	4,800
3. Shed				
Posts	piece	600	9	5,400
Roofing sheets	piece	3450	34	117300
Transparent roofing sheets	piece	8450	6	50,700
Nails (90 mm)	kg	450	3	1,350
Roofing nails	kg	1250	2	2,500
Laths	piece	1000	24	24,000
Labour	workdays	1200	10	12,000
4. non-mist propagators (3)				
Planks	m	1600	75	120,000
Laths	piece	1000	18	18,000
Nails (80 mm)	kg	350	2	700
Hinges	piece	200	18	3,600
Screws	piece	30	54	1,620
Fine sand	wheelbarrow	750	3	2250
River sand	wheelbarrow	500	7.5	3,750
Stones	wheelbarrow	1700	9	15,300
Gravel	wheelbarrow	1500	9	13,500
Sawdust	wheelbarrow	500	7.5	3,750
Pipe	m	408	2.7	1,102
Transparent plastic sheet	m	775	45	34,875
Pins	packet	3500	3	10,500
Labour	workdays	1200	12	14,400
5. Humidity chamber (1)				
Laths	piece	1000	6	6,000
Cement bricks	piece	210	20	4,200
Hinges	piece	200	2	400
Pins	packet	3500	1	3500
Transparent plastic sheet	m	775	10	7,750
River sand	wheelbarrow	500	6	3,000
Labour	workdays	1200	2	2,400

6. Fence				
Pickets	piece	50	400	20,000
Iron wire	roll	1500	2	3,000
Bamboo sticks	piece	500	60	30,000
Labour	workdays	1200	20	24,000
GRAND TOTAL				**879,747**

Nursery equipment and tools

Item	**Unit Cost (F CFA)**	**Number of units**	**Total Cost (F CFA)**
1. Rooting of cuttings			
Secateur	2500	1	2,500
Surgical scalpel and blades	3000	1	3,000
Scissors	2000	2	4,000
Knapsack sprayer	45000	2	90,000
Watering can	5000	2	10,000
Digger	7500	1	7,500
Bucket of 10 l	1500	1	1,500
Wheelbarrow	18000	1	18,000
Spade	1500	1	1,500
Hammer	2000	1	2000
Cutlass	4000	2	8,000
Hoe	1000	3	3,000
File	1500	1	1,500
Barrel	8000	2	16,000
Sieve	5000	1	5,000
2. Rooting of marcotts			
Ladder	5000	1	5,000
Knife	500	2	1,000
Saw	4500	1	4,500
Bucket of 5 l	750	1	750
Rope (approx. 15 m)	2250	1	2,250
GRAND TOTAL			**186,500**

Variable Costs

Item	Unit	Unit Cost (F CFA)	Number of units	Total Cost (F CFA)
1. Rooting of cuttings				
Polythene bags (17 x 40 cm)	piece	14	1588	22,232
River sand	wheelbarrow	500	22	11,000
Black soil	wheelbarrow	500	46	23,000
Fertiliser	kg	270	3.054	825
Labour for setting of cuttings				
Dacryodes edulis	workdays	1200	4	4,800
Irvingia gabonensis	workdays	1200	1.3	1,560
Ricinodendron heudelotii	workdays	1200	4	4,800
Labour for assessment of rooting				
Dacryodes edulis	workdays	1200	2	2,400
Irvingia gabonensis	workdays	1200	0.65	780
Ricinodendron heudelotii	workdays	1200	2	2,400
2. Rooting of marcotts				
Polythene bags (40 x 24 cm)	piece	41	100	4,100
River sand	wheelbarrow	500	7	3,500
Black soil	Wheelbarrow	500	14	7,000
Transparent plastic wrappings	m	408	67	27,336
Rubber band	piece	2.5	334	835
Fertiliser	kg	270	0.6	162
Labour for marcott setting	workdays	1200	6.68	8,016
Labour for marcott harvesting	workdays	1200	6.68	8,016
3. General nursery maintenance				
Insecticides + fungicides	(Lump sum)			6,000
Labour	workdays	1200	106	127,200
GRAND TOTAL				**265,962**

Sensitivity Analysis (in FCFA)

1. Base analysis

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(- 1,332,209)	1,077,538	1,077,538	1,077,538	1,077,538
Net Present Value	1,214,376				
Internal Rate of Return	72 %				

2. Decrease in annual production and limit rooting of cuttings to 2 species (more irvingia than dacryodes)

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	251,995	251,995	251,995	251,995	251,995
Sales	0	845,500	845,500	845,500	845,500
Income flux	(- 1,318,242)	539,505	539,505	539,505	539,505
Net Present Value	181,821				
Internal Rate of Return	29 %				

3. Decrease in annual production and limit rooting of cuttings to 2 species (more Dacryodes than Irvingia)

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	266,818	266,818	266,818	266,818	266,818
Sales	0	940,500	940,500	940,500	940,500
Income flux	(- 1,333,065)	673,682	673,682	673,682	673,682
Net Present Value	342,432				
Internal Rate of Return	36 %				

4. Decrease in selling price (500 FCFA for cuttings; 1000 FCFA for marcotts)

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	693,000	693,000	693,000	693,000
Income flux	(- 1,332,209)	427,038	427,038	427,038	427,038
Net Present Value	(- 188,934)				
Internal Rate of Return	11 %				

5. Decrease in valuation rate (75% of plants is sold)

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	1,007,625	1,007,625	1,007,625	1,007,625
Income flux	(- 1,332,209)	741,663	741,663	741,663	741,663
Net Present Value	489,800				
Internal Rate of Return	42 %				

6. Labour cost + 20%

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,077,767	0	0	0	0
Production costs	297,956	297,956	297,956	297,956	297,956
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(- 1,375,723)	1,045,544	1,045,544	1,045,544	1,045,544
Net Present Value	1,109,094				
Internal Rate of Return	66 %				

7. Labour cost – 20%

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,054,727	0	0	0	0
Production costs	233,967	233,967	233,967	233,967	233,967
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(- 1,288,694)	1,109,533	1,109,533	1,109,533	1,109,533
Net Present Value	1,319,660				
Internal Rate of Return	77 %				

8. Discount rate at 30%

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(- 1,332,209)	1,077,538	1,077,538	1,077,538	1,077,538
Net Present Value	770,767				
Internal Rate of Return	72 %				

9. Discount rate at 10%

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	1,066,247	0	0	0	0
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(- 1,332,209)	1,077,538	1,077,538	1,077,538	1,077,538
Net Present Value	1,894,038				
Internal Rate of Return	72 %				

10. Investment costs – 20%

	Year 1	Year 2	Year 3	Year 4	Year 5
Investment costs	852,998				
Production costs	265,962	265,962	265,962	265,962	265,962
Sales	0	1,343,500	1,343,500	1,343,500	1,343,500
Income flux	(-1,118,960)	1,077,538	1,077,538	1,077,538	1,077,538
Net Present Value	2,087,901				
Internal Rate of Return	89%				

Annex 7: Glossary

Adoption potential is the likelihood of uptake of a new technology or practice when required information and material are made available to the farmer. (Rogers 1995)

Agroforestry is a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms, ranches and in other landscapes, diversifies and increases production and promotes social, economic and environmental benefits for land users. (Leakey 1996)

Agroforestry Tree Products (AFTPs) are tree products that are sourced from trees cultivated outside of forests. This new term is required to avoid ambiguity with Non-Timber Forest Products, which are traditionally sourced from forests, but are now more and more cultivated on farm. Some species also provide valuable timber. (Simons and Leakey 2004)

Air layering or marcotting is the development of roots on a stem while it is still attached to the parent plant. The rooted stem is then detached to become a new plant growing from its own roots. Air layering is most practical for trees because their heights do not allow branches to touch the soil and enable conventional layering (Tchoundjeu *et al.* 1997).

Alley Cropping also known as 'hedgerow intercropping' and 'contour farming' is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees and shrubs, preferably nitrogen-fixing species. During the cropping period the hedgerows are periodically pruned to reduce shading and competition with crops for light, nutrients and moisture. When there are no crops in the field, the hedgerows are allowed to grow freely to cover the land. (Kang *et al.* 1999)

Benefit/Cost ratio (B/C) is the outcome of dividing the discounted benefits by the discounted costs. (Van Rooyen *et al.* n.d.)

Boundary conditions are the biophysical and socio-economic circumstances that affect the adoption potential of a practice (Franzel and Scherr 2002)

Cost-benefit analysis involves assessing resource inputs, costs and benefits over the whole lifetime of a planned or existing agroforestry technology, considering it as a medium or long-term investment (Swinkels and Scherr 1991)

Discounting entails using an interest rate to bring back (= discount) all costs and benefits to the same year (Swinkels and Scherr 1991)

Economic analysis is done from the perspective of the society as a whole; market prices of inputs and outputs are corrected if these do not reflect their real values (Swinkels and Scherr 1991)

Evaluation is any form of assessment, appraisal, analysis, or review of a project/programme and /or activity. It is the period assessment of the relevance, performance, efficiency, quality and impact of a project or activity in relation to the objectives and goals that should be achieved. (Van Rooyen *et al.* n.d.)

Ex-ante analyses help to determine the feasibility of a possible future allocation of resources. Carried out for planning purposes on the basis of estimates of costs and returns. The aim is to estimate the probable effect of a new practice on farm resource requirements, farm income, or the larger economy, or to test its expected economic viability (Swinkels and Scherr 1991)

Ex-post analyses are used to evaluate a past allocation of resources. They are evaluations of existing technologies based on actual inputs and outputs during the full production cycle, either on-station or on-farm (Swinkels and Scherr 1991)

Fallow is land resting from cropping, which may be grazed or left unused; often colonized by spontaneous vegetation (Kang *et al.* 1999)

Financial analysis is done from the perspective of the individual farmer; inputs and outputs are valued at market prices (Swinkels and Scherr 1991)

Germplasm consists of the reproductive structures of species through which genes are transmitted from one generation to another. The germplasm of all species manifest differing degrees of variability expressed as traits or characteristics that are the result of genetic mutations. It is this variability that supplies plant breeders with the building blocks necessary for improving agricultural crops. (ICRAF glossary)

Humidity chamber, also called **weaning propagator** or **giant propagator** is a wooden frame covered with a clear polythene sheet. There is no rooting medium, but a layer of stones, sand and water ensures high humidity and constant temperature. (Mbile *et al.* 2004)

Indigenous means native to a specified area, not introduced. An indigenous tree is one that grows naturally within a specific environment or within certain predetermined boundaries (ICRAF glossary).

Internal Rate of Return (IRR) is the interest rate at which the Net Present Value equals zero, or Benefits/Costs-ratio equals 1 (Swinkels and Scherr 1991)

Innovation is an idea (practice or object) that is perceived as new by an individual or group (Rogers 1995)

Impact assessment describes a discrete exercise which attempts to bring together information, evidence and opinion to weigh up the effect of an intervention on people, production, the environment, policy, and so on. (Reij and Waters-Bayer 2001)

Improved fallow is an enrichment of a natural fallow with trees or shrubs to improve soil fertility (ICRAF glossary)

Livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living (DFID 1999).

Livelihood Assets are capital endowments on which livelihoods are built. Although the term 'capital' is used, not all the assets are capital stocks in the strict economic sense of the term (in which capital is the product of investment which yields a flow of benefits over time). Human, natural, financial, physical and social capitals are best thought of as livelihood building blocks (DFID 1999).

Monitoring is a continuous assessment of both the functioning of the project activities in the context of implementation schedules and the use of project inputs by the targeted population in the context of design expectations. (Van Rooyen *et al*. n.d.)

Net Present Value (NPV) is the discounted flow of costs and benefits, obtained by calculating the discounted benefits minus discounted costs (Swinkels and Scherr 1991)

Non-mist propagator is an air- and water-tight wooden frame completely covered with a clear polythene sheet. The rooting medium lies over two layers of small stones and gravel filled with water, resulting in a permanently humid environment (RH=80-90%) and moist substrate throughout the propagation period. (Leakey *et al*. 1990; Mbile *et al*. 2004)

Poverty is defined as the inability to meet needs that are essential for survival. It is usually expressed in terms of food, and may or may not include requirements for shelter, education and health. If these needs are not met, a person or household is unable to enjoy a minimum acceptable living standard. These needs can be translated into the requirement to possess commodities (goods and services) and into a minimum income to acquire them – the poverty line. (IFAD 2001b)

Rooting of stem cuttings consists of cutting a portion of a stem with a leaf and axillary bud from the parent plant and then set it in an environment where humidity is high (Tchoundjeu *et al*. 1997).

Rotational Hedgerow Intercropping is a type of improved fallow whereby N-fixing trees are planted in rows with distances of 4 m between the hedges and 0.25 m within rows. Two years after establishment, trees are cut back and crops are planted in the alleys. During the cropping phase, tree coppices are pruned to reduce competition between trees and crops. After 2 years of cropping, the field goes back into fallow and the trees are left to grow. After another 2 years, the cycle recommences. (Kanmegne and Degrande 2002)

Shifting cultivation refers to one of the most important traditional farming systems in the tropics in which relatively short periods of cultivation (2-3 years) are followed by relatively long periods of fallow (10-20 years). (Gichuru *et al*. n.d.)

Slash-and-Burn is a traditional farming practice that involves hand clearing of land followed by burning of natural vegetation, in preparation for cropping (Kang *et al*. 1999)

Stock plant area is a collection of plants grown from seed, cuttings, grafts or marcotts, with the aim of producing good quality material for taking cuttings. (Mialoundama *et al*. 2002)

Sustainability is when a system can cope with and recover from stresses and shocks and maintain or enhance its capability and assets both now and in the future, while not undermining the natural resource base. (DFID 1999)

Tree domestication involves accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven and market-led process (Simons 1997). Tree domestication is a process that is farmer driven and about matching the intra-specific diversity of many locally important tree species to the needs of subsistence farmers, the markets for a wide range of products and the diversity of agricultural environments (Simons and Leakey 2004).

Vulnerability is defined as the probability of an acute decline in access to food or consumption, which leads to inability to meet minimum survival needs. It includes two main elements that need to be simultaneously present: the exposure to risk, and the inability to cope with it. (IFAD 2001a)

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