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a look at activies on preferred trees in the farming systems

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Cocoa agroforests in West Africa

A look at activities on preferred trees in the farming systems

Richard Asare

WCF
WORLD COCOA FOUNDATION

STCP

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Immature cocoa pods. Photo: Dorthe Jøker, FLD

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Preface

This report has been prepared by *Danish Centre for Forest, Landscape and Planning,* KVL in collaboration with the *Sustainable Tree Crop Programme* with funding from the *World Cocoa Foundation* and it forms part of the Project entitled 'Enhancing the Knowledge Base on Valuable Trees in Cocoa In West Africa'. The objective of this project is to contribute to ecologically sustainable cocoa production and improved livelihoods of small-scale cocoa farmers in West Africa by presenting a comprehensive and accessible information and knowledge on suitable tree species and their planting materials in cocoa growing systems.

The integration of suitable and valuable forest tree species at various stages and levels of cocoa farms is a practice that is widespread in smallholder cocoa farms in West Africa. None the less, research exploring the interactions between these forest species and cocoa trees is limited. In addition, few attempts have been made to mobilise country based knowledge on forest tree species in cocoa growing systems into a form that is accessible to cocoa farmers, extension workers, development workers, government officials and researchers in order to improve decision making for cocoa farm management and environmental conservation across the sub region.

This report presents a network and overview of organisations and institutions working on cocoa and tree research and their respective activities in Ghana, Côte d'Ivoire, Cameroon, and Nigeria. It also provides lists of farmer preferred and research recommended tree species in cocoa growing systems in the various countries and indicates the need for a systematic, multi-regional survey to determine farmers' selection criteria of preferred species, coupled with rigorous research on the autoecology and compatibility of valuable trees with cocoa.

Acknowledgement

The author of this report is very grateful to all the institutions and their contact persons for their contributions. In Ghana I am grateful to Cocoa Research Institute of Ghana (CRIG), Forestry Research Institute of Ghana (FORIG), Conservation International-Ghana, CARE-Ghana, and Kuapa Kooko.

In Côte d'Ivoire sincere thanks go to Centre National de Recherche Agronomique (CNRA), Societe de Development des Forets (SODEFOR), Centre National Floristique (CNF-Universite de Cocody). National and international programmes include, Projet de Stabilisation des Systemes de Production Agricole (PROSTAB).

In Cameroon and Nigeria my gratitude goes to Institut de Recherche Agronomique pour le Developpement (IRAD), World Agroforestry Centre (ICRAF), Centre for International Forestry Research (CIFOR), International Institute of Tropical Agriculture (IITA), Cocoa Research Institute of Nigeria, Cross River State's Cocoa Board and Forestry Development Department, and Tree Crop Unit of Ondo State Ministry of Agriculture.

Sincere thanks also go to the STCP for facilitating my field work in the various countries, especially Mr. Isaac Gymafi, Mr. Sylvanus Agordorku, and Mary Adu-Kumi of Ghana; Mr. Robert Yapo Assamoi and Madam Aka of Côte d'Ivoire; Dr. Stefan Weise and Mr. Jonas Mva Mva of Cameroon and; Drs. Chris Okafor and Innocent Okuku of Nigeria.

Also, I acknowledge the constructive contributions of Ms. Rebecca Ashley (School of Forestry and Environmental Studies-Yale University) during fieldwork in Ghana and Côte d'Ivoire and initial write-up of this report. Similarly, I express my sincere thanks to Mr. Peter Aikpokpodion (CRIN) for his help during my fieldwork in Nigeria. I also thank Mr. Peter Van Grinsven (Master Food) and Mr. Christian Pilegaard Hansen (*Forest & Landscape Denmark*) for their constructive comments on this report.

Last but most certainly not the least, I express my appreciation to the farmers who took time off and walked me through their farms and shared knowledge with me. To these hard working people I say well done.

Acronyms

ADADER	Agence Nationale d'Appui au Development Rural
ASANET	African Safou Network
CARE	CARE-International, Ghana
CCAP	Conservation Cocoa Agroforestry Programme
CI	Conservation International-Ghana
CIFOR	Centre for International Forestry Research
CNF	Centre National Floristique-Universite de Cocody
CNRA	Centre National de Recherche Agronomique
CRIG	Cocoa Research Institute of Ghana
CRIN	Cocoa Research Institute of Nigeria
CSSD	Cocoa Swollen Shoot Disease
CSSV	Cocoa Swollen Shoot Virus
FFS	Farmer Field School
FLD	*Forest & Landscape Denmark*
FORIG	Forestry Research Institute of Ghana
GIC	Gruppe Initiativ Commune
GTZ	German Association for Technical Co-operation
ICRAF	World Agroforestry Centre
IITA	International Institute of Tropical Agriculture
IRAD	Institut de Recherche Agronomique pour le Developpement
MT	Master Trainer
NGO	Non Governmental Organisation
PROSTAB	Projet de Stabilisation des Systemes de Production Agricole
STCP	Sustainable Tree Crop Programme
SODEFOR	Societe de Development des Forets
TCU	Tree Crop Unit
WCF	World Cocoa Foundation

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Executive summary

This study was initiated by *Forest & Landscape Denmark* and the *World Cocoa Foundation* with the objectives of (i) providing an information base to co-ordinate activities on trees in cocoa growing systems and (ii) creating a network of researchers and institutions working on trees in cocoa in the sub region. The aim of this report therefore is to provide an overview of organisations and institutions working on cocoa and tree research and their respective activities in Ghana, Côte d'Ivoire, Cameroon, and Nigeria.

In order to achieve this, a study tour was conducted between April 26 and October 6, 2004 in the countries where interviews were held with NGO staff, key informants, and research scientists from research institutions. In addition, informal discussions were held with individual cocoa farmers and farmer co-operatives, as well as field visits and observations on farms.

Cocoa production plays a significant role in the economies of the mentioned countries even though the process of cultivation has been alleged to have compromised a large portion of the natural forest since farmers expand into forest areas to increase production. None the less, the integration of suitable and valuable trees at various stages and levels of the cocoa farm, is a practice that is widespread in smallholder cocoa farms.

The current body of work aimed at improving sustainable cocoa cultivation with trees in Ghana, Côte d'Ivoire, Cameroon, and Nigeria by governmental and international research institutions, and NGOs both local and international is extensive and growing in scope. The majority of this work is conducted as on-station research with a few isolated cases of on-farm research.

In Ghana maintaining or increasing cocoa production has required the rehabilitation of ageing cocoa farms and the recycling of land in response to the extensive deforestation and loss of traditional cocoa growing land. Research activities tend to focus on finding appropriate balance of shade, and on identifying compatible tree species including traditional exotic agroforestry species and local species. These activities are being carried out by CRIG, FORIG, CI, CARE, Kuapa Kooko, and STCP-Ghana.

Côte d'Ivoire focuses on limiting shade and identifying and disseminating information on species that are incompatible with cocoa. In maintaining and increasing productivity, work is being done using exotic leguminous species to reduce fallow lengths through soil fertility improvement and creating appropriate vegetation cover as initial shade for cocoa in farm rehabilitation. Institutions undertaking these tasks are CNRA, SODEFOR, CNF, and STCP-Côte d'Ivoire.

In Cameroon and Nigeria, cocoa agroforests currently have high levels of shade, making research and development focused on reducing shade to a more productive level while maintaining important indigenous fruit trees. Hence, attention is on indigenous fruit trees that have strong demand in national and regional markets. Institutions in Nigeria spear-heading this work are CRIN, TCU, and

STCP-Nigeria, whereas in Cameroon we have ICRAF, IRAD, IITA, and STCP-Cameroon.

As indicated earlier, work on trees in cocoa is extensive and growing. However, little attention is being paid to the improvement of cocoa agroforests as a whole. While farmers are concerned about exploiting all the necessary components in the system to maximise income and reduce risks, research has focused only on parts of the system, in most cases the improvement of the cocoa tree. The future challenge for research and development in cocoa agroforestry therefore, is to provide farmers with models of how to arrange the various species in time and space such that competition between trees (both above ground and below ground) is reduced significantly, while enhancing complementarity. In the process the autoecology (individual tree ecology) of farmer preferred species should be studied in order to help enhance local knowledge.

Farmer preferred and research recommended species in cocoa growing systems in Ghana, Côte d'Ivoire, Cameroon, and Nigeria have been given in this report. However, these results should be used cautiously, as there is probable overlap between research sources and likely recycling of farmer-based information between different groups. Therefore, while this information provides a good starting point, it does highlight the need for a systematic, multi-regional survey to determine farmers' selection criteria of preferred species, which can be coupled with rigorous research on the autoecology and compatibility of valuable trees with cocoa.

1 Introduction

Neighbour[1] trees play a vital role in cocoa agroforests in West Africa. Many authors (Willey, 1975; Alvim, 1979; Hutcheon, 1979; Olaniran, 1979; Abbiw, 1990; Wessel and Gerritsma, 1994; Beer *et al,*. 1998; Leakey, 1998; Ruf and Zadi, 1998; Schroth, 1999; Rice and Greenberg, 2000; Duguma *et al.,* 2001;Van Himme and Snoek, 2001; Zapfack *et al.,* 2002; Schroth *et al.*, 2004; Bidzanga *et al.,* in press) have described the physiological, environmental and economic values of these trees in cocoa growing systems. They cite benefits such as shade to cocoa, soil fertility maintenance by recycling nutrients in the soil, biodiversity conservation, protection against drought, bush fires and insect attacks and additional income through sales of timber species, fuelwood, and non-wood forest products.

None the less, research exploring the interactions between these forest species and cocoa trees is limited. In addition, few attempts have been made to mobilise country based knowledge on forest tree species in cocoa growing systems into a form that is accessible to cocoa farmers, extension workers, development workers, government officials and researchers in order to improve decision making for cocoa farm management and environmental conservation across the sub region.

It is for this reason that *Forest & Landscape Denmark* (FLD)[2] at the Royal Veterinary and Agricultural University (KVL) and the *World Cocoa Foundation* (WCF) came together to co-fund an initiative, which sought to investigate and document all relevant research and development work done on *neighbour* trees in cocoa cultivation in the West African countries of Ghana, Côte d'Ivoire, Cameroon, and Nigeria. The objectives of this work are:

1. To provide an information base to co-ordinate activities on trees on cocoa farms, which may serve as a reference for future work on valuable trees and cocoa in West Africa and;
2. To create a network of researchers and institutions working on trees in cocoa in the sub region to share information on a common theme.

This report provides an overview of organisations and institutions working on cocoa research and development and their respective activities. In particular, it focuses on farmers' as well as researchers' perspective on preferred trees on cocoa farms. It also presents abstracts of relevant research work done on trees used in the cocoa agroforests in the countries in the form of annotated bibliographies.

Information presented in this report was collected in Ghana, Côte d'Ivoire, Cameroon, and Nigeria between April 26 and October 6, 2004. Data was collected through interviews with NGO staff and key informants, interviews with research scientists from research institutions, informal discussions and interviews with individual cocoa farmers and farmer co-operatives, and field visits and observations.

[1] This refers to trees in cocoa agroforest other than the cocoa trees.

[2] Forest & Landscape Denmark became a strategic partner to the WCF in this initiative due to its renowned reputation in propagation techniques of tropical forest tree species and the establishment of seed sources/'seed gardens' and dissemination of planting material. These capacities have been established over more than 30 years through various projects and research activities in developing countries, with funding from the Danish development assistance (Danida).

1.1 Background

Cocoa cultivation in the West African sub region has generally been dependent on cultivation on partly cleared forestland utilising the 'forest rent' of newly cleared areas (Ruf and Zadi, 1998), i.e. soil fertility built up in the forest soil and the shade provided by the remaining trees. However, in recent years the prospects of this practice have diminished drastically in most areas due to dwindled forest areas.

According to Niesten *et al* (2004) the remaining forest cover in West Africa constitutes only one-fifth of its original extent. This partially indicates the beginning of the end of expansion of cocoa farms into forested areas. Hence increased access and co-ordination of information on shade trees in cocoa systems will help to improve the decision-making process on cocoa farm management.

In Côte d'Ivoire and Ghana this is critically important since an extensive use of the forest rent to maintain and increase cocoa production has led to a considerable reduction of the forest cover (Ruf and Zadi, 1998; Ministry of Science and Environment, 2002). In these countries cocoa contributes a greater proportion of foreign exchange earnings (Crook, 1990; ISSER, 2003). As a result government policies in the two countries have always favoured production increase, which has mostly depended on expansion of farmlands at the expense of forested areas.

In Côte d'Ivoire in the 1960s, the launching of a new policy with the motto '*land belongs to those who develop it*' by the government, encouraged immigrant farmers to migrate to the forest zone to cultivate cocoa (Ruf, 2001). The policy initiated an interest for forest clearing as a means to establish land ownership by both migrants and inhabitants. This policy coupled with research recommendations of the use of high yielding Upper-Amazon hybrid cultivated under direct sunlight and government's subsidies on cocoa cultivation contributed to increased production using forested areas (N'Goran, 1998; Ruf and Schroth, 2004).

Similarly in Ghana, colonial policies that imposed taxes on males facilitated the movement of migrant labour from the north into the high forest zone to seek wage labour to meet this obligation (Konings, 1986: *cf.* Amanor, 1996). In addition, cocoa production spread from the eastern parts of the country to the west into new forest frontiers due to deterioration of cocoa farms in the old growing areas. Farmers neglected and abandoned farms, and migrated westwards instead of re-investing in their ageing and ailing farms. The deterioration was due to diseases and pest damage, soil depletion, and loss of appropriate vegetation cover (Ministry of Finance, 1999). Furthermore, with the adoption of hybrid varieties that favour no to low shade systems (Padi and Owusu, 1998) farmers found it necessary to eliminate forest tree species to effect high performance of these new varieties and as a result large areas of forested land were lost.

In Ghana and Côte d'Ivoire, studies conducted on levels of permanent shade in cocoa farms indicate that about 50% of total cocoa farm area in both countries is under mild shade while an average of 10% and 35% was under no shade in Ghana and Côte d'Ivoire respectively (Freud *et al.,* 1996: *cf.* Padi and Owusu, 1998).

According to Padi and Owusu there is a gradual shift towards the elimination of shade trees in the cocoa agroforests. However, giving the absence of a 'New Forest Frontier' in both countries (Amanor, 1996; Ruf and Zadi, 1998), production can only be sustained over the long term if cultivation methods that incorporate rehabilitation and recycling of land through the use of forest tree species are adopted.

Cameroon and Nigeria’s national economies never depended on cocoa production as heavily as those of Ghana and Côte d’Ivoire. Therefore government policies did not prioritise cocoa production to the same extent leading to cocoa farmers neglecting their farms and shifting labour to other sectors of the economy (Ndoye and Kaimowitz, 2000; Ayoola *et al.*, 2000). As a consequence, cocoa farms in Cameroon and Nigeria are noted to be heavily shaded with high numbers of forest tree species. In a study by Gockowski *et al.* (2004) Cameroon and Nigeria were classified as having high and medium shade levels respectively compared to Ghana and Côte d’Ivoire who were classified as both having low shade levels.

None the less, the shade dominated cocoa farms in places like southern Cameroon has been described as one of the best forms of permanent agriculture that has preserved a forest environment and some of its biodiversity (Ruf and Schroth, 2004). The challenge for policy makers in Cameroon and Nigeria at the moment is how to reduce shade in cocoa orchards but at the same time maintain their diversity to enhance cocoa production and conserve biodiversity.

2 Trends in research and development on trees in cocoa growing systems in West Africa

Current research trends on trees in cocoa growing systems in West Africa predominantly focus on tree species found in cocoa systems and their uses to farmers. Extensive research work on associated trees in cocoa growing systems have been reported by individual researchers in Ghana, Côte d'Ivoire, Cameroon, and Nigeria (sections 3, 4, and 5). National and international research institutes, and environmental NGOs are also engaged in long-term research on the ecology and compatibility of shade and neighbour trees in cocoa systems. The majority of this work is conducted as on-station research with isolated cases of on-farm research.

While research is focusing on trees in cocoa systems, opinions differ in the various countries on optimal levels of shade and those trees that are compatible or incompatible with cocoa. For example, Ghana tends to focus on finding an appropriate balance of shade, and on identifying compatible tree species, whereas Côte d'Ivoire focuses on limiting shade and identifying and disseminating information on species that are incompatible with cocoa. In Cameroon and Nigeria cocoa agroforests currently have high levels of shade, making research and development focused on reducing shade to a more productive level while maintaining important indigenous fruit trees.

A second trend across all four countries is a focus on maintaining or increasing cocoa production, particularly in Cameroon and Nigeria where production has been relatively low. In Côte d'Ivoire and Ghana maintaining or increasing production have required the rehabilitation of ageing cocoa farms and the recycling of land in response to the extensive deforestation and loss of traditional cocoa growing land. This strategy involves using exotic leguminous species and native forest species to reduce fallow lengths through soil fertility improvement and creating appropriate vegetation cover as initial shade for cocoa.

Cameroon and Nigeria have not experienced such extensive loss of their humid forests through cocoa production. Consequently, their efforts to increase production depend upon an increase in the area under cocoa cultivation, and rehabilitation of neglected cocoa orchards. In the transitional zones where forest loss and degradation are more important factors both countries are aiming to recycle land through the planting of leguminous agroforestry species.

A third trend particularly developed in Cameroon and Nigeria, but also evident in Ghana and Côte d'Ivoire, is diversified cocoa systems using fruit trees. In Nigeria and Cameroon the attention is on indigenous fruit trees that have a strong demand in national and regional markets. In Nigeria for instance work conducted by the Cocoa Research Institute of Nigeria (CRIN) place more emphasis on research into the planting arrangement, distance and densities of some indigenous fruit trees. In Cameroon the attention is on how to domesticate the indigenous fruit trees and integrate them in the cocoa agroforests. The World

Agroforestry Centre (ICRAF) and the Institut de Recherche Agronomique pour le Developpement (IRAD) are spearheading the domestication process.

A fourth crosscutting trend is the research and development work being undertaken by The Sustainable Tree Crop Programme (STCP), which is an agriculture programme, hosted by the International Institute of Tropical Agriculture (IITA). Its goal is to improve the economic and social well being of smallholders and the environmental sustainability of tree crop systems in West Africa. The objective of STCP is to compare, test, and validate different approaches and intervention to develop socially responsible, profitable and environmentally sustainable cocoa productions systems in a child labour-free environment. In order to achieve this the STCP has constituted a comprehensive and integrated regional programme in Ghana, Côte d'Ivoire, Guinea, Cameroon, and Nigeria where community-focused pilot projects have been launched.

The pilot projects are serviced by three regional projects, which include (I) Child Labour issues; (II) Trade and Information Systems and; (III) Technology Delivery, Research and Impact. To accomplish these the pilot projects in the various countries use the Farmer Field School (FFS) concept to introduce cocoa farmers to integrated pest and disease management and general farm management practices (for more details on this programme see www.treecrops.org).

3 Cocoa and Trees in Ghana

Ghana is currently the second largest producer of cocoa beans in the world (ICCO, 2004) with an estimated total cultivation area of about 1.2 million hectares (COCOBOD, 1998). Since its introduction to Ghana in 1879 (COCOBOD, 2000), cocoa has become both economically as well as culturally significant to the country. Despite this fact, cocoa farming has been alleged to be one of the factors that has contributed to deforestation in Ghana (Ministry of Science and Environment, 2002).

Traditionally, most cocoa farms are established by removing the forest understory and thinning the forest canopy so that cocoa seedling can grow into productive trees by utilising the 'forest rent' of the newly cleared area and the shade provided by the remaining trees. Cocoa is cultivated in six geographical regions (Eastern, Western, Central, Brong-Ahafo, Ashanti and Volta) of Ghana, which fall under two broad ecological zones (Amanor, 1996):

- Moist Forest: which consists of the wet evergreen, moist ever green and moist semi-decideous with rainfall in excess of 1200 mm per annum and;
- Dry Forests: which consist of semi-decideous inner zone and dry semi-decideous outer fire zone with rainfall between 1000-1200 mm per annum.

Currently the Western Region remains the last frontier for the expansion of cocoa due to the presence of patches of non-reserved and reserved forest in the country. Many farms in the other cocoa growing areas are denuded and have been abandoned (Ministry of Finance, 1999). The government and associated national and international research institutes are promoting agroforestry technologies that facilitate rehabilitation of old farms and recycling of degraded lands in order to solve this problem.

Research conducted in Ghana attest to the fact that farmers are very knowledgeable of the trees and their importance. Individuals and organisations including Amanor (1996) Asare (1999), Osei-Bonsu *et al* (2000), Osei-Bonsu *et al* (2002), Osei-Bonsu *et al.,* (2003), Anim-Kwapong (2003), Padi and Owusu (2003), CI (2003) have documented those species commonly found in cocoa agroforests and their uses. However, there is limited research investigating the ecology, compatibility, and propagation of forest trees. The research that does exist tends to remain within institutions and is relatively site specific.

3.1 Institutions and Cocoa in Ghana

Ghana has a wide range of institutions working with cocoa growing systems. These groups can be divided into national research institutions and NGOs. The government research institutions include Cocoa Research Institute of Ghana (CRIG) and Forestry Research Institute of Ghana (FORIG); non-governmental organisations include Conservation International (CI), CARE International, and The Sustainable Tree Crop Programme (STCP). National non-governmental organisations include the licensed cocoa buyer Kuapa Kokoo, which also serves as a farmer co-operative and credit union.

Cocoa Research Institute of Ghana (CRIG)

Contact: Dr. Gilbert Anim-Kwapong (research officer soil science and agronomy department), CRIG-Ghana, e-mail: gkwapong@crig.org, Telephone: + 233 27 609900

Cocoa Research Institute of Ghana (CRIG) is the government's appointed research institution that conducts research on cocoa coffee, cola, and cashew with the aim of enhancing productivity. Presently CRIG is involved in research that looks at specific tree species combinations with cocoa.

These include trials with cocoa and coconut tree intercropping (see Osei-Bonsu *et al.* 2002 in Annotated Bibliography), research on shade trees as alternative hosts of *Phytophthora megakarya* (see Opoku *et al.*, 2002 in Annotated Bibliography), and trials for the selection of forest trees for cocoa cultivation[3]. Tree species under investigation include *Newbouldia laevis*, *Ricinodendron heudelotii*, *Spathodea campanulata*, *Terminalia superba,* and *T. ivorensis*. Initial results of these trials indicate that:

- Though *Newbouldia laevis*, was planted at the same densities as *Ricinodendron heudelotii*, *Spathodea campanulata*, *Terminalia superba,* and *T. ivorensis*, it provides low light transmission (below 21% at its peak in February) due to the orientation of its dense foliage, crown architecture as well as its non-deciduous nature;
- However, *Terminalia ivorensis* and *T. superba* provides light transmission of 30% at 4 peaks of the year- even though the genus is deciduous, flowering and leaf abscission occur at different times of the year and so the stand is not devoid of foliage and has low light transmission in November and February when other species like *Ricinodendron heudelotii*, *Spathodea campanulata* shed their foliage;
- But there were no significant differences among species to their effect on gravimetric moisture content and bulk density of soil.

Initial conclusions are that CRIG's recommendation of 15 to 18 desirable trees per hectare when planting cocoa may not be appropriate for all shade tree species. Since results demonstrate that when planting patterns of *Terminalia ivorensis* and *T. superba* are manipulated, a density of 20-25 trees per hectare can provide appropriate shade for mature cocoa (average 30% shade) all year round.

A field trial has also been conducted since 1993 on ' Preliminary studies of the control of cocoa swollen shoot disease by the use of immune crops as barriers. This study investigates the effectiveness of using fruit trees like *Citrus* species, *Elaies guinensis* and *Cola nitida* that are immune to Cocoa Swollen Shoot Virus (CSSV) as barriers between new cocoa trees from old cocoa trees (see Ollennu *et al.,* 2003 in annotated bibliography). Results show that *Citrus* and *Elaies guinensis* are effective in isolating test cocoa trees from CSSV infection, but *Cola* is not due to poor establishment.

[4] This trial, 'Shade trees for the management of the cocoa ecosystem- selection of forest trees for cocoa cultivation' was previously reported under 'Evaluation of some fast growing crops, shrubs and trees for cocoa ecosystem management' (Rep. Cocoa Res. Inst., Ghana, 1995/96, 28).

CRIG has also conducted extensive research on *Albizia coriaria* and other *Albizia* species for use in the cocoa agroforestry system (see Anim-Kwapong 2003 in Annotated Bibliography)[4].

CRIG has a vast number of forest and other tree species present on most of its cocoa research plots for observation on their compatibility with cocoa. These include *Alstonia boonei*, *Antheanus africana*, *Ficus capensis*, *Gliricidia sepium*, *Hannoa klaineana* (open canopy and small leaves), *Gmelina arborea* (accumulates calcium and is very aggressive with many seedlings), *Piptadeniastrum africanum* (leguminous), *Pterocarpus mildraedii* (fixes nitrogen and drops leaves slowly), *Rauvolfia vomitoria*, *Ricinodendron heudelotti* (causes mechanical damage from branch shedding), *Terminalia superba*, *T. ivorensis* (deciduous species whose leaf shedding occurs at different times of the year), *Spathodea campanulata*, *Tetrapleura tetraptera*, *Trema spp.*, and *Triplochiton scleroxylon*.

In the mid 1980s CRIG through the work of Manu and Tetteh (1987) came up with a list of desirable and undesirable forest shade tree species in the cocoa agroforests in Ghana (Table 1).

Table 1: Desirable and undesirable shade trees given by CRIG

Desirable species	**Local name**	**Undesirable species**	**Local name**
Albizia coriaria	Awiamfo semina	*Adansonia digitata*	Odadee
Alstonia boonei	Nyamedua	*Blighia sapida*	Ankyewobiri/Akye
Entandrophragma angolense	Edinam	*Canthium glabriflorum*	Gyapam
Funtumia elastica	Funtum	*Carapa procera*	Kwakuo bese
Milicia excelsa	Odum	*Ceiba pentandra*	Onyina
Pycnanthus angolensis	Otie	*Cola chlamydantha*	Kra bese
Terminalia ivorensis	Emire	*Cola gigantia*	Watapuo
Terminalia superba	Ofram	*Lecaniodiscus cupanoides*	Dwindwera
-------------------------	----------------------------	*Musanga cecropoides*	Odwuma
-------------------------	----------------------------	*Myrianthus arboreus*	Nyankuma

Source: Manu and Tetteh (1987)

In an interview with Dr. Anim-Kwapong, a researcher within the agronomy and soil science department, he stressed that even though CRIG has come up with the species in Table 1 above, desirable or 'preferred' shade trees are different in each area depending on farmers' concept of a 'good tree'. He also highlighted that though farmers may prefer certain CRIG named undesirable trees, these trees may harbour diseases like the Cocoa Swollen Shoot Disease (CSSD) or promote the condition for the Black Pod disease.

In the case of the CSSD, the disease co-evolved with tree families like the *Bombacaceaes* (e.g., *Ceiba pentandra*) and *Sterculeaceaes* (e.g., *Cola spp*). According to Anim-Kwapong, the mealy bugs carrying the virus can only transmit the disease within 48 hour, hence the initiation of the research above using fruit trees as 'sanitary corridors' using *Citrus sp.* and *Elaies guinensis*, and *Cola* as blocks to stop the spread of the disease.

[5] Information is also available in CRIG's Annual Report, 'Evaluation of some exotic Albizia species for use in the Cocoa Agroforestry System- HX5, Tafo' (Report, Cocoa Research Institute of Ghana, 1996/97, p. 28).

Forestry Research Institute of Ghana (FORIG)
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FORIG is a government research institute, which conducts research on forest trees and recently has been working in collaboration with University of Wales Bangor on a project entitled 'Improving the productivity and sustainability of cocoa farms in West Africa through utilisation of native forest trees in agroforestry systems'. The objectives of the programme are to: 1) develop criteria for native tree selection for cocoa farms based on farmer needs and preference; and 2) use existing data on the ecology of native West African species to enhance biodiversity utilisation by selecting site specific species. The project worked on gathering information on indigenous knowledge in Gogoikrom in the Atwima District.

In terms of cocoa, two PhD studies[5] were developed to research the socio-economic and ecological aspects of indigenous forest trees in cocoa agroforestry systems. Both studies occurred in the Atwima District of the Ashanti Region and are trying to look at the following:

- Investigating farmers' indigenous knowledge about the ecology and management of the cocoa multi-strata systems;
- Identifying indigenous forest tree species that have potential for use as cocoa shade;
- Determining the natural distribution of some selected tree species in different ecological systems;
- Evaluating the phenology and crown structure of the selected species;
- Determining means of raising planting stock of some promising species;
- Evaluating the field performance of selected forest tree species planted in combination with cocoa;
- Determining the competitive effect of the planted tree species on the cocoa crop and;
- Evaluating the contribution of the cocoa-shade tree agroforestry system to nutrient cycling and the carbon budget.

In the course of the study farmers identified over 50 indigenous forest tree species and indicated their effect in the cocoa agroforests. Out of these, seven economically valuable timber species were selected for on-farm trials in 2001 with the hypothesis that the indigenous shade trees planted will sustain cocoa yield and prolong its productive life. These tree including *Albizia adianthifolia*, *Newbouldia laevis, Pericopsis elata, Tetrapleura tetraptera*, *Entandrophragma angolense*, *Entandrophragma utile*, and *Terminalia ivorensis*.

During the experimentation each farmer plot consisted of 24 m x 54 m (1296m^2). This was then divided into two plots. Each block was planted with 160 seedlings of hybrid cocoa and seven indigenous shade tree species at a distance of 12 x 12 m triangular spacing inter-planted with cassava, plantain and other food crops to mimic the traditional cocoa farms in the area (Obiri, 2003: *cf.* McDonald *et al*., 2003).

[5] The theses are by (i) Beatrice Darko Obiri – looking at the socio economic aspects of shade trees in the cocoa agroforest and (ii) Luke Angulaare - investigating the ecology of these trees and the possibility for incorporation in the cocoa agroforest. The theses are still pending and will be made available when completed.

Five out of the seven, namely *Newbouldia laevis*, *Tetrapleura tetraptera*, *Entandrophragma angolense*, *Entandrophragma utile*, and *Terminalia ivorensis* were selected for more detailed investigation of cocoa-shade tree interaction on-station. The natural distribution, phenology, and crown structure of the trial species in mature cocoa farms, fallow lands, and natural forest was also evaluated. In addition, growth performance of all the planted species was evaluated over a two-year period, while the root structure of *E. angolensis*, *T. ivorensis*, and *T. tetraptera* was also investigated. Seed pre-treatment and vegetative propagation of *T. tetraptera* was investigated (Angulaare, *in press*).

During interviews with key informants at FORIG it was mentioned that information on seed sources for the above mentioned species were known. However, it was stressed that in an attempt to select trees for cocoa agroforestry system, one does not want trees that will compete with cocoa for phosphorus and potassium, particularly during pod setting (Owusu Sekyere, *pers. comm.*)[6]. He suggested identifying experimenting with tree species that can form mycorrhizal associations in the cocoa agroforest, e.g., *Afzelia africana*.

FORIG is also collaborating with Tony Simons of the World Agroforestry Centre (ICRAF) on *Allanblakia* species and their potential to produce oil. Even though this fruit tree is not commonly found in cocoa farms, it does occur on the fringes (Siaw, *pers. comm.*)[7]. At the moment work is focused on collecting leaf samples for genetic and population analysis, and investigating indigenous knowledge. The tree is commonly found in moist-evergreen and wet evergreen forests on slopes of 45°.

Research[8] is also going on to determine the effects of different micro-catchments on the growth and survival of indigenous tree species, including *Ceiba pentandra* and *Khaya senegalensis*. Another activity includes the establishment of clonal seed orchards for *Ceiba pentandra*, *Nauclea diderrichii*, and *Terminalia spp.* to make seed collection easier and less costly.

A tour of the on-campus nursery counted approximately 130,000 seedlings, a majority of which was Teak due to a high demand for this species. There were also seedlings of *Cedrela odorata*, *Triplochiton scleroxylon*, *Tieghemella heckelii*, *Terminalia superba*, *Milicia excelsa*, *Ceiba pentandra*, *Nauclea diderrichii*, and *Pinus carribea*.

A tour of FORIG's campus identified over 33 species with which they have various levels of experience and for that matter may serve as source of planting materials for farmers who want to plant these trees on farm. The species include the following:

[6] Owusu Sekyere is a Research officer at FORIG.
[7] P.S.K. Siaw is a Research Officer at FORIG.
[8] FORIG Annual Report 2000, University Post Office Box 63, Kumasi.

Acacia hockii (seyal)
Acacia polycantha
Acacia beriana
Afzelia africana
Albizia lebeck
Alstonia boonei
Blighea sapida
Dialium guineense
Entandrophragma angolense
Entandrophragma utile
Ficus exasperate
Khaya ivorensis
Khaya senegalensis
Lagerstroemia speciosa
Mansonia altissima
Milicia excelsa
Milletia zacheana
Morinda lucida
Nauclea diderrichii
Pericopsis elata
Pterygota macrocarpa
Pycnanthus angolensis
Senna/Cassia siamea
Spathodea campanulata
Terminalia montalis
Terminalia superba
Tetrapleura tetraptera
Triplochiton scleroxylon
Veitchia palm
Vitelleria paradoxa
Voacanga africana

Conservation International (CI)

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Conservation International-Ghana (non-governmental international organisation) has been involved in services that include training farmers in various farm management techniques in the country through projects. According to CI one of such activities was the Conservation Cocoa Agroforestry Programme (CCAP) carried out in communities surrounding the Kakum National Park in the Central Region. These communities included Bobi, Abeka Nkwanta, Antokrom, Kruwa, Somnyame-Kodu, Camp, Afiaso, Nyamebebu, and Damstekrom. The programme, which was initiated in 2000, consisted of a conceptual model that used agroforestry as a means for boosting biodiversity conservation in the area.

Research activities developed in the CCAP focused on cocoa farmers and used agricultural agencies to identify ways of promoting rehabilitation and replanting of abandoned cocoa farms. One of the desired results of their activities was to reduce pressure on surrounding forests and to increase connectivity between forest patches.

In a baseline survey carried out in 2001, 100 farm plots were appraised. For each of the 9 communities selected, 11 farms were chosen where various categories of farm data were obtained. These include data on tree species on farm (both desirable and undesirable), shade management, shade composition, shade density, and food crops in association with cocoa. In the process trees identified on cocoa farms were documented as indicated in Table 1. In addition, farmers' perspectives and preferences on desirable and undesirable trees (Table 2) on cocoa farms were compared with 'recommended' cocoa shade trees.

However, CI observed that farmers were uncertain about which species are 'desirable' and 'undesirable' from researchers point of view. Further, they noted that there has been little research conducted on desirable and undesirable shade trees in cocoa systems in Ghana.

Table 2: Desirable and undesirable shade trees obtained from farmers in the CI survey

Desirable tree species	**Local name**	**Undesirable tree species**	**Local name**
Alstonia boonei	Nyamedua	*Albizia zygia*	Okoro
Ceiba pentandra	Onyina	*Anthocleista nobilis*	Bontodie
Entandrophragma angolense	Edinam	*Antiaris toxicaria*	Kyenkyen
Ficus sur	Dominin	*Ceiba pentandra*	Onyina
Funtumia elastica	Funtum	*Chaetachme aristata*	Osonoaka
Gliricidia sepium	Gliricidia	*Cola gigantia*	Watapuo
Milicia excelsa	Odum	*Ficus elasticoides*	Nyankyerenie
Nesogodia papaverifera	Danta	*Ficus sur*	Dominin
Pycnanthus angolense	Otie	*Pycnanthus angolense*	Otie
Petersianthus macrocarpa	Esia	*Ricinodendron heudelotii*	Wama
Rauvolfia vomitoria	Kakapenpen	*Solanum erianthum*	Pepediawuo
Ricinodendron heudelotti	Wama	*Sterculia tragacantha*	Sofo
Spathodea campanulata	Kuakuanisuo	*Terminalia superba*	Ofram
Triplochiton scleroxylon	Wawa		
Citrus sinensis			
Mangifera indica			
Psidium guajava			
Musa paradisiacal			
Carica papaya			
Cocoa nucifera			
Elaies guineensis			

Source: Adopted and modified from CI (2003)

The CCAP research recommended that native and economic trees that are desirable for cocoa production (see Table 3) must be integrated in the cocoa agroforests as a means to maintain natural ecological functions such as nutrient recycling, soil fertility, weed and pest reduction, water retention and erosion control. The project advised farmers to plant desirable trees along the borders of their plantations in combination with plantain suckers before planting cocoa seedlings.

CI found shade management to be a problem for most farmers. 63% of the farms were over shaded, 32% were under shaded, and 2% had no shade. On young farms, however, food crops were the primary source of shade with few forest trees. Accordingly, the focus should primarily be on helping farmers with over shaded fields to identify, maintain, and manage desirable trees, while eliminating undesirable species. On younger or under shaded farms the focus should be on integrating desirable species either through planting or natural regeneration.

In implementing research recommendations CI collaborated with government agencies like CRIG and Kuapa Kokoo to train farmers in proper farm management through the farmer field schools (Baah *et al.*, 2003). Currently, CI has a draft report[9] on the CCAP that can be obtained at the country office in Ghana.

CI's current interests include linking forest fragments in the western region using cocoa farms, promoting positive tree policies and ownership, and maintaining shade on cocoa farms. They also involve understanding the beneficial aspects of

[9] CI. 2003. Habitat survey for the conservation cocoa agroforestry project implemented in the Kakum conservation area. (Unpublished), Conservation International, Accra-Ghana.

certain wildlife species on farm, promoting the relationship between trees and sustainable water sources, stopping people from farming on riverbanks, and using pesticides judiciously close to water sources.

CARE International - Ghana

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CARE International Ghana (non-governmental international organisation) has been collaborating with Dalhoff-Larsen and Horneman A/S, and Ghana Primewood Company on a Joint Forest Management Project (JFMP) in the south-western part of Ghana. The project was initiated to empower farmers to go into agro-diversification of cocoa farms because this area hosts the last remaining forest frontier in the country (Amanor, 1997). The JFMP encouraged farmers to plant and preserve trees on cocoa farm as a means of increasing tree diversity in an area gradually losing its tree cover (Prah, 1994).

The trees that were selected and promoted on farm according to farmer preference include *Khaya ivorensis, Entandrophragma angolense, Musanga cecropoides, Piptadeniastrum africanum, Rauvolfia vomitoria, Ricinodendron heudelotii, Tieghemella heckelii, Heritiera utili, Milicia excelsa, Cola nitida, Ceiba pentandra, Citrus sp., Magnifera indica, Cedrela odorata* (Asare, 1999).

In a recent study[10] on cost-benefit analysis of cocoa, oil palm and black pepper production it was revealed that cocoa is not profitable when future incomes and expenses are discounted in the south-western part of the country. Oil palm and black pepper, although not as well known in the area as cocoa, seem to have better prospects. Black pepper in particular has good prospect because it costs less to establish and maintain, and provides environmental benefits as a shade tolerant crop that can be grown in combination with timber species as well as cocoa.

Sustainable Tree Crop Programme (STCP)-Ghana

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The main objectives of STCP-Ghana are to strengthen community based farmer groups through technical support and to establish and improve direct linkages between rural associations. Its work focuses on training farmer leaders, and establishing and supporting FFS within cocoa growing areas. Originating from the CI-CCAP project, Ghana-STCP FFS are currently in a pilot phase that solely focuses on Ashanti Region, but hopes to expand into other regions, including the Brong-Ahafo.

FFS operate under the guidance of two Master Trainers (MT) who train farmer leaders to facilitate the FFS within their communities. These schools typically

[10] Cruz, R.J. 2002. Cost benefit analysis of cash crops at the Gwira-Banso Joint Forest Management Project. CARE-Ghana Internal Report.

enrol 25-30 farmers to follow 8 to 10 months of training through experiential learning techniques. As of March 5, 2004, 650 farmers from 24 communities in the Atwima and Amansi West Districts in the Ashanti Region had completed 8-month courses in various farm management techniques. As of May, a second phase of FFS had just started which aims to train 900 farmers from the same region.

FFS focus on integrated pest management (IPM) and disease control. Each school session follows interactive, guiding protocols[11] that centre on bud breaking, fermentation of cocoa beans, drying of beans, shade management and special topic presentations by visiting experts. The hope is that farmers will take their school experiences and apply them to their individual farms. Tests are administered at the beginning and end of each school year to track farmers' acquisition of knowledge.

Ghana's over-all FFS curriculum[12] is a work in progress, as the MT are still testing and adapting the individual protocols. In addition, the MT commented that the curriculum on trees on cocoa farms was not well developed, and a specific shade tree curriculum would be useful.

Kuapa Kokoo

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Kuapa Kokoo (Kuapa) is a farmer co-operative, a credit union, and a licensed cocoa buying company, which undertakes extension programmes to educate its members on sustainable cocoa cultivation. Kuapa's work in sustainable cocoa began with an Organic Cocoa Programme together with CI. This programme later developed into the Conservation Cocoa Agroforestry Programme (CCAP) as earlier mentioned. Kuapa's role in CCAP was to disseminate project recommendations to farmers through its strong extension network in the project area. To date, 90 farmer leaders have been trained, and 2000 farmers are participating in Kuapa's FFS from 5 communities in the Assin-Nyankomase and Praso Districts in the Central Region.

At the moment Kuapa is funded by CI's Critical Ecosystem Partnership Fund to continue with FFS extension programmes. The aim is to disseminate information on integrated pest management and conservation to farmers in poor communities using farmer-to-farmer extension in order to achieve sustained yield in cocoa cultivation and to reduce the rate of expansion into nearby forests. The FFS typically uses field tests to disseminate information to farmer participants. At one field school site seedlings were growing under the shade of *Gliricidia sepium* (planted), *Rauvolfia vomitoria* (coppice), banana, cocoyam, and cassava.

[11] Lesson plan of specific agronomic and farm management practices used to teach farmers during school sessions.

[12] The original draft curriculum was developed during a workshop in Mbalmayo, Cameroon (March 24-28, 2003), entitled 'Curriculum development workshop for cocoa IPM using the farmer field school approach'. This workshop was sponsored by the Sustainable Tree Crop Programme of West Africa and Central Africa, and organised by the International Institute of Tropical Agriculture (IITA) and CABI Bioscience.

3.2 Farmers and Cocoa in Ghana

In an effort to reconcile farmers' preferred species in cocoa farms and tree species that have been researched and recommended in coca farms, discussions were held with farmers to capture their perspectives. Focus group discussions and informal interviews were held with farmers participating in Kuapa's FFS in two districts in the Central Region – these are Aben and Nsuakyire in the Assin-Nyankomase District and Bobi in the Praso District.

Assin-Nyankomase District

Sixteen participants from the Kuapa run FFS at Aben and Nsuakyire in the Assin-Nyankomase District in the Cape Coast Region were met in a focal group discussion. These farmers have been engaged in the FFS since 2001. The farmers attested that the schools have influenced them to change their techniques. They are using shade trees for their ability to recycle nutrients. They are also starting new fields in fallow fields instead of clearing 'virgin forest'.

In the fallow areas, saplings are nurtured to grow and serve as temporary shade trees for cocoa, however it was observed that these farmers are not typically planting shade trees. Perhaps the only exception was with *Gliricidia,* which Kuapa promoted and provided the planting materials. In addition, they now plant cocoa trees in lines and use certified hybrid cocoa seeds, and do not plant seeds from their own trees. The farmers also explained that while they used to clear with fire and use the ash for maize, they have stopped these practises since they are detrimental to cocoa trees.

Even as farmers integrate trees into their farms, they are also eliminating trees. Large trees are most frequently taken out, (e.g. *Ceiba pentandra* and *Triplochiton scleroxylon*) for fear of crop damage caused by chainsaw operators or because the trees are not compatible with cocoa. Farmers, however, will leave their saplings for future shade. In fact they primarily depend on the buried seedbed to serve as source of planting material for shade trees, especially when planting new cocoa trees. According to these farmers, actively planting shade trees will lead to an excess number of trees since natural regeneration is very prolific in the area.

Indigenous forest shade trees on their farms include *Alstonia boonei*, *Terminalia superba*, *Rauvolfia vomitoria*, *Cola nitida*, *Musanga cecropoides*, *Gliricidia sepium* (shade for seedlings), *Citrus sinensis,* and *Persea americana*. They have not noticed any significant differences between using timber trees or fruit trees as shade for cocoa, but they did indicate that some trees harbour insects, including *Cola nitida*. According to the farmers, *Ceiba pentandra* is good for recycling nutrients but farmers also realise that it harbours some diseases. As one woman explained, she has *Ceiba* on her field and she can see insects, but she does not have the capacity to cut it down.

Praso District

In separate discussions with farmers from Bobi in the Praso District, farmers indicated that the FFS has initiated changes in their production techniques. While they were previously cutting the forest they are now using fallow areas and are leaving saplings and already established trees as shade for cocoa. They also used to burn for the benefit of crops, but now they use the trees to shade the cocoa. Finally they have learned that burning kills soil organisms and makes the soil very dry following the burn.

With regards to the care and planting of trees, one farmer claims that he leaves certain rare trees species like *Milicia excelsa* on his farm for posterity since it could remain for 50-60 years. Another man has taken wildlings of *Triplochiton scleroxylon* and *Terminalia superba* and planted them on his farm. He also nurtures seedlings that grow naturally in the field. Others weed around valuable wildlings in order to prevent them from being cut by farm labourers.

According to this group of farmers, desirable shade trees include a number of species. *Gliricidia sepium* and *Rauvolfia vomitoria* are commonly used as initial shade. *R. vomitoria* in particular does not grow very tall so the shade effects is good for young cocoa trees. *Milicia excelsa* can be left and cut for wood for building. *Alstonia boonei* maintains moisture on the soils, and even gathers dew in the dry season. They also believe there are some larvae on the tree that increase soil moisture through their excreta. *Terminalia ivorensis*, *Funtumia elastica*, *Ficus exasperate*, and *Musanga cecropoides* are used as shade and increase soil moisture.

Alternately, these farmers identified the following trees as undesirable for cocoa. *Piptadeniastrum africanum* has a dense canopy, dries the soil, and competes for water. *Celtis mildbraedii* is a hardwood whose canopy is too broad, allows no dew to fall, and competes for water. *Triplochiton scleroxylon* and *Ceiba pentandra* harbour insect pests. *Cola nitida* emits a powdery substance (perhaps a fungal spore or pollen) that is considered bad for cocoa, and finally *Carapa procera* leaves prevent rain through-fall and the soil beneath the tree tends to be too dry.

Some farmers are informed about their rights to trees on farm. One man stated that he does know his rights, and is aware that without his permission no one can cut trees on his farm. But, he explained that he recently allowed people to cut two of his timber trees because he did not want those trees on his cocoa farm. He was paid a compensation of 150,000 cedis[13], approximately US$ 17 for the two trees. Everyone present agreed that the chainsaw operators typically take advantage of those farmers who do not know their rights in order to fell the economic trees from farms.

3.3 Preferred trees in cocoa growing systems in Ghana

A number of organisations and individuals have conducted research on preferred shade species based on farmer preferences and compatibility of these trees with cocoa. Table 4 represents the top recommended species according to farmer preferences and research recommendations. It is important to note that even though CRIG warns about the placement of *Ceiba pentandra* and *Triplochiton scleroxylon* in cocoa farms, farmers prefer them due to the economic importance in the system. These species have become valuable economic timber species in recent times. Hence their preference by farmers.

[13] Ghanaian cedis (GHC): 9000 GHC = 1US$ as at the time of field visit (May, 2004)

Table 3: Preferred species in Cocoa in Ghana

Most preferred species	Number of sources mentioning species (n=11)	Number of research sources mentioning species (n=2)	Traditional mode of farmer tree propagation
Alstonia boonei	9		Natural regeneration
Milicia excelsa	9		Natural regeneration
Rauvolfia vomitoria	8		Natural regeneration
Terminalia ivorensis	7	2	Natural regeneration
T. superba	7	2	Natural regeneration
Triplochiton scleroxylon	7		Natural regeneration
Ceiba pentandra	6		Natural regeneration
Pycnanthus angolensis	6		Natural regeneration
Entandrophragma angolense	6		Natural regeneration
Funtumia elastica	5	2	Natural regeneration
Gliricidia sepium	5		Cuttings
Citrus sinensis	4	1	Sown seed
Mangifera indica	4	1	Sown seed
Persea americana	4	1	Sown seed
Cocos nucifera	3	2	Sown seed
Cola nitida	3		Sown seed
Elaies guineensis	3	1	Sown seed, natural regeneration
Ricinodendron heudelotti	3		Natural regeneration
Carica papaya	2	1	Sown seed
Psidium guajava	2	1	Sown seed
Tetrapleura tetraptera	2	1	Natural regeneration

Source CRIG, CI and FORIG recommendations, Amanor (19996), Asare (1999), and responses from farmer interviews conducted during this study.

These results should be used cautiously as there is probable over-lap between the two ‘research’ sources and likely recycling of farmer-based information between different groups.

4 Cocoa and trees in Côte d'Ivoire

Côte d'Ivoire is the world's largest producer of cocoa beans, and has a long history of successful production since the introduction of cocoa in 1892 (IFCC, 1979). However this success has come at a price. From the socio-political view point Woods (2003) argues that the current civil war can be traced back to cocoa policies that encouraged migration and migrant labour, and made forestland readily available to producers.

From an environmental perspective cocoa currently occupies an area of about two million hectares and is one of the major causes of deforestation in the country (Pallix et Comolet, 1996: *cf.* N'Goran, 1998). According to N'Goran (1998), increased production was dependent on an expansion of cultivation into the forest areas. Furthermore, government and research recommendations promoted cultivation of hybrid cocoa variety under minimal shade or without shade in order to optimise yields and also prevent cocoa from being stressed by the forest trees. In a cocoa cultivation manual released by the Ministry of Agriculture (SATMACI, 1984), 45 native forest tree species were named as being undesirable in cocoa plantation and therefore should be eliminated. Nevertheless, Herzog (1994), N'Goran (1998) and Ruf and Zadi (1998) document that farmers still use certain forest tree species in the cocoa systems because of their added importance to the household.
The alarming rate by which the country is losing its forest cover has recently prompted research and development in the country to look for a more sustainable method of cocoa cultivation through intensification and diversification using valuable trees instead of through expansion (Aguilar *et al.*, 2003; Ruf *et al.*, 2003). The following sections therefore elaborate on research and development work involving trees and cocoa in Côte d'Ivoire.

4.1 Institutions and cocoa in Côte d'Ivoire

Efforts to maintain and increase cocoa production in Côte d'Ivoire using more sustainable methods are the clear priority of development organisations and government institutions and the interest of key researchers at the moment.
Five main institutions play a role in cocoa research and development. National research and development institutions include Centre National de Recherche Agronomique (CNRA), Societe de Development des Forets (SODEFOR), Centre National Floristique (CNF-Universite de Cocody). National and international programmes include, Projet de Stabilisation des Systemes de Production Agricole (PROSTAB), and Sustainable Tree Crop Programme (STCP), and Centre for the Development of International Co-operation in Agronomic Research (CIRAD)[14].

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[14] CIRAD's country offices in Côte were closed down during this exercise, hence, no information was obtained

CNRA was created from the merging of three former research institutions in Côte d'Ivoire - Institute des Savanes (IDESSA), Institut des Forets (IDEFOR) and the Centre Ivoirien de Recherche Technologique (CIRT). CNRA's main objectives are the sustainable development of production and productivity in the areas of agriculture and agro-industry, the conservation and development of scientific and technical property. Cocoa research within CNRA represents one of 22 different research programs.

CNRA and Centre for the Development of International Co-operation in Agronomic Research (CIRAD) have been involved in a framework of Research-Action Project to generate, update and widen existing information on cocoa production. This being undertaken in seven representative cocoa growing zones in the country (Deheuvels *et al.*, 2003; Assiri *et al.*, 2003; Konan and N'Goran, 2003; Ruf *et al.*, 2003 see Annotated Bibliography). The project involves surveys looking at the following topics:

- Measure the actuality and level of plantation degradation, forest loss, and cocoa production across the country from the East to the West;
- Identify the forest patches that exist within farmland;
- Understand farmers' land-use decisions;
- Identify farmers' techniques for regeneration of forest trees and;
- Validate farmer technologies and improve upon their methods, and use participatory research to allow the farmers to compare the two methods side by side.

The project is on going and so there are no concrete findings as of now. However, research at CNRA's research station in Gagnoa is responding to the threat to forest species through domestication of indigenous medicinal, fodder and fruit species like *Ricinodendron heudelotti, Ficus exasperate,* and *Irvingia gabonensis* (Assiri, *per. com.*)[15]**.**

CNRA in collaboration with GTZ and MARS Inc. since 2001 have been undertaken the 'Projet de Production Durable et Amélioration de la Qualité de Cacao (PRODUCAO) ' in the western and south-western part of the country. This project is an on-farm research, aimed at providing farmers with new technologies to facilitate rehabilitation of old cocoa farms and replanting of abandoned fallow and degraded parcels into cocoa farms. The project selected 'leaders' from COOPAGA (Co-operative Agricole de Gabiadje) to adopt the technology in their fields, which will serve as demonstration sites. The project primarily uses *Gliricidia sepium, Albizia lebbeck,* and *A. guachepele*[16] for the rehabilitation and improved fallow process.

The use of these exotic leguminous species originated from the 'Projet Jachere' which was initiated in the Central regions of Oumé of Côte d'Ivoire in 1994 by CNRA. In the process improved fallows were tried with over 30 leguminous species out of which preferences were given to species like *Gliricidia sepium*, *Acacia mangium*, *Albizia lebbeck*, and *A. guachepele*. This has led to the use of these few species in cocoa farm rehabilitation activities or improved fallow.

[15]A.A. Assiri (pers. com., 2004). Agronomist at CNRA.
[16] Personal communication, COOPAGA General Secretary, Koffi Kanga, July, 2004.

In Gabiadje there is a demonstration plot of a three-year fallow land being rehabilitated. The land was initially planting with *Gliricidia sepium* and *Acacia mangium* (70-80 cuttings/hectare). Cocoa seedlings and plantains were planted after the third years. In the process *Milicia excelsa* saplings were left for its economic value. Trees removed included *Anthocleista dialonensis* and *Bombax buonobozense***.** On another demonstration plot on which a 25-year-old cocoa farm is being rehabilitated in the same Gabiadje area *Gliricidia sepium* was planted in the first year after which seedlings of a high yielding cocoa variety called 'Mercedes' provided by CNRA were planted. The field is in its third year and some of the cocoa trees are already producing cherelles. Even though the farmer needs to thin the *Gliricidia* he is not since he is also using the *Gliricidia* as yam stakes, and will wait to thin until the yam is harvested.

Still in the Southwest, a similar demonstration farm which is on-going was observed in the village town of Meagui in Assablikro where a 30-year-old farm is being rehabilitated with *Gliricidia sepium*. On this farm majority of the old cocoa trees were eliminated, but the farmer retained a section of the old trees in order to reduce risks. Cocoa seedlings were planted a year after the *Gliricidia sepium*. The cocoa trees are three years old and already producing pods. The farmer had just thinned the *Gliricidia* and distributed them as planting material to family and neighbours.

However, the remaining section with 'old' cocoa had diverse forest timber trees as shade. These include *Milicia excelsa*, *Monodora myristica*, and *Terminalia superba*. Another improved fallow land intended for cocoa cultivation, in the same area with a three-year-old *Albizia lebbeck, A. guachepele, Acacia mangium*, and a strong undergrowth of shrubs and other naturally regenerated tree species, resembling a small secondary forest of pioneer species was observed. Results from these on-farm trials are not ready but CNRA is monitoring the progress and will publish results in due course.

Societe de Development des Forets (SODEFOR)
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Societe de Development des Forets (SODEFOR) is a government forestry institution with the following mission: participate in the development and implementation of the government's policy to enrich the national forest, develop the forestry production, improve the quality of forest products, and protect the forest zone. Hence, SODEFOR's focus is on forest trees with commercial value, not species of agroforestry importance.

However, researchers in the institution have been making observation on a 6-year plantation using the Taungya Agroforestry System. There is also observation going on with improved fallow but official results from the trials are not available. There is also evidence[17] that in the 1970s and 80s SODEFOR embarked on forest plantations in the three ecological zones (evergreen forest, transitional forest - mixed evergreen and semi-decideous, and semi-decideous forest) with species including *Terminalia superba, Terminalia ivorensis, Entandrophragma utile, Khaya ivo-*

[17] Aitken *et al*., 1992. Evaluation of the SODEFOR forestry project Côte d'Ivoire. Evaluation report EV520

rensis, and *Triplochiton scleroxylon*. These plantations are of importance for shade cocoa since these species are preferred on cocoa farm and the plantations can serve as seed sources for those species.

According to researchers in SODEFOR it is estimated that 20% of cocoa plantations are within reserved forests (*forêt classées*). This makes it very urgent for researchers to develop models for rehabilitating forests, and old cocoa fields outside forest areas where these farmers can move and find new areas of production but this requires a transitory phase of perhaps 30 years in order not to reduce cocoa production.

Centre National Floristique, CNF-University of Cocody
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Centre National Floristique is the Department of Botany at the University of Cocody in Abidjan and a government research institute. The centre's herbarium holds over 60,000 specimens and serves as a strategic centre in any attempt to research into local tree species in Côte d'Ivoire. In an interview with Professor Ake-Assi, he provided a list for the most common tree species found on cocoa farms as shade trees in Côte d'Ivoire.

These species include *Monodora myristica (Annonaceae), Nesogordonia papaverifera (Sterculiaceae), Pterygota macrocarpa (Sterculiaceae), Ricinodendron heudelotti (Euphorbiaceae), Dialium guineense (Caesalpiniaceae), Paramacrolobium caeruleum (Caesalpiniaceae), Albizia adianthifolia (Mimosaceae), Albizia glaberrima (Mimosaceae), Erythrina addisoniae (Papilionaceae), Morus mesozygia (Moraceae), Dacryodes klaineana (Burseraceaea), Trichilia monadelpha (Meliaceae), Blighia unijugata (Sapindaceae), Lannea welwitschii (Anacardiaceae), Chrysophyllum africanum (Sapotaceae), Omphalocarpum pachysteloides (Sapotaceae), Alstonia boonei (Apacynaceae), Nauclea diderrichii (Rubiaceae),* and *Vitex fosteri (Verbenaceae).*

Ake-Assi is responsible for rehabilitating a land around the centre into a forest with over 750 species of tropical forest trees, most of that are native to West Africa. He also pointed out the possibilities of domesticating species like *Spondias mombin* as a valued fruit tree on farm, and *Anthocleista dialonensis* for its medicinal purpose.

Projet de Stabilisation des Systemes de Production Agricole (PROSTAB)
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PROSTAB Project was established in 1993. It is a collaboration between GTZ and Agence Nationale d'Appui au Development Rural (ANADER)[18] with funds from the German government. It operates around six Classified Forests of Abengourou within the Middle Comoé region in eastern Côte d'Ivoire. PROSTAB's mission is to research sustainable agriculture systems and to contribute to the protection of natural resources. PROSTAB targets a variety of farmers in-

[18] ANADER is the national extension agency

cluding heads of households, women, youth, and formal and informal groups using a participatory approach in their research and project implementation cycles.

Their technical focus is in five different areas[19] one of which includes the intensification and quality improvement of cocoa and coffee. Intensification of cocoa is being promoted by planting a variety of agroforestry species. These include *Gliricidia sepium, Albizia lebbeck, A. guachepele, Flamengia congesta,* and *Acacia mangium*. PROSTAB chose these species as a recommendation from CNRA for their ability to improve soils and their easy modes of propagation (i.e., cuttings, direct seeding).

PROSTAB is actively involved in farmers' rehabilitation of cocoa farms through the following strategies:

- Thinning overly dense cocoa plantation and filling the gaps with *Gliricidia spp. t*o ameliorate the soil;
- Complete removal of old cocoa trees, and replanting seedlings under *Gliricidia* shade and groundnut as a first year crop (for soil fertility and income);
- Filling in the gaps in young plantations using *Gliricidia* shade;
- Improving fallows using *Gliricidia*, and *Albizia spp*, prior to replanting cocoa- the idea is to improve soil fertility and to provide temporary shade for young cocoa trees and;
- Experimenting with Neem bio-treatments on cocoa.

A field trial on improved fallow system using a single stand of *Albizia spp* interplanted with cocoa in Abengourou area was observed. This farm was planted with *Albizia* in 1995 and cocoa in 1998 but cocoa survival rate was extremely low. A second trial, which consisted of a natural fallow that was enriched with *Gliricidia sepium,* mimicked a secondary forest due to the natural regeneration of a diversity of forest species. Though cocoa is yet to be planted, this improved fallow tend to provide a good environment for cocoa establishment compared the surrounding area, which was virtually barren.

Sustainable Tree Crop Programme (STCP)-Côte d'Ivoire
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STCP in Côte d'Ivoire is actively engaged in establishing and supporting farmer field schools (FFS) in the principle cocoa growing regions of the country, including the East, Central, and Southwest. These schools aim to help farmers to rehabilitate/replant ageing or abandoned farms, and intensify their cocoa system through the introduction of leguminous species (*Gliricidia sepium*). The overall objective is to increase the longevity and sustainability of the cocoa farms.

STCP works in strong collaboration with the government's rural agricultural extension service, Agence Nationale d'Appui au Development Rural (ANADER) and regional cocoa co-operatives. A two-person team, one ANADER agent and a trained farmer leader are paired to facilitate each FFS. All of the field school participants are also members of their respective co-operatives.

[19] PROSTAB's five technical areas are: Agroforestry (improved fallow, plantation rehabilitation, increasing production, reduce weeding labour), Rational Use of Chemical Treatment, Intensification and quality improvement of Cocoa and Coffee, Promotion of Agriculture in Low Lying Areas (Rice, Market, Pisciculture) and Development of Biological Agriculture (Appropriate use of pesticides, Biological/Natural Pesticides from Neem). Finally, PROSTAB focuses on supporting the needs of groups (organisation, credit, services, diversification, and commercialisation).

To date, STCP has conducted 64 FFS. Sixteen new schools were established in 2004. The themes of each FFS session include[20]; rehabilitating and/or replanting of cocoa farms, creating initial shade for young cocoa with *Gliricidia sepium* and plantain, managing shade with focus on eliminating undesirable trees and promoting full sun systems, pruning and managing the cocoa tree, and integrated pest and disease management. STCP also creates demonstration plots and makes sources of *Gliricidia* planting material available to the wider community in order to promote their technologies and achievements.

4.2 Farmers and Cocoa in Côte d'Ivoire

Discussions were held with participants in the STCPs FFS. The farmers discussed their concepts of compatible and incompatible trees.

Aboisso

At a field visit to the FFS in Affienou in the Aboisso area, five participants and their farmer leader conducted a tour of their field school and demonstration plot. At the time, the school was thinning shade trees (ring barking) so as to reduce humidity within the farm. The first demonstration plot consisted of newly planted *Gliricidia* stakes, depicting initial steps in the rehabilitation process. The second demonstration plots, located at 'Entente AFFEMA' co-operative headquarters in Maffere, and was a source for *Gliricidia* planting material.

For these farmers desirable trees include trees that give economic benefits or improve soil fertility. Specific species included *Terminalia superba* and *Terminalia ivorensis* (good wood for furniture), Coconut, and *Citrus spp*. Undesirable species included; *Elaies guineensis* (attracts squirrels), *Cola spp*., *Persea americana* (harbours pests and mistletoe), and Bamboo.

Abengourou

Also in the town of Ebouassue in the Abengourou area, two field schools were engaged in training on how to rehabilitate a 30-year-old cocoa farm. They were involved in planting new cocoa seedlings under the partial shade of old cocoa trees, and planned to integrate *Gliricidia sepium* and plantains in the near future to serve as temporary shade. A number of mature canopy trees had been felled to reduce shade, including *Ceiba pentandra*, but desirable shade species had been retained on the edges of the farm, including *Terminalia superba*.

The FFS participants identified desirable tree species; *Terminalia superba* (the wood is good for building houses), *Garcinia kola*, *Citrus* spp., and *Persea americana* (this tree has a high canopy, the wood is good for mortars and building, and it is used to cure malaria). They added that desirable trees have high canopies. The common characteristics of undesirable trees are those with low canopies, trees that provide too much shade, trees that compete with or antagonise cocoa, and trees that harbour pests. Specific trees included; *Chlorophora excelsa / Milicia excelsa* (the wood is expensive and good but the tree harbours Mirids), *Cola cordifolia / C. gigantea* (the leaves are too large), *Cola chlamydantha* (harbours insects during the dry season), *Ceiba pentandra* (harbours Mirids), *Ricinodendron heudelotti* (fruits

[20] Examples of FFS 'protocols' are available in, STCP-Côte d'Ivoire. 2004. Composante diffusion des connaissances et des technologies: Curriculum sur les techniques de regeneration cacaoyere dans les champs ecoles paysans et sur les parcelles de demonstration. Abidjan.

have good market value but it provides too much shade), *Elaies guineensis*, *Mangifera indica, Nesogordonia papaverifera.*

Angibilekro
Farmer leaders from Angibilekro identified critical characteristics of desirable shade trees and their relationship with cocoa trees. For the farmer leaders, their concept of a good tree allows aeration, that is a tree with a high and open canopy. The trees should also improve the moisture condition in the soil and not compete with the cocoa tree for available moisture. The rate of decomposition of the leaves should be high. Desirable tree species include; *Gliricidia sepium*, *Khaya* ivorensis, Persea *americana*, *Citrus spp*., plantain. Undesirable tree species include *Cola spp*., and *Ceiba pentandra*.

4.3 Preferred Trees in Cocoa Growing Systems in Côte d'Ivoire

In Côte d'Ivoire research work on trees in cocoa has focused very much on exotic agroforestry species like *Gliricidia sepium, Acacia mangium, Albizia lebbeck*, and *A*. *guachepele*, which are used for cocoa farm rehabilitation activities or improved fallow. According to Petihuguenin (1995), research and extension also promoted *Terminalia spp*. in the country even though the success rate was low compared to the leguminous species.
Despite this farmers have also preserved indigenous forest tree species from which they derive economic, social and agronomic benefits. Table5 below represents both farmers preferred and/or research recommended tree species as recorded by this study.

Table 5: Preferred species in cocoa in Côte d'Ivoire

Most preferred species	Number of sources mentioning species (n=11)	Number of research sources mentioning species (n= 3)	Traditional mode of farmer tree propagation method
Gliricidia sepium	7	3	Cutting
Terminalia ivorensis	5	2	Natural regeneration
Acacia mangium	5	3	Cutting
Albizia guachepele	4	3	Cutting
Albizia lebbeck	4	3	Cutting
Terminalia superba	4	2	Natural regeneration
Milicia excelsa	4	1	Natural regeneration
Alstonia boonei	2	1	Natural regeneration
Ficus spp	2	1	Natural regeneration
Khaya ivorensis	2	1	Natural regeneration
Citrus spp	3		Planted seed
Cola nitida	2		Planted seed
Ricinodendron heudelotti	2	2	Natural regeneration
Spondias mombin	2	2	Natural regeneration
Elaies guineensis	1		Planted seed and Natural regeneration
Cocos nucifera	1		Planted seed
Mangifera indica	1		Planted seed

Sources: CNRA, PROSTAB, and SODEFOR research recommendations, Ruf and Zadi (2003), N'Goran (2003), and Herzog (1994), interviews with Prof. L. Ake-Assi, and field interviews with farmers

5 Cocoa and Trees in Cameroon

Since the introduction of cocoa into Cameroon in 1886 (Nnama, 1995), it has become the most important cash crop in the farming system of the humid forest (Coulibaly *et al.*, 2002). In addition it has become the major foreign exchange earner for the economy of the country in terms of value and volume (Duguma *et al.,* 2001). In 2003 Cameroon supplied 5% of the world's cocoa production making it the sixth largest producing country in the world and the fourth in West Africa (ICCO, 2003).

In Cameroon, deforestation is commonly associated with food crop production as opposed to cocoa production (Duguma *et al.,* 2001; Sunderlin *et al.,* 2000). None the less, cocoa production involves growing cocoa trees in combination with trees in the shade of forest trees, as a result creating a degraded forest environment (Sonwa *et al.*, 2001). According to Losch *et al.,* (1991), three-quarters of Cameroon's cocoa agroforests are found in the Centre, South, and East Provinces of the Country.

However, in the Southern Province cocoa cultivation is credited with preserving parts of the humid forest environment and some of its biodiversity (Ruf and Schroth *et al.,* 2004) due to the high shade density in cocoa farms (Gockowski *et al.,* 2004). These shade levels were not strategies by farmers to maintain biodiversity but a neglect of farms after the oil boom period and beyond when government policies reduced prices on cocoa and coffee (Ndoye and Kaimowitz, 2000) and also withdrew interventions like fertiliser and pesticide subsidies from the cocoa sector (Coulibaly *et al.,* 2002).

However, in recent times cocoa productivity improvement has become one of the government's main focuses in the process to increase export revenue and reduce poverty. In 2000 the government presented a 10-year plan with an objective to increase the market share level of global cocoa market. The goal include increasing the production from 100,000 tonnes in 1999 to 200,000 tonnes by the year 2010 which maybe achieved through productivity gains in existing orchards, rehabilitation of old orchards, and opening up new-forested areas (Ministry of Agriculture, 2001). These according to Kazianga (2002) could be achieved by adopting a combined technology of low shade system that uses fertiliser application and pest control. The dilemma is what type of trees need to be eliminated in order to create a balanced cocoa system that satisfies the agronomic, social and economic needs of the farmer.

Shade trees in cocoa systems have been recorded by various work and researchers in Cameroon (Gockowski and Dury, 1999; ASB 2000; Sonwa *et al.*, 2001; Zapfack *et al.,* 2002; Sonwa, 2004; Bidzanga, *in press*). Species recorded involve timber species and fruit trees. However, according to research fruit trees dominate due to their domestic and market value in the sub region.

5.1 Institutions and Cocoa in Cameroon

One national research institution and three international research and development institutions contribute to research and development works in the cocoa sector in Cameroon. They are the Institut de Recherche Agronomique pour le Developpement (IRAD), World Agroforestry Centre (ICRAF), Centre for International Forestry Research (CIFOR), and International Institute of Tropical Agriculture (IITA).

Institut de Recherche Agronomique pour le Developpement (IRAD)
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IRAD is the government research institute that conducts research on cocoa among other crops in Cameroon. It cultivated the idea of conducting research in indigenous fruit tree genetics conservation and initiated the African Safou Network (ASANET). Tree species considered in the network are *Dacryodes edulis, Irvingia gabonensis,* and *Ricinodendron heudelotti* due to their economic and nutritional importance. The aim of the network is to develop scientific knowledge about these species to promote their cultivation in the farming systems in West and Central Africa. IRAD works closely with ICRAF in domesticating indigenous fruit tree species in the farming system.

World Agroforestry Centre (ICRAF) Africa Humid Tropics region office in Cameroon
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ICRAF from 1995 and 1997 conducted a wild fruit species prioritisation exercise in Cameroon, Gabon, Ghana, and Nigeria to determine the wild fruit species that were medicinally, economically and nutritiously preferred by farmers. Top preferred trees recorded were *Dacryodes edulis, Irvingia gabonensis, Ricinodendron heudelotti, Garcinia kola,* and *Chrysophyllum albidum* (Franzel *et al.*, 1996; Tchoundjeu *et al.,* 2002). In 1998 ICRAF, IRAD, and FIDA in partnership with farmers launched a participatory domestication process to test vegetative techniques to propagate and cultivate the above mentioned species in the Fruit and Medicinal Tree Domestication Project.

In the process, farmers provided the land, labour and selected the trees to be domesticated and ICRAF provided the propagators and the technical know-how for propagation. The vegetative techniques developed for propagation include grafting, marcotting, root cuttings, and seedling germination.

As part of the domestication programme, ICRAF and IRAD in collaboration with existing farmer groups (GIC-Gruppe Initiativ Commune) established over 60 tree nurseries in Cameroon, the first of which was created in 1999 (see 5.2).

There are between 5-17 members in a GIC and currently ICRAF has trained more than 60 farmer groups, NGOs, and governmental institutions in tree propagation methods. In addition four demonstration plots have also been established where on-field studies are being conducted between farmers and ICRAF on the integration of fruit trees in various farming systems i.e., food crops and tree crop (cocoa agroforests) systems. ICRAF also facilitates sales of propagules and promote synergy between nurseries.

Centre for International Forestry Research (CIFOR)
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CIFOR has been based in Cameroon since 1994 conducting research on forest related issues. One of such issues is the 'Forest Products and Market'. This is a ten-year research experience on commercialisation of non-timber forests and relationship between markets and forest in the Humid Forest Zones of Cameroon, Gabon, Equatorial Guinea and Nigeria. The research is based on the idea that food security is linked to access to food through food supply and demand.

In general the idea of food security, household well-being and income generation is looked at from traditional agriculture, which is a mixed cropping system with food crops, cash crops, and timber and non-timber forest products. In Cameroon and the rest of Central Africa CIFOR has worked a lot on the economic analysis and market potential of indigenous fruit trees in various farming system. Such species include *Irvingia gabonensis, Dacryodes edulis, Garcinia kola, Garcinia lucida, Cola nitida, Cola acuminata, Ricinodendron heudelotti, and Elaies guinensis* (Pèrez *et al.,* 2000 see Annotated Bibliography for specific work).

International Institute of Tropical Agriculture (IITA) Humid Forest Ecoregional Centre in Cameroon
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IITA, which is also the host or convenor of the STCP, is conducting research that spans the natural and social sciences. Current studies focus on indigenous knowledge and the management and structure of cocoa multi-strata systems. Research also focuses on the opportunities, constraints and dynamics of establishing cocoa in three different agro-ecosystems so as to gain knowledge about rehabilitating existing tree crop farms and establishing new farms on already deforested land. The particular research projects include:

- Farmers' agronomic and ecological knowledge and management of cocoa multi-strata systems;
- Diversification and biomass management in cocoa agroforests;
- Establishment of multi-strata cocoa agroforests in *Chromoleana odorata* and *Imperata cylindrical* fallows;
- Effects of shading, soil water content, fertilizer, soil type on germination and growth of local cocoa and;
- Establishment of cocoa in timber plantations thinned to various densities.

1. The first project[21] aims to acquire local knowledge about the agronomy and ecology of multi-strata systems in Southern Cameroon, and then combine the information with scientific knowledge to improve and diversify systems productivity and provide ecosystem services. Initial findings suggest that local knowledge varies across locations and is influenced by ecology and socio-economic factors, and within locations according to age groups and gender with the largest proportion of knowledge being held by older men.

2. The second project, which is a PhD study (Sonwa, 2004 see Annotated Bibliography) studies diversification and evaluates biomass management in cocoa agroforests in Southern Cameroon. The particular focus of this work is on characteristics of farmers and their choice of species, diversity of plants associated with cocoa, structure and typology, phytomass, litter dynamics, cocoa production, and carbon stocks of the cocoa agroforests. Key findings show that farmers use an average of six accompanying plant species for intensification and diversification (93% use fruit trees, the majority being exotic, and 81% use non-fruit species). On average, 21 species were found within each cocoa agroforests, though diversity was less in fragmented forest landscapes.

3. The third mentioned research project[22] seeks to determine options, with farmers, for establishing cocoa agroforests in degraded short fallow bush land. A second aspect is to assess the ability of two *Musa* spp. varieties to provide initial shade and provide income. The third objective is to determine the effect of fertilizer on cocoa, fruit and timber trees, and the yield of *Musa* spp. The fourth objective is to evaluate the economic costs and returns of establishing a multi-strata cocoa agroforests in a *Chromolaena odorata* and *Imperata cylindrical* fallow. Finally, the research strives to determine the dynamics of carbon sequestration in such a cocoa agroforests.

   To date, key findings show that two indigenous fruit trees (*Dacryodes edulis* and *Ricinodendron heudelotti*) and *Terminalia ivorensis* are robust enough to establish on short fallow land, with survival being lowest in the bush fallow treatments compared to the other shade treatments. Fertilizer had few impacts on survival or early growth of these species so it is not recommended. Further, neither initial shade treatment nor fertilizer had an impact on cocoa seedlings but growth was best in the plantain temporary shade.

4. The fourth research[23] initiative looks at the effects of shading, soil water content, fertilizer, and soil type of germination and growth of cocoa. Trials were initiated in May 2003 and will end in December 2004. As of yet there are no results.

5. The final project[24] aims to rehabilitate over-logged forest by converting the land to timber plantations of *Terminalia ivorensis* with a cocoa understory. As of now there are no initial results.

[21] Scientists involved are N. Bidzanga, IRAD, F. Sinclair, University of Wales-Bangor, J. Gockowski and S. Weise, STCP/IITA.
[22] Scientists involved are S. Hauser, and J. Gockowski, IITA, L. Norgrove, University of Hohenheim, Stuttgart-Germany.
[23] S. Hauser, and L. Norgrove.
[24] S. Hauser, and L. Norgrove.

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STCP-Cameroon has been operating farmer field schools in two geographic locations, i.e., the humid forest zone in the southern province and the savannah zone in the central province. STCP has been on the ground for one year with an objective of building farmer capacity on crop management through training in pest management, shade management, judicial use of pesticides, and social issues like the child labour.

As of now there are 19 schools in the humid forest zone and 6 in the savannah. Number of farmers trained is 600 for the last year and approximately the same number for this year. Among them are 25 farmer facilitators (22 farmers and 3 public extension officers).

5.2 Farmers and Cocoa in Cameroon

Farmers from the ICRAF/IRAD domestication project and the STCP-Cameroon project were interviewed to obtain information on preferred trees on cocoa farms.

Lekie-Assi
For the ICRAF/IRAD project an interview with a farmer leader[25] of the GIC took place in Lekie-Assi west of Yaounde. The farmer indicated that since the establishment of their nursery in 2000 they have learnt the various propagation skills and now they are involved in sales of propagule. Species recorded on the nursery include *Persea americana* (grafted), *Garcinia kola* (seedlings), *Psidium guajava* (marcotted and root cuttings), *Entandrophragma cylindricum* (seedlings), *Citrus sinensis* (grafted and seedlings), *Citrus grandis* (grafted and seedlings), *Dacryodes edulis* (marcotted), *Ricinodendron heudelotti* (grafted and seedlings), *Cola nitida* (seedlings), *Elaies guinensis* (seedlings), *Mangifera indica* (grafted), *Irvingia gabonensis* (grafted), *Theobroma cacao* (seedlings), and *Irvingia wombulu* (marcotted).

Farmers in this GIC have also established two demonstration plots of one hectare each in collaboration with ICRAF. One plot is a system that involves tree crops like *Irvingia gabonensis, Dacryodes edulis* with arable crops like groundnuts, maize and pineapple. The second plot is a newly established cocoa farm planted in combination with other tree crops like D*acryodes edulis, Irvingia gabonensis, Garcinia kola, Ricinodendron heudelotti*, cassava, and plantain. The cocoa is planted at a distance of 10m x 10m and the plot is divided into 4 compartment of 50 x 50m each. Timber species like *Milicia excelsa, Terminalia superba, Mansonia altissima, Baillonella toxisperma, Alstonia boonei, Triplochiton scleroxylon* and *Ceiba pentandra* were left to provide shade.

In a discussion with 3 members of the group they indicated that these demonstration plots are a joint on-farm study between the group and ICRAF. The purpose is to study the tree interaction between the various planting materials in the food crop system and the cocoa system to come out with applicable recom-

[25] Mr. M. Misse Christophe ICRAF contact farmer in a GIC at Lekie-Assi

mendations. Another purpose is to use the plots as advertisement for other farmers that domesticated indigenous species take shorter time to produce and they can exist naturally in various cropping systems. In addition to the demonstration plots and nursery, the group also has a root stock garden planted with *Calliandra calothyrsus* for soil fertility and shade and a home garden planted with *Dacryodes edulis* and *Citrus grandis* from 2001, which have each fruited twice. All the plots are situated close to the nursery and the farmer leader.

Elig Nkouma

In Elig Nkouma[26] a town about four kilometres from Lekie-Assi, another nursery has been established on a small scale compared to the one at Lekie-Assi. Propagules recorded on nursery include root cuttings, marcots, and seedlings of the following: *Dacryodes edulis* (marcotted, root cuttings), *Cola nitida* (seedlings), *Irvingia gabonensis* (marcotted, grafted), *Baillonella toxisperma* (seedlings) and *Mansonia altissima* (seedlings).

Nkom-Effoufoum

In another interview with the GIC leader[27] of another nursery at Nkom-Effoufoum he reiterated that cocoa is more profitable both in terms of cash and sustainability when it exists in mixture with other crops. Due to the high labour and input demand of cocoa it always advisable to have other crops, which could share the labour and input cost and also bring additional income to the household. He indicated that no shade cocoa increases capsid attack. However, too much shade can also lead to Black pod incidence. Therefore one needs to create a careful balance to maintain the optimum shade as possible. Trees that his group prefers and for that matter engage in producing planting materials for their cocoa farms are *Dacryodes edulis, Irvingia gabonensis, Cola nitida, Citrus sinensis, Ricinodendron heudelotti, Persea americana, Mangifera indica, Baillonella toxisperma, Entandrophragma cylindricum* (grows naturally for shade, bark for medicine, and timber), *Triplochiton scleroxylon* (grows naturally for shade and timber), and *Milicia excelsa* (grows naturally for shade and timber).

Bakoa

In interviews with STCPs FFS participants in Bakoa the following tree species were mentioned as preferred species on cocoa farm: *Ceiba pentandra* (ability to maintain moisture in the dry season), *Milicia excelsa* (for construction and sale of wood), *Persea americana* (though harbours Mirids, fruits all season and brings income at all times), *Mangifera indica* (fruit for sale and consumption but it's seasonal), *Citrus reticula* (fruits have high market demand), *Dacryodes edulis* (fruits for consumption and sale), *Elaies guinensis* (fruits for oil consumed and sale), and *Spondias cytherea* (fruits are consumed and preferred), *Cola nitida* (kola nuts for sale and consumption despite being alternative host for Mirids), Raffia palm (for construction). According to farmers, these species are both planted and regenerated from the seed bank, especially timber species.

Baliana

In another interaction with STCPs FFS participants in Baliana preferred tree species mentioned are *Milicia excelsa* (for timber), *Terminalia superba* (for timber and initial shade because of rapid growth), *Mansonia altissima* (for timber), *Afzelia*

[26] Mr. Pierre Ambene Contact farmer GIC, Elig Nkouma.
[27] Mr. John Ebody contact farmer GIC, Nkom-Effoufoum.

africana (good with cocoa), *Cola nitida* (kola nut for consumption and sale), *Persea americana* (fruits for consumption and sale), *Mangifera indica, Dacryodes edulis, Citrus reticula*, and *Citrus sinensis*. However, farmers also reiterated the importance of balancing the effects of these trees on cocoa. They sometimes reduce the numbers of shade species in order to maintain a fine balance for mutual benefits.

Lendon II
In Lendon II participants of the STCPs FFS in this area identified the following as species preferred in cocoa farms and why. *Mangifera indica* (planted for consumption, sale, and shade), *Citrus reticula* (planted), *Persea americana* (planted), *Irvingia gabonensis* (planted and natural regeneration), *Dacryodes edulis* (planted for shade, sales and consumption), *Cola nitida* (planted and natural regeneration), *Ricinodendron heudelotti* (planted and natural regeneration), *Garcinia kola* (planted), *Citrus sinensis* (planted), *Elaies guinensis* (grows naturally), and *Citrus grandis* (planted). All these species are consumed home and also sold for income.

However, farmers expressed concern that at the peak season so much fruits are produced and so market drops drastically and most of them perish. If research can work to prolong the perishability of the fruit or come out with how to store them or process them this will go a long way to influence tree diversity on cocoa farm. Farmers also prefer the following timber species: *Milicia excelsa*, *Nauclea pobeguinii* (grows naturally), *Triplochiton scleroxylon, Entandrophragma cylindricum, Ceiba pentandra, Terminalia superba, Khaya sp., Mansonia altissima, Pycnanthus angolensis, Markhamia lutea,* and *Lovoa trichilioides*. All these are used for furniture, construction, shade, and sold as timber.

Akok Akas
In discussions with farmers at Akok Akas in the humid forest zone farmers with farms over 25 years indicated that mixed cropping with cocoa and other useful trees has sustained the farms. They enumerated preferred trees on farm as *Citrus sinensis* (plants for sale and consumption), *Persea americana* (plants for sale, consumption and shade), *Irvingia gabonensis* (plants for sale, consumption and shade), *Dacryodes edulis* (planted sale, consumption and shade).

Timber trees include *Triplochiton scleroxylon* (for construction, furniture and shade), *Terminalia superba* (moisture retention, construction), *Entandrophragma cylindricum* (for construction, furniture and shade), *Milicia excelsa* (for shade, construction and furniture). All the timber species grow naturally. One of the farmers is planning to establish a new farm with mainly fruit trees and a few timber species due to the income they provide. In a separate discussion with a sharecropper he reiterated that fruit trees are his only preference on the farm since his farm owner always takes the timber species. He mentioned *Persea americana* and *Citrus sinensis* as the only fruit trees he has at the moment.

Mimetalla
In the village of Mimetalla still in the humid forest zone, two farmers, a male and female were interviewed. The male inherited a 20 year-old farm from his father and has maintained the species diversity of the farm since he claims he obtains income throughout the year compared to if it were only one crop. He

said that for instance his cocoa fruit produces only once a year so he depends on the other trees to meet his financial obligations. Trees that he has and prefer on the farm are *Dacryodes edulis* (planted for sale, consumption and shade), *Irvingia gabonensis* (sale, consumption and shade), *Mangifera indica* (sale, consumption and shade), *Citrus sinensis* (sale, consumption and shade), *Elaies guinensis* (sale and consumption). Timber trees include *Milicia excelsa* (construction and shade) and *Triplochiton scleroxylon* (construction and shade).

The female farmer's farm is 30 years old and her interest is on the fruit trees even though she appreciates the role that the timber species components play. The trees preferred are *Persea americana* (planted for consumption, sale and shade), *Dacryodes edulis* (planted for sale, shade and consumption), *Mangifera indica* (planted for sale, shade and consumption), *Irvingia gabonensis* (natural regeneration for sale, consumption and shade), *Elaies guinensis* (natural regeneration for sale and consumption), *Cola nitida* (natural regeneration for sale), *Tetrapleura tetraptera* (natural regeneration for medicine), *Alstonia boonei* (natural regeneration for medicine), *Antrocaryon klaineanum* (natural regeneration for medicine), *Cylicodiscus gabunensis* (natural regeneration for medicine), *Entandrophragma cylindricum* (natural regeneration for timber), *Terminalia superba* (natural regeneration for medicine) and *Milicia excelsa* (natural regeneration for medicine).

5.3 Preferred Trees in Cocoa Growing Systems in Cameroon

Indigenous and exotic fruit trees dominate preferred tree species in the cocoa growing systems in Cameroon (table 5). This is due to a vibrant market that exist locally and also across borders with Nigeria and Gabon. Farmers interviewed reiterated that the economic contribution of these species in the off season makes it important for them to inter plant such species in the system. As a support for farmers' preferences research in the country has been very focused on the socioeconomics and ecology of these indigenous species.

Table 5: Preferred species in cocoa in Cameroon

Most preferred species	Number of sources mentioning species (n=16)	Number of research sources mentioning species (n=3)	Traditional mode of farmer tree propagation
Dacryodes edulis	16	3	Natural regeneration, planted seed
Irvingia gabonensis	16	4	Natural regeneration, planted seed
Persea americana	12		Planted seed
Ricinodendron heudelotti	12	4	Natural regeneration
Citrus sinensis	11		Sown seed
Mangifera indica	11		Sown seed
Milicia excelsa	11		Natural regeneration
Triplochiton scleroxylon	11		Natural regeneration
Cola nitida	10	1	Natural regeneration, planted seed
Elaies guinensis	10	1	Sown seed
Garcinia kola	10	3	Natural regeneration
Entandrophragma cylindricum	9		Natural regeneration
Terminalia superba	8		Natural regeneration
Ceiba pentandra	8		Natural regeneration
Citrus reticula	8		Sown seed
Mansonia altissima	8		Natural regeneration
Citrus grandis	7		Sown seed
Pycnanthus angolensis	7		Natural regeneration,
Khaya ivorensis	6		Natural regeneration,
Lovoa trichilioides	6		Natural regeneration,
Markhamia lutea	6		Natural regeneration,
Baillonella toxisperma	3		Natural regeneration,
Alstonia boonei	2		Natural regeneration,

Sources: ICRAF, IRAD, and CIFOR research recommendations, Duguma *et al*., (2001), Sonwa (2004), Gockowski *et al*. (2004), Zapfack *et al*. (2002), Gockowski and Dury, (1999), and farmer interviews.

6 Trees and Cocoa in Nigeria

Cocoa was introduced in Nigeria in 1874 and despite its varying fortunes, cocoa plays a significant socio-economic role in the country (Ayoola *et al* 2000). Nigeria used be the second leading producer in the world, but due to a combination of factors its production has dwindled over time and Nigeria is currently the fifth largest producer after Côte d'Ivoire, Ghana, Indonesia, and Brazil (ICCO, 2003). According to Ayanlaja (2000) cocoa production declined from 310,000 tonnes in the 1960s to the current production level of 160,000 tonnes despite increase in land area, fertiliser and insecticides application, and the introduction of high yielding F_3 Amazon varieties.

The causes of decline in production have been attributed to the Nigerian civil war in the mid-1960s and the oil boom, which led to the neglect of cocoa due to a shift in labour from cocoa farms to the industrial sector (Ayoola *et al* 2000). At the same time farmlands were exploited for other resources, mainly food crops. This caused considerable deforestation and land degradation, making the land unsuitable for cocoa production because of the depletion of nutrients, loss of organic matter, and deterioration of soil physical properties (Ayanlaja, 2000; Ayoola *et al.,* 2000).

According to Ayanlaja (2000), future success of cocoa in Nigeria depends on the introduction of an ecologically prudent farming system, which can prevent soil degradation - one that increases soil organic matter but employs less external inputs. Researchers like Agboola (1987), CRIN (1995) and Adeyemi (2000) report on the diversified nature of cocoa farms in Nigeria and the importance of shade and shade trees in cocoa cultivation.

Cocoa currently occupies a total area of 700,000 ha of arable land (Fasina, 1999) and cultivation is confined in 3 main ecological zones:

- Ideal cocoa climate ecology – Ondo, Ekiti, and parts of Oshun States in the Ilesha Region. Here there is rainfall of about 2000-2500 mm per annum;
- Ideal cocoa soil ecology – Cross River State (deep soil). Rainfall is in excess of 4000 mm per annum and;
- Marginal ecology (Southern Guinea Savannah) – Ibadan, Kwara, Ogun, and larger parts of Oshun States.

6.1 Institutions and Cocoa in Nigeria

Cocoa Research Institute of Nigeria, Cross River State Cocoa Board and Forestry Development Department, Tree Crop Unit, Ondo State Ministry of Agriculture, and the STCP conduct work on trees in cocoa growing systems in Nigeria.

Cocoa Research Institute of Nigeria (CRIN)
Contact: Mr. A.O. Olaiya (Senior Research Officer – Agronomy) CRIN, Email: alikhlasolaitan@yahoo.com: Telephone: + 234 8034 105252

Cocoa Research Institute of Nigeria is the government appointed institution with the mandate to conduct research on the following tree crops, oil palm, cocoa, cashew, coffee, tea, and cola (both *nitida* and *acuminata*). CRIN works on cocoa establishment, cocoa farming system, soil nutrition, cocoa farm rehabilitation, and sustainable cocoa systems. CRINs role in research has been to determine the adaptability of these crops in association with cocoa. Intercropping of these tree crops in complex farming systems have been researched since the 1960s.

One of such trial was established in 1965 at the Gambari Experimental Station of CRIN of F_3 Amazon cocoa and oil palm planted at 1.55 x 1.55 m and 9 x 9 m respectively (Adenikinji *et al.,* 1991 see annotated bibliography). The experimental design was randomised block design of six blocks and three treatments. The treatments consisted of the following:

- Control: pure stands oil palm containing 81 palms and 1995 cocoa stands per hectare
- Avenue planting containing one line in three of oil palm omitted and the space planted with cocoa resulting in 81 palms and 1688 cocoa stands and
- Hollow Square treatment: created by omitting one palm out of each square of nine palms planted with cocoa resulting in 99 palms and 1600 cocoa stands per hectare.

Results for annual potential yield of cocoa between 1968/79 has been reported earlier (Kolade, 1986; Onwubuya, Iremiren and Kolade, 1981; *cf.* Adenikinji *et al.,* 1991). However, Adenikinji and Afolami *et al.,* (1991) found that intercropping of F_3 Amazon and oil palm using the Hollow Square arrangements appears to be a viable option for the ecological zone comprising Oyo State and its environs.

In another trial researchers in CRIN have been investigating the appropriate planting distance and densities of suitable intercropping cocoa with *Cola* and *Citrus* for sustainable productivity at the Ajassor Substation Tropical Rainforest Zone since 1995 (Famaye *et al.,* 2003 see annotated bibliography). The experiment, which was established in 1995, is a randomised complete block design with eight treatments and three replicates. The treatments are as follows:

- Cocoa planted 3 x 3 m planted with Cola/Citrus planted at 24 x 24 m making 17 trees/ha each for Cola and Citrus
- Cocoa planted 3 x 3 m planted with Cola/Citrus planted at 24 x 12 m making 34 trees/ha each for Cola and Citrus
- Cocoa planted 3 x 3 m planted with Cola/Citrus planted at 21 x 10.5 m making 45 trees/ha each for Cola and Citrus
- Cocoa planted 3 x 3 m planted with Cola/Citrus planted at 12 x 12 m making 69 trees/ha each for Cola and Citrus
- Cocoa planted 3 x 3 m planted with Cola/Citrus planted at 9 x 9 m making 123 trees/ha Cola and Citrus
- Sole Cola planted at 7.5 x 7.5 m making 177 plants/ha
- Sole cocoa planted at 3 x 3 m making 1,111 plants/ha
- Sole Citrus planted at 7.5 x 7.5 m making 177 plants/ha

Initial results show that growth and development of intercropped cocoa, cola, and citrus tend to be better at large spacing and lower plant population densities of 17 plants/ha each of cola and citrus compared to smaller spacing and higher plant population of 69 plants/ha. In addition there were no deleterious or allelopathic effects on any of the component crops in the poly-cultured cocoa, cola and citrus system. However, data on yield is still on going.

Cross River State Cocoa Board
Contact: Mr. D.O. Otu, Forestry Headquarters, PMB 1009 Calabar, Cross River State.

Since 1988 the Cross River State Cocoa Board in collaboration with the Forestry Development Department have been conducting research in the cocoa Tuangya plantation termed the Cross River State North Forest Reserve Cocoa Project. The objective is to investigate the synergistic effect of *Triplochiton scleroxylon, Tectona grandis, Nauclea derrichii,* and *Terminalia ivorensis* on cocoa establishment and yield. Results from this research were not available when compiling this report.

Tree Crop Unit, Ondo State Ministry of Agriculture
Contact: Mr. J.K. Adekagun (Chief tree crop officer), Ondo State Government, Ministry of Agriculture and Rural development (MARD), Akure.

The Tree Crop Unit (TCU) at the Ondo State Ministry of Agriculture has the mandate from government to produce and distribute planting materials for tree crops like oil palm, *Cola nitida* and *acuminata*, cocoa, cashew, and rubber. These operations are carried out by establishing community nurseries and facilitating material distribution to farmers. There are 5 seed gardens in the state situated in Ibula, Owena, Otu, Alabe, and Ilu-Oluja. Planting material for cocoa is developed by hand pollination, a technology prescribed by CRIN.

In an interview with the Chief Tree Crop Officer, he reiterated that TCU has developed enormous skills over time on nursery management and propagation techniques for the above mentioned crops. At the moment they are developing a framework to collaborate with STCP-Nigeria to establish a community based, participatory group nurseries in their working area.

Sustainable Tree Crop Programme (STCP)- Nigeria
Contact: Dr. Chris Okafor (Pilot Project Manager), Email: c.okafor@cgiar.org, Telephone: + 234 8033801225/8033815904

The STCPs pilot programme in Nigeria is geared toward providing a framework for designing, testing, and assessing the impact of intervention strategies for developing environmentally sustainable and socially responsible cocoa production systems. Its activities are aimed at the following:

- Strengthening farmers co-operatives;
- Developing and disseminating productive-enhancing technologies with low negative environmental impact through FFS;
- Developing useful market information systems that are sensitive to markets

to facilitate agro-enterprise development and;
- Promoting socially responsible cocoa cultivation devoid of child labour.

As of September 2004 activities of STCP-Nigeria have been going on only in Ondo State, an area which produces almost 60% of Nigeria's cocoa (Akinwale, 2000). Currently STCP is backstopping some 42 FFS involving 1200 farmers. STCP at the moment is serving as a platform for the dissemination of available research results in the area of trees in cocoa and is working in collaboration with CRIN to promote the concept of active cocoa agroforestry in their working area.

6.2 Farmer and cocoa in Nigeria

Cross River State
In an effort to obtain farmers opinion on preferred tree species in the cocoa agroforests and reasons behind this idea interviews were conducted with contact farmers identified by the CRIN experimental station in the Ikom Local Government Area in Cross River State.

An interview was held with Mr. Nicolas Ekuri Njos, a 68-year-old farmer who lives on the farm with his family in Agbokim. He has been farming all his live and has over 26 acres of cultivated land. He believes in mixed cropping since according to him it averts risks and also allows for proper space utilisation and brings various sources of income to the household. Knowledge of time and spatial arrangement was acquired through many years of owned observations and practise. He intercrops various crops on his cocoa farm. The following are some valuable trees preferred and identified on his cocoa farm.

- *Citrus sinensis* planted in alternative rows with cocoa. The citrus is sold for income, consumed at home and used as temporary shade until the cocoa canopy closes. This according to him also signifies a judicious use of space;
- *Irvingia gabonensis* (bush mango) also interplanted with cocoa as both shade tree and also sold for income. This is planted at 1 tree to about 20-30 stands of cocoa. According to him *I. gabonensis* grows rapidly, and in 5-6 years it gives a good canopy, which serves as a good shade for cocoa. In a good season he makes an extra profit of 20,000 Naira (ca. 154 US$)[28] from a single tree;
- Other tree crops interplanted are *Cola acuminata, Persea americana*, *Psidium guajava*, *Dacryodes edulis*, *Garcinia kola* (bitter kola – very difficult to propagate but brings more money and has traditional significance) and *Elaies guinensis*.

Apart from these tree crops he also has quite a number of valuable timber species. These include *Milicia excelsa* which are not planted since the seed bank is reliable, wildlings and sapling are nurtured to promote diversity and wood for construction. *Khaya ivorensis* is deliberately inter planted. He collects seed of this species and sows them in a nursery for future transplanting on cocoa farm. According to him special preference is given to the timber species since they are heavily logged in the area. However, most of these species are useful for the cocoa microclimate, hence the decision to maintain them on farm. In his nursery were over 1000 seedlings each of *Khaya ivorensis* and *Irvingia gabonensis*.

[28]As of sept. 2004 when the interview was made 1 US$ = 130 Naira.

In his explanation for keeping such a complex farming system and not mono-cultured cocoa he indicated that the labour and inputs costs involved in cocoa is enormous. Meanwhile there are no price guarantees for cocoa beans. But with a mixed cropping one can depend on other produce for extra income and also use labour effectively. He also lamented on the lack of government's help in the form of credit facilities. As a result they are exploited by cocoa-buying merchants. This according to him has resulted to low quality of cocoa in the area since farmers are not motivated to go the extra mile for quality when they know they are not going to get any incentive.

In a separate incident, an interview was held with another contact farm, Mr. Anyambe Takon in Okondi. This farmer has been farming with his father in the area and in 1986 he established his own farm. He applies multipurpose planting and inter cropping of cocoa with other useful and valuable tree crops and timber species. According to him cocoa does well in combination with other trees. However, inasmuch as he believes this is true he also knows that there is the problem of competition and stress. So he thins some of the non-cocoa components when necessary.

Some timber trees that he plants or nurture in his cocoa farm are *Terminalia superba* (for shade, timber, and construction, *Lophira alata* (for treatment of malaria), *Milicia excelsa* (collects seed and wildlings for planting). He interplants *Garcinia kola* with cocoa for the extra income since the nuts are very marketable. Also he inter plants *Dacryodes edulis, Persea americana, Irvingia gabonensis,* and *Citrus sinensis*. All these species serve as shade and also provide products that are sold for extra income for the household.

Another interview was held with Chief Ojong Odey who is the chairman of the cocoa farmers in Ekimkae village. He established his cocoa farm in the mid 1950s. With time he has rehabilitated the old farm by selective planting with what he termed 'good materials'. According to him researchers from CRIN have been collecting cocoa germplasm from his farm since 2002, this was corroborated by CRIN[29]. From his observation black pod is the major problem in the area, hence it is very necessary for one to reduce humidity on the farm. This process he said was difficult considering that they are in the humid forest zone. None the less, trees that are useful in combination with cocoa and either preserved or planted are

- *Milicia excelsa* – planted or nurtured for timber and shade;
- *Gmelina arborea* – fast growing species which is planted for shade at places where there is an opening in the canopy, used for furniture;
- *Antiaris* species - planted timber and shade;
- *Lovoa trichilioides* – nurtured or wildlings from nearby forest are transplanted for wood and shade

Other tree species preferred and interplanted on farm include *Irvingia gabonensis* (created nursery and transplants to cocoa farm), *Dacryodes edulis, Citrus sinensis, Mangifera indica, Persea americana*, and *Artocarpus altilis*. Products from these species are consumed, and sold for income.

Lastly another interview was held with Mr. Ogon Mbeku in Bendeghe-Ekim. His

[29] Peter Aikpokpodion (*per. com.*, 2004). Plant Breeder at CRIN

cocoa farm was established in 1982 and has a diverse collection of trees interplanted with cocoa. These include *Milicia excelsa* for shade and timber, *Antiaris* species, *Gmelina arborea, Triplochiton scleroxylon, Garcinia kola*, African Wall nuts, *Elaies guinensis, Irvingia gabonensis, Citrus sinensis, Cola acuminata, Terminalia superba*, *Artocarpus altilis*, *Ceiba pentandra, Dacryodes edulis,* and *Mangifera indica.* The fruit trees according to him bring extra income to the household.

Ondo State

In Ondo State a different approach was used to obtain farmers perspective on preferred trees. Group discussions with participants from STCPs farmer field schools were used.

Discussions were held with 3 farmers (2 women and a man) from the FFS in Onipanu village, which is east of Akure, the State capital. The women had different land titles. One was a widow who inherited the farm from her diseased husband and the other was a sharecropper. According to the widow, her farm has been in existence for the past 60 years. Preferred species on her farm include:

- *Milicia excelsa* – grows naturally and she nurtures it for shade and timber;
- *Cocos nucifera* –planted for shade, sales and home consumption;
- *Triplochiton scleroxylon* –grows naturally and nurtured for shade and timber;
- *Artocarpus altilis* - seed collected and planted for consumption,
- *Citrus sinensis* –planted for sale and consumption and;
- *Cola nitida* –planted for sale.

The sharecropper does not know the age of the farm. However, she prefers the fruit trees on the farm to the timber species. This is due to the fact that she has no rights to the timber trees since they belong to the landowner. According to her the farm owner comes and fells the timber species and destroys her farm. As a result, she maintains only fruit trees and leaves very few timber species for shade. Among the species preferred are

- *Elaies guinensis* – planted for sale and consumption;
- *Citrus sinensis* - planted for sale and consumption;
- *Terminalia superba* – nurtured for shade, especially in the dry season and;
- *Milicia excelsa* – nurtured for shade.

The male farmer has a field established in 1972. Species identified and preferred on the farm include

- *Terminalia superba* – this was first transplanted from neighbour's farm but now he has his own nursery where he propagates own seedlings, they are fast growing and used for shade and sold as timber;
- *Lophira alata* – nurtured for shade;
- *Milicia excelsa* – nurtured for timber and shade;
- *Elaies guinensis* – planted for home consumption;
- African Wall nuts – planted for home consumption and sale;
- *Cola nitida* – planted for home consumption and sale;

- *Mangifera indica* - planted for consumption and;
- *Persea americana* – planted for consumption.

In another group discussion with FFS participants at Wassimi area farmers indicated that their cocoa farms have always been a mixed cropping system since different crops bring different kinds of income and also there is a positive interaction between various crops. Trees preferred on cocoa farm include both fruit and timber trees. These are:

- *Elaies guinensis* - planted for sale and home consumption;
- *Artocarpus altilis* – planted for home consumption;
- *Garcinia kola* – nurtured and planted for sale;
- *Cola nitida* - planted for sale and consumption;
- *Irvingia gabonensis* - planted for sale and consumption;
- *Mangifera indica* – planted for home consumption;
- *Citrus sinensis* - planted for sale;
- *Citrus reticula* - planted for sale;
- *Persea americana* - planted for sale and consumption;
- *Cocoa nucifera* - planted for sale;
- *Milicia excelsa* - nurtured for shade and timber;
- *Heavea brasiliensis* - planted for shade and the wood,
- *Khaya sp.* – nurtured for sale and shade;
- *Terminalia superba* – nurtured for sale and shade;
- *Triplochiton scleroxylon* - nurtured for sale and shade;
- *Entandrophragma sp*. – nurtured for sale and shade and;
- *Mansonia altissima* – nurtured for sale and shade.

6.3 Preferred trees in cocoa growing systems in Nigeria

Farmers in Nigeria just like their counterparts in Cameroon prefer fruit trees with cocoa for the same reason, available market in the country and across its borders.

Table 6: Preferred species trees in cocoa in Nigeria

Most preferred species	Number of sources mentioning species (n=10)	Number of researched species sources mentioning species (n= 3)	Traditional mode of farmer tree propagation
Elaies guinensis	8	2	Natural regeneration, planted seed
Milicia excelsa	8		Natural regeneration
Citrus sinensis	7		Planted seed
Cola nitida	6	2	Natural regeneration, planted seed
Irvingia gabonensis	6	1	Natural regeneration, planted seed
Persea americana	5		Planted seed
Terminalia superba	5		Natural regeneration
Dacryodes edulis	5	1	Natural regeneration, planted seed
Garcinia kola	5	1	Natural regeneration, planted seed
Artocarpus altilis	4		Natural regeneration
Cola acuminata	4	2	Natural regeneration, planted seed
Mangifera indica	4		Sown seed
Triplochiton scleroxylon	4	1	Natural regeneration
Anacardium occidentale	3		Sown seed
Lovoa trichilioides	2		Natural regeneration
Antiaris spp.	2		Natural regeneration
Cocos nucifera	2		Sown seed
Gmelina arborea	2		Sown seed
Heavea brasiliensis	2		Sown seed
Khaya ivorensis	2		Natural regeneration
Lophira alata	2		Natural regeneration

Sources: CRIN, CIFOR, ICRAF research recommendations, the Cross River Cocoa Board project, Agboola (1987), and farmer interviews.

7 Way forward in future work on preferred tree species in cocoa growing systems in West Africa

This work was initiated with the aim of providing an overview of organisations and institutions working on cocoa and shade tree research and their respective activities. In order to achieve this, a study tour was conducted in Ghana Côte d'Ivoire, Cameroon, and Nigeria. In these countries interviews were held with NGO staff, key informants, and research scientists from research institutions. Also, informal discussions were held with individual cocoa farmers and farmer co-operatives, as well as field visits and observations. In the process, preferred trees by farmers and research recommended trees for cocoa cultivation in the various countries were documented. Preferred tree species that cut across almost all the four countries include *Milicia excelsa*, *Terminalia superba*, *Citrus sinensis*, *Elaies guinensis*, *Cola nitida*, *Mangifera indica*, *Triplochiton scleroxylon*, *Alstonia boonei, Recinodendron heudelotti*, *Cocos nucifera*, *Khaya ivorensis and Persea americana*.

The results from the preferred trees should be used cautiously as there is probable over-lap between research sources and likely recycling of farmer-based information between different groups. Therefore, while this information provides a good starting point, it does highlight the need for a systematic, multi-regional survey to determine farmers' selection criteria on preferred species, which can be coupled with rigorous research on the autoecology and compatibility of valuable trees with cocoa.

As indicated in previous sections, cocoa production plays a significant role in the economies of Ghana, Côte d'Ivoire, Cameroon, and Nigeria even though its cultivation has been alleged to have compromised a large portion of the natural forest since farmers expand into forest areas to increase production. None the less, the integration of suitable and valuable trees at various stages and levels of the cocoa farm, is a practice that is widespread in smallholder cocoa farms.

A practice, which according to farmers provides them with extra income and services, while environmentalists credit it for sustaining and maintaining biodiversity in this part of the world. However, very little work has been dedicated to the improvement of this practice. While farmers are concerned about exploiting all the necessary components in the system and their interactions to maximise income and reduce risks, research has focused heavily on parts of the system, which is in most cases the improvement of the cocoa tree.

This has resulted in a situation where research recommendations serve as a barrier to farmer innovation instead of improving local knowledge. For instance in Ghana and Côte d'Ivoire, research recommendations have come out with a long list of trees species that are claimed to be incompatible and for that matter should be eliminated from cocoa farms since they serve as alternative hosts for pests and diseases. Most common on the list are *Ceiba pentandra* and *Triplochiton scleroxylon*. In a conflict of interest, these species happen to be among the most preferred species of farmers due to their economic values. Hence, it was not uncommon to find stands of these species on cocoa farms even though there is a campaign against them.

Similarly in Nigeria and Cameroon, a lot of work has been put into the domestication of indigenous fruit trees due to available local and international markets but virtually nothing has been done on forest timber species, which farmers also prefer. New propagation methods in addition to natural regeneration and seedlings have been developed for some of these indigenous species particularly *Dacryodes edulis, Irvingia gabonensis, Ricinodendron heudelotti,* and *Garcinia kola*, giving them shorter gestation period, reduced height and relatively smaller canopy. These specifications place these domesticated species in the same stratum as the cocoa tree in the system, hence, the concern that competition between the various species will be increased rather than decreased. The challenge therefore is how to arrange these various species in time and space such that competition between trees is reduced significantly in the cocoa agroforest.

In the light of the above, future research and development in cocoa agroforestry and the prospects of increasing cocoa yield in the face of dwindling forests may occur through:

1. Diversified species configuration - intensification through tree species diversification;

2. Shortening of fallow periods by using appropriate tree species for effective farm rehabilitation and land recycling.

In the first, research should consider the cocoa tree as one of many tree species in the system and test various farmer-tree-combinations and come out with common but useful configurations. In the process, the autoecology of most common preferred species should be studied on-farm and appropriate spatial design developed to effect appropriate *neighbour* tree densities, spacing and arrangements of the various species in time and space.

The second approach involves land recycling through farm and fallow rehabilitation. In this approach various exotic and native agroforestry species may be used in on-farm fallow experiments. This process should involve the development of random mixtures of various exotic and native species for soil fertility regeneration and the creation of appropriate microclimate for cocoa cultivation. These experiments are being carried out in Côte d'Ivoire on very small-scale and need to be encouraged and scaled up for a broader impact.

The current body of work aimed at improving sustainable cocoa cultivation with shade trees in Ghana, Côte d'Ivoire, Cameroon, and Nigeria by governmental and international research institutions, and NGOs is extensive and growing in scope. However, inasmuch as the research and development work conducted on country basis are important, there is the need to consider the possibility of a regional forum that will co-ordinate and promote the sharing of experience and information. This may be done through the creation of a regional network of scientists, who will source and pull resources together, for a common goal (an initial list of such a network is presented in appendix 2). In this way various countries will benefits from research from other countries in the region, which is not the case at the moment since most research are site specific.

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Appendix 1. Annotated bibliography of shade in cocoa

This annotated bibliography consists of abstracts of papers and books, which touch on the subject of trees and shade in cocoa cultivation. Copies of these papers and books can either be found with the respective institutions highlighted in this exercise, or at Forest and Landscape-Denmark.

Trees and cocoa

Abbiw, D. K. 1990. Useful Plants of Ghana: West African uses of wild and cultivated plants. Kew (England). I.T.P. Royal Botanical Gardens.

Summary
A section of this book summarises the wide variety of edible wild fruits from Ghana's forests.

Adenikinju, S.A., C.A., Afolami and O. Ajobo, 1991. Preliminary comparative analysis of cocoa yield under treatments in combination with oil palm in Nigeria. Ghana Journal of Agricultural Science, 24-27, 37-41.

Summary
The study investigates the pattern of cocoa yield when cocoa is grown in combination with oil palm in specific layout patterns. The experimental design of six blocks and three treatments each containing cocoa and oil palm. The three treatments were Control, Avenue planting, and the Hollow square arrangements. Equal size area of land was used for cocoa in each plot. The experiment was started at Cocoa Research Institute of Nigeria, at the old Gambari experiment Station in 1965 in collaboration with the Nigerian Institute of Oil Palm Research. The data in pods and dry weight beans per plot analysed covered the period from 1968/69 to 1978/79. The method used was the analysis of covariance. The adjusted mean yield of each treatment for the Control, Avenue and Hollow square arrangements was in proportion 1.000 : 1.183 :3.515 respectively. There were significant differences among the treatments, with the Hollow square arrangements > Avenue >Control at $P<0.05$.

Ahenkorah, Y., Halm, B.J., Akrofi G.S., 1979. Some agronomic factors affecting cocoa rehabilitation in Ghana. Proceedings of the 5th International Cocoa Research Conference, Ibadan, Nigeria. Pp. 199-203.

Summary
This paper deals with the agronomic factors affecting cocoa rehabilitation in Ghana. Reasons have been given for the need to rehabilitate the cocoa industry in Ghana. The fundamental problems causing the declining trend in the cocoa production have been identified. Some of the constraints are sociological, economic and legal. Solutions to the agronomic problems have been discussed. Neglect of good farm husbandry is one of the major causes in the current low yields of cocoa.

Ahenkorah, Y., 1979. The influence of environment on growth and production of the cacao tree: soils and nutrition. Proceedings of the 7th international Cocoa Research Conference, Doula, Cameroun. Pp. 167-176.

Summary
The soils and nutrition aspect of the Conference theme: 'the influence of environmental growth and production of the cocoa tree', was reviewed and discussed. The main determining factors of good cocoa soils are the rate of release of soil moisture and the status and availability of phosphate. It was noted that cacao nutrition should always be considered in relation to the overhead shade conditions. The need to standardise soil available phosphorus and quantify shade was stressed. A multi-disciplinary and inter-institutional approach to solving the complex problem of shade and nutrition interaction is recommended.

Aitken, J.D., Donaldson, D., Gardiner, L., Harrison, M., Massey, P., Stirrat, R.L., Tout, G. 1992. Evaluation of the SODEFOR Forestry Project Côte d'Ivoire. Evaluation Report EV520.

Summary
This report evaluates the SODEFOR Forestry Project that was implemented in two phases between 1980 and 1990. The objectives of the project were to establish timber plantations in place of partially exploited forest; effective management of SODEFOR's existing plantation area and; institution building. It mentions nine valuable timber species that were planted in the plantation in phase I i.e., early 1980s

Akrofi, A.Y., Appiah, A.A., Opoku, I.Y., 2003. Management of Phytophthora pod rot disease on cocoa farms in Ghana. Crop Protection 22: 469-477.

Summary
From 1991 to 1997, field observations on trials involving the use of metalaxyl and copper-based fungicides were made on farmers' farms in four *Phytophthora megakarya* affected cocoa growing regions of Ghana to control *Phytophthora* pod rot disease. Data on farm management practices, cocoa and shade tree types and densities, plot sizes, yield, land tenure and labour arrangements for farm operations, disease incidence and profitability of disease control were collected. Lower disease incidence and higher yields were recorded on fungicide-treated plots than on the untreated plots. The profitability of fungicide application depended on the level of farm management, nature of land tenure and labour arrangements for farm operations. The challenges involved in conducting trials with active participation by farmers are discussed. The involvement of farmers in the development of the disease control programme is crucial for subsequent adoption of the technology.

Alvim, P.T., 1979. Ecological and physiological determinants of cacao yield. Proceedings of the 5th International Cocoa Research Conference, Ibadan, Nigeria, pp. 25-38.

Summary
Based on a literature review and on some studies of the ecophysiology of the cocoa tree, an attempt is made to define (a) the ecological conditions most suitable for growing this crop and (b) the physiological processes that control its yield, in terms of both total fruit production and the distribution of the crop during the year. The ecological factors discussed are: temperature, rainfall, shade, wind, soil physics, soil chemistry, and the interaction among these factors, especially shade and soil fertility. Attention is called to the role played by shade trees in protecting the cacao plants against wind damages. Data are also presented comparing the climatic conditions of different cacao producing areas.

With regard to the physiological determinants of yield, emphasis is placed especially on the architecture and size of the leaf canopy (leaf area index), the potential photosynthetic production of the plant, and on the partitioning of photosynthates between the fruits and other parts of the plants. Factors responsible for fruit losses by physiological wilt are also discussed.
On the basis of data so far reported, it appears that, with present cultivars the maximum potential yield of cacao is around 3.5-4 tons/ha/year.

Amanor, K.S., 1996. Managing trees in the farming system: The perspective of farmers. Forest Farming Series No. 1, Forestry Department, Ghana.

Summary
This book is the result of a multi-regional survey of farmers and their farming systems, including cocoa fields. It provides an in-depth look at farmers' perspective management strategies, particularly with regard to managing seedbeds and coppice systems in order to create appropriate shade environments for the production of food and cash crops. The book also focuses on many of the associated tree species within these systems.

Ameyaw Oduro, C., Osei-Bonsu, K., Tetteh, J.P., 2003. Traditional cocoa agroforestry: 2. Indigenous selection criteria for shade trees on cocoa farms in a typical cocoa growing district of Ghana. 14th International Cocoa Research Conference, Accra, Ghana. 13-18 October.

Summary
Sixty cocoa farmers were interviewed in the Osino District of the Eastern Region of Ghana to determine the selection criteria used to manage forest tree shade on their farms. The major reason for eliminating certain tree species during land preparation appeared to be to create a congenial environment for the establishment of food crops for the farmer. Sixty three percent of farmers interviewed gave this as the main reason for grubbing some forest shade trees. Indigenous farmer knowledge of the tree species however identified tree species which are not compatible with food crops and some which serve as alternate hosts for pests and diseases of cocoa. In established cocoa farms, the main reasons (55% of respondents) for eliminating forest tree species was concerned with shade reduction and improving the microclimate for the cocoa. Only a few farmers were able to identify trees with disease (9%) or pest associations (9%) whilst another 9 percent identified some trees which were incompatible with cocoa on account of making the soil too dry or causing yield reduction in cocoa. Up to nine percent of the trees felled from cocoa farms were used for household construction, for timber or for canoe construction. Other reasons for eliminating some tree species was to reduce the incidence of rodent attack (4%) or reduce damage to cocoa trees from falling branches (1.8%). A tree species like *Cola gigantia* was noted to create a nuisance by causing a lot of seedling sprouts and producing litter which takes too long to rot. Farmers' knowledge of the morphology of desirable trees was impressive. Various tree species were retained on cocoa farms for providing good adequate shade throughout the year (40% respondents). Contrary to expectations, a high proportion of the trees on cocoa farms which can be exploited for timber are consciously left by farmers. Indigenous knowledge also protects species with multipurpose uses for firewood, gun butt construction, fruit for income generation, soil improvement or even to attract snails for farmers' use. Undesirable trees perceived by farmers as having other beneficial effects are inadvertently conserved in the cocoa system. Further dialogue with farmers should be undertaken on which tree species should be eliminated or retained to make the ecosystem sustainable for cocoa production.

Ampofo, S.T. and Bonaparte, E.E.N.A. 1981. Flushing, flowering and pod setting of hybrid cocoa in a cocoa shade/spacing/cultivar experiment. Proceedings of the 7^th^ International cocoa Research Conference, Cameroon. Pp 103 – 108.

Summary

Recording of flushing, flowering and pod-setting in cultivar *c.* (T85/799 x S84) of shade/spacing/cultivar experiment were carried out for four years under shaded and unshaded conditions and at close (1.7 x 1.7 m) and wide (2.4 x 2.4 m) spacing. Records were taken on twenty randomly selected trees on each of four plots and the records summarised on weekly basis. Results show that the cultivar tended to flush with similar periodicity from year to year but the periods of flushing peaks differed slightly from year to year. Intensity of flushing also differed from year to year within the same plot and between plots. There were generally five flushing peaks in a year with fairly dormant period in August. The hybrid cocoa was found to produce flowers all the year round in varying degrees although there was usually a major flowering season occurring between April and July. The pattern of pod-setting closely followed the pattern of flower production. The effect of shade and spacing on the periodicity of flushing, flowering and pod setting was negligible but the onset of flushing was delayed slightly by shade. Shading and close spacing suppressed both flowering and pod setting. These results have been discussed in relation to microclimatic records taken in the plots and it was concluded that although the periodicity of flushing and flowering may be controlled by endogenous factors, microclimatic parameters influence and modify these responses.

Anim-Kwapong, G.J. 2003. Potential of some Neotropical Albizia species as shade trees when replanting cocoa in Ghana. Agroforestry Systems 58: 185-193.

Summary

The Cocoa Research Institute of Ghana has embarked on studies to support the replanting of cacao (*Theobroma cacao* L) in areas, which previously carried the crop but are now degraded. A key component of the studies is to identify fast growing tree species capable of ameliorating degraded soils and ultimately providing suitable shade for cacao. A screening trail involving ten Albizia species in a randomized complete block design experiment was therefore initiated in 1996 to evaluate growth rate, leaf biomass production, carbon and nitrogen contents and decomposition rates. Over a four-year period, *Albizia adenocephala, A..guachapele, A. niopoides, A. plurijuga, A. saman* and *A. tomentosa* show promising results, with 12.2 to 14.5 m height and between 12.4 and 22.4 cm stem diameter (DBH). Crown diameter ranged between 6.1 and 10.1 m, with light transmission through crowns averaging 50-65% of full sunlight throughout the year. Half-yearly leaf biomass production ranged between 3 and 10 t ha ^{1} from each coppicing. Half-life for carbon and nitrogen release from leaves of the six species averaged 31.0 and 32.0 days respectively. This short-term release of C and N is an indication of the quality of the leaf pruning. These species can provide early ground cover, appropriate shade, N and organic matter requirements for re-establishing cacao on denuded and degraded lands.

Appiah, M. 2003. Domestication of an indigenous tropical forest tree: silvicultural and socio-economic studies of Iroko (Milicia excelsa) in Ghana. PhD dissertation presented to the University of Helsinki. Tropical Forestry Reports No. 25.

Summary

This thesis analyses and designs incentives to promote co-partnership in resource management in the high forest zone in western Ghana. It also studies growth and other traits to help facilitate selection of suitable populations of *Milicia excelsa* for utilisation on farms.

Asare, R. 1999. Managing trees on farm levels: impact on crop production: a case study of the joint forest management project, Gwira-Banso, Ghana. M.Sc. Thesis submitted to KVL, 1999. 131 pp.

Summary
This thesis assesses trees on farmland and acknowledges farmers' in-depth knowledge on trees on farm and lists farmer preferred trees and reasons. It goes on to conclude that farmers enticement to manage trees on farm are dependent on (1) the beneficial effects of trees on crops, and (2) the economic value of the trees in relation to crops.

Asomaning, E.J.A., Kwakwa, R.S., Hutcheon, W.V., 1971. Physiological studies on an Amazon shade and fertiliser trial at the Cocoa Research Institute, Ghana. Ghana Journal of Agriculture Science 4:47-64.

Summary
Data on flushing, flowering, pod setting, cherelle wilting and production of mature pods under various regimes are presented and analysed to give information on the physiological basis of yield differences. Deshading and NPK fertiliser application promoted flushing and significantly increased flower numbers. Most cherelles set on lightly shaded fertilised cocoa. Pod setting pattern was not reflected in that of mature pod production, the latter being markedly altered by the degree of cherelle wilt. Final yield bore no relation to the degree of flowering and setting, and was apparently limited by the nutritional status of the tree. Deshading and fertiliser application effected a 10% and 2% reduction in wilt respectively. Possible mechanisms of cherelle wilt are discussed critically, the present result suggesting the involvement of carbohydrates and possibly minerals. Seasonal patterns of physiological behaviour and climate are presented and the phenology of cocoa is discussed in detail. Flushing occurred in cycles throughout the year, apparently being promoted be adequate soil moisture and high temperature or radiation. Flowering pattern could not be readily explained, though, in general, it corresponded with that of rainfall. Pod setting and cherelle wilting accentuated earlier flower peaks to give very marked cropping periods.

Assiri, A.A., O. Deheuvels, B.I. Kebe, and P. Petithuguenin. 2003. Farmer techniques for cocoa rehabilitation in Côte d'Ivoire. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary
Created by the dynamics of extending the pioneer fronts by felling and burning forests, the Ivorian cocoa tree stocks have progressed historically from the East to the West of the country. Today, only vestiges remain of the virgin forest which has been denuded by this phenomenon for over a century. In this framework, a research-action project led by the National Centre for Agronomic Research (CNRA) and the Centre for the Development of International Co-operation in Agronomic Research (CIRAD) is attempting to perfect alternative planting techniques on newly-broken forest land.
Amongst techniques already known, rehabilitation and 'rejuvenation' of cocoa trees are studied under this research programme. A definition of 'rehabilitation' is proposed firstly. The second method employed relies on knowledge sharing. This involves identifying cocoa rehabilitation techniques practised in rural environments and comparing them with those already perfected by research, the final objective being to validate some of them jointly by researchers and producers.
Over 1,000 farmers were therefore surveyed over 4 months in 7 representative sectors of the main cocoa producing areas. These surveys showed that rehabilitation methods in the widest sense, from soil regeneration to different techniques for cutting back and pruning, are

employed by less than 15% of the farmers' questioned. A detailed agro-economic description of existing farmer rehabilitation techniques could also be produced using these surveys. The decision rules applied by producers in the choice of rehabilitation method are analysed based on these elements. It appears that rehabilitation initiatives most frequently involve plantations that have been temporarily abandoned rather than plantations reaching the end of their life, which are usually maintained until their spontaneous transformation into bush fallow or plantations for other perennial crops, particularly rubber, oil palm or coffee depending on the region.

Beer, J., Muschler, R., Kass, D. and Somarriba, E. 1998. Shade management in coffee and cacao plantations. Agroforestry systems 38: 139 – 164.

Summary
Shade trees reduce the stress of coffee (*Coffee* spp.) and cacao (*Theobroma cacao*) by ameliorating adverse climatic conditions and nutritional imbalances, but they may also compete for growth resources. For example, shade trees buffer high and low temperature extremes by as much as 5 °C and can produce up to 14 Mg ha ^{1} yr ^{1} of litter fall and pruning residues, containing up to 340 kg N ha ^{1}. However, N_2 fixation by leguminous shade trees grown at a density of 100 to 300 trees ha ^{1} may not exceed 60 kg of N ha ^{1} yr ^{1}. Shade tree selection and management are potentially important tools for integrated pest management because increased shade may increase the incidence of some commercially important pests and diseases (such as *Phytophthora palmivora* and *Mycena citricolor*) and decrease the incidence of others (such as *Colletotrichum gloesporioides* and *Cercospora coffeicola*). In Central America, merchantable timber production from commercially important shade tree species, such as *Cordia alliodora* is in the range of 4-6 m^{3} ha ^{1} yr ^{1}.
The relative importance and overall effect of the different interactions between shade trees and coffee/cacao are dependent upon site conditions (soil/climate), component selection (species/varieties/provenances), below ground and aboveground characteristics of the trees and crops, and management practices. On optimal sites, coffee can be grown without shade using high agrochemical inputs. However, economic evaluations, which include off-site impacts such as ground water contamination, are needed to judge the desirability of this approach. Moreover, standard silvicultural practices for closed plantations need to be adapted for open-grown trees within coffee/cacao plantations.

Dakwa, J.T., 1976. The effects of shade and NPK fertilisers on the incidence of cocoa black pod disease in Ghana. Ghana Journal of Agriculture Science 9: 179-184.

Summary
The investigations were based on Amazon shade and manurial experiment conducted at the Cocoa Research Institute, Tafo, Ghana, between 1965 and 1972. Black pod incidence was consistently and significantly higher on plots with medium (S_1) or dense (S_2) overhead shade than on plots without shade (S_0); differences between S_1 and S_2 were not significant. Under the same shade regime, disease fluctuated from year to year, this being associated with variable weather, particularly the distribution of rainfall. Direct fertiliser effects were variable; they were generally small but sometimes significant. The number of black pods were higher on plots receiving fertilisers than on control plots and this may be attributed to the higher yields following fertiliser application. Disease on plots receiving NP or PK fertilisers was higher on control plots, but infection on plots with NK was lower than on the control plots. The N x P

x K interaction significantly increased disease incidence in 1965/66 and 1966/67 minor crops (April-August) but reduced incidence in the main crops (September-March). Black pod disease on plots receiving the three elements were sometimes lower than on plots receiving any two. None of the shade x fertiliser interactions except the shade x N x P x K interactions, significantly increased disease. The four-factor interaction effects were significant only in 1965/66, 1966/67 and 1967/68. It is suggested that reports on the incidence of black pod disease should include both percentage and the corresponding yield so that the number of pod diseases can be appreciated.

Deheuvels, O., A.A. Assiri, P. Petithuguenin and B.I. Kebe, 2003. Farmer techniques for cocoa planting and replanting in Cote d'Ivoire. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

Since its inception into Côte d'Ivoire at the end of the 19th century, cocoa production has increased in the main through planting areas being extended through forest clearance. These pioneer front dynamics have made the country the leading producer for the last twenty-five years. But today, Ivorian cocoa culture viability is comprised by the depletion of forest reserves and therefore of the 'forest rent' provided by clearing and burning them.

A research-action project has been initiated by the National Centre for Agronomic Research (CNRA) and the Centre for the Development of International Co-operation in Agronomic Research (CIRAD) to attempt to find answers to this pressure. One of the project's avenues of research involves knowledge of farmer techniques for replanting on land not previously covered by forest.

Farmer techniques for cocoa planting on forest land and replanting on land previously given over to different crops have been surveyed, therefore, involving 650 farmers questioned over 5 months in seven representative sectors of the main cocoa producing areas in the country. Following a suggested definition of the terms 'planting' and 'replanting', existing farmer techniques are described in agro-economic detail in the first instance. The decision rules applied by the producers on the choice of land, planting material, propagation and installation technique methods are analysed based on these elements. Lastly, technical planting itineraries are compared with those use for replanting to demonstrate the adaptations by producers when planting cocoa trees on land not previously covered by forest. The most suitable of these innovative techniques will be adopted and validated at a research station and in a farmer environment. This is a knowledge-sharing approach adopted between researchers, farmers and developers.

Deheuvels, O., A.A. Assiri, P. Petithuguenin and B.I. Kebe, 2003. Cocoa production in Côte d'Ivoire: current state of the tree stock and farmer practices. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

It is generally agreed that the Ivoirien cocoa tree stocks are currently entering an ageing phase following significant waves of extension during the 1970s and 1980s. What little work exists on this phenomenon deals with frequently restrictive geographical areas. In the framework of the Research-Action Project to regenerate Ivorian tree stocks, led jointly by the National Centre for Agronomic Research (CNRA) and the Centre for the Development of International Co-operation in Agronomic Research (CIRAD), it was agreed to update and widen existing knowledge to have available a reliable and recent description of all production zones.

A survey network was therefore set up by the project in seven representative zones of the coun-

try's producing regions. Information on 900 cocoa farmers was collected by semi-structured surveys for six months. Four analytical levels can be presented using the results of these surveys:

- An updated age pyramid by region of cocoa plantations
- A description by region of yields and factors explaining its variations (geographic location, population densities, technical itineraries applied, etc.)
- A detailed presentation of peasant technical itineraries and innovations adopted
- A status report on peasant holdings incorporating cocoa culture (surface areas, cropping plans and planned changes)

This presentation will end with an analysis of farmer technical itineraries, with particular emphasis on the existing relationship between farmer maintenance practices and current health conditions of the plantations. In conclusion the interest of such a diagnosis will be discussed. This work has identified accurately with the farmer production constraints and has thus resulted in better understanding of the determining factors and cocoa replanting and rehabilitation dynamics in Côte d'Ivoire.

Duguma, B., Gockowski, J. and Bakala, J. 2001. Smallholder cacao (Theobroma cacao Linn.) cultivation in agroforestry systems of West and Central Africa: Challenges and opportunities. Agroforestry Systems 51: 177-188.

Summary

The cultural features, management practice, environmental sustainability, and economic profitability of smallholder cacao (*Theobroma cacao*) production in West and Central Africa are reviewed. The aim is to highlight factors affecting the cacao production and marketing sector and to propose appropriate strategies to ensure sustainable and profitable cacao production in the region. The cacao cultivation system causes minimum damage to soil resources. In terms of carbon sequestration and below-and above-ground bio-diversity, the cacao agroforest is superior to the alternative food crop production land use. The food crop production system is based on the practice of slash-and-burn farming, which, due to population pressure and reduced fallow cycle, is no longer sustainable. Economic profitability analysis of this system in Cameroon showed that, at current prices, even with no value assigned to the tree species, the sector could still be profitable. Based on the current review and our knowledge of West and Central Africa, there is an urgent need to: (a) rationalise and optimise arrangement of the various components in the cacao agroforest, (b) domesticate high value and shade tolerant species such as *Gnetum africanum* and integrate into the system in order to enhance the system's diversity and profitability, (c) develop shade-tolerant and disease –resistant cacao varieties, (d) integrate small-stock production into the system, and (e) develop an enabling policy environment addressing cacao marketing, plant protection, land tenure and transformation of non-cacao primary products from the cacao agroforests.

Famaye, A.O., E.A., Adeyemi and A.O. Olaiya, 2003. Spacing trials in cocoa/kola/citrus interccrop. Paper presented at the 14th International Cocoa Research Conference, Accra-Ghana. 13-18 October

Summary

Spacing experiment on cocoa/kola/citrus intercrop was established in 1995 at Ajassor substation of Cocoa Research Institute of Nigeria to determine the optimum spacing and plant population for cocoa/kola/citrus intercrop. The experiment was laid-out in Randomized Complete Block Design with seven treatments of kola and citrus each at 17,34,54 and 69 plants/ha and cocoa, kola and citrus at 1,110, 173 and 173 plants/ha respectively under three replications. Data was collected on growth parameters such as number of leaves, leaf area, plant height, stem girth and canopy scores during the first 4 years of establishment. The results showed that stem

girth and canopy scores of cocoa, kola and citrus in cocoa/kola/citrus were better at larger spacing and lower plant population densities of 17 plants/ha each of kola and citrus than at smaller spacing and higher plant population of 69 plants/ha, although the differences were not significant (P = 0,05). Similarly, the growth performance of poly-cultured cocoa, kola and citrus was comparable to that of their corresponding pure stands indicating that there were no deleterious or allelopathy effects on any of the component crops.

FORIG Annual Report 2000, University Post Office Box 63, Kumasi.

Micro-catchment trials: Project leader- Mr. I.K. Abebrese

This work determines the effects of different micro-catchments on the growth and survival of indigenous trees species including Ceiba pentandra, Khaya senegalensis.

Frimpong, E.B., Y. Adu-Ampomah, A.O. Dwapanyin and A. Abdul-Karimu, 2003. Efforts to re-establish cocoa in denuded cocoa growing areas of Ghana. Paper presented at the 14th International Cocoa Research Conference, Accra-Ghana. 13-18 October

Summary

Ghana 's cocoa crop is produced under rain fed conditions in forest areas with rainfall of at least 1000mm per year. Protracted and severe drought has recently become a major limiting factor mitigating efforts armed at increasing cocoa production. The wide spread deterioration of shade and soil conditions over much of the old and denuded cocoa growing region make the re-establishment of cocoa very difficult for farmers who in certain years report of 100% seedling mortality. This situation taunts farmers desire to rehabilitate old farms and or establish new ones. Field trials were set up at three locations (Afosu, Bechem and Akumadan) in the affected areas to evaluate the prospects of some agronomic techniques in reducing cocoa seedling mortality in the target areas. These involved the use of mulch, anti-transpirant, growth regulators, soil-moisture conditioner and temporary shade provision. A split plot design with three replications was used for trials on mulches anti-transpirant and shade treatment, while a randomised block design was used for those involving soil-moisture conditions and growth regulators. The plantation pseudo-stem mulch significantly improved seedling survival rate by 31.7 percent over the control treatment, whilst the black polythene sheet mulch improved survival by 25.5% over the control., Folicote '20' the anti -transpirant, reduced seedling mortality by 8.4% compared to the control. A growth retardant, Paclobutrazol (Cultar), increased cocoa seedling survival by 11.2% whilst the growth promoter, Ergostin decreased seedling survival by 14.4%. The soil-moisture conditioner, Grow-soak 400, achieved 8.7% success over the control. Using Cassava as temporary shade gave a survival improvement of 14.7% over the control treatment. Amongst the agronomic techniques evaluated in these trials plantain pseudo stem as mulch offers the most effective means of improving seedling survival during re-establishment of cocoa in degraded areas.

Frimpong, E.B. and S.T. Lowor, 2003. The effects of shade on pod set, cherelle wilt, free sugar and moisture content on cocoa plants. Paper presented at the 14th International Cocoa Research Conference, Accra-Ghana. 13-18 October.

Summary

As part of the long-term study of factors affecting the vegetative and reproductive characteristic of cocoa, the total free sugar level of the pulp and bean were determined for Amazon hybrids and Amalonado cocoa trees growing under two shade regimes (Heavy shade -30% of full sunlight and No shade -100% of full sunlight) provided by Gliricidia sepium staud. The levels of pod set and physiological cherelle wilt were also studied. The experiments were conducted in a field of cocoa located at Cocoa Research Institute of Ghana (CRIG), Tafo . The genotypes included Amalonado and Amazon hybrids. Plants were spaced at 3m x 3m . A split - plot design with three blocks were used with shade regimes as main plots and cultivars as sub-plot. Pod set and cherelle wilt were recorded every other week. Mature - ripe pods were harvested every other week for the determination of pulp and bean sugar and moisture content. In the Amazons where flowers were produced through the year, two distinct peaks of pods set were recorded in April and September for the minor and major seasons respectively. The shaded trees showed a wilt increase of 57.14% over the unshaded trees. The average quantity of sugars in the pulp was 310.2 mg for the non-shaded trees and 224.5 mg for the shaded trees. Thus heavily shaded cocoa trees produced pods with lower pulp sugar content, which may impact on the fermentation process and thus affect quality of fermented beans. Values for pulp sugar content were 238.8 mg and 2567.8 mg. for Amazon hybrids. And Amalonado cultivas respectively but the difference was not significant. Notably, the greatest variations in sugar content of the pulp were encountered in the Amazon hybrids. Shaded trees produced beans with significantly lower content of fermentable sugar/beans (78.9mglbeans compare to the non-shaded trees (155.2 mg/bean). Differences amongst the cultivars were however not significant. Shading of the trees showed no significant effect on the moisture content of the bean. The findings help to partially explain the high acidity often associated with large scale fermentation particularly of Amazon cultivars thus suggesting the beneficial effects of shade removal (adjustment) as a major management practice affecting cocoa yield and bean quality.

Herzog, F. 1994. Multipurpose shade trees in coffee and cocoa plantations in Côte d'Ivoire. Agroforestry Systems. 27: 259-267.

Summary
Coffee and cocoa are the main cash crops in Côte d'Ivoire. They are mainly produced by small farmers in a rather extensive way. The shade trees used are mostly wild forest species yielding many products. In the Baoulé region, an inventory of those trees and their, often multiple, uses was established. Of the 41 tree species, 22 are used as firewood and 16 as timber for local consumption. Nineteen furnish pharmaceutical product for traditional medicine and 15 have edible parts (fruits, leaves, flowers, and palm wine). Those products are essential in daily life and play an important role in the local economy. The plantations can therefore be considered as agroforestry systems. Part of the world-wide research on coffee and cocoa should be reoriented to such systems, adapted to small farmer holdings where little input are available and conditions of production are less favourable

Holmes, K.A., H. C. Evans, J. Smith and S. Wayne, 2003. The discovery of Phytophthora megakarya on a forest host in Korup National Park (Cameroon). Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October, 2003.

Summary
Phytophthora megakarya is having an increasing impact on cocoa production in Central and West Africa and poses a direct threat to the Ivory Coast following recent reports of its occurrence near the border with Ghana. Current cultural and chemical control strategies are either ineffective or too expensive for the resource-poor farmers to implement. Alternative control measures are urgently required, preferably sustainable, cheap and easily integrated into existing management practices. Classical biological control, which has been successfully used to control invasive alien weeds, is one such option but is dependent on identifying the centre of origin or diversity of the target weed, pathogen or pest. The humid forest zone and the Nigerian/

Cameroon border has been highlighted as a possible centre of origin of *Phytophthora megakarya*, and thus a potential source of highly adapted or co-evolved natural enemies.
During 2001, an exploratory survey was undertaken in the primary forests of Korup National Park in south-west Cameroon, concentrating particularly on potential *Sterculiaceae* hosts such as Cola spp., in which this ancient forest ecosystem is particularly rich. There was no evidence of *Phytophthora megakarya* disease of Cola pods but black pod lesions were observed on fallen but still green fruit of a member of the *Irvingiaceae*, probably *Irvingia gabonensis* (elephant mango). Isolations were made from these lesions onto selective media.
Following molecular characteristics in the UK, using ITS fingerprinting, these isolates have been positively identified as belonging to *Phytophthora megakarya*. However, AFLP comparisons with other isolates of *P. megakarya*, derived from cocoa agro-ecosystems in West Africa, revealed that the forest strain is distinct, suggesting that it probably represents an ancient progenitor of the cocoa pathogen. In addition, a range of fungal antagonists was consistently associated with P. *megakarya* on the isolation plates, often severely restricting or completely inhibiting its subsequent growth and development. It is concluded that this forest habitat and host represent a potential source of novel, co-evolved natural enemies which could be exploited as classical biocontrol agents for either innoculative release or inundative application (mycofungicide) in the cocoa plantations of Central and West Africa.

Gockowski, J., S. Weise, D. Sonwa, M. Tchatat and M. Ngobo, 2004. Conservation because it pays: shaded Cocoa Agroforests in West Africa. Paper presented at the National Academy of Sciences in Washington DC on February 10, 2004 at a symposium titled 'The science behind cocoa's benefits'. Document available at: http://www.chocolateandcocoa.org/Library/Documents/NAS.doc.

Summary
The shade cocoa cropping system found throughout West Africa but particularly well represented in Cameroon and Nigeria is a sustainable agricultural land use system that provides relatively high values of environmental services. The paper describes and quantifies some of its non-cocoa economic and environmental values and examines the economic logic underlying smallholder management. Estimates of these values are developed from field surveys and on-farm research conducted with cocoa producers in West Africa over the last four years. The secondary products evaluated include the fruits of shade trees commonly associated and occupying the mid and upper canopy such as the African plum (*Dacryodes edulis*) and Ndjanssang (*Ricinodendron heudelotti*) along with introduced fruit species such as citrus and avocado. The nutritional contribution of selected associated species such as the bush mango, avocado, wild oil palm (*Elaies guinensis*), and African plum is examined. Timber is another economically important component of the upper canopy, with some species managed and maintained at densities above those found in primary and secondary forests for local exploitation and construction. Many medicinal plants are also maintained in the cocoa farm, which often serves as an in-situ herbal pharmacy for the household. The environmental and ecological benefits of these systems include habitat conservation, climate change mitigation, hydrological cycling and watershed protection. The degree to which these services are provided depends in large parts on the type and degree of shade maintained as well as their spatial coverage in the landscape. An econometric model of the determinants of shade level explores some of the driving forces behind shade management in Côte d'Ivoire, Ghana, Nigeria, and Cameroon. We conclude by arguing that because of the significant public goods associated with this land use system that there is a need for direct efforts to publicly support the development and maintenance of shaded systems.

Hutcheon, W.V., 1979. Physiological aspects of cocoa agronomy. Proceedings of the 5th International Cocoa Research Conference, Ibadan, Nigeria. Pp.39-48.

Summary
The aim of this contribution is to assess in general terms the present state of knowledge in the field of cocoa physiology/agronomy and to highlight some topics, which seem to merit further research. The paper presents a detailed outline of the basic physiology of cocoa, including; photosynthesis, mineral nutrition, respiratory losses, nutrient storage, partitioning of dry matter, and reproductive and vegetative growth. The author then applies these principles to cocoa agronomy, focusing on water relations and irrigation, shade and fertiliser, and spacing and pruning. Regarding shade, the author stresses that while cocoa can be grown without shade, in most cases some shade or protection is retained. As the effect of shade removal on cocoa depends on several interacting factors, the optimal shade intensity varies considerably from one area to another, depending on local edaphic, climatic and agronomic conditions. Another complicating factor in the concept of optimal shade intensity is the area over which the shade is reduced or removed; small blocks of cocoa surrounded by forest may respond very favourably to shade removal but the long term effects of more extensive destruction of shade are not fully established. Therefore, if we accept that in poor conditions shade is required, and in favourable conditions side protection (from air movement) is beneficial, then more thought might be given to growing cocoa as part of a system. The author concludes with reflections on 'possible future developments' and the importance of passing the benefits of improved planting material onto the growers.

Kengue, J. F.N. Tchuenguem Fohouo, H.G. Adewusi, 2002. Towards the improvement of Safou (Dacryodes edulis): Population variation and reproductive biology. Forests, Trees and Livelihoods, Vol. 12. Pp 73-84.

Summary
In the last two decades, growing interest in the production and utilisation of Safou *(Dacryodes edulis),* an indigenous fruit tree species of West and Central Africa, has stimulated work on the selection of genetic resources with desired traits, timing of fruit collection and the tree's reproductive biology. In this context, 58 germplasm accessions were collected in Nigeria during 1998. The periodicity of fruiting was found to vary geographically and a preliminary characterisation showed a wide range of variation in fruit traits. About 4% of fruits were seedless. The importance of this knowledge is discussed with regard to genetic selection and improvement, and the need to extend germplasm collection activities to wild relatives of the species. In the humid forest zone, the main insect pollinator is *Meliponula erythra.* Allogamy has been found to be the main reproduction system of *D. edulis,* while hermaphrodite flowers are self-compatible.

Konan, Amani and Koffi N'Goran. 2003. Cocoa replanting on improved fallow land: a solution for sustainable cocoa culture. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary
Cocoa, cultivated on two million hectares, remains the driving force of the Ivorian economy, and today provides over 20% of the Gross Domestic Product and over 70% of the country's domestic savings. It is also a major source of income for many farmers and their families. However, these performances are not synonymous with the modernisation of Ivorian cocoa culture–its continuing shifting and extensive nature has resulted in the production zones moving from East to the South-West of the country, thereby clearing several thousand hectares of forest. The fallow lands thus created are covered with *Chromolaena odorata*, which prevents

forest re-growth and planting of cocoa, which usually requires a forest environment. Work has started to plant the fallow lands with fast-growing legumes for two to three years. Planting of cocoa trees on these fallow lands has been compared with the cocoa tree-banana palm association. Using fast-growing legumes to improve the fallow lands has produced some very convincing results, which give hope to the sustainable replanting of cocoa.

Leakey, R.R.B., Z. Tchoundjeu, R.I. Smith, R.C. Munro, J.M. Fondoun, J. Kengue, P.O Angbeh, A.R. Atangana, A.N. Waruhiu, E. Asaah, C. Usoro and V. Ukafor, 2004. Evidence that subsistence farmers have domesticated indigenous fruits (Dacryodes edulis and Irvingia gabonensis) in Cameroon and Nigeria. Agroforestry Systems 60: 101-111.

Summary
Ten fruits and kernel traits were measured in 152 *Irvingia gabonensis* and 293 *Dacryodes edulis* trees from 6 villages in Cameroon and Nigeria. Frequency distribution curves were used to examine the range of variation of each trait of each species in each village and aggregated into national and regional population. There were differences in between the village sub-populations, with regards to the normality (e.g., mean kernel mass of *D. edulis*) or skewness (e.g., flesh depth of *D. edulis*) of the distribution curves and in the degree of separation between the individual village population along the x axis, resulting in the development of bimodal distribution in the regional population. For all traits, population of both species differed significantly between countries, but only in D. edulis were there significant differences between the Cameroon populations. On the basis of the results of these study, D. edulis can be said to be virtually wild in Nigeria but semi-domesticated in Cameroon, while I. gabonensis is wild in Cameroon and semi-domesticated in Nigeria. These results are discussed with regard to a hypothesis that the range and frequency of variation in the different populations can be used to identify five stages of domestication. From a comparison of the frequency distribution curves of desirable versus undesirable traits, and statistically identifiable changes in skewness and kurtosis, it is concluded that as a result of the farmers' own efforts by truncated selection, D. edulis is between Stages 2 and 3 of domestication (with a 67% relative gain in flesh depth) in Cameroon, while I. *gabonensis* in Nigeria is at Stage 2 (with a 44% relative gain in flesh depth). In this study, genetic diversity seems to have been increased, and not reduced, by domestication.

Leakey, R.R.B. and A.J. Simons, 1998. The domestication and commercialisation of indigenous trees in agroforestry for the alleviation of poverty. Agroforestry Systems 38: 165-176.

Summary
New initiatives in agroforestry are seeking to integrate into tropical farming systems indigenous trees whose products have traditionally been gathered from natural forests. This is being done in order to provide marketable products from farms that will generate cash for resource-poor rural and peri-urban households. This poverty-alleviating agroforestry strategy is at the same time linked to one in which perennial, biologically diverse and complex mature stage agro-ecosystems are developed as sustainable alternatives to slash-and-burn agriculture.
One important component of this approach is the domestication of the local tree species that have commercial potential in local, regional or even international markets. Because of the number of potential candidate species for domestication, one crucial first step is the identification of priority species and the formulation of a domestication strategy that is appropriate to the use, marketability and genetic potential of each species.
For most of these hitherto wild species little or no formal research has been carried out to assess their food value, potential for genetic improvement or reproductive biology. To date their mar-

ketability can only be assessed by their position in the local rural and urban marketplaces, since few have attracted international commercial interest. To meet the objective of poverty alleviation, however, it is crucial that market expansion and creation are possible, hence for example it is important to determine which marketable traits are amenable to genetic improvement. While some traits that are relatively easy to identify do benefit the farmer, there are undoubtedly others that are important to the food, pharmaceutical or other industries that require more sophisticated evaluation. This paper presents the current thinking and strategies of ICRAF in this new area of work and draws on examples from our programme.

Leakey, R.R.B., 1998. Agroforestry in the humid lowlands of West Africa: some reflections on the future directions for research. Agroforestry Systems 40: 253-262.

Summary
Means have to be found for rural people to supply both their own needs and those of the urban dwellers, without further loss of natural resources. Some examples from around the humid tropics suggest that complex agroforests may be able to achieve this goal. In West Africa, the concepts of the cocoa *(Theobroma cacao)* farm and compound garden, coupled with the domestication of indigenous trees for the production of improved non-timber forest products, need to be developed. There are numerous candidate species both for domestication and for inclusion in multi-strata systems. Research is needed on the development of various forms of multi-strata agroforests, coupled with short-term tree fallows especially to rehabilitate degraded land. More ecologically-oriented studies are required to build sustainable and productive multi-strata agro-ecosystems, while domestication requires greater understanding of the needs of the food and pharmaceutical industries and the development of marketing infrastructures. Incentives are required to promote entreprenurism in rural communities, especially near urban centres.

Manu, M., Tetteh, E.K. (eds), 1987. A guide to cocoa cultivation. Cocoa Research Institute of Ghana (CRIG).

Summary
This short book serves a guide to each step in cocoa cultivation and provides a list of both desirable and undesirable shade tree species.

Mapongmetsem, P.M., Duguma, B., Nkongmeneck, B.A., 1999. Domestication of Ricinodendron heudelotii (Baill.) Pierre Ex. Pax. in the humid lowlands of Cameroon. Ghana Journal of Science 39: 3-8.

Summary
Ricinodendron heudelotti is one of the top ranking indigenous multipurpose tree species retained for improvement in the humid lowlands of West Africa. It is a common species known as Djangsang in Cameroon, producing highly oleaginous nutritious seeds. It is harvested by local populations for consumption and sale. In addition, it is an integral part of traditional farming systems and, therefore, is protected in cropping fields. There is, therefore, an urgent need for its domestication. Phenology and propagation are among the first steps of the domestication process. Therefore, to know the probably fruiting periods of the species, a weekly phenological study was undertaken in three localities at each of two sites in the forest zone of Cameroon from July 1989 to July 1992. The experimental design was a 2x3 factorial located in a randomized complete block design with three replications. The sites (Yaounde, Sangmelima) were taken as the main treatments while years (1989, 1990, 1991), during which observations were carried out, were considered as sub-treatments. The effect of site, year and their interaction were significant respectively at 0.05, 0.01, and 0.001 level of probabilities. To overcome seed

dormancy, a germination test was carried out in the laboratory using a randomized complete block design with four replicates and five treatments. The experimental unit was made up of 60 seeds. Results indicated a significant difference between treatments. Hand scarification increased the germination rate up 60 percent, whereas the control gave a germination rate of only 3.3 per cent. Due to the dioecious nature of the plant (separate male and female plants), vegetative propagation by cuttings was conducted in the open field. The experimental design was a split-plot design with three replicates. The main plot was the type of wood (basal, median and extreme) whereas the sub-plot was the position of the cutting (vertical, slanting). The experimental unit was made up of 20 cuttings. Significant differences were observed between the types of wood (P=0.05) as indicated by the median wood which showed a high sprouting potential.

Mialoundama, F. M.-L. Avana, E. Youmbi, P.C. Mampouya, Z. Tchoundjeu, M. Mbeuyo, G.R. Galamo, J.M. Bell, F. Kopguep, A.C. Tsobeng and J. Abega, 2002. Vegetative propagation of Dacryodes edulis (G: Don) H.J. Lam by marcots, cuttings and micropropagation. Forests, Trees and Livelihoods, Vol. 12. Pp 85-96.

Summary

Air layering (or marcotting) of `Safou' *(Dacryodes edulis) is* most successful with large diameter, horizontal branches with thick bark. However, rooting remains slow and severance is only possible five months after setting the marcots. Application of growth regulators helps to accelerate rooting and reduces the severance period from five to three months. The best results were obtained with IBA. The most effective rooting medium for *D. edulis* juvenile leafy stem cuttings was found to be sawdust or a sand/sawdust mixture, but no significant effect of hormonal stimulation on rooting was recorded. A technique for disinfecting mature plant material of *D. edulis* for *in vitro* propagation is reported. The reputation of *D. edulis* as a species that is difficult to propagate vegetatively is incorrect. This has important implications for the domestication of the species.

N'Goran, K. 1998. Reflections on a durable cacao production: the situation in the Ivory Coast, Africa. Paper presented at a workshop held in Panama, March 30 – April 2 1998. Smithsonian Institution, Washington, D.C.

Summary

Cocoa tree cultivation plays an integral role among the Côte d'Ivoire's traditional activities. Farmers use an ambulatory method of exploitation, and the establishment of plantations has gone through three phases: cultivation of Amelonado variety on the cleared forest floor, cultivation under forest re-growth, and cultivation of high-yield, Upper-Amazonian species in direct sunlight and in association with fruit trees and other food-producing plants. Today, most plantations are products of the last phase, which has resulted in considerable deforestation. The techniques recommended by research have shown varying levels of success among the farmers, and the exploitations with a satisfactory level of productivity are few. Phytosanitary treatments and fertilisers are applied only partially or not at all, which can result in the plantations' premature degradation. In order to assure a long-lasting cocoa production, plantations in Côte d'Ivoire need be rehabilitated through the use of pesticides and fertilisers. Also an effective system of association needs to be developed between cocoa trees and shade trees that, while protecting the cocoa, contributes to satisfying the producers needs and protecting the environment during orchard renewal.

Olaniran, Y.A.O., 1979. Focus on light climate in cocoa production. Proceedings of the 5th International Cocoa Research Conference, Ibadan, Nigeria. Pp. 271-277.

Summary

Literature on the direct effects of solar radiation on cocoa is reviewed. It is concluded that the scarcity of light data is not peculiar to cocoa but rather a problem of the tropical world. Reasons have been adduced for the inadequacy in our knowledge of the amount of incoming solar energy received by cocoa canopies. Literature on some climatic factors governed by incoming solar energy, e.g. soil and ambient temperatures, relative humidity, with species reference to their influence on cocoa performance have also been reviewed. Work done by some researchers on the effect of shade trees on cocoa and the environment have been given especially species like *Erythrina glauca* and *Terminalia ivorensis*. A simple, relatively cheap integrating photometer is proposed for a meaningful study of the incoming solar energy in cocoa.

Ofori-Frimpong, K., A.A. Afrifa, K. Osei-Bonsu and M.R. Appiah, 2003. Cocoa/Coconut intercropping trial in Ghana: effect of the cropping systems on soil nutrient dynamics. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

The effects of some cropping systems on soil properties at three soil depths of tropical ferric lixisol were investigated at the Cocoa Research Institute of Ghana as part of efforts to search for an evergreen permanent shade for cocoa in Ghana. The cropping systems were cocoa planted at 2.5m triangular with coconut at 8.8m triangular; cocoa planted at 3m x 3m with Glyricidia sepium planted at 12.1m x 12.1 m; cocoa planted at 2.5m triangular with coconut at 9.8m triangular; cocoa planted at 3.Om x 3.Om with coconut planted at 9. lm triangular; cocoa planted at 3.Om x 3.Om with coconut planted at 12.2m x 11.0m. The experimental design was a randomised block with four replicates. The soils were sampled from the cropping systems and an uncultivated bush in an adjacent plot used as the standard. Land clearing and the cultivation of the crops I crop combinations generally influenced the soil chemical properties determined at the end of fifteen years of cropping. Soil pH and organic matter content increased with cultivation. Irrespective of the intercrop system, total N, available P and exchangeable K contents of the soils declined. The cocoa I G. sepium plot recorded the highest level of nitrogen among the intercrop systems but cultivation significantly decreased the nitrogen content of the soils especially in the cocoa spaced at 3.0 x 3m and coconut spaced at 12.2m x 11.0m plot. Cocoa spaced at 3 x 3.Om with G. sepium or with coconut spaced at 12.2m x 1 l.Orr treatments had significantly (P=0.05) lower available P contents. The exchangeable K contents were however similar among the intercrop systems. The results are discussed in relation to the nutrient requirements of mature cocoa as well as cocoa fertilization programme in Ghana.

Ollennu, L.A.A., K. Osei-Bonsu, K. Acheampong and F. Aneani. 2003. Preliminary studies of the control of cocoa swollen shoot disease by the use of immune crops as barrier. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

A field trial was established at the Cocoa Research Institute of Ghana in 1993 to investigate effectiveness of using crops such as citrus, oil palm and kola which are immune to cocoa swollen badnavirus (CSSV) to separate new cocoa planting from old after, monthly inspections were carried out in the outer cocoa for spread of CSSV. Cocoa yields as well as yields from the establishments to reduce the risk of CSSV re-infection. The trial was planted in a randomized block design replicated three times. The crops used for the barriers formed the treatments. These cocoa trees planted at 3m x 3m were surrounded by two rows of barrier crops. Four years after establishment, the inner core of 25 plants were inoculated with CSSV severe strain IA. There after monthly inspections were carried out in the outer cocoa for spread of CSSV. Cocoa yield as well as yield from the barrier crops were recorded. Five years after CSSV severe IA inoculations, 30 trees across the barrier have been infected by the CSSV. Eighteen of the infections were across the cocoa barrier, while eleven were across kola and one across the oil palm. These results indicated that the citrus and oil palm barriers are effective in isolating the test cocoa trees from CSSV infection. The kola barrier has not been effective due to poor establishment. Economic analysis of the produce from the three barrier crops suggests that the citrus and oil palm adequately compensated for the cocoa space they occupied. The results are discussed in relation to swollen shoot disease control in West African sub-region with particular reference to Ghana.

Opoku, I.Y., Akrofi, A.Y., Appiah, A.A., 2002. Shade trees are alternative hosts of the cocoa pathogen Phytophthora megakarya. Crop Protection 21: 629-634.

Summary
Two methods of isolation direct planting on selective agar medium and baiting with cocoa pod husks were used to isolate *Phytophthora megakarya* from root pieces of some shade trees. Isolates were identified on the basis of their growth rates, colony morphology and sporangium characteristics. Pathogenicity tests were conducted on detached green mature cocoa pods and stems of the relevant host trees. After 35 months of sampling and baiting, *P. megakarya* was isolated from the roots of four out of 34 shade tree species examined. The host trees were *Funtumia elastica,* (*Apocynaceae*), *Sterculia tragacantha* (Sterculiaceae), *Dracaena mannii* (*Agavaceae*) and *Ricinodendron heudelotii* (Euphorbiaceae). *P. megakarya* isolations were made in both the dry and the wet seasons. The rate of recoveries were very low in both seasons ranging from 0.6% to 1.2%. The highest recoveries were in October and the lowest in December and February. In general, planting onto medium was slightly superior to cocoa pod husk baiting for the recovery of *P. megakarya*. Colonies of *P. megakarya* isolates from the trees were morphologically indistinguishable from a reference isolate, but were less virulent on cocoa pods than the reference isolate from cocoa. The epidemiological significance of these findings are not clear, but roots of the host trees were likely to be sites for survival and not for multiplication of *P. megakarya*. Field observation indicated that levels of black pod incidence on cocoa trees around the affected shade trees were not greater than those in other parts of cocoa plantation. This is the first reported isolation of *P. megakarya* from roots of plants other than cocoa.

Osei-Bonsu, K., Ameyaw Oduro, C., Tetteh, J.P., 2003. Traditional cocoa agroforestry: 1. Species encountered in the cocoa ecosystem of a typical cocoa growing district in Ghana. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary
A survey was undertaken in the Osino District of the Eastern Region of Ghana between 1997and 1998 to identify tree species retained by farmers on their cocoa farms. The exercise covered four different farm classes denoted as newly established (0 to 7 years old), juvenile (8 to 15 years old), mature (16 to 23 years old) and old (above 24 years old) farms from four large extension units each covering about one thousand hectares in the erstwhile Cocoa Services Division. The sample size chosen from each age class in each extension unit was based on prob-

ability proportional sampling and the unit of farm size taken for the survey was one hectare. The data collected on each farm included the number of different tree species found on the farm, the frequency of occurrence of different species on the farm, the frequency of occurrence of each tree species and the presence of non-tree species. One hundred and sixteen different tree species were recorded from the sixty farms surveyed. Newly established farms contained three times as many trees per hectare than the other age classes to provide nursing shade for the young cocoa. An average of nine different tree species were encountered per hectare on newly established cocoa farms compared to six on the mature farms and about four on the juvenile and old farms. About twenty-one tree species were the commonest on all the farm classes with *Rauvolfia vomitoria* occurring on 95% of newly established and juvenile farms whilst *Milicia excelsa* was found on 82% of the mature and old farms. An undesirable tree species, *Sterculia tragacantha* was found in a large number of farms and in very high frequencies indicating possible ignorance by farmers of the types of tree species required for managing the cocoa ecosystem. Fruit trees like *Citrus sinensis, Cola nitida, Persea americana, Mangifera indica,* and *Elaies guineensis* and non-tree/fruit species like plantain, banana, pawpaw and cassava were frequently encountered in the farms providing shade as well as food/fruit for the farmers. The study reveals that the cocoa ecosystem in this district has a rich tree species diversity, which needs to be managed properly for cocoa cultivation.

Osei-Bonsu, K., Amoah, F.M., Oppong, F.K., 1998. The establishment and early yield of cocoa intercropped with food crops in Ghana. Ghana Journal of Agriculture Science 31: 45-53.

Summary
A cocoa-food crop-intercropping trail was set up in 1988 at the Cocoa Research Institute of Ghana, Tafo. The effects of plantain, cassava, and maize as intercrops with cocoa only and in their various combinations on the establishment, growth of cocoa, and profitability of the food crops were studied in a randomised block experiment with five replicates. Mixed hybrids cocoa seedlings were planted at 3 m x 3 m and *Gliricidia maculata* provided permanent shade in all plots. Three years after planting, the sole cocoa with *Gliricidia maculata* was inferior in growth to the cocoa interplanted with food crops. Cocoa in treatments, which included maize, showed superior growth and better precocity. Yield of each food intercrop with cocoa only was higher than when combined with other food crops. Sole cocoa gave less revenue equivalent to the operational costs during the establishment phase. The other food crop combinations with cocoa gave net revenue gain in the first 2 years after planting. The economic evaluation of the food crop combination indicated that treatments, which included cassava were the most profitable.

Osei-Bonsu, K., Opoku-Ameyaw, K., Amoah, F.M., Oppong, F.K., 2002. Cacao-coconut intercropping in Ghana: agronomic and economic perspectives. Agroforestry Systems 55: 1-8.

Summary
In Ghana, shade for cocoa (*Theobroma cacao*) is becoming a critical issue because of extensive deforestation. Unlike in some other cacao-growing countries, cacao is not grown under the shade of coconut (*Cocos nucifera*) in Ghana. An experiment to compare the merits of four cacao-coconut intercropping systems with the traditional cultivation of cocoa under *Gliricidia sepium* shade was undertaken at the Cocoa Research Institute of Ghana. Cacao seedling girth was not affected when intercropped with coconut but was significantly ($P = 0.01$) reduced when intercropped with *G. sepium*. High-density cacao facilitated better canopy formation. Yield of cocoa spaced at 2.5 m triangular (1739 plants ha ^{1}) with coconut at 9.8 m triangular (105 plants

ha ^{1}) was significantly higher ($P = 0.05$) than from the other treatments during 1993/94 to 1995/96. There were no major disease problems associated with intercropping cacao with coconuts. Widely spaced coconut intercropped with cacao spaced at 3 m x 3 m showed better flowering and gave higher coconut yields, but cacao spaced at 2.4 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture stress was the greatest in cacao system with *G. sepium* shade and this could be responsible for the low yield of cacao in that treatment. It is suggested that properly arranged high-density cacao under widely spaced coconuts can be a profitable intercrop system for adoption by cacao farmers in Ghana.

Osei-Bonsu, K., K. Acheampong, F.K., Amoah, 2000. The effect of shade, variety and spacing on cocoa yield at the Cocoa Research Institute of Ghana. Proceedings of the 13th International Cocoa Research Conference, Sabah, Malaysia. Pp. 1223-1228

Summary

A split-split plot experiment was started in 1987 to evaluate the response of some Series II and inter-Amazon cocoa hybrids to shade and planting density at the Bunso Sub-station of the Cocoa Research Institute of Ghana (CRIG). Temporary shade comprising a mixture of *Gliricidia sepium* and plantain planted in all the plots during establishment was later judiciously eliminated, depending on the growth of the cocoa and permanent shade was provided be mature forest trees at the density of 16-18 trees per hectare. The main plot was shade or no shade and the sub-plots consisted of the hybrid varieties T85/799 x Amel (as control), T85/799 x Pa7, T87/799 x T79/501, T63/971 x T60/887. The sub-sub plot of spacing was made up of 2.0 m x 3.0 m, 2.5 m x 2.5m, 2.0m x 3.5m, 2.5m x 3.0m, 3.0m x 3.0m, and 3.0m x 3.5m giving densities of 1667, 1600, 1428, 1333, 1111, and 952 plants per hectare. Varieties T87/799 x T79/501 and T85/799 x Pa7 produced more vigorous seedlings than the other varieties within 24 months. No significant differences were observed in the yield of cocoa varieties under shade and no shade conditions. This could be due to the effect of the rigid (split-split plot) design on the main plots and partly to the staggered removal of the shade from the no shade treatment. T85/799 x Amel gave significantly ($P = 0.05$) higher yields than the other varieties in 1993/94 and 1994/95 but in 1995/1996, T85/799 x Pa7 gave the highest yield. Subsequently yield differences between the varieties have been negligible although T63/971 x T60/887 gave the lowest cumulative yield. High plant densities resulted in higher yields of cocoa in this trial over the years. No consistent interaction effects of the factors on yield were observed.

Pèrez, M.R., O. Ndoye, A. Yebe and A. Puntodewo, 2000. Spatial characterisation of non-timber forest products markets in the humid forest zone of Cameroon. International Forestry Review 2(2). 71-82 pp.

Summary

The paper analyses the structure of non-timber forest products (NTFP) markets in the humid forest zone (HFZ) of Cameroon from a spatial perspective. A characterisation of 25 markets based on a set of products, traders, and marketplace attributes was produced. The combination of the attributes size and self sufficiency results in four main types of markets (national, provincial, local and frontier), whereas clustering based on all the attributes clearly distinguishes the northern and southern areas of the HFZ, and an urban-rural, core-periphery relationship with in each area. This separation reflects different product specialisation and diversity, as well as market size. *Dacryodes* and *Gnetum* predominate in the northern markets, which tend to be larger, whereas *Garcinia lucida, G. Kola and Irvingia* are relatively more abundant in the southern markets. In general, larger markets are more diversified and their traders are more specialised than the smaller ones. There are also differences in product storage time, distance from source of products, level of taxation, and transportation problems. The need to understand the multiple, non-linear interactions among these factors is stressed.

Rice, R.A. and Greenberg, R. 2000. Cacao cultivation and the conservation of biological diversity. Ambio Vol. 29 No. 3. May 2000.

Summary

Cacao (*Theobroma cacao*) is a crop of the humid lowland tropics produced largely by small-scale producers and often on farms with a canopy of shade trees. Where a diverse shaded canopy is used, cacao farms support higher levels of biological diversity than most other tropical crops. A host of viral and fungal diseases, loss of soil fertility, and numerous socio economic problems facing producers, often make cacao production locally unsustainable. Continued clearing of new lands threatens biodiversity. Moreover, new frontiers for cacao expansion are rapidly disappearing. Such problems can be addressed by increasing the long-term productivity of existing cacao farms and restoring abandoned lands. Improved shade management offers guidance along this path. Institutions involved with cocoa should establish collaborations with groups concerned with development, environmental protection, and most importantly producers themselves to pursue a program of research, extension and policy initiatives focused on the ecologically and economically sustainable cacao production on farms with a diverse shade canopy.

Ruf, Francois, Fiko, Yao Armand, Sayam Villy, Marie Panarin and Serges Bailly. 2003. Diversification and sustainability of cocoa farms: The case of Côte d'Ivoire. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

Surveys conducted in Côte d'Ivoire between 1999 and 2002 under two successive major research projects covered almost 1,000 farms in the country's major cocoa-producing regions. The most significant results tally, independently from crop diversification, the first determining factor for diversification of cocoa farms is neither price nor market, but the key problem of cocoa sustainability–the difficulties of cocoa replanting. Farmers actively seek new sources of revenue when the cocoa trees age and they race or re-face difficulties in replanting. Investment should therefore be made in information, access to new planting material and new plantations. Some crops, rubber for example, involve a relatively sophisticated planting material, clonal material and a wait of 5 to 6 years before it starts producing. The 'information/capital' binomial is therefore the second major determining factor in diversification. Farmers do not have available a credit market and information to enable them to make the most of their production systems individually. Producer and sector organisations are still in their infancy. Indeed, in many cases, particularly those studied under these research projects, the 'information/capital' binomial is provided by a development project. In Côte d'Ivoire, the rubber and oil palm plantations and the fishing sector, all of which require both information and capital inputs, have been developed historically through development plans and public funds. Once this type of crop or activity is firmly established, the farmers themselves are frequently sufficiently dynamic to boost diversification without a project or outside capital. Nevertheless, the rate is far lower than if the country received some financing. When less capital is required for diversification, cashew, for example, with its easily accessible seed, the crop can develop spontaneously, but a certain amount of information was necessary, firstly provided by the forestry projects of the 50s and 60s. Raising small ruminants is another possibility which many farmers wish to develop, but find themselves faced with technical (disease) and social (theft) problems. They need external aid. This does not involve reproducing full-scale projects as for the first oil palm or rubber

programmes, but to draw lessons from them to encourage diversification at reduced cost. This cocoa diversification offers two advantages. It expands the country's agricultural and economic base and in return consolidates the chances of cocoa replanting. Diversification is a key factor in cocoa sustainability.

SATMACI, 1984. Manuel de cacaoculture. Societe d'Assistance Technique la Modernisation Agricole de la Côte d'Ivoire. Ministere de l'Agriculture. Abidjan, Avril 1984.

Summary
This manual provides guidelines for cultivating cocoa. It presents a list of 45 forest tree species, which are undesirable for cocoa cultivation due to their antagonist nature, dense and low shade, and as alternative host for diseases and pests.

Schroth, G., 1999. A review of below-ground interactions in agroforestry, focusing on mechanisms and management options. Agroforestry Systems 43: 5-34

Summary
This review summarises current knowledge on root interactions in agroforestry systems, discussing cases from the temperate and tropical ecosystems and drawing on experiences from natural plant communities where data from agroforestry systems are lacking. There is an inherent conflict in agroforestry between expected favourable effects of tree root systems, e.g. on soil fertility and nutrient cycling, and competition between tree and crop roots. Root management attempts to optimise root functions and to stimulate facilitative and complementary interactions. It makes use of the plasticity of root systems to respond to environmental factor, including other root systems, with altered growth and physiology. Root management tools include species selection, spacing, nutrient distribution, and shoot pruning, among others. Root distribution determines potential zones of root interactions in the soil, but are also a result of such interactions. Plants tend to avoid excessive root competition both at the root system level and at the single-root level by spatial segregation. As a consequence, associated plant species develop vertically stratified root systems under certain conditions, leading to complementarity in the use of soil resources. Parameters of root competitiveness, such as root length density, mycorrhization and flexibility in response to water and nutrient patches in the soil, have to be considered for predicting the outcome of inter-specific root interactions. The patterns of root activity around individual plants differ between species; knowing these may help to avoid excessive competition and unproductive nutrient losses in agroforestry systems through suitable spacing and fertiliser placement. The possibility of alleviating root competition by supplying limiting growth factors in critically assessed. A wide range of physical, chemical and biological interactions occurs not only in spatial agroforestry, but also in rotational systems. In a final part, the reviewed information is applied to different types of agroforestry systems: associations of trees with annual crops; associations of trees with grasses or perennial fodder and cover crops; associations of different tree and shrub species; and improved fallows.

Sonwa, D.J., J.C. Okafor, P. Mpungi Buyungu, S.F. Weise, M. Tchatat, A.A. Adesina, A.B. Nkongmeneck, O. Ndoye and D. Endamana, 2002. Dacryodes edulis, a neglected non-timber forest species for the agroforestry systems of West and Central Africa. Forests, Trees and Livelihoods, Vol. 12. Pp 41-55.

Summary
Dacryodes edulis, or Safou, is a fruit tree native to Central Africa and the Gulf of Guinea region. It is usually present in agroforestry systems in the region, particularly in homegardens and

cocoa and coffee agroforests. It plays an important role in household consumption and the surplus is sold on the rural and urban market. A lack of attention by research and extension services means that there is neither scientific knowledge nor official recommendations for its management in agroforestry systems. The attempt to introduce it into forest fallows in Côte d'Ivoire is a good example of industrial involvement in the development of agroforestry and the expansion of tree production in West Africa. Drawing on experience from Cameroon, Nigeria and Côte d'Ivoire, this paper presents indigenous management techniques and emerging opportunities to promote Safou in West and Central African agroforestry systems for food security, income generation and rehabilitation of the environment.

Sonwa, Denis J., Stephen F. Weis and Marc J.J. Janssens. 2003. The role of cocoa agroforest management in view of poverty alleviation in rural forest area of southern Cameroon. Paper presented at the 14th International Cocoa Research Conference, Accra Ghana. 13-18 October.

Summary

In southern Cameroon, the forest has supplied timber, fuelwood, Non Timber Forest Products (NTFP like food, medicine, etc), animal resources (meat and fish) and land for food and cash crops such as cocoa, to the population on a regular basis. The practice of cultivating cocoa in the forest, for several decades, has contributed not only to shape a new forest landscape in the area, but also to sustain the rural economy (by being responsible for meeting food, health needs, etc) of villages.

The poverty period, Cameroon went through in the middle of the 80's, was fuelled in the cocoa agroforest sector by a drop in the price of cocoa. This occurred when food and health needs required more money than before following the liberalisation of many sectors (economy, health, agriculture, etc). This thus led to an increased dependence on natural resources for survival. In this context, local dynamics forced people to (i) create farmer associations dealing with the management and commercialisation of outputs from the cocoa agroforest and to (ii) search for alternatives by increasing food crops and/or diversifying forest resources in plantations. This makes these systems open for (a) providing the same services as the forest in meeting farmers' needs, but mostly (b) for conserving biodiversity thus in keeping with a clearly expressed will of the international community i.e. that of better conserving forest resources while using these resources as rationally as possible to meet the needs of local people.

This paper highlights (i) the place of cocoa agroforest in the mosaic of various land modes, (ii) the influences of the international context on the management of cocoa agroforest, (iii) the dependence on cocoa agroforest within the context of rural poverty, (iv) the sustainability of cocoa agroforestry systems within the perspective of poverty alleviation and (v) concludes by giving some recommendations for the better utilisation of cocoa agroforest as one of the driving forces in poverty alleviation in forest areas.

Sonwa, D.J. (2004). Biomass management and diversification within cocoa agroforests in the humid forest zone of Southern Cameroon. PhD thesis. Institut für Gartenbauwissenshaft der Rheinischen Friedrich-Wilhelms-Universität Bonn. 126 p.

Summary

The aim of this work was to study diversification and evaluate biomass management in cocoa agroforests of Southern Cameroon. More specifically, research efforts were focused on (1) characteristics of farmers and their choice of species, (2) diversity of the plants associated with cocoa, (3) structure and typology, (4) phytomass, (5) litter dynamics, (6) cocoa production and (7) carbon stock of the cocoa agroforests. To collect all this information, 300 farmers were

interviewed, vegetation survey was conducted in 60 cocoa agroforests, and experimental plots followed during two years in 8 representative cocoa plantations. The following findings were obtained:

Each farmer used on average six accompanying plant species for intensification and diversification of his cocoa agroforest. Among farmers, 93 % use fruit and 81 % use non-fruit species. Some 63 % of the fruit species are exotic while 17 % of the non-fruits are high value timber (i.e. regularly exported from Cameroon).

Within each cocoa agroforest, there are on average 21 species. A total of 206 were found in all the agroforests. In fragmented forest landscapes, agroforests are less diverse. Food species tend to be more frequent while timber species are among the best shade providers (i.e. having enough basal area). Among all food plant species listed in these agroforests, 2/3 yields non-wood forest products (NWFP).

The average basal area of an agroforest is 36 $m^2.ha^{-1}$ out of which 85% are taken up by the plants associated with cocoa. Food species tend to be denser around Yaounde, while timber and medicinal species are more likely to be found in forested areas. A cluster analysis, taking into consideration the age of plantations and the density of cocoa and other trees (including *Musa* species and oil palms), allowed the identification of three types of cocoa plantations. Types A and C have lower densities of cocoa, - 918 and 1060 plants/ha -, against 1757 in type B. In contrast, type A plantations have a higher density of *Musa* spp. and oil palms, while type C contains more high-value timber and indigenous fruit trees. Total tree density is highest in type B plantations.

The phytomass average is 451 mg.ha,$^{-1}$ with associated plants accounting for 83 % of this value. Unshaded cocoa orchards contain only 56 $mg.ha^{-1}$ of phytomass. In the phytomass contribution of plants associated with cocoa, food plants account for 15% and timber for 25%. The carbon stock obtained was 243 $mg.ha^{-1}$, with above ground carbon accounting for 50 to 75 % under shade conditions. Beside cocoa, the first 10 associated species account for more than half of the phytomass of the accompanying plants. Agroforests with high timber and NWFP plants (Type C) store two to three times the amount of carbon as stored under shade types A and B. Unshaded cocoa orchards stored 60 $mg.ha^{-1}$ of carbon.

A total of 10.7 $mg.ha^{-1}$of litter fell, on average, in cocoa agroforests on a yearly basis. In the absence of shade, only 4.78 $mg.ha^{-1}$ was recorded. As a result of slashing by farmers, an additional 1.21 $mg.ha^{-1}$ of weeds is returned to the soil. The absence of shade increases this weed biomass to 3.3 $mg.ha^{-1}$.per $year^{-1}$. The Olson degradation rate (K) is 1.7 on average in the entire area (1.3 under unshaded conditions).

Each cocoa tree produces on average 11 healthy pods per year when well treated against black pod disease and 5 when untreated. Production of 258 to 445 $Kg.ha^{-1}$ could be obtained under shade against 768 under direct sun when fungicide is applied. When pesticides are not applied, densification of cocoa is harmful to production (only 80 $Kg.ha^{-1}.year^{-1}$) against 194 or 169 where cocoa density is lower. Black pod incidence was more than 61% when fungicide was not applied.

The structure and characteristics of cocoa agroforests are affected by management methods and are influenced by the surrounding forest landscape. Understanding interactions between cocoa agroforests and other land uses as well as interactions between components within the system will help in fulfilling household needs, conserving forest resources and providing ecosystem services in an improved way.

Tchoundjeu, Z., J. Kengue and R.R.B. Leakey, 2002. Domestication of Dacryodes edulis: state-of-the-art. Forests, Trees and Livelihoods, Vol. 12. Pp 3-13 .

Summary

Dacryodes edulis is one of the important local fruit tree species of West and Central Africa. This paper reviews the activities of a regional programme to domesticate high-value indigenous fruit trees in the region. This programme is co-ordinated by the International Centre for Research in Agroforestry (ICRAF) and implemented in Cameroon in collaboration with the Institute of Agricultural Research for Development (IRAD), National Agricultural Extension and Research Programme (PNVRA) agents and NGOs and universities of the region. It is based on a participatory approach to domestication that is in marked contrast to that of food crop domestication under the Green Revolution. The participatory process with farmers started with priority setting between species, progressed to germplasm collection and the establishment of village nurseries for clonal propagation of superior trees, and is currently involved in the selection of superior trees for cultivar development. Work is also in progress on post-harvest processing, market development and the integration of cultivars into agroforestry systems.

Waruhiu, A.N., J. Kengue, A.R. Atangana, Z. Tchoundjeu and R.R.B. Leakey, 2004. Domestication of Dacryodes edulis. 2. Phenotypic variation of fruit traits in 200 trees from four population in the humid lowlands of Cameroon. Food, Agriculture and Environment Vol. 2 (1): 340-346

Summary

Within a wider tree domestication programme, the purpose of this study was to quantify the tree-to-tree variation in fruit traits as an aid to plus tree selection. Detailed measurements of 10 fruit traits for 24 fruits from each of 200 *Dacryodes edulis* trees were made from four villages in the humid lowlands of Cameroon. Highly significant ($p<0.001$) differences were found in mean fruit length (33.5 to 122.4 mm), fruit width (23.3 to 53.5 mm), flesh depth (0.6 to 11.1 mm), fruit mass (10.0 to 114.0 g) and flesh mass (12.5 to 106.0 g). For each of these traits, continuous variation was evident. In addition, fruits displayed differences in skin and flesh colour, taste and oiliness. The most frequent skin colour was greyish-violet (Methuen Colour Code 18D) and for flesh colour was yellowish (Methuen Colour Code 29A7). With the exception of kernel mass, traits differed significantly between the four villages but no significant differences were found between the different land use systems (home garden, cocoa farms, forest fallow, or crop field). This paper provides the first quantified description of tree-to-tree variation in fruit characteristics within populations of D. *edulis* in Cameroon, and also describes a methodology for evaluating future collections from which to select superior phenotypes for cultivar development.

Wessel, M., Gerritsma, W., 1994. Re-thinking the shade policy for cocoa growing in West Africa. Proceedings of the 11th International Cocoa Research Conference, Yamoussoukro, Côte d'Ivoire, 18-24 July, 1993. Pp. 681-686.

Summary

In West Africa, since the early nineteen sixties, often a no-shade approach for mature cocoa has been followed. The high yield potential of unshaded cocoa has clearly been demonstrated on experimental fields but is not reflected in the present average yields from farmers' fields. The combined effects of new planting material and absence of shade have often resulted in a short economic lifetime. Under sub-optimal conditions serious dieback diseases occur while in good environments excessive vegetative growth at the expense of cropping is found. Another problem has been that the inputs required by unshaded cocoa are too expensive for small farmers and often not timely available.

In view of these observations and the low cocoa prices the question arises whether newly planted and replanted fields should not be developed towards low input productions systems with economically beneficial shade trees, such as timber and fruit trees, in addition to cocoa. Results from long-term experiments in Costa Rica and plantation practice in Malaysia indicate that shaded cocoa offers a sustainable cropping system which can combine yields of 700-1000 kg dry beans per ha with economically attractive returns from shade trees. Although farmers' cocoa in West Africa is usually interplanted with some oil palms, fruit trees and forest trees, the full potential of these mixed plantings has so far not been fully exploited.
A re-orientation towards shaded cocoa requires a thorough analysis of the economic returns of various cocoa-shade tree combinations. As to research, more information is needed on the relationship between vegetative growth and cropping under shaded conditions and on the effects of light on flowering and pod setting. A shaded cocoa is a complex system, process-oriented models will be needed for a quantitative assessment of the interactions and feed-back processes.

Willey, R.W. 1975. The use of shade in coffee, cocoa and tea. Horticultural Abstract 45 (12): 791 – 798.

Summary
In this literature review of shade on coffee, cocoa, and tea the author provides examples which demonstrate that shading consistently reduces yield, and causes less intense and shorter periods of flushing. However, the author cites examples, which show that cocoa planted under shade achieves the highest yield levels under low nutrient conditions, but with the addition of fertiliser the highest yields are obtained under no-shade conditions. The author also speaks to shade reducing the diurnal ambient air temperature, and an improved water balance in terms of leaf moisture.

Zapfack, L., Engwald, S., Sonké, B., Achoundong, G. and Madong, B.A. 2002. The impact of land use conversion on plant biodiversity in the forest zone of Cameroon. Biodiversity and Conservation 11(11): 2047-2061

Summary
Floristic surveys were carried out in different land use systems (primary and secondary forest, fallows of different ages, cocoa plantations, crop fields) within the forest zone of Cameroon, to assess the impact of land conversion on above-ground plant biodiversity. Beside various diversity studies, plant density was measured and diameter at breast height was estimated. The results showed that the forest areas, which represent the historic biodiversity of the region, preserve the greatest number of species (160 species in primary forest and 171 in secondary forest). Our results indicate the relatively great importance of secondary forest as refuge areas for primary forest plant species that may function as a starting point for possible regeneration original biodiversity. Species richness is reduced progressively from the original forest (160 spp.) and secondary forest (171 spp.) to *Chromolaena odorata* (*Asteraceae*) fallow fields (149 spp.) to an old fallow field (139 spp.) to a cocoa plantation (116 spp.) and to the farmland (64 spp.) where only weeds and crops contribute essentially to plant biodiversity. Also the number of species that are for non-timber products (construction, food and medicines) decreased with increased land conversion.

Appendix 2. List of institutions and researchers working on sustainable cocoa in West Africa

Institution	Contact Person	Position	Address
Ghana			
Cocoa Research Institute of Ghana-CRIG	Dr. Gilbert Anim-Kwapong	Research Officer-Agronomy and Soil Science Dept.	P.O.Box 8, New-Tafo, Ghana Email: gkwapong@crig.org Tele: + 233 27 60 99 00
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Centre National Floristique, Universuty of Cocody	Dr. N'Guessan Kouakou Edouard Prof. Ake-Assi Laurent	Director Botanist	08 B.P. 172, Abidjan 08, Cote d'Ivoire Email: k_nguessan@yahoo.fr Tele: + 225 22 44 86 14/22 43 43 09
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ICRAF-Africa Humid Tropics Region Office	Dr. Zac Tchoundjeu	Regional Co-ordinator	P.O.Box 2067 yaounde-Cameroon Email: z.tchoundjeu@cgiar.org Tele: + 237 221 5084
Centre for International Forestry Research-CIFOR	Dr. Ousseynou Ndoye	Regional Co-ordinator	P.O.Box 2008 Yaounde-Cameroon Email: o.ndoye@cgiar.org Tele: + 237 223 7434/223 7522

Institution	Contact Person	Position	Address
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Nigeria			
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