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Farmers' ecological and agronomic knowledge about the management of multistrata cocoa systems in Southern Cameroon.

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FARMERS' ECOLOGICAL AND AGRONOMIC KNOWLEDGE ABOUT THE MANAGEMENT OF MULTISTRATA COCOA SYSTEMS IN SOUTHERN CAMEROON

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A thesis submitted in candidature of the degree of Doctor of Philosophy

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DEDICATION

To those who have filled my life with encouragement and love

In loving memory of my beloved mother, Messina Stéphanie

In loving memory of my beloved father, Nomo Germain

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This thesis is the fruit of a collaborative research project between the Institute of Agricultural Research for Development (IARD) of Cameroon, the International Institute of Tropical Agriculture's (IITA) Humid Forest Ecoregional Centre in Yaoundé, Cameroon and the School of Agricultural and Forest Science of the University of Wales, Bangor, UK. The Sustainable Tree Crops Programme (STCP) founded the research. I wish to acknowledge all for providing an ideal framework for the execution of the research.

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ABSTRACT

This thesis presents research on local agronomic and ecological knowledge about agroforestry systems using the knowledge-based system (KBS) approach. The research focused on the cocoa multi-strata systems of southern Cameroon. Its objectives were to investigate farmers' agronomic and ecological knowledge about the management of these systems, and to identify key gaps in farmers' knowledge as a means to facilitating planning and prioritisation of research and extension activities.

In order to achieve this, farmers' knowledge was investigated in four contrasting locations distinguished by ecological zone, population density and access to market, and was relating to: i) their perceptions of the above and belowground ecological processes occurring in their cocoa fields, ii) their knowledge on cocoa pests and diseases occurrence and management, iii) Their systems of soil classification and implications of these for soil resources availability and management and, iv) their perceptions of soil-tree interactions and effects on system sustainability and productivity. A knowledge base documenting farmers' understanding of these issues was developed. In-built features of the KBS software were used to access knowledge contained in the knowledge base, and to retrieve and analyse information on specific topics or set of topics.

Key findings indicated that farmers' in southern Cameroon possessed sophisticated knowledge on the subjects investigated, and that they actively use that knowledge as the basis for making decisions about the management options of their multistrata cocoa systems. There were indications of induced knowledge formation in some locations as a result of intensification of the system with introduction of non-native species or domestication of native species of interest. The analysis of the numbers of statements provided by individual informants shows a fairly continuous distribution, with about half of the informants providing less than 25% of the statements.

The study also found that farmers' overall knowledge was likely similar to what is known scientifically, though the management options usually differ between the two communities for various reasons that are discussed. Key issues having implications for further research and extension activities are identified. The study concludes by suggesting an effective integration of global science and local knowledge for sustainable and productive cocoa systems, rather than reliance on one source at the expense of the other. As local knowledge is being eroded pointing to its inevitable loss as socio-economic and environmental circumstances change, the study recommends use of the knowledge-based systems methodology as a means to documenting this valuable domain of knowledge.

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ACRONYMS

AKT	Agroecological Knowledge Toolkit for Windows
Ca	Calcium
CABI	International Center for Agriculture and Bioscience
CCSP	Cocoa and Coffee Seedlings Project
CEC	Cation Exchange Capacity
CENADEFOR	Centre National de Développpement des Forêts
CFC	Common Food Commodity
CIG	Common Initiative Group
CIRAD	The International Cooperation Centre in Agronomic Research for Development
DFID	Department for International Development of the UK
FAO	Food and Agricultural Organisation of the United Nations
FFS	Farmers' Field School
GRO-Cocoa	Global Research On Cocoa
IAR	Institute of Agronomic Research of Cameroon
IARC	International Agricultural Research Centres
IARD	Institute of Agricultural Research for Development of Cameroon
ICCO	International Cocoa and Coffee organisation
ICCRAF	International Center for Research in Agroforestry
IITA	International Institute for Tropical Agriculture
IITA-HFC	International Institute for Tropical Agriculture – Humid Forest Centre
IK	Indigenous Knowledge
IMP	Integrated Pest Management
IPR	Intellectual Property Rights
KBS	Knowledge-Based Systems
K	Potassium
Mg	Magnesium
MINAGRI	Ministry of Agriculture of Cameroon
NARES	National Agricultural Research and Extension Services
NGO	Non Governmental Organization
ONADEF	Office National de Development des Forêts
PRA	Participatory Rural Appraisal
RRA	Rapid Rural Appraisal
SAFS	School of Agricultural and Forest Sciences of the University of Wales, Bangor UK
SODECAO	Société de Dévelopment du Cacao
STCP	Sustainable Tree Crops Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USDA classification	United State Department of Agriculture classification

WinAKT	Windows for Agroecological Knowledge Toolkit
WWF	The Global Conservation Organisation. (former World Wide Fund for Nature)

CHAPTER 1
GENERAL INTRODUCTION

1.1 GENERAL

The results presented in this thesis are the fruit of a collaborative research project within the framework of the Sustainable Tree Crops Programme[1] (STCP), between the Cameroon Institute of Agricultural Research for Development (IARD), the International Institute for Tropical Agriculture (IITA), and the School of Agricultural and Forest Sciences (SAFS) of the University of Wales, Bangor. The focus of the research was the ecology and management of multistrata cocoa (*Theobroma cacao*) agroforests of southern Cameroon. The working hypothesis of the study was that there is a substantial body of farmer knowledge about the ecological functioning of the complex cocoa agroforests in southern Cameroon, which if captured and put to good use, can offer important directions for both research and extension to improve and diversify system productivity and provision of ecosystem services.

In recent years, there has been a growing awareness among the various partners involved in the cocoa production chain in Cameroon of the need to incorporate farmers' views and experiences in research projects aimed at revamping the sector. It was fortunate that this initiative coincided with the development of computer software that enables acquisition, storage and exploration of ecological knowledge at the School of Agricultural and Forest Sciences of the University of Wales, Bangor. This software, together with

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[1] The Sustainable Tree Crops Program was created to achieve a shared vision for sustainable tree crop development. It is a public-private partnership between industry, producers, researchers, government agencies, public sector institutions and conservation groups. Its mission is to "improve the economic and social well-being of smallholders and their communities, and ensure the environmental sustainability of tree crop systems."

techniques of knowledge elicitation, was used to acquire, store and explore farmers' knowledge about cocoa systems. Further, analysis and evaluation of the content of the knowledge base was carried out, major gaps in farmers' knowledge systems highlighted and key lessons drawn. This chapter outlines the background to the present research, the research objectives and the structure of the thesis.

1.2 BACKGROUND

1.2.1 Overview of Congo basin rainforest

The tropical forest in southern Cameroon is part of the Congo basin rainforest whose borders encompass the world's second largest area of contiguous rainforest. This makes the Congo basin a region of global priority in terms of biodiversity and other ecosystem services. Biodiversity in the region is threatened by the high rate of deforestation that has occurred over recent years. In 1998, the annual rate of deforestation in the region as a whole was estimated at 6% (1 201 000 $hayear^{-1}$. FAO, 1997).

In Cameroon, the annual rate of deforestation is also estimated at 6%, with about 129 000 ha of the remaining 19 M ha of closed canopy forest lost annually (FAO, 1999). Most (85%) of the deforestation in Cameroon is attributed to smallholder agriculturalists using extensive slash-and-burn techniques to clear forest for the creation of new farms (Gockowski et al., 1998; Kotto-Same et al., 2000). The low productivity of agriculture, in combination with rapid population growth, results in a continual extension of the forest margin (Gockowski et al., 1998a). Thus, rural population density plays a significant role in determining the extent of closed canopy forest in a given area.

1.2.2 Multistrata cocoa systems in southern Cameroon

Cocoa (*Theobroma cacao*) is one of the most important cash crops in Cameroon, grown by an estimated 350 000 small-scale farmers (Assoumou, 1977; Duguma et al., 2001) in the forest and forest-savanna transition regions. Compared to other agricultural activities, cocoa production has been a leading sub-sector in the economic growth and development of these regions. However, since the late 1980s, the cocoa sector has been subjected to several economic shocks, the most important being a drastic fall in world prices for cocoa and other commodities that has led to new organisational frameworks. Cocoa farmers responded to these shocks by diversifying their sources of household revenue, especially by increasing their activity in food crop production, and intensifying their cocoa systems with the introduction of fruit tree species and oil palm (*Elaeis guineensis*) (Gockowski et al., 1998; Aulong, 1998; Duguma et al., 2001).

One of the main identifying characteristics of southern Cameroon cocoa systems is their high level of product diversity and their forest-like structure relative to most other cocoa production systems in the world (Leplaideur, 1985; ICRAF, 1987; Ruf and Schroth, 2004). This is most noticeable in areas with scarcity of land and high population density, where cocoa agroforests often represent the main forest remnants in the landscape. That complex agroforests have developed, as the predominant form of cocoa growing in this region, is best explained by the predominance of indigenous farmers amongst the cocoa growers (Losch et al., 1991; Ruf and Schroth, 2004). Other cocoa production areas in Cameroon, such as the Mbam region and the southwest region, have received more immigrants and followed more monocultural systems of cocoa growing. Where farmers have maintained multi-product features, this has been to sustain system productivity and to contribute to household livelihoods, while also enhancing biodiversity conservation.

The cabrucagem system[2] along the Atlantic coast rainforest of Bahia in Brazil is the other major example of shade cocoa agroforest. These systems are often cited for their conservation functions (Johns, 1999). However, unlike the cabrucagem systems, which are relatively large-scale single owner farms (100-200 ha), the median size of typical Cameroonian cocoa farms does not exceed 2 ha (Gockowski et al., 1998; Kotto-Same et al., 2000). Also, in contrast to the cabrucagem systems, which are encouraged by the Brazilian government because they help to preserve the diversity of the rare plant and animal species that inhabit that region, the management options of the cocoa systems in southern Cameroon are essentially initiated and conducted by local communities. These systems, many of which have been in continuous production for over sixty years, rely on relatively closed nutrient cycling, with agrochemicals for the control of pests and diseases. Yields are stable but low, typically ranging from 100 kg to 500 kg ha^{-1} y^{-1} on actively managed farms (Gockowski et al., 1998).

1.2.3 Justification.

Cocoa trees are grown on the major soil types found in southern Cameroon (Gockowski et al., 1998; Duguma et al., 2001). Cocoa was preferred by indigenous farmers to other cash crops such as coffee (*Coffea canephora*) or oil palm (*Elaeis guineensis*) because of its lower capital and labour requirements, together with the existence of a ready market. However, in recent years, farmers have been experiencing continuous drops in yield, which they attribute to soil fertility depletion, and more importantly to a build up of cocoa pest and disease pressure (Nyasse, 1997; Gockowski et al., 1998; Duguma et al., 2001).

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[2] Traditional system of farming cocoa found in the Atlantic rainforest in Bahia, a major cocoa-producing region in Brazil. Cocoa trees are planted in the understorey of the existing forest. Minimal removal of smaller herbaceous plant species leaves much of the forest intact, saving it from destruction. Close to 60-70% shade is maintained in the fields.

In the first issue of GRO-Cocoa[3] of June 2002, the International Cocoa and Coffee Organisation (ICCO) predicted not only a rise in world cocoa consumption over the coming years, but also a continuing drop in production, with demand exceeding production for the first time. It is anticipated that the increasing integration of valuable non-cocoa species into cocoa systems that has been observed in recent years as farmers have responded to the drastic fall in cocoa market prices, and the observed decreases in farm yields, may contribute further to the drop in cocoa production. Increasing complexity of the system coupled with yield decline may engender new challenges in farm management.

In the meantime, new technologies proposed by research and extension agents especially in the field of farm management and strategies for the control of cocoa pests and diseases, have not been widely implemented by farmers because of lack of means to afford the minimum package of inputs required. Until the early 1990s, the government provided fungicides at no cost to farmers and implemented the treatment of their plantations with insecticides. Following the fall in cocoa prices and subsequent liberalisation in the cocoa market sector, the government discontinued the service (Duguma et al., 2001). In the depressed cocoa market, farmers were unwilling to pay for the inputs and even if they were willing, they had difficulties finding private suppliers. Consequently, cocoa production suffered neglect and in some cases was abandoned (Losch et al., 1990).

Developing cost-effective, and thus feasible strategies towards enhancing the sustainability and productivity of cocoa agroforests in southern Cameroon appeared to be a worthwhile approach to making sustainable cocoa agroforests more attractive to farmers. This approach is increasingly gaining ground

[3] Global Research on Cocoa – working with and for farmers newsletter. Produced biannually with financial assistance from the US Department of Agriculture by CABI Commodities.

among the scientific community and development agencies. One of the sustainable ways to reach that goal is by taking into account the farmers' long-term experience and the knowledge they have developed, which has enabled them to maintain these systems in production for decades. It is increasingly recognised in the international environment that the knowledge of local peoples and communities embodying local lifestyles has a major role to play in system productivity and biodiversity conservation (Gonzalo et al., 2000). Consequently, one of the most important tasks in this connection is to counter the erosion of local knowledge by putting in place mechanisms and systems for the revitalisation and protection of such knowledge.

1.2.4 Indigenous knowledge systems

1.2.4.1 What do we mean by "knowledge"?

Knowledge has been variably defined and can be regarded as a philosophical concept that may lead to ambiguity and confusion if the context in which it is used has not been explicitly defined. In this study, knowledge is viewed as: the outcome of the interpretation of data, independent of the interpreter (Sinclair and Walker, 1999) and a basis for prediction of future events (Joshi et al., 2004). Data is the present context is defined as a recorded set of either qualitative or quantitative observations; and information is a continuum that has data and knowledge as two extremes. Information, data and knowledge are different from understanding. Understanding in the present context is used to mean the outcome, specific to the interpreter, of the interpretation of data or knowledge: the comprehension that the interpreter achieves. Knowledge is thus seen as a central aspect of culture, derived from education and experience, that may be used, in conjunction with consideration of a value system and competing priorities and possibilities, to make decisions and, therefore, lead to action (Sinclair and Walker, 1999).

1.2.4.2 Indigenous knowledge systems: definitions

The complexity and diversity of ideas surrounding local knowledge have led to the term "indigenous knowledge" being used loosely in the literature (Thapa, 1994). In many of the major texts on the subject, readers are left to formulate their own definitions. The confusion and ambiguity that surround the term in an agricultural context are partly due to its oral, rural and powerless nature that has made it largely invisible to the development community and to global science[4] (Warren, 1992). A range of similar terms have been used by previous authors such as "local technical knowledge" (Bodley, 1976: 48) "peoples' science" (Richards, 1985), "indigenous technical knowledge" (Sharland, 1989; Fairhead, 1990), "traditional knowledge" (Barrow, 1991; Gonzalo et al. 2000), "ethnoscience" (Barker et al., 1977), "rural peoples' knowledge" (Chambers, 1983) and "indigenous ecological knowledge" (Walker et al., 1991).

It can however be observed that the numerous terms used to indicate knowledge held by peoples or communities often reflect the disciplinary context or specific circumstances within which the term is used. In this regard, anthropologists will preferably use the term "ethnoscience" or "ethnoecology"; the WWF will preferably use the term "traditional knowledge" because of the nature of the interactions they develop with indigenous[5] and traditional peoples; whilst agroforesters may likely prefer the term "indigenous ecological knowledge" or "local ecological knowledge" because of the interest they attach to farmers' interpretation of the interactions and processes that occur in agroforestry systems.

[4] Global science comprises agricultural research, extension workers, and NGOs.
[5] The term "indigenous" in the understanding of WWF, stands for "indigenous and tribal", according to the definition in Article 1 of the International Labour Organisations' Convention 169 on Indigenous and Tribal Peoples in Independent Countries.

Warren and Rajasekaran (1993) define indigenous knowledge as "local knowledge that is unique to a given culture or society. It is the information base for society, which facilitates communication and decision-making. Indigenous knowledge is the systematic body of knowledge acquired by local people through the accumulation of experiences, informant experiments, and intimate understanding of the environment in a given culture". According to Thrupp (1989), indigenous knowledge systems are adaptive skills of local people, usually derived from many years of experience that have often been communicated through "oral traditions" and learned through family members and generations. These two definitions, which summarise the numerous definitions of terms used to refer to indigenous knowledge, suggest interchangeability in the use of indigenous knowledge and local knowledge. However, it is possible to distinguish between the two if local knowledge is used to denote local understanding which is based on experience and observation, and indigenous knowledge is used to denote that same understanding but modified by the incorporation of cultural beliefs and values as well (Walker et al., 1994; Dixon et al., 2001).

The distinction between indigenous knowledge and scientific knowledge (often referred to as "international knowledge" (Warren, 1991)) is contentious, the main difference noted is that the former concentrates on adaptation of knowledge and is less formal in both its social organisation and its research methods (Biggs and Clay, 1981; Thapa, 1994). Howes and Chambers (1980) suggested that "science and indigenous knowledge may be contrasted and evaluated according to three criteria: as systems of classification; as systems of explanation and prediction; and, in terms of speed of accumulation". They also suggested that while indigenous knowledge and science are comparable with respect to the first criterion, science is generally superior with respect to the second and the third criteria. Similarly, Walker et al. (1991) note that "the differences between indigenous and scientific knowledge are not at a fundamental, conceptual level but in terms of formal structure, institutional framework, technical facility and ability and scale of perspective".

The present research is basically focused on farmers' ecological knowledge about interactions and processes that occur in multistrata cocoa systems in southern Cameroon. For the purpose of this research, a working definition proposed by Walker et al. (1991) is used. The authors define ecological knowledge as "farmers' knowledge about components of established production systems that they operate, and interactions amongst those components and between them and the environment".

1.2.4.3 Indigenous knowledge in agricultural research in Cameroon

Until recently, little attention has been paid by scientists in Cameroon to indigenous knowledge in their various strategies to address problems confronting local farmers. The interactions between farmers and scientists have long been characterised by a top-down, delivery of message approach, where scientists usually identified and proposed remedies to what they thought were constraints to production at the farmers' level, with little room for attention to ecological principles behind recommendations or particular circumstances of the farmers. Farmers were mainly seen as the recipients of technical messages but not the originators of either technical knowledge or improved practice. This approach has led to a critically low rate of adoption of the proposed innovations. Warren (1991) suggested that farmers' decisions to adopt or reject an innovation are often rational when viewed from their indigenous perspective. Thus, understanding the way that local knowledge provides the basis for farmers' decision making could help science more relevant to farmers' present circumstances and in the communication of innovations.

Recent thinking aimed at enhancing the sustainability and productivity of farming systems suggested the necessity of incorporating farmers' knowledge in agricultural development programmes. This has resulted in the widespread use of many models of participatory diagnosis of the major socio-economic and agronomic production constraints that involve farmers, extension workers and researchers in southern Africa, Asia and Latin America. The model adopted in Cameroon, which uses rapid rural appraisal techniques (RRA), is characterised by strong interactions between extension workers and farmers on the one hand, and extension workers and researchers on the other hand (Figure 1.1). The interactions between researchers and farmers, though existing, are usually limited to group meetings mentioned above or to individual researcher's initiatives with no clearly defined institutional framework, as is the case with extension workers.

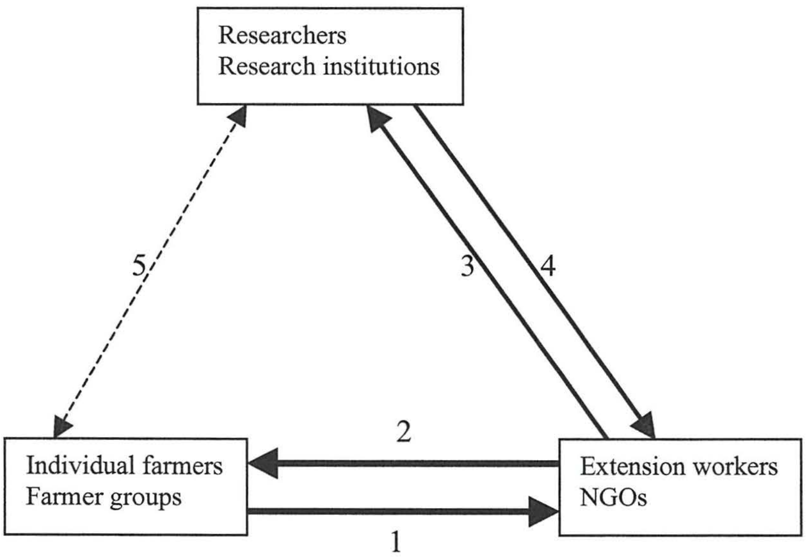

Figure 1.1 Interactions between farmers and scientists about diagnosing constraints to production in Cameroon.

1. Farmers report problems faced during farming activities, mainly those considered as constraints to production to the nearest extension worker or development agent.
2. The extension worker or development agent organises a field visit to assess the problem and proposes solutions if available.
3. The problem is relayed to research or any relevant institutions if he cannot address the issue with available means.
4. Researchers propose solutions if available, or go for further investigations otherwise.
5. Informal contacts.

1.3 PURPOSE OF THE STUDY

The purpose of this study was to acquire and document farmers' ecological knowledge associated with the management of their complex multistrata cocoa systems in a computer readable form, then to contrast farmers' knowledge with what is known scientifically to bridge knowledge gaps. More specifically, the study aimed at:

1. investigating farmers' knowledge of interactions occurring among the major components of their cocoa systems, and their effects on system sustainability and productivity,
2. investigating how farmers used this knowledge for decision-making about the management of their cocoa systems,
3. exploring the knowledge base in order to identify inadequacies in knowledge that may have significant detrimental effects on system productivity and,
4. identifying key gaps in current knowledge as a means of facilitating planning and prioritising of research and extension activities.

Finally, the study aimed to assess the value and pertinence of local farmers' understanding of the processes occurring in their cocoa systems and the management decisions derived from it. This is an efficient method of using available knowledge to formulate and target research, while facilitating effective communication among stakeholders (Sinclair, 2003[6]).

1.4 STRUCTURE OF THE THESIS

This thesis is organised in seven chapters structured as follows:

The present introduction chapter was outlining the background and the context of the research.

Chapter Two gives an insight into the physical environment and socio-economic organisation of the study communities. Issues concerning landscape and vegetation, social and economic infrastructures, farming systems and land use intensity, together with a characterisation of the livelihoods of the study communities are covered.

Chapter Three describes the methodology used in acquiring farmers' ecological knowledge about cocoa systems in southern Cameroon and the creation of a formal record of their knowledge base. Further, an exploration and analysis of the knowledge base is carried out, using inbuilt software facilities.

Chapter Four presents farmers' long-term observations and experience about circumstances favouring the break out of cocoa pests and diseases in their farms and the strategies they use to circumvent these epidemics, with a focus on locally developed strategies.

Chapter Five is about capturing farmers' rationale underlying the selection of suitable land for the creation or extension of cocoa farms. Important features

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[6] Working paper on the Sustainable Tree Cops Programme in Cameroon.

include farmers' system of soil classification and the effects of site selection on cocoa growth, and farmers' perceptions about the soil-tree interactions.

Chapter Six assesses local knowledge about the impact of tree species dynamics on system sustainability and productivity, as well as the impact of human interventions on the ecology of cocoa systems. Farmer assessment of tree species in terms of: i) site suitability prediction, ii) soil water uptake, iii) competitiveness with cocoa as regards soil water and, iv) frequency of usage of non-cocoa tree species products are presented together with an inventory of non-cocoa tree species on cocoa farms.

In the concluding Chapter Seven, the understanding that can be derived from this study and implications for future cocoa agroforest research in Cameroon are addressed. Some institutional issues raised by the study are discussed.

CHAPTER 2
STUDY LOCATIONS AND THEIR COMMUNITIES

2.1 GENERAL

The present research on farmers' knowledge about their multistrata cocoa systems was conducted in four locations; three of which fall within the forest margins benchmark area of southern Cameroon, and one outside in the forest-savanna transition zone. The forest margins benchmark area spans a gradient of population density, and also encompasses significant variation in biophysical and socio-economic conditions. The area was defined in 1993 by IITA, in close collaboration with the National Agricultural Research and Extension Services (NARES) of west and central Africa and other International Agricultural Research Centres (IARCs) and agricultural organisations (Ngobo, 2002).

The main objective of the research reported in this chapter was to obtain basic information about the study area and communities including:

- the physical and socio-economic context of farming systems
- the major land use systems, with emphasis on cocoa production, and
- local livelihoods.

2.2 THE OVERALL STUDY AREA

2.2.1 General presentation

The forest margins benchmark area of Cameroon, which covers 1.54 Mha of land, lies from latitudes 2°20'N to 4°30'N and longitudes 11°00'E to 11°50'E. The benchmark has been divided into three major blocks (Figure 2.1) that are representative of the range of biophysical features and resource use intensity found in the area, and which can be ranked from low to high as follows.

In the southern part is the Ebolowa block, with low population density (2-15 inhabitants km^{-2}) and large tracts of intact primary forest (59% of land cover) (Gockowski et al, 1998; Ngobo, 2002). The land use intensity is low compared to the other blocks. There is still significant reliance on natural resource-based activities such as gathering of non-timber forest products. Local agricultural markets are comparatively small, agricultural input markets are undeveloped, and road infrastructure is poor and not maintained. During the rainiest period of the year, roads are not usually accessible.

In the central part is the Mbalmayo block, with moderate population density ranging from 10 to 41 inhabitants km^{-2} and the predominance of heavily degraded secondary forest with moderate land use intensity. Local agricultural markets are comparatively small and market access relatively poor, especially in remote locations.

In the northern part of the benchmark is the Yaoundé[7] block, with an average population density of around 80 inhabitants km^{-2} and most of the land in some phase of an agricultural cycle; only 4% of land remains covered by primary forest (Gockowski et al, 1998). Proximity to the Yaoundé market and better-

[7] Yaoundé is the capital city and second largest city of Cameroon.

developed market access has led to the process of agricultural intensification, diversification and commercialisation.

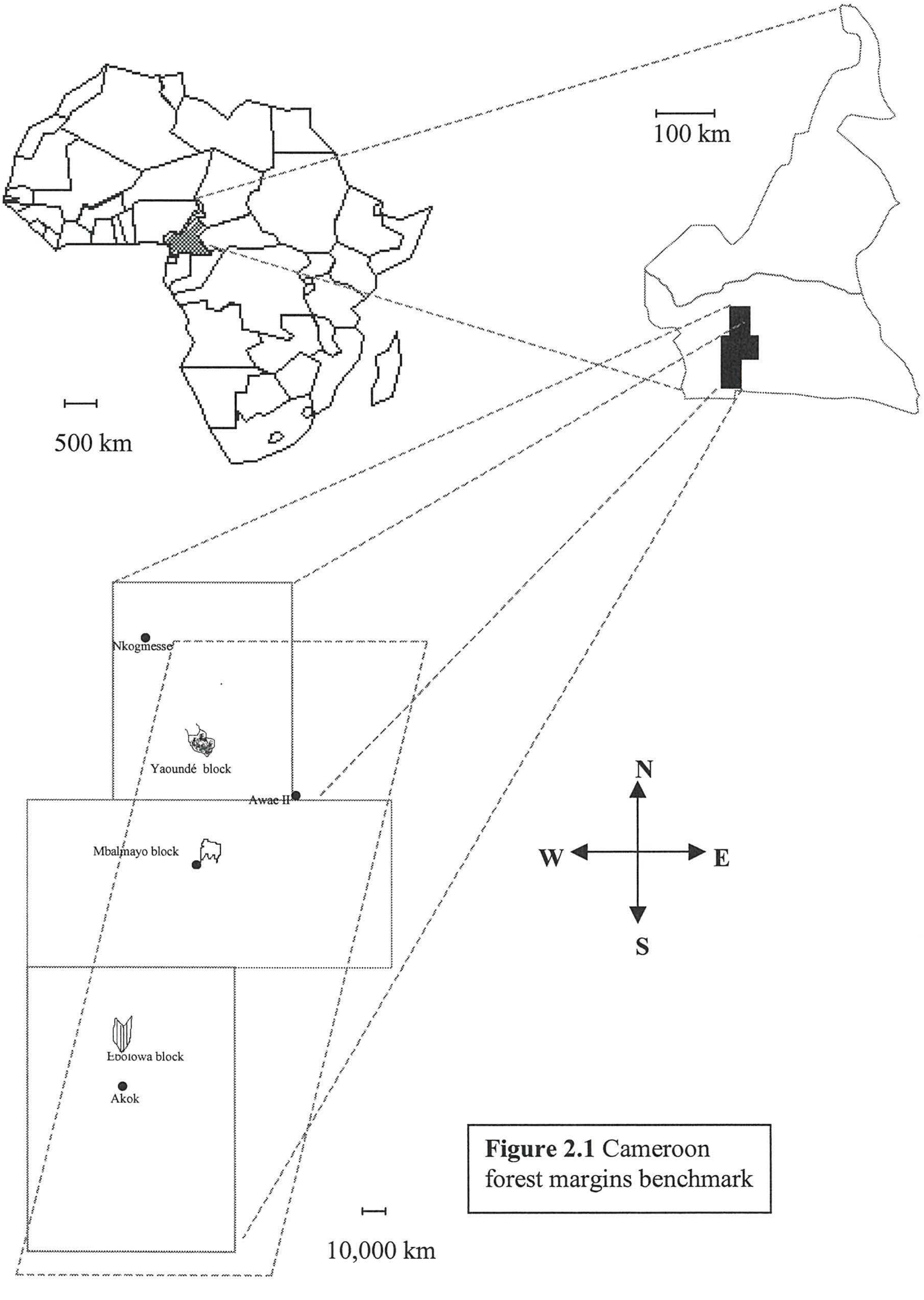

Figure 2.1 Cameroon forest margins benchmark

2.2.2 Selection of the study locations

There are four major cocoa producing basins in Cameroon (Figure 2.2), which are:

1. The southwest basin that represents 50% of national production with a predominance of intensive cocoa production systems. The area is characterised by favourable soil and climatic conditions for cocoa growth and abundant land resources (50 inhabitants km^{-2}). Farmers have been receiving technical assistance from the Cocoa and Coffee Seedling Project (CCSP), a government sponsored body. The area is also characterised by high immigration, with more than 90% of cocoa farms owned or managed[8] by migrants.
2. The centre north basin, which is contiguous with the southern basin, corresponds to the pioneer front of Mbam with relatively young cocoa farms. About 23 000 ha of cocoa were planted in 1989 with the technical and material assistance of SODECAO, a parastatal company in charge of promoting cocoa production in the area. The migration dynamic is also important in this area, but more indigenous people are involved in farming than in the southwest basin.
3. The southern basin, which is the oldest cocoa producing basin in Cameroon, is characterised by extensive cocoa production systems. Cocoa farms are generally old and the production is in a continuous decline. Unlike the southwest and the centre north production basins, cocoa farmers in the southern basin are mainly indigenous forest dwellers.
4. The eastern Cameroon basin also has extensive cocoa production systems. The land resource is abundant, but the road infrastructure is

[8] There is a common practice in the area, which consists of cocoa farm owners for one reason or another conferring the management of their cocoa farms to a third party (generally migrants) under specific agreements.

very poor and market institutions critically undeveloped. As a consequence, farmers in this area face numerous difficulties in acquiring manufactured inputs to control cocoa pests and diseases or to get buyers for their produce. This usually leads to temporary abandonment of management of farms for part of the year, especially during rainfall seasons.

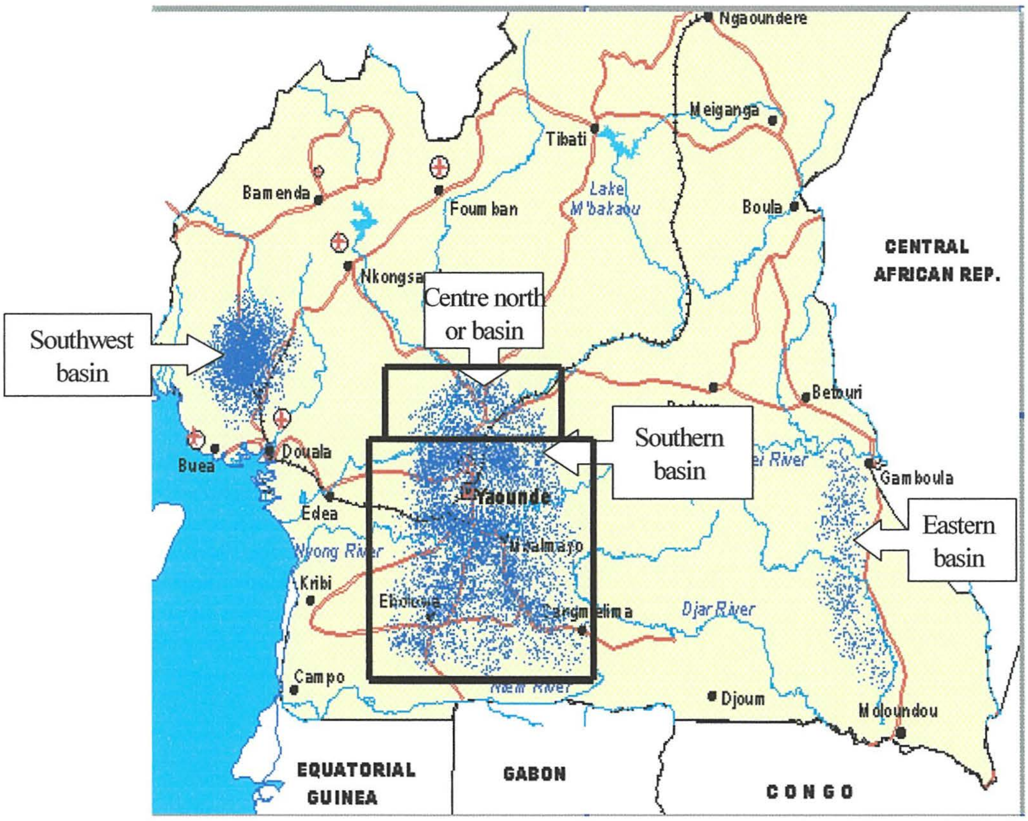

Figure 2.2 Major cocoa producing basins in Cameroon

Given that the primary aim of the present study was to learn from local communities about their knowledge of the multistrata cocoa systems, it was important to select an area where farmers had a long tradition of growing cocoa or where farmers were facing acute constraints to the management and productivity of their cocoa systems. It was anticipated that such constraints were potentially important inducements to knowledge formation, as farmers in such areas would constantly seek for strategies to address the challenges confronting them. The southern Cameroon cocoa-producing basin was, therefore, chosen because of the numerous challenges faced by cocoa growers in the area and their long-term experience of growing cocoa. In this regard, three distinct locations, representing the three blocks of the forest margins benchmark, and reflecting contrasting availability of natural resources and land use intensity were selected for the study. They were: Akok in the Ebolowa block, Awae in the Mbalayo block and Nkongmesse in the Yaounde block. A fourth location, Ndikinimeki, was selected outside the benchmark in the pioneer front of Mbam at the forest-savanna transition zone to contrast knowledge held by farmers from the two ecozones (Figure 2.3).

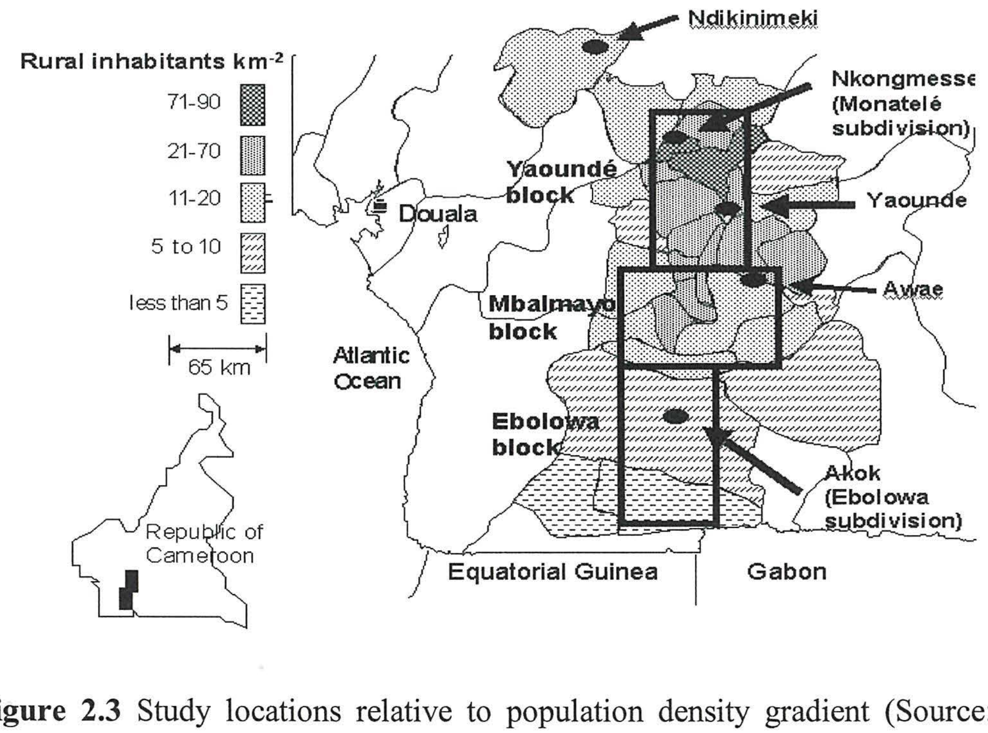

Figure 2.3 Study locations relative to population density gradient (Source: Densities from 1987 population census)

2.2.3 Biophysical context of the study area

2.2.3.1 Vegetation and landscape

The climax vegetation in the forest benchmark of Cameroon is of two types: the dense semi-deciduous forests characteristic of the Yaoundé block extending southwards into the Mbalmayo block, and the dense, humid, Congolese block reaches of the Mbalmayo block extending to the Ebolowa block (Kotto-Same et al., 2000). The major canopy tree species that characterise these vegetation types are *Terminalia superba* (Combretaceae), *Triplochiton scleroxylon* (Sterculiaceae), *Canarium schweinfuthii* (Burseraceae), *Ceiba pentandra* (Malvaceae), *Milicia excelsa* (Moraceae) and *Albizia* spp (Mimosaceae). Numerous other tree species belonging to monospecific genera endemic to Africa are also found in this vegetation (Letouzey, 1985). Along the western border of the Ebolowa and Mbalmayo blocks, there are small pockets of the biologically diverse, moist evergreen forest (Letouzey, 1985; Gockowski et al, 1998). The understorey vegetation is generally depleted. Increased population pressure combined with human activity has favoured the extension of semi-deciduous forest into the evergreen forest, mainly for the creation of cocoa and food crops farms, thus creating what Letouzey (1985) referred to as a "domesticated landscape". The Ndikinimeki area is characterised by forest-savanna transition zone vegetation, with forest galleries in the valleys and along the banks of streams and rivers. The herbaceous layer is mainly comprised of *Imperata cylindrica* that can reach 2 to 3 m in height at the end of the rainy season (Letouzey, 1985).

The topography of the study area is a peneplain that varies from level undulating to rolling hilly terrain. Average elevations are lowest (350 m) in the northernmost portion along the Sanaga and Mbam Rivers. Elevation then quickly rises to 700-800 m around the Yaounde area, then descends into the

Nyong river valley (640 m) around the Mbalmayo area, and finally moves down to 550 m in the southernmost part of the study area along the Ntem River.

The area is drained by an important network of streams and small rivers that flow in open "V"-shaped valleys towards the main rivers that are: the Sanaga and Mbam Rivers in the Yaounde block, the Nyong and the So'o Rivers in the Mbalmayo block, and the river Ntem in the Ebolowa block (Sanctoir and Bopda, 1995; Ngobo, 2002).

2.2.3.2 Soils

Soils in the study area fall into the FAO grouping of ferralsols, which are the largest soil class in the tropics. Physical and hydraulic characteristics of these soils reveal, by their variation in the ferralitic field, the existence of a zonal arrangement due to climate and human activity. The south, moist and covered with evergreen forest stands in contrast to the north, which is more dry and covered with savanna and forest galleries (Humbel 1974). Soil profiles of the domain present minor differences in terms of mineralogy and structure. The surface layers are generally low in clay content and organic matter is not evenly distributed. The cation exchange capacity (CEC) of these soils is generally low due to their high rate of leaching, indicating low fertility (Humbel, 1974; Van Ranst, 1983). From the moist zones in the south to more contrasted zones in the north, the apparent soil modifications lie in the change of soil colour from yellow to red. However, Humbel (1974) does not link this to the climate transition, or to the change from forest to savanna. Other soil classes found in the area are: Ferralic Arenosols, Humic Gleysols, Acrisols and Lixisols. A FAO (1977) evaluation of these soils for farming activities (Table 2.1) indicates that they are suitable for a wide range of tree crops.

Table 2.1 Land evaluation for some of the major soil units found in the Cameroon forest margins benchmark area.

Soil Class	Crop suitability	Comments
Orthic Ferralsols (Oxisols, Ustox or Orthox)	Cocoa, coffee, oil palm, rubber if clay content is high and humus-bearing horizon with good base saturation; rubber only for poorer sandy units.	Low content for fertilizing elements. Dark-red or red-yellow soils
Rhodic Ferralsols (Oxisols-Eutrustox)	Cocoa, coffee, plantain/banana, maize, groundnuts and traditional crops.	Highest agricultural value of ferrasols. Dusky-red.
Xanthic Ferralsols (Oxisol-Ustox)	If clay content is > 30%, very suitable for rubber and oil palm, suitable for coffee and moderately suitable for cocoa. If clay content is < 30%, suitable for rubber, moderately suitable for coffee, not suitable for cocoa.	Low base saturation, no mineral reserve. Yellow.
Dystric Nitisols (Ultisols)	Good for rubber, oil palm and coffee. Moderately suitable for cocoa.	Soil of medium value, subject to erosion.
Eutric Nitisols (Alfisols)	Best soil for cocoa. Also very suitable for coffee, oil palm and rubber. Suitable for all food crops.	High fertility, among best soils of the tropics.
Humic Gleysols	Those under swamp forest are not suitable for agriculture	Require considerable agricultural engineering to make suitable.

Source: FAO-UNESCO (1977).

2.2.3.3 The climate

The Cameroon forest margins benchmark area falls into the tropical climate regime. Locally, this climate is characterised by a bimodal rainfall pattern (Figure 2.4). Annual rainfall varies from 1350 mm to the north of Yaoundé to 1900 mm in the Ebolowa block (Gockowski et al., 1998a). The longer rainy season occurs during the period March/April-May/June, although more rain falls in the shorter period of September-November. The longer dry period in the year ("essep") extends from December to February, whilst the July to August period, though dry, has sporadic rainfall ("oyon"). In this period, the temperatures are lowest and the air saturation relatively high. Annual mean temperatures are lower at Yaoundé block (22.5° C), compared with Mbalmayo block (25° C) and Ebolowa block (24° C). Climatic data for Ndikinimeki were not available. In general, annual mean temperatures here are expected to be higher than in the other locations, and annual rainfall close to that in the north of Yaoundé.

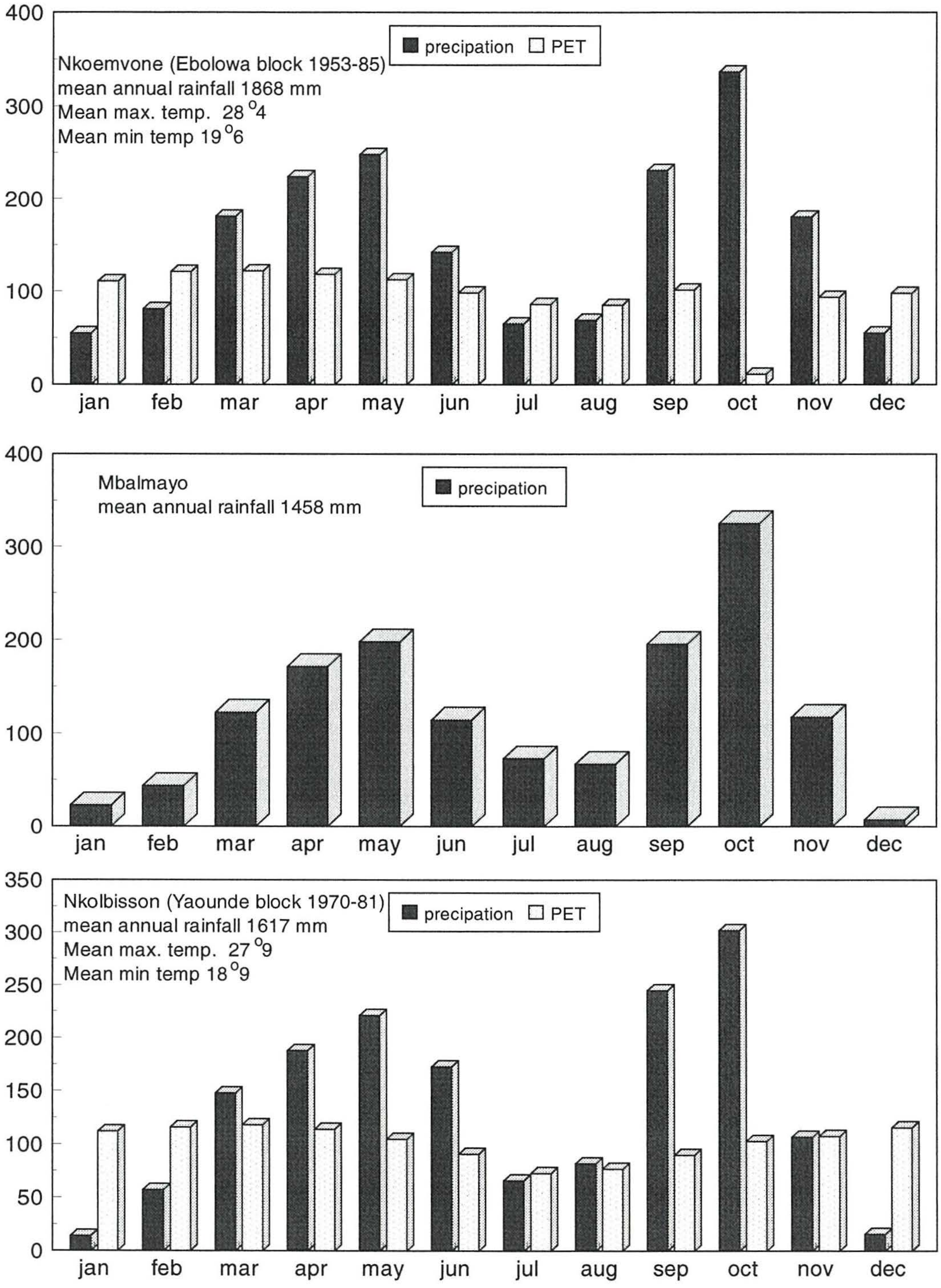

Figure 2.4 Meteorological data of Ebolowa, Mbalmayo and Yaounde blocks. Climatic data for Ndikinimeki were not available.

2.2.3.4 Farming systems

Major soil units in the study area are suitable for a wide range of both food crops and perennial crops (see Table 2.1). Most food crops are grown in multi-cropping systems although there is a tendency towards monoculture for commercial food production (for example the plantain/banana fields) in areas with reasonable market access. In general, farming systems in the study area vary a great deal as a function of land and labour endowments, market development and access and climate (Gockowski et al., 1998a). However, the one constant in the study area is the importance of the groundnut-based mixed field ("afub owondo"), which is a mixed food crop system. This farming system is the main source of household food security in the area, and is generally managed by women. In total, eight main farming systems have been identified in the study area (Gockowski et al., 1998a), and are ranked in order of importance as follows: the groundnut-mixed fields, the cocoa systems, the plantain/banana fields, the horticultural and other monocrop fields, the other mixed food crop fields, the *Cucumeropsis/Cucumis*-based fields, the home gardens, and the robusta coffee systems.

Three agricultural cycles can be distinguished for food crops (Van Dijk, 1999). Most land for the creation of food crop fields ("afup") is cleared during the longer dry season ("essep"). The cultivation period extends till the end of the rainy season depending on the crops. The second period of creating fields starts at the beginning of the short dry season ("oyon") and cultivation is usually limited to short cycle crops such as groundnuts, maize, cucumbers and cassava. A third type of field ("assan") makes use of depressions in the landscape or well-drained swamps ("elobi") and here the production cycle is restricted to the long dry season (December-March).

Unlike the cocoa and robusta coffee farming systems, the maintenance of soil fertility in the other farming systems is achieved largely though the system of fallow rotation. The effectiveness of fallow rotation in restoring soil fertility is determined by such parameters as the length of the fallow period, the number of previous cropping cycles and the natural soil fertility status (Floret and Pontanier, 2000; Ngobo, 2002). The fallow period and frequency are strongly determined by the amount of agricultural land available per household and the land use intensity. Longer and less frequent fallows are therefore likely to be more common in Ebolowa and Mbalmayo domains, as compared to Yaoundé and Ndikinimeki.

2.2.3.5 Livestock and fish farming systems

Livestock systems are generally undeveloped throughout the study areas, so that there are relatively few interactions amongst crops and livestock. Animal manures are not generally used in the study area except in the peri-urban production of leafy vegetables and other horticultural crops. The intensive production of pigs and chickens occurs predominantly in the Yaoundé urban periphery and is generally seasonal (Gockowski et al., 1998). In rural areas, households usually possess small livestock that are generally allowed to range freely across the landscape.

The introduction of fish farming systems to the study area is recent. At present, only a few fishponds limited to areas with accessible inland valleys around Yaoundé are recorded. The enthusiasm of fishpond owners is however compromised because of insufficient material support; inadequate technical assistance and scarcity of appropriate natural sites, thus leading to a gradual abandonment of the sector to those who can afford the inputs necessary to conduct the activity. In remote areas with abundant water resources, local people seasonally collect fish for local consumption from streams and rivers in their surroundings, using inadequate equipment. Local people in the study area rely mainly on institutional market centres for fish needs.

2.2.4 Overview of cocoa systems in southern Cameroon

The introduction of cocoa as a crop goes as far back as the late 1800s when the German colonial authorities administered the southernmost part of the study area. Since then, its cultivation has been intensively stimulated, with the then missionaries as pioneers. Cocoa pods as well as coffee seeds were selectively distributed to the employees of the missions as compensation for services rendered. These employees in turn gradually distributed cocoa seeds to relatives. Cocoa seedlings were usually planted besides settlements to ensure proper management, especially during the establishment phase. The colonial authorities further reinforced this disposition when cocoa became a major subject of economic interest in the area, in order to increase control over management standards of cocoa farms during administrative inspections.

2.2.4.1 Cocoa ecology

The cocoa tree is of small size; reaching a height of 7-8 m on average at maturity. Trees start to bear fruit at the age of three years where ecological conditions are favourable and selected cocoa varieties are used, as is the case in the southwest production basin. Under such conditions, cocoa trees can fully express their productivity potential after ten years, and maintain it for 20-25 years where farms are properly managed (Mossu, 1990).

The root system comprises a taproot and lateral roots. The taproot length varies from 0.80 m to 1.5 m or 2 m ten years after planting (Wood and Lass, 1985; Mossu, 1990). The taproot is very important for the uptake of water from the sub-soil during the dry season. The lateral roots are very abundant and spread mainly in the top humus layers of the soil.

The variability of cocoa yield from one season to another is mainly affected by rainfall as compared to other climatic factors. The cocoa tree requires annual rainfall ranging from 1500 mm to 2000 mm, and rains should fall the whole year round. A dry season of three consecutive months is in general the maximum tolerated by the cocoa tree. Many authors (Wood, 1985; Mossu, 1990) have mentioned soil water deficiency, as critically affecting tree productivity, especially when cocoa is in competition with other trees, as is generally the case in the cocoa systems in southern Cameroon. The atmospheric humidity should be constantly high (80%), but should not be excessive; otherwise an increase in black pod disease may occur (Lass, 1985; Mossu, 1990; Nyasse, 1997). The temperature should be relatively high, with annual mean maxima ranging from 30°C to 32°C and mean minima ranging from 18°C to 21°C.

Cocoa is an understorey tree species, and is usually grown under natural or artificial shade. However, taking into account its photosynthetic potential and the amount of solar radiation it can utilise, cocoa cannot be considered as a typical understorey species (Mossu, 1990). On the other hand, cocoa can normally grow under dense shade provided the temperature is near to the optimum (32°C) and photosynthetic activity is not critically reduced. In this respect, cocoa cannot be considered as a typical "light-demanding species". However, it is agreed that shade should be dense for young cocoa trees (one to three years) admitting only 25% to 50% of sunshine (i.e. 50% to 75% shade) (Mossu, 1990). The need for shade diminishes as growth progresses, depending on soil and climatic conditions and the self-shading ability of cocoa trees.

Cocoa is very exacting in its soil requirements. In general, it grows well on deep, homogenous and permeable soils, rich in nutrients and organic matter (Wood, 1985; Mossu, 1990). However, soil permeability should not be excessive, especially in situations where there is a risk of severe or prolonged dry season. Hard lateritic concretions if present will not allow the penetration of the taproot and thus are very detrimental to the proper development of cocoa.

This overview of the ecology of cocoa gives an indication of the numerous ecological factors that are necessary for an optimum growth and development of cocoa. The complexity of their interactions points to the difficulty of dissociating the effects of one factor on cocoa from the others, thus the need for an integrated approach to understanding and managing these interactions.

2.2.4.2 Cocoa establishment

The cocoa agroforests under heavy shade formed by natural forest trees in southern Cameroon are amongst the best examples in Africa of seemingly permanent agriculture that has preserved a forest environment and some of its biodiversity (Ruf and Schroth, 2004). Similar to the cabrucagem cocoa systems in Brazil, complex agroforest systems have developed in this region as the predominant form of cocoa growing, in contrast to most of the southwest and the centre north cocoa production basin in Cameroon, and most of Côte d'Ivoire.

The dominant cultural practice of cocoa production in southern Cameroon involves planting the trees in former forestland, which has been selectively cleared and planted to various types of food crops for one or two seasons (Leplaideur, 1985; ICRAF, 1987; Duguma and Franzel, 1996; Duguma et al., 1990). The objective is to improve the soil structure and to increase the rate of infiltration of water. When land is cleared, indigenous tree species of spiritual value or socio-economic importance are deliberately maintained in the fields, alongside large to very large individuals of other species that could not be easily removed because of lack of appropriate means. Some species of socio-economic importance include indigenous fruit trees such as *Irvingia gabonensis, Ricinodendron heudelotii, Cola acuminata*; high timber value species such as *Terminalia superba, Triplochiton scleroxylon, Baillonella toxisperma, Pygnanthus angolensis, Distemonanthus benthamianus* or species of medicinal value such as *Morinda lucida, Alstonia congensis*. The field is initially planted with a mixture of egussi melon *(Cucumeropsis mannii)* and maize *(Zea mays)*. After harvesting, cocoa is inter-planted with maize, plantain/banana *(Musa spp)* and other food crops during subsequent farming seasons. In areas with fewer land resources as is the case for the Yaoundé block, cocoa is usually planted in long fallows, together with plantain/banana, which serve as temporary shade to cocoa seedlings. Fast growing shrubs are maintained in the field, as they will serve as permanent shade to cocoa later on. In recent years, short fallows have been increasingly contributing to the creation of new cocoa farms or the extension of existing ones in the Yaoundé block and the northernmost area of the Mbalmayo block.

Depending on the density of the retained species and the mortality rate of cocoa seedlings, the system is enriched by planting additional indigenous tree species, but mainly fruit species such as Andogo ntangani *(Mangifera indica)*, Assa *(Dacryodes edulis)*, Fia *(Persea americana)*, Afoumbi *(Citrus sinensis)*, mandarin *(Citrus reticulatata)* and oil palm *(Elaeis guineensis)* (Gockowski and Dury, 1999). This has led to two major types of cocoa system (Figure 2.5), which are:

1. Extensive cocoa systems with shade canopy planted in forestland or long fallows, which are characteristic of less populated areas in

southern Cameroon. The rate of introduction of exotic fruit tree species to the system depends mainly on market access.

2. Intensive cocoa systems with shade canopy planted in short fallows, which represent the "higher" end of the existing intensification gradient found within cocoa agroforests in southern Cameroon (Kotto-Same et al., 2000). These systems are mostly found in areas of more pronounced land pressure and are associated with reasonable market access.

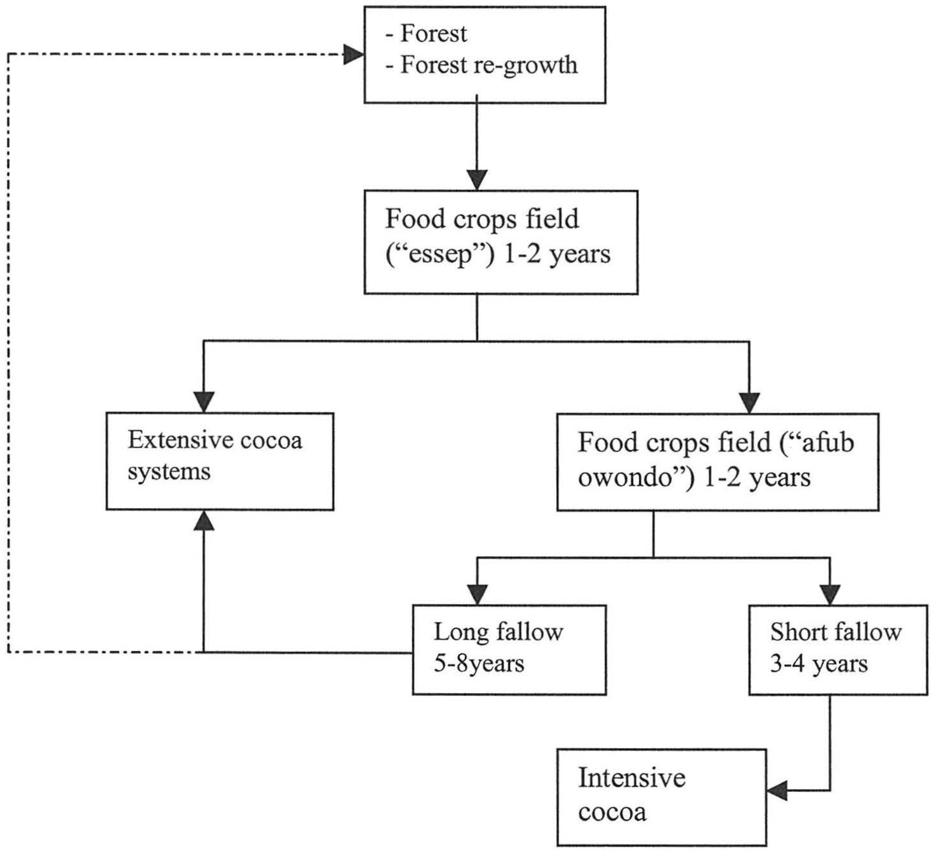

Figure 2.5 Land use flow diagram for the establishment of cocoa fields.

2.2.4.3 Farm management

The major management requirements of cocoa systems are shade control, weeding and pest and disease control (Braudeau, 1969; Lass, 1985; Wassel, 1987; Mossu, 1990, Duguma et al., 2001). The role of shade in the management of cocoa agroforests is rather complex, as it affects or is related to other growth factors such as light intensity and photosynthesis, temperature and air movement, and air humidity in the farm that indirectly influence pest and disease occurrence. Yield loss due to cocoa pests and diseases is very important in southern Cameroon and is estimated at 50-80% of the potential production (Nyasse, 1987; Bakala and Kone, 1998; Duguma et al., 2001); this contributes a great deal to the low yields of the cocoa systems of the area (Table 2.2). Among the several diseases that are responsible for such loss, black pod disease is the most important (Nyasse, 1997; Bakala and Kone, 1998). Several insects are also reported to attack different parts of the cocoa tree at different stages of development. Mirids, capsid-sucking bugs (Heterptera: Miridae*)* with two species, *Sahlbergera singularis* and *Distantiella theobroma* were identified as the most harmfull in Cameroon (Entwistle, 1987; Bakala and Kone, 1998).

Table 2.2 Statistics on cocoa production in Cameroon (1996 – 2001)

Year	1996	1997	1998	1999	2000	2001
Area harvested (ha)	300 000	300 000	300 000	370 000	370 000	370 000
Production (tonnes)	110 726	120 807	110 000	115 000	120 000	115 000
Yield (K/ha)	369	402	366	311	324	311

Source: Sustainable tree crop programme (STCP)

Most cocoa farms in southern Cameroon are family-managed with all the household members occasionally contributing to production. The major production decisions are however taken by the household head and are motivated by such considerations as labour availability, and the availability of planting material and other inputs. Labour availability is a major issue of concern. In the late 1980s, SODECAO, the government parastatal company that provided services to cocoa farmers in southern Cameroon estimated the median age of cocoa farmers to be over fifty years. Legal institutions perceived this as a major threat for farm management because of the decrease in labour force potential. In response to this, farmers have developed several types of labour arrangements and institutions that comprise: i) labour exchange in work groups known locally as "eka's", ii) hired labour mainly constituted of immigrants, and iii) individual labour exchanges.

Depending on farmers' capability to access necessary inputs, chemical fungicides and pesticides are generally used for the control of pests and diseases. Otherwise, farmers increasingly use cultural practices and locally developed strategies as the main means for the control of pests and diseases, whilst enhancing other growth factors such as shade regulation, light intensity, temperature and air movement. An annual calendar of cocoa farm management activities as practised by farmers (Figure 2.6) indicates intensification of activities in the period of July to October.

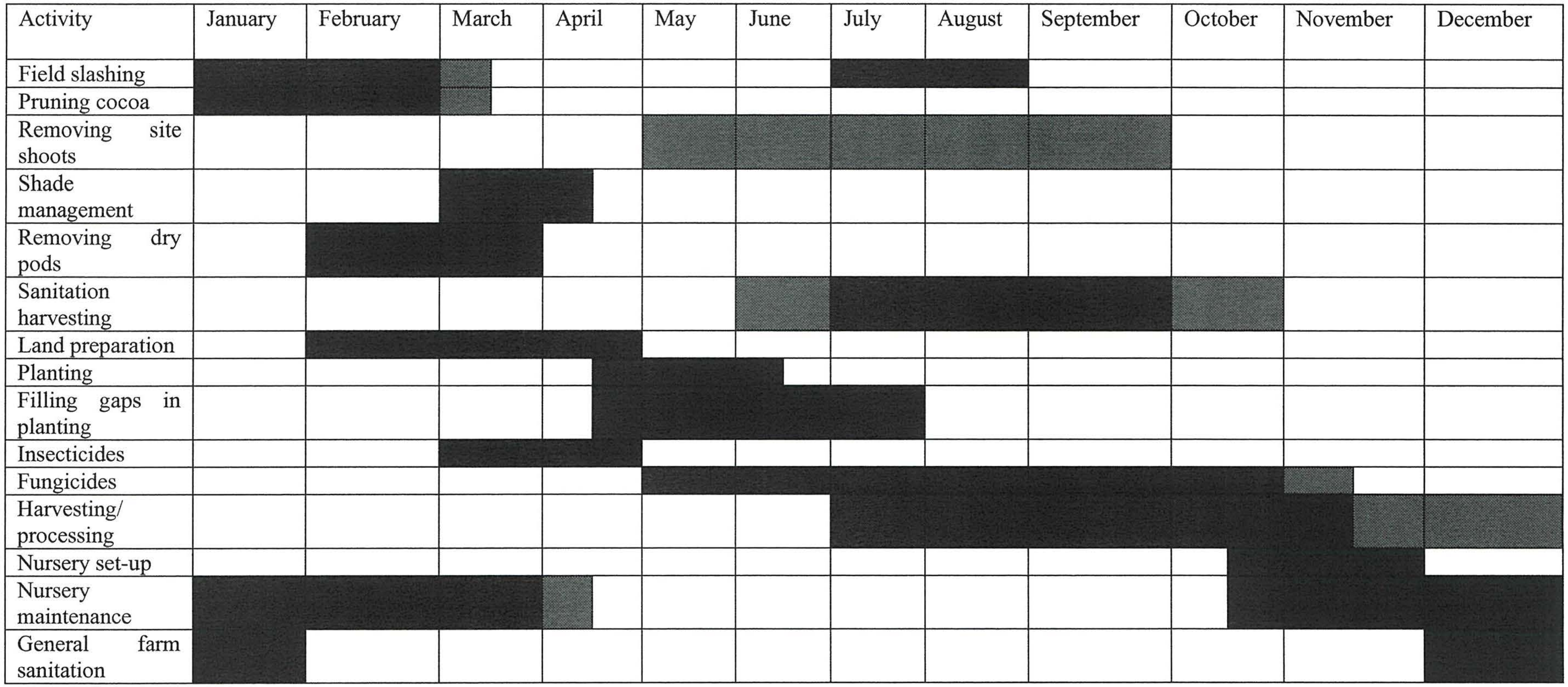

Figure 2.6 Seasonal calendar of cocoa farming activities in Southern Cameroon (data compiled from farmers' knowledge by the author). Dense shading indicates intense activity. Grey shading indicates light activity. No shading indicates that the activity is not carried out during that period.

2.3 THE STUDY COMMUNITIES

2.3.1 Facilities and infrastructure

The facilities and infrastructure in the study area differ from one location to another and are generally influenced by population densities. They are better in locations with high population densities like those in the Yaoundé block than in the Mbalmayo and Ebolowa blocks. Remote sensing estimates indicate a rural road density in Yaoundé that is three times the density in the Ambam area in the Ebolowa block (Kotto-Same et al., 2000). Besides the road infrastructure network, social facilities such as schools (primary and in some locations, secondary), primary health care centres (public and private), shops and many other social facilities including electricity and potable water from boreholes, are available in the majority of locations in the Yaoundé block. In contrast, some locations in Mbalmayo and Ebolowa blocks critically lack such minimum facilities as primary health care centres, primary education and electricity. Market institutions for both inputs and outputs are also fairly well developed in the Yaoundé block. Farmers in this block have easier access to purchased agricultural inputs, thus could more easily maintain or increase their crop yields than those in the rest of the benchmark area.

2.3.2 The population

The estimated population of the humid forest zone is over five million inhabitants (MINAGRI, 1988), of which 47% live in rural areas (Sanctoir and Bopda, 1995; Ngobo, 2002). These figures may have changed considerably following the shock imposed on the populations by the economic crisis, the growth in population in some areas, and subsequent migratory movements. However, the trend in the gradient of population densities across the three blocks as mentioned earlier still stands. In general, households in the Yaoundé block face higher land pressures as a result of high population density, and have intensified their production systems to a much greater degree than households in Mbalmayo and Ebolowa blocks. The average size of a household ranges from five to six persons with variations related to the accessibility of the location and the period in the year, and usually comprises the spouses, the children and close dependants.

Throughout the study area, the population comprises a dense ethnic mosaic including various components of the Beti, Bulu, Fang and Kwasi'o ethnic formation, which belong to the western Bantou forest dwellers group (Diaw, 1997). The Ndikinimeki area is formed by the Banen ethnic group, whilst the majority of the Yaoundé block is formed by the Eton group. The other main ethnic groups are the Ewondo and Bulu in the Mbalmayo and Ebolowa areas respectively. There is no cultural characteristic specific to a given ethnic group in the study area. This is because of the complexity of the population structure, as a result of the mixture between different ethnic groups that occurred during the migratory movements, and which have led to the current settlement pattern (Sanctoir and Bopda, 1995; Diaw, 1997).

The populations in the study area are patrilineal people. Following the principle of patrilineal descent, sons are supposed to be heirs of their father's heritage, including and most importantly, land resources and cash crop farms. In that respect, all male members of the lineage have the right to inheritance, including all natural sons of a daughter who are adopted by her parental lineage. However, daughters have no right to inherit because they are bound to leave the clan at some point in their life and cannot therefore be the guarantor of the preservation of their father's assets (Diaw, 1997). Widows can inherit from their deceased husband in specific cases: the sons may be still too young to guarantee the preservation of the father's assets, or the couple did not have any sons at all. Heirs or family heads are responsible for the provision of shelter to family members and fulfilment of their financial needs. They are also the most significant decision makers. In this respect, the contributions of spouses or any other relevant family member as regards to specific issues, though not generally publicly acknowledged, are usually required.

2.3.3 Livelihoods

Farming activities are the principal occupation of the rural people of southern Cameroon. Household livelihoods are typically met through the integration of multiple crop and tree-based farming systems, complemented with a range of farming activities that include cropping options, fish farming, hunting, fishing, and gathering of non-timber forest products. Generally, these activities are gender-based. The most difficult tasks such as clearing of forestland or fallows, felling of trees or maintaining cash crop farms are executed by men. Women's activities are more oriented towards food crop production and the collection of non-timber forest products. To understand livelihood strategies of the study area, farmers were stratified in three groups, namely older men, women and younger men. Older men in the context of this study were referred to family heads, whilst younger men were generally referred to youths below twenty-five with no specific familial responsibility. Women were not stratified because unlike younger men, younger women generally stay beside their mother until they are married, and thus don't have a role in the management of household assets.

Family responsibilities are also gender-based, with the well being of all the family members usually falling under the direct care of older men, in their capacity as family heads. In this regard, they provide shelter and cater for the family's financial needs, including for education and for health care. This is presumably why their farming activities are mainly oriented towards cash crop production, which they control at household level. Women, in their capacity as spouses and mothers, are mainly responsible for providing food for the household. However, in cases where older men's financial efforts alone are not enough to address certain issues confronting family members, the financial contribution of women is usually requested. Similarly, in cases where the amount of food crops produced is not sufficient to fulfil household needs, as is the case in the relatively highly populated locations of Nkongmesse and Ndikinimeki, older men usually complement women's efforts to feed the family with financial assistance to acquire food from local markets. There is, therefore, a mutual assistance between older men and women in household management.

2.3.3.1 Livelihoods of older men

The sources of income of older men are usually varied and more important as compared to other household members (Figure 2.7). As family heads, older men usually control the major family resources, especially the cash resources. As mentioned earlier, cocoa is the most important cash earner in southern Cameroon in general and, therefore, constitutes the main cash activity for older men. Also considered as an important cash farming activity for older men is the monocropping of plantain/banana in locations with reasonable market access. In recent years, the sale of oil palm products (palm oil, palm wine, palm nuts) and exotic fruits (oranges, mandarins, mangoes, lemons, avocado) have been increasingly gaining ground among older men's cash earning activities. In some cases, the sale of these products procured more net revenue than the sale of cocoa.

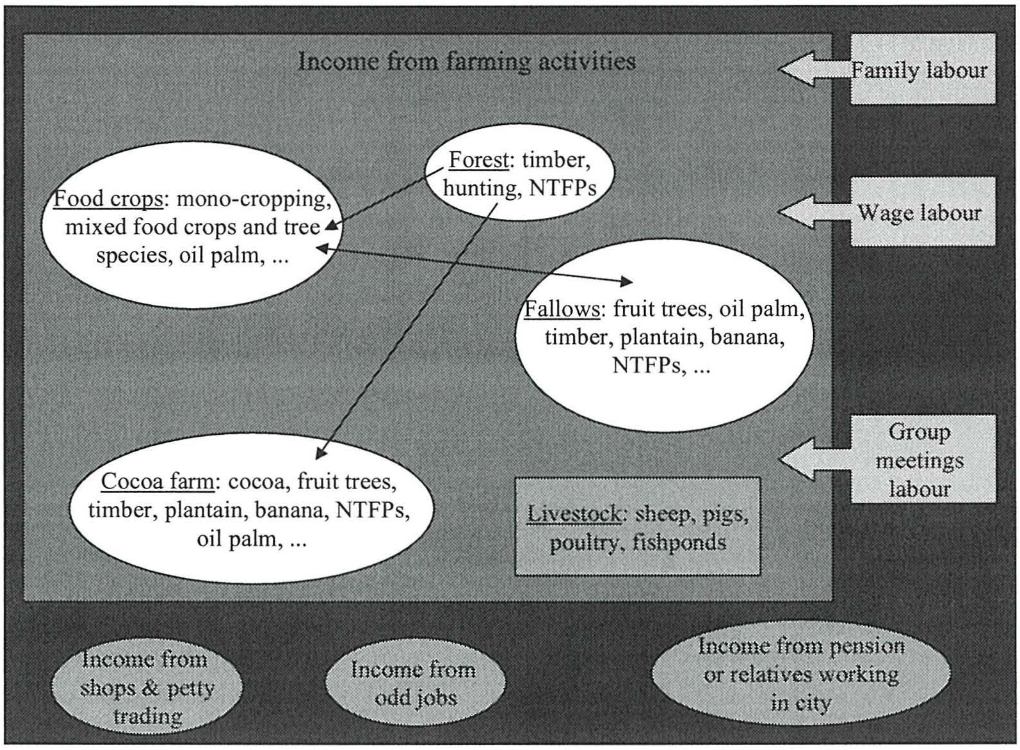

Figure 2.7 Livelihood diagrams for older men in southern Cameroon. Nodes within the box represent characteristics of income of older men. The biggest node (square) represents land use diagram with the main land use systems identified (oval or rectangular nodes). Arrows represent temporal relationships between components. External independent nodes to the square represent other income generating activities than farming. Arrows pointing to the biggest square indicate the source of labour used for farming activities. (Adapted from Moss et al., 2001)

A substantial population of older men in the study locations are retired agents, or have practised various jobs in surrounding towns and cities. Back home, they continue to practise a wide range of odd jobs related to their formal profession as part time activities. Richer individuals have opened relatively important shops locally or in near-by towns.

2.3.3.2 Livelihoods of younger men

The sources of income of younger men are usually less than those of older men and generally precarious (Figure 2.8). Younger men usually help their parents or other relatives in their farming activities. However, many of those who have left school increasingly express the desire to live on their own, especially in locations close to towns or important agglomerations. This is because youngsters do not consider farming an attractive activity due to its hard labour aspect, and efforts are not often remunerated accordingly. Scarcity of agricultural land is also contributing significantly to orientating youngsters towards more lucrative, or ready cash revenue activities. In this respect, they are usually employed as casual workers for various non-professional jobs, including waged agricultural labour. More often, they are organised in common initiative groups and wage their labour to whoever is in need. The sharing of the income generated is made on the basis of rules governing the group. In this sense, they are considered as the main agricultural labour suppliers, after household members.

Younger men usually practise farming as a part time activity, and their farming activities are often oriented towards horticulture or the production of short rotation and ready to market crops. Where land resources are abundant, they have a similar source of income to older men, except for cocoa. In locations with reasonable market access, they are increasingly planting various fruit tree species in vacant spaces in their home gardens and farm fields, including cocoa agroforests. More younger men, individually or in the framework of common initiative groups, in locations with appropriate sites, are getting more involved in fish farming systems through the creation of fish ponds or animal husbandry-fish pond complexes. These activities, though not yet properly structured, are perceived as potentially important sources of revenue to local people, while contributing to household food security requirements.

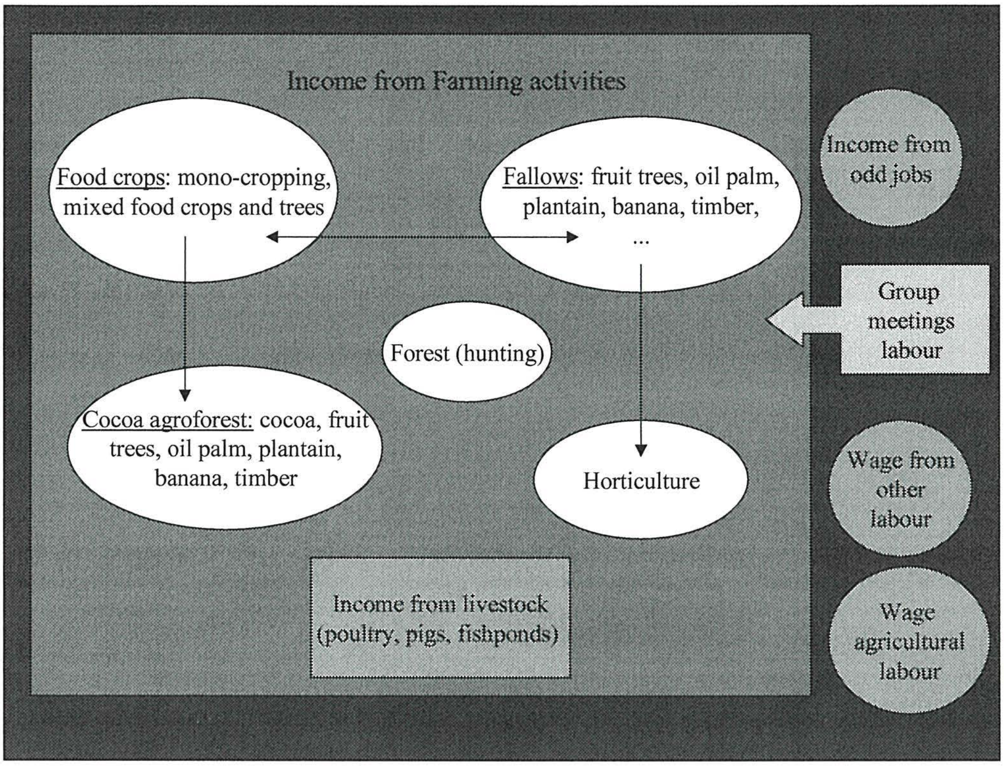

Figure 2.8 Livelihood diagram for younger men in southern Cameroon. Legend as for Figure 2.7

2.3.3.3 Livelihoods of women

Similarly to younger men, the sources of income of women are less than those of older men (Figure 2.9). Women are generally responsible for food crop production for the household food security requirements, with the surplus being sold. In this regard, the size of the farm will depend on farmland availability, market access and the size of the family. Another important source of revenue is the selling of non-timber forest products, such as Okok *(Gnetum africanum),* Njangsang or Ezezang *(Ricinodendron heudelotii),* Azanga or Andog *(Irvingia gabonensis),* and Kome *(Coula edulis)* to name a few. In rare cases (widows), women receive revenue from the sale of cocoa. Substantial revenue is also generated from the sale of fish in locations with abundant streams and rivers of reasonable size that can permit fishing activities. Off-farm income generating activities consist essentially of small-scale trading, particularly in cooked foodstuffs, tailoring and other handicrafts.

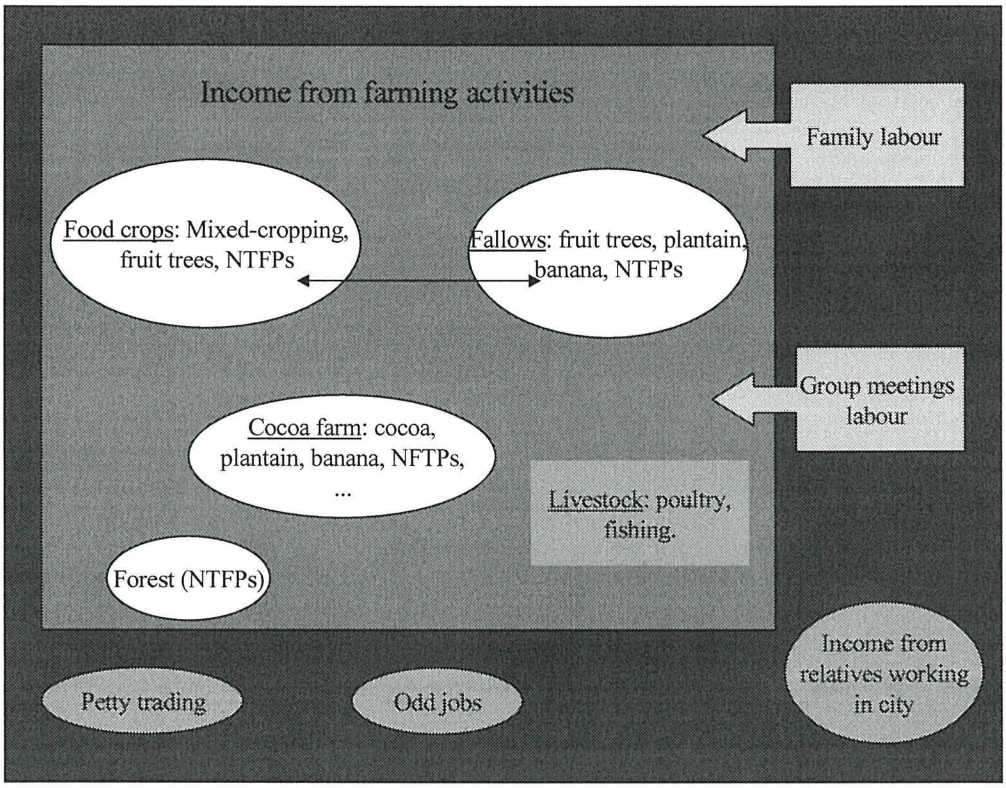

Figure 2.9 Livelihood diagram for women in southern Cameroon. Legend as for Figure 2.7.

2.4 CONCLUSION

An overview of the physical features and socio-economic context of the study area has been presented, with highlights of the differences across locations.

These differences are most notable with respect to vegetation and landscape, land resources and land use intensity, population density, and existing socio-economic infrastructures and institutions. Cultural differences between the study communities were found to be minor because of significant inter-ethnic mixing as a result of migratory movement of populations observed in the area. Also discussed were the ecology of cocoa and the cocoa systems in the context of southern Cameroon land uses and population livelihoods. The information provided is expected to give an insight into issues that are discussed in subsequent chapters.

CHAPTER 3

FARMERS' KNOWLEDGE ABOUT INTERACTIONS IN MULTISTRATA COCOA SYSTEMS

ABSTRACT

Agronomic and ecological knowledge about multistrata cocoa systems held by farmers in southern Cameroon was acquired and investigated using knowledge based systems methods. Four contrasting locations distinguished by agroecological zone, population density and market access were selected for the research. Knowledge was elicited through semi-structured interviews and field visits with a purposive sample of fifteen farmers per location drawn from three strata presupposed to be associated with differences in knowledge (older men, younger men and women).

Farmers had detailed knowledge related to factors affecting sustainability and productivity of their multistrata cocoa farms, including micro-environmental conditions within cocoa fields and the availability of resources (light, water and nutrients) for cocoa growth. Population pressure and land and market access appeared to be major inducements to technical change in the management of cocoa associated with the introduction of exotic, mainly fruit tree species, and progressive domestication of other native species. The findings of this research suggest new directions for cocoa research and extension in Cameroon, as populations and market demands grow and production systems evolve towards more intensive and integrated cocoa-fruit tree systems.

3.1 INTRODUCTION

As outlined previously (section 1.2.2), cocoa (*Theobroma cacao*) is one of the most important cash crops of Cameroon, and is grown by an estimated 350 000 small-scale farmers (Assoumou 1977, Duguma et al. 2001). One of the main identifying characteristics of southern Cameroon cocoa systems is their high level of forest biodiversity and shade relative to most other cocoa production systems in the world (Duguma et al., 2001).

Unlike in much of West Africa, most cocoa farmers in the study area are indigenous forest dwellers rather than migrants from outside the forest zone. Anthropologists estimate that these groups have been living in the forest environment for the past 300-400 years (Assoumou, 1977). This invites the hypothesis that they may have well developed knowledge of forest diversity, which could have been utilised in developing the biologically diverse cocoa systems that are now the basis of their livelihoods. Understanding current knowledge and practice of farmers and incorporating this in research and extension programmes may, therefore, be vital for improving livelihoods of cocoa smallholders and the sustainability of cocoa production. However, studies investigating farmers' ecological knowledge and management of cocoa systems are few and recent. They include farmers' knowledge of trees used for shade within cocoa farms in Ghana, West Africa (Saunders, 2002), new farmer-developed pest management strategies in cocoa systems in southern Cameroon (Coulibaly et al., 2002; Sonwa et al. 2002), and diversity of plants associated with cocoa systems in southern Cameroon and farmers' species preferences (Sonwa, 2004). The impact of the expanse of cocoa on forest margins and how farmers used their knowledge to preserve a forest-like environment and some of its biodiversity in two cocoa producing regions in Africa, southern Cameroon with high conservation value and Cote d'Ivoire with low conservation value, have also been reported (Ruf and Schroth, 2004).

The present chapter reports on the acquisition and systematic analysis of southern Cameroonian farmers' knowledge about the ecology, agronomy and management of their multistrata cocoa systems using a knowledge based systems approach. An evaluation of the content of the knowledge base and comparative analysis within and across the study locations is carried out, and possible reasons for similarities and/or differences are highlighted.

3.2 METHODOLOGY

3.2.1 Knowledge acquisition

The approach used in this study involved application of the AKT5 Knowledge Based System (KBS) methodology for the acquisition and use of agroecological knowledge, together with participatory rural appraisal techniques. AKT5 (Agroecological Knowledge Toolkit) is a tailor-made computer software package that enables formal representation of knowledge in a computer-readable form, which facilitates evaluation of local knowledge using computer-based search facilities and automated reasoning procedures. This software was developed by the School of Agricultural and Forest Sciences (SAFS) at the University of Wales, Bangor, U.K (Sinclair and Walker, 1998; Dixon et al, 2001). Sinclair et al. (1993) define a knowledge base as an articulated and defined set of knowledge stored in a computer.

In the present context, the knowledge domain of interest is defined as southern Cameroon farmers' knowledge about multistrata cocoa systems, with a focus on their understanding about interactions amongst system components and how these are managed. The recorded knowledge is stored in a computer in such a way that it can be accessed, evaluated and used. Two main stages were involved in the creation of this knowledge base: knowledge elicitation (getting farmers to articulate what they knew) and knowledge representation (recording the knowledge that was elicited). Knowledge elicitation and knowledge representation are referred to collectively as knowledge acquisition (Walker et al., 1995; Sinclair and Walker, 1998; Walker and Sinclair, 1998).

3.2.2 Knowledge elicitation

The elicitation of the knowledge held by farmers involved four stages that were: i) the specification of the research topics, ii) the selection of key informants and sampling strategy, iii) the interview strategy and checklist prompts and, iv) the field work strategy. They are described below.

3.2.2.1 Research topics

The subject domain of the research was defined in a scoping study, through group interviews with stakeholders in the cocoa sector. These stakeholders included: non-governmental organisations (NGO's), traditional leaders (chiefs and elders of the targeted locations), the staff of the Ministry of Agriculture and most importantly, individual farmers and common initiative groups (CIG's). At this specification stage, farmers' preoccupations appeared to be mainly related to the implications of the interactions amongst the major components of the system for its sustainability and productivity. Two broad considerations emerged from farmers' understanding of these interactions; they were aboveground interactions mediated by the atmosphere and belowground interactions mediated via the soil. The major components involved were non-cocoa plant species aboveground and soils below.

As research on cocoa agroforest systems was in its infancy in Cameroon, little was known scientifically about the interactions mentioned above. It was, therefore, proposed by the various stakeholders during the fieldwork specification phase that investigation of the following aspects of farmer knowledge would be of considerable value:

1. functions of non-cocoa tree species and their implications for the sustainability and productivity of cocoa systems,
2. soil fertility, its management and consequent implications for cocoa growth and productivity,
3. selection of sites to establish cocoa, and,
4. the occurrence and management of cocoa pests and diseases.

It was envisaged that this knowledge acquisition would facilitate a strong partnership between farmers and scientists.

3.2.2.2 Selection of key informants and sampling strategy

Key informants are defined as a selected group of individuals who are likely to provide the needed information, ideas and insights on a particular subject (Kumar, 1987a). Purposive sampling can be expected to improve the productivity of fieldwork in knowledge acquisition over random sampling because many randomly selected key informants may be unwilling to cooperate or may not be very knowledgeable. However, Kumar (1987b) and Thapa (1994) both emphasise that efforts should be made to ensure that key informants are representative of the target population. Walker and Sinclair (1998) suggest classifying the target population on the basis of criteria relevant to the study objectives and including key informants from each category to achieve an acceptable coverage of their common knowledge. For the purposes of knowledge acquisition, populations have often been stratified according to gender, age, ethnic origin and economic status, with sample size depending on the size of the source communities, their homogeneity, and how much time is available for acquisition. Where deeper explanatory knowledge is sought, interviewing a small number of people several times, rather than a large sample less frequently has been found to be effective and around five people per stratum is considered sufficient to obtain good coverage of common knowledge (Walker and Sinclair, 1998).

A small purposive sample of fifteen cocoa farm owners per study location stratified by age and gender, were selected. Two age groups, of younger men cocoa farm owners (< 50 years) and older men cocoa farm owners (≥ 50 years), as well as a group of women farm owners were selected in each location. Initially, it was intended to have an equal number (5) of key informants in each stratum, but insufficient women owning cocoa farms were found in Akok and Ndikinimeki[9] so extra informants from other strata were included (Table 3.1). Ethnicity and location were confounded since, as mentioned previously (Section 2.3.2), the principal ethnic groups were Bulu, Ewondo, Eton and Banen in Akok, Awae, Nkongmesse and Ndikinimeki respectively but as there was little cultural distinction amongst the groups because of mixing during a common migratory past (Section 2.3.2) no attempt was made to explore ethnic differences in knowledge within locations.

Table 3.1. Number of key informants from each stratum at each location

Location	Young men	Old men	Women	Total per location
Akok	7	8	1	16
Awae	5	5	5	15
Ndikinimeki	5	6	4	15
Nkongmesse	5	5	5	15
Total	22	24	15	61

[9] As mentioned in chapter 2, cocoa farms in southern Cameroon generally belong to the household head, who takes decisions about the management options. Ownership can only be transferred to a son of mature age or to spouses in cases where the household head is too old or is dead. That is why it is not usual to have women owning cocoa farms.

3.2.2.3 Interview strategy and checklist prompts

The objectives of the interviews were: i) to elicit farmers' knowledge about the interactions occurring amongst the major components of their cocoa systems and ii) to record how the knowledge was used to manage these interactions. Semi-structured interviews[10] were used. In recent years, semi-structured interviews have become an increasingly popular tool among those working in rural development for collecting information where the emphasis is on qualitative rather than quantitative information (Rhoades 1984, Dove 1989). The reasons for using semi-structured interviews were to put farmers at their ease and gain information through the creation and maintenance of a friendly environment. The interviews were guided by a checklist with questions as prompts to kick-start discussion (Table 3.2). The basic questions "how" and "why" were asked during discussions and more questions were framed as the discussions progressed until the farmer could not explain any further.

[10] Semi-structured interviews are interviews of the expert by the elicitor in which although the content is pre-determined, the sequence of interview may vary imposing minimal constraints on the response (Cooke, 1994)

Table 3.2 Research topics and checklist prompts for semi-structured interviews

Aspects of local knowledge investigated	Checklist prompts
Functions of non-cocoa tree species and implications for productivity and sustainability of the systems	Why do farmers maintain non-cocoa tree species in their cocoa systems? How do they classify those species? What do they understand about interactions between cocoa and non-cocoa species? Are there species that they particularly like to maintain or introduce to the system? If yes, why?
. Soil fertility and its management	How do farmers classify soils of their location? What soil characteristics influence soil fertility? How do farmers assess soil fertility status? Are there ways to improve soil fertility status? If yes, how?
Farmland suitability	How do farmers select suitable land for cocoa?
Occurrence and control of cocoa pests and diseses	What pests and diseases affect cocoa growth or production? How do these pests and diseases occur? How do farmers control them?

3.2.2.4 Fieldwork strategy

Interviews were conducted from 2001 to 2003 during agriculturally slack periods in the year, which occur from December to April. Key informants were informed at least a week ahead of visits and the time of the appointment for the interview was confirmed the day before. The interviews were conducted at farmers' houses, either very early in the morning or in the evening. Field visits for illustration or demonstration of the information given were organised during daytime. Farmers were interviewed individually to avoid uncertainty that could arise as a result of contradictory understanding of processes amongst farmers. Many such cases had been recorded during contact visits with farmer groups during the specification phase. However, individual interviews were often compromised by passers-by who usually showed interest in the exercise and insisted on participating. In such circumstances, the interview was not recorded.

The sequence of activities leading to knowledge acquisition constitutes a cycle that was repeated until a comprehensive understanding of the topic studied had been gained (Figure 3.1). Knowledge acquisition was considered complete when further questioning of key informants no longer resulted in modification of the knowledge base.

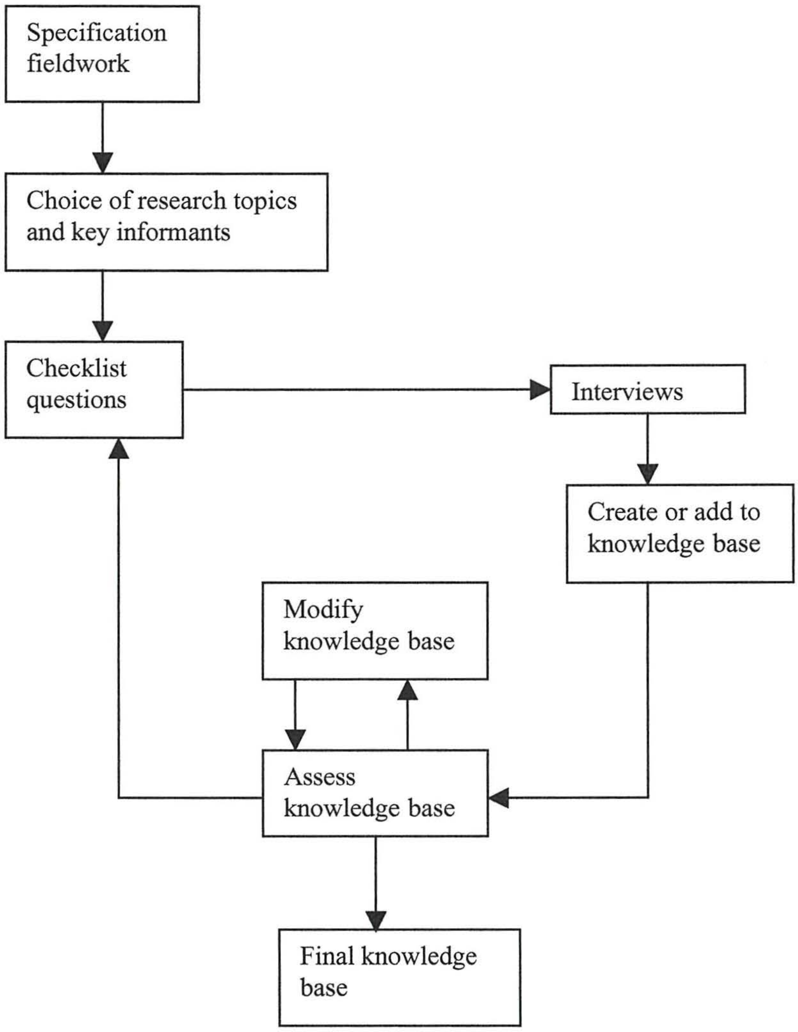

Figure 3.1. Procedural flow diagram of the sequence of activities used to create the cocoa knowledge-based systems

3.2.3 Knowledge representation

Knowledge representation comprises three key processes that are; abstracting knowledge, formal representation of knowledge and formal term specification. The methodological approaches and the techniques for representing knowledge using the AKT5 methodology have been discussed by many authors (Walker et al., 1995a; Sinclair and Walker, 1998; Walker and Sinclair, 1998) and are set out in the manual for the software system (Dixon et al., 2001). In this section, therefore, only key procedures as they were applied in the present research are presented.

The approach to representation views of the knowledge given by an informant is being made up of a combination of basic meaningful units of knowledge referred to as "unitary statements". In the creation of a knowledge base, most interest is focussed on the unitary statements because, as the smallest useful unit of knowledge, they are used in combination with other knowledge in reasoning. These basic units of knowledge are abstracted in a form that reflects knowledge as articulated by key informants and recorded using a formal syntax developed for the AKT5[11] software. This process is known as formal representation.

The process also provides a means of evaluating sets of statements to avoid repetition, ambiguity or contradiction and for ensuring completeness and consistent use of terms that leads to a concise knowledge base, which optimises its utility. Hierarchical arrangement of terms for objects within a knowledge base is a powerful feature that enables representation of local taxonomy and this helps compact a knowledge base significantly. For example, farmers said that airflow in cocoa farms was facilitated by tall trees, further statements revealed that this reduced the spread of *Phytophthora spp* fungus and encouraged cocoa flowering. Rather than having many statements about different tall tree species affecting airflow, one for each tall tree species, one general statement together with an object hierarchy defining which trees were tall, allowed the knowledge to be represented concisely.

[11]AKT stands for Agroecological Knowledge Toolkit.

The following three types of statements were used for formal representation:

1. attribute value statements. These are the most basic form of statement and describe an object[12], a process[13] or an action[14] by assigning attributes[15] and values[16] to them, such as "The life cycle of a cocoa pod is four to six months",
2. causal statements describe change(s) in the value of an attribute caused by another attribute statement, a process, an action or an object. Causation may be 2-way (if an increase in x causes a decrease in y then also a decrease in x will cause an increase in y) or 1-way where the reciprocation does not apply, as for example with aging where it is possible to get older but not younger (e.g. "An increase in compactness of soil causes2way a decrease in the rate of development of cocoa root system),
3. comparison statements compare the relative values of a pair of objects (e.g. "Local cocoa variety is more vigorous than SODECAO variety")

Another type of statement, the user-specified link statement that allows objects to be linked by a term specified by the user (e.g. bees pollinate x trees), while available in the system, were not used in the present study.

Most knowledge is not universally true but only applies in certain circumstances, so any statement can be made conditional by appending condition(s), and multiple conditions can be linked by using "and" or "or" (e.g. yellow soil causes an increase in the development of cocoa if the clay content of the soil is low, and the soil profile is deep). The full formal

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[12]Object is normally physical item in the real world, like "tree", and "crops", but may be conceptual, for example "dry season"
[13] Process describes changes or fluxes in the real world, e.g. "airflow" or "soil erosion"
[14] Action is similar to process but is initiated by man, e.g. "clearing" or "harvesting"
[15] Attribute describes an object, process or action and is generally measurable, e.g. "rate", "height"
[16] A value is always attached to an attribute, and describes that attribute. They can be in units, e.g. "4months to 6months", or can describe value, e.g. "tall", "wide", "compact".

grammar that provides the basis of the formal representation is presented in Table 3.3. This was developed as the minimum syntax that was required to represent a wide range of farmers' agroecological knowledge (Walker and Sinclair, 1998).

Table 3.3 The AKT5 definite clause grammar. Terms in bold are reserved terms in the grammar (i.e. words reserved for use by the system); terms starting with a capital letter are variables; => means "can take the form of". (Source, Dixon et al., 2001)

Formal Sentence => statement **if** formal conditions.
Formal sentence => Statements.
Statement => Cause **Causes** Effect
Where Causes is an element of the set: {**causes1way,causes2way**}
Statement =>Attribute Statement
Statement => **not**(AttributeStatements)
Statements => **link**(influence,Thinks,Think)
Statement => **link**(Link,Object,Object)
Statement => **link**(Link,ProcessBit,ProcessBit)
Statement => **link**(Link,ProcessBit,Object)
Statement => **comparison**(Attribute,Object,Comparison,Object)
FormalConditions => FormalConditions **and** FormalConditions
FormalConditions => FormalConditions **or** FormalConditions
FormalConditions => Statement
FormalConditions => ActionBit
FormalConditions => ProcessBit
AttributeStatement => **att_value**(Object,Attribute,Value)
AttributeStatement => **att_value**(ProcessBit,Attribute,Value)
AttributeStatement => **att_value**(ActionBit,Attribute,Value)
Cause => AttributeStatement
Cause => ProcessBit
Cause => ActionBit
Cause => Object
Cause => **not**(Cause)
ActionBit => **action**(Action,Object,Object)
ActionBit => **action**(Action,Object)
Effect => AttributeStatement
Effect => ProcessBit
Effect => ActionBit
Effect => **not**(Effect)
Process_bit => **process**(Process)
Process_bit => **process**(Object,Process)
Process_bit => **process**(Object,Process,Object)
Thing => Object
Thing => ProcessBit
Attribute => atom

Process => atom
Link => atom
Object => atom
Object => **part**(Object,Object)
Action => atom
Comparison => Atom
where Atom is an element of the set:**{greater_than, less_than, same_as, different_from}**
Value => Atom
Where atom is an element of the set:{ **increase, decrease, change, no_change** }
Value => Atom
Value => Number where Number is either a floating point number or an integer
Value => **range**(Value,Value)

Examples of how units of knowledge are combined to form formal statements are presented in Table 3.4.

Table 3.4 Examples of types of statements together with the natural language and the formal representation.

Type of statement	Natural language	Formal language
1. Attribute-value	Cocoa pod life cycle is four to six months	att_value(part(cocoa,pod),life_cycle, range("4months", "6months"))
2. Causal	An increase in the humidity rate causes an increase in the rate of black pod disease	att_value(humidity,rate,increase) causes2way att_value(black_pod_disease,rate,increase)
3. Comparison	Local cocoa variety is more vigorous than SODECAO variety	comparison(vigour,sodecao, greater_than,local_cocoa)
4.User-specified link statement	Bees pollinate *Citrus reticulata*	link(pollinate,bees,citrus_reticulata)
5. Conditional	Red soil causes an increase in the development of cocoa root systems if the clay content of the soil is low.	att_value(soil,colour,red) causes1way att_value(process(part(cocoa,root_system), development),rate,increase) if att_value(part(soil,clay),content,low)

3.2.4 Knowledge analysis and exploration

There are a number of features within the AKT5 software that have been discussed in detail by other authors (Walker et al., 1995; Kendon et al., 1995; Sinclair and Walker, 1998) and summarised in Dixon et al. (2001), which were used to analyse and explore the content of the present knowledge base. The key features used in the present research were as follows.

1. The Boolean search facility allowed specification of search criteria for creating subsets of knowledge, referred to as topics (Sinclair and Walker, 1998). This involved collecting all statements including particular terms or from particular sources, or with particular combinations of terms and sources. For example, women's knowledge about black pod disease.
2. The diagram interface served a number of purposes. It provided a means to explore causal linkages amongst sets of unitary statements. It also gave a pictorial view of the unitary statements entered into the knowledge base via the statement interface (which essentially creates a list) and it provided a number of functions to manipulate and organise the knowledge presented in the diagram.
3. A series of customisable automated reasoning tools (Kendon et al., 1995) facilitated systematic evaluation and exploration of the knowledge base and facilitated its refinement.

3.3 RESULTS AND DISCUSSION

3.3.1 General

Results of the knowledge base report (Table 3.5) showed that 198 out of 239 statements of farmers' knowledge (83%) were causal statements, indicating a high degree of explanatory as opposed to descriptive knowledge had been acquired. This is probably because farmers in southern Cameroon had developed this knowledge through a "trial-and-error problem-solving approach" (Roling and Engel, 1988) with an objective to meet the challenges they faced to maintain their cocoa farms in continuous production in their local environment over generations.

Table 3.5 Number of statements of each type used in the knowledge base

Type of statement	Number of statements	Conditions attached
All	239	12
Attribute	28	6
Causal	198	6
Comparison	13	0
Link	0	0

As mentioned above (Section 3.2.2.1), farmers considered the interactions in their multistrata cocoa systems at two broad levels, which were above ground and below ground.

3.3.2 Knowledge about aboveground interactions

Farmers' knowledge of aboveground interactions was basically developed around the way non-cocoa plant species, especially trees and weeds, modify the microenvironmental conditions in cocoa fields, which in turn had implications for system productivity (Figure 3.2).

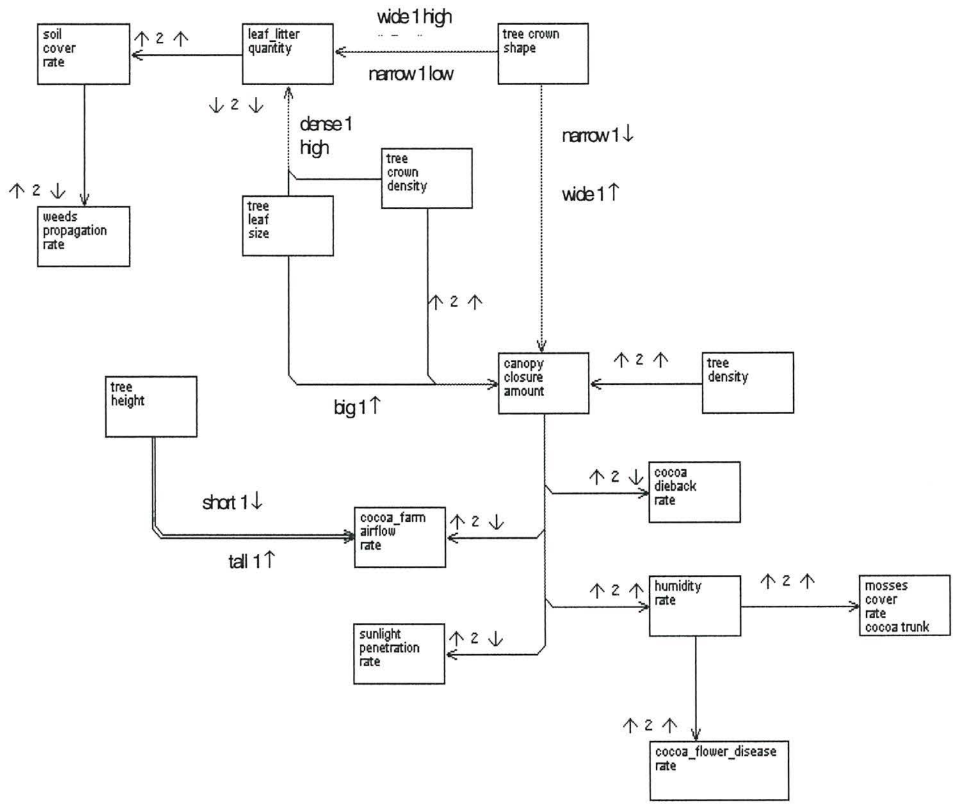

Figure 3.2 Diagrammatic representation of farmers' causal knowledge about non-cocoa tree species attributes and effects on microenvironmental conditions in cocoa fields. Nodes represent attributes, actions or processes of components of the system. Arrows indicate the causal node from which the arrow emanates has an influence on the "effect" node to which arrow points, or indicate an increase or a decrease. "1" or "2" beside the link indicates whether the link is a "causes1way" or "causes2way". "↑" indicates an increase of the value and "↓" indicates a decrease of the value. Information about the nature of the relationship is also held within the knowledge base.

It was apparent that farmers strongly linked aboveground interactions to the shade level in their farm. Indeed, they said that plant density, together with the architecture of the aerial parts of the non-cocoa tree species concerned, mainly determined the shade level, which in turn influenced the microenvironmental conditions in the field especially the amount of solar radiation getting to the understorey, humidity and air circulation. Amongst the tree species attributes identified as influencing the shade level in the farm, farmers put most emphasis on crown density and shape, tree height and the extent of canopy closure. The crown density principally referred to tree foliage abundance. Farmers did not clearly articulate the distinction between foliage abundance and leaf size, it was apparent from their description that leaf size was influencing the overall foliage abundance, and consequently the crown density. In this regard, bigger leaf size tended to be associated with higher crown density, and vice versa (Table 3.6). Farmers said the crowns were importantly shaped by the spatial development of tree branches; they clearly distinguished between the following shapes:

- Wide crown shape: where tree branches had a pronounced plagiotropic development, with few branches developing on the trunk.
- Narrow crown shape: where tree branches had a pronounced orthotropic development, with few branches in general and few developing on the trunk.
- Intermediate crown shape: where there was a somewhat balanced mixture of both plagiotropic and orthotropic branches, with no predominant development of either type. The crown shape usually presented a parasol form.

Table 3.6 Farmers' systems of assessment of the principal effects of trees on the microenvironmental conditions of the multistrta cocoa fields.

Tree species	Attributes				Effects on conditions in farm			
	height	crown density	crown shape	leaf size	shade	solar radiation	wind velocity	humidity
Albizia glaberrima	tall	dense	wide	big	excessive	low	adequate	high
Afzelia pachiloba	tall	sparse	wide	small	adequate	adequate	high	medium
Albizia adianthifolia	short	sparse	narrow	small	light	excessive	high	low
Alstonia congensis	tall	sparse	wide	medium	light	excessive	high	low
Dacryodes edulis	short	dense	wide	medium	excessive	low	low	high
Erythrophloeum ivorense	tall	sparse	wide	small	light	adequate	high	low
Grewia brevis	tall	dense	wide	small	excessive	low	adequate	high
Citrus sinensis	short	sparse	narrow	small	light	excessive	high	low
Cola acuminata	short	dense	narrow	big	adequate	adequate	adequate	medium
Beilschmiedia obscura	tall	dense	narrow	small	moderate	adequate	adequate	low
Baillonella toxisperma	tall	dense	wide	big	adequate	adequate	adequate	medium
Voacanga sp	short	dense	wide	big	excessive	low	low	high

Farmers said that the shade level was generally a result of a combination of at least two of the tree attributes, and that extreme value of tree attributes except for tree height usually led to important disturbances of the ecosystem of the farm. It can be summarised that in situations where non-cocoa trees' crowns were denser and wider, the canopy was likely more closed, more solar radiation was intercepted, and the amount of air circulating within the farm was less, and as a consequence the shade was more important, leading to a high humidity (Table 3.6). In contrast, when the tree crowns were narrow and sparse, more solar radiation could reach the understorey, wind velocity within the farm was higher, and the humidity within the farm was lower.

Farmers were fully aware of the implications of the microenvironmental conditions in the field for some major processes having an impact on cocoa tree productivity such as cocoa pests and diseases, as well as some aspects of cocoa tree phenology such as rate of flowering. For example, they said that a high humidity rate in the farm generally favoured the development and dissemination of cocoa diseases, thus causing substantial drop in farm yield or increase in the cost of maintenance. In contrast, low humidity due to low shading usually encouraged important cocoa pest outbreaks (these aspects are explored in more detail in Chapter 4).

Farmers also observed that the flowering of cocoa trees was enhanced under adequate solar radiation and airflow in the farm, which in turn were influenced by the level of canopy closure and tree density and height. A high velocity of air circulation because of lack of or insufficient wind breaks usually formed by non-cocoa tree species, or excessive exposure of cocoa trees to solar radiation because of low shade usually led to poor flowering of cocoa trees or massive destruction of flowers present on cocoa trunks. In contrast, high humidity and poor circulation of air in the farm generally exposed cocoa flowers to diseases, thus negatively affecting their potential to develop into fruit. Farmers also suspected some non-cocoa plant species to be temporary hosts for cocoa pests when they were not active on cocoa because of various circumstances, including changes in microenvironmental conditions in the farm.

Between the extreme shade levels, farmers said there was a range of intermediate situations that generally maintained balanced environmental conditions in farms, and which were reported to be compatible with efficient development of cocoa trees, provided the other growth requirements were not limiting.

Physiologists and ecologists have long argued that a sound understanding of the processes and mechanisms of resource capture and use and their interactions with the environment is essential for the development of more reliable and productive systems (Trenbath, 1976; Willey, 1979; Ong, 1996). Brenner (1996) pointed out that some of the most important effects of combining plant species in mixtures resulted from changes in the microclimate which in turn influence the growth and development of all the components of the system. In this regard, changes of particular importance in cocoa systems are changes in the solar radiation balance in the understorey and the wind pattern, which in turn have a direct influence on air humidity and temperature in the farm and their effects on evaporation of water and plant growth. Other effects mentioned (Brenner, 1996) were pest incidence under such circumstances, because the population of pests and birds, as well as disease development patterns were subject to modification because of changes in the ecosystem. Saunders (2002) reported that farmers in Ghana had noticed a significant level of cocoa flower rot disease in farms with excessive shading and have attributed this to the high humidity prevailing under such conditions.

Many authors (Brenner, 1996; Ong, 1996) reported that solar radiation was intercepted by increased leaf area of the overstorey components, and that the surface wind pattern was influenced by tree density. Cournac et al. (2002) pointed out that Leaf Area Index (LAI) had an impact on tree growth through the interception of solar radiation and solar radiation availability was the principal limiting factor of plant growth productivity in the tropics. He also reported that light attenuation by successive leaf layers is related to leaf area index and approximated by the Beer-Lambert law[17]. Thapa (1994) reported that farmers in the mid-hills of eastern Nepal recognised that light extinction or interception by trees was determined both by the incident radiation regime and the canopy structure, since a number of structural aspects of the canopy were recognised and known to affect shade. They recognised attributes of tree canopy that affected shade at two levels; that of individual tree crowns and that of individual leaf size and leaf inclination angle.

The above descriptions have many similarities with those made by farmers in southern Cameroon (Figure 3.2), except that in their case, no explicit mention was made of the leaf inclination attribute. However, they mentioned that some types of leaves usually retained water long after rainfall and this could be attributed to that. Farmers were aware that the effects of shading level and wind velocity in cocoa farms were also associated with non-cocoa tree height and density. The shading by tall trees were recognised to have less negative effects on farm microenvironmental conditions than by short trees, because there was more distance between the overstorey and understorey canopies, and that also their effect on air circulation was less for the same reasons.

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[17] The Beer-Lambert law is as follows: $I = Ioe^{-kL}$ where I is the irradiance at the ground level and Io the irradiance above the canopy; the extension coefficient k is related to partly to optical properties of the leaves and mainly to the structural properties of the canopy (height, stem density, leaf clustering and inclination, etc) and L is the leaf area index

3.3.3 Knowledge about belowground interactions

Farmers' knowledge of belowground interactions and effects on cocoa growth and productivity were based on their knowledge about soil, and the interactions between soils and plants, especially trees.

3.3.3.1 Soil

The importance of the roles that the soil substrate plays in conserving belowground resources and supporting plant growth was emphasised by all farmers. Their systems of soil classification were basically focussed on soil types and conditions that could have an impact on system sustainability and productivity. They were fully aware of the fact that some plants had specific soil requirements and this had led them to develop keys to assessment of soils in the landscape. For example, they said species with deep rooting habit like cocoa, were preferably grown on deep soils because soil depth was a limiting factor for the development of their root system, whilst species with shallow rooting habits were grown on either deep or shallow soils.

The relation between soil types and soil conditions, especially as concerned farmer perceptions of the suitability status of soils, were also established by locally developed observation methods. Classification of soil types was based on colour, depth, structure and position in the landscape (more fully discussed in Section 5.3.1), while the condition of soil of any type was assessed through the presence of biological indicators on the site such as plant species, earthworms and termites (more fully described in Section 5.3.2). Farmers actively used their knowledge of soil type and condition, in combination with other indicators, to identify suitable farmland for specific plant species and allocated the available land accordingly.

3.3.3.2 Soil-tree interactions

Farmers were fully aware of the effects of tree species on soil properties and their understanding of these effects was mainly based on the activities of plant roots and leaf litter. Depending on rooting habit, principally the depth, lateral spread and morphology, roots were known to considerably modify soil structure, thus influencing the quantity and the availability of soil resources to plants in general and to cocoa in particular. Farmers also exhibited a sophisticated understanding of effects of organic matter, through the process of leaf litter decomposition, on some aspects of soil condition such as soil fertility, soil moisture and soil compaction. In this regard, the quantities of leaf litter produced together with its decomposition rate were key factors in the process (Figure 3.3).

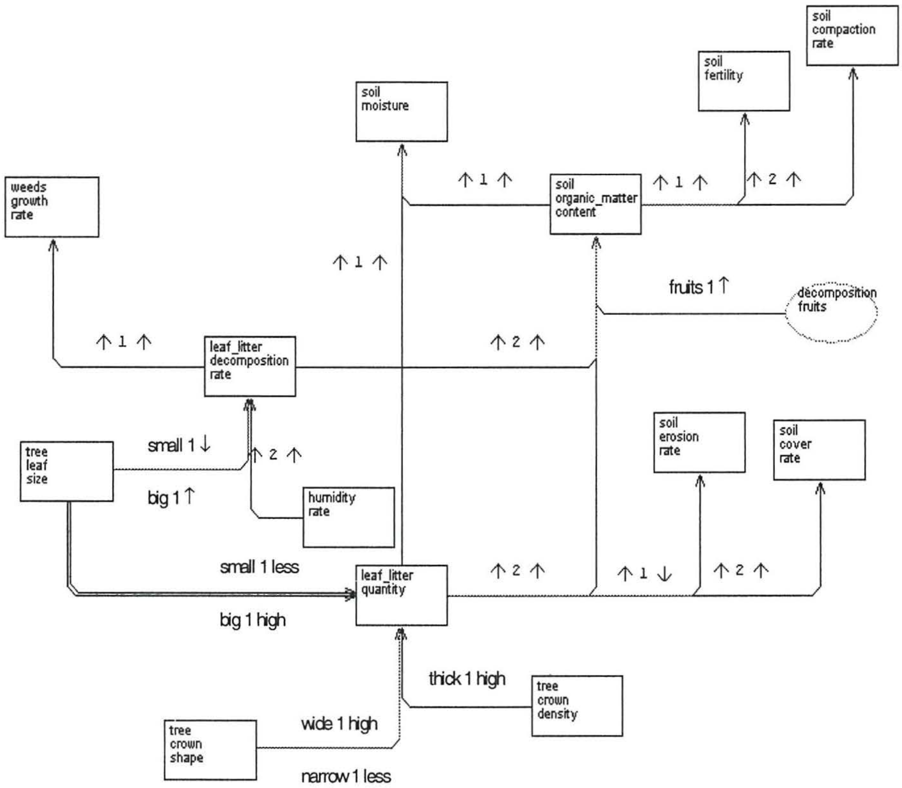

Figure 3.3 Diagrammatic representation of farmers' causal knowledge about organic matter and effects on soil conditions. Legend as for Figure 3.2. Oval node represents a process.

Farmers reported the existence of tree-tree interactions below ground and said they were strongly influenced by rooting habit. Farmers revealed that species with similar rooting habit usually explore the same soil layers for the same soil resources. They had also observed that the different tree components of the system did not have the same ability to capture soil resources especially where they were limiting, thus leading to competition amongst them. In this respect, the availability of soil resources to cocoa was a critical issue in the cocoa farm context in southern Cameroon because according to farmers, soils of the area had a low fertility status, and cocoa was known to be sensitive to competition.

It is well established (Smith et al., 2004) that for agroforestry to succeed, competition for natural resources between the various components of a system should be avoided. Cannell et al. (1996) expressed this as the central biophysical hypothesis for agroforestry. They stated that, in the case of water in a tree-crop association: "benefits of growing trees with crops will occur only when the trees are able to acquire resource of water that crops would not otherwise acquire". This can also apply to a tree-tree association, as is the case for cocoa systems in southern Cameroon.

Farmers' systems of soil classification as well as soil-tree interrelationships, and implications for cocoa system sustainability and productivity are more fully explored in Chapter 5 of this thesis.

In summary, an evaluation of farmers' perceptions of the above ground and below ground interactions occurring amongst the various components of their cocoa systems suggests that the role of non-cocoa trees is predominant in both cases. A general classification of trees found in cocoa systems of southern Cameroon according to their ecological functions together with their socio-economic importance drawn from farmers' appraisal led to four major classes:

- species planted: cocoa, fruit trees and palm oil,
- naturally regenerating species of interest for the sustainability and productivity of the system, and for household livelihoods: fertility value, timber value, fruit value, medicinal value and spiritual value,
- naturally regenerating species of minor value for system sustainability and productivity, and local use: shade value, fuel wood value and,

- naturally regenerating species with negative effects on cocoa: host for cocoa pests, belowground and aboveground highly competitive and allelopathic functions.

Details of farmers' knowledge about the ecological functions as well as the uses of the products of 65 out of 165 non-cocoa species inventoried in cocoa systems in southern Cameroon were established and are presented in Annex 3.1. The most commonly cited ecological functions and useful values of the 65 non-cocoa tree species were shade canopy representing 92% of the species, fuelwood 78%, soil fertility 51%, timber 46%, fruits/nuts/spices 40% and medicinal 38% (Table 3.7). 46% of the species had both shade canopy and fertility functions.

Table 3.7 Ecological functions and uses perceived amongst 65 non-cocoa tree species.

	Shade	Fuelwood	Fertility	Timber	Fruits	Medicinal
Shade	92%					
Fuel wood	72%	78%				
Fertility	46%	40%	51%			
Timber	37%	40%	23%	46%		
Fruits	11%	17%	11%	5%	40%	
Medicinal	31%	24%	20%	9%	7%	38%

These figures suggest that shade canopy and fertility values are farmers' most important ecological criteria for maintaining non-cocoa tree species in the cocoa fields in southern Cameroon, whilst species products such as fuel wood, timber, medicinal and fruits/nuts/spices are the most common uses of those species products. It should be however noted that despite the higher percentage of maintained species used as fuelwood, this only occurs at the end of the life cycle of the species, hence cannot be considered as a frequently harvestable product as are fruits, nuts or spices. In some locations with alternative source of fuelwood as is the case for Akok and Awae, collecting fuel wood from cocoa fields is marginal.

3.3.4 Induced knowledge formulation

The process through which increasing population pressure leads to technical change is well established (Boserup, 1965; Pingali et al., 1987; Binswanger and McIntire, 1987). As land availability per household and the amount of forest and forest resources declines with population growth over time, farmers who value useful tree species such as fruit trees may actively pursue their integration in the cocoa system.

Trees in cocoa systems in southern Cameroon include not only native species from regeneration but, as mentioned in Chapter 2 (Section 2.4.2.2), in locations with reasonable market access and high population density, farmers were increasingly introducing fruit and timber species to their cocoa systems. Depending on the extent of these introductions, farmers recognised that the introduced components were liable to induce changes in the ecosystem of the farm. As a result, they have developed management strategies to address some of the challenges derived from these changes while others remain as constraints.

For example, farmers observed that fruit tree species were negatively influencing cocoa growth and productivity because both components occupied similar strata, and were permanently competing for the same resources. One of the strategies used by farmers to address this issue was through shaping the aerial architecture of introduced fruit trees species in a way that differentiates the heights of their crowns from that of cocoa, by systematically pruning fruit tree branches below the height occupied by cocoa crowns at an early stage of growth. This was said to increase the gaps between the crowns of the two components, and thus the amount of solar radiation reaching the cocoa crown, as well as enhancing air circulation within the farm. Another strategy consisted of simply increasing the space between fruit trees to lessen the additive effects of their crowns and hence overall canopy cover.

The implementation of these strategies was, however, constrained in situations where fruit trees regenerated naturally, which was common in much of the study area. In this case, shade could not be easily regulated to satisfy the needs of only the cocoa plants. For example, farmers reported that modification of canopy cover of fruit trees in a mature cocoa farm by removal of redundant branches or severe pruning caused reduction of the production potential of both cocoa trees, from damage by falling trunks and branches, and fruit trees, because of removal of productive branches. No strategy was developed by farmers to address this constraint.

In the southern Cameroon context, farmers developed an understanding of the interactions between cocoa and fruit trees both above and belowground. However, if they could control the aboveground interactions by shaping the architecture of the aerial parts of introduced species, this was not always the case with the belowground interactions. They unanimously recognised the competition between introduced fruit trees and cocoa, especially for soil water, but were short of practically adapted means to control this.

3.3.5 Distribution of knowledge

The distribution of the knowledge in terms of number of statements provided by informants across the study locations (Table 3.7) showed that farmers in Nkongmesse provided more statements, as compared to those in Awae, Akok or Ndikinimeki.

Table 3.8 Distribution of knowledge across locations

Location	Number of statements	Percentage of number of staments provided
Akok	164	68%
Awae	155	65%
Nkongmesse	189	79%
Ndikinimeki	166	69%

From the scoping phase, knowledge was expected to vary more with environmental conditions and socio-economic circumstances, rather than cultural inheritance, because there was little evidence of cocoa farm management practices being specific to particular ethnic groups. Where differences in practices were observed, they tended to be associated with different soils, vegetation or socio-economic conditions.

The larger amount of knowledge developed by farmers of Nkongmesse as compared to other locations was therefore expected, as farmers of that location are presumably facing more constraints to maintain the sustainability and productivity of their cocoa systems due to "high impact system[18]". Indeed, the population pressure at that location, coupled with the scarcity of arable land, has led farmers to intensify their cocoa systems by the introduction of food crop components, especially plantain *(Musa sapientum)* and banana *(Musa paradisiacal)*. In addition, the differing socio-economic inducement factors characterised by an intensified cocoa-fruit tree system practised at Nkongmesse had also led farmers of this location to actively develop an understanding of induced modifications in their cocoa systems as a

[18] Management of relatively large territories or areas in relation to population density and intensity of land use (Gonzalo Oviedo, 2000)

consequence of the introduction of a larger amount of fruit trees (Section 3.3.4).

Figures about how statements were provided by different informants according to gender (Figure 3.4), and to locations (Figure 3.5) show a fairly continuous distribution, with about half of the informants providing more than 60 statements of knowledge and half less. The difference in the number of statements provided by men, as compared to women was highly significant (t-value = 5.75, p-value = 0.000). This could be attributed to the small sample of women interviewed (16 women against 45 men), but also, as mentioned in Chapter 2 (Sections 2.3.2 & 2.3.3), to the gender-based division of work that usually limits the involvement of women in the cash crop production chain in general and particularly, the cocoa sector.

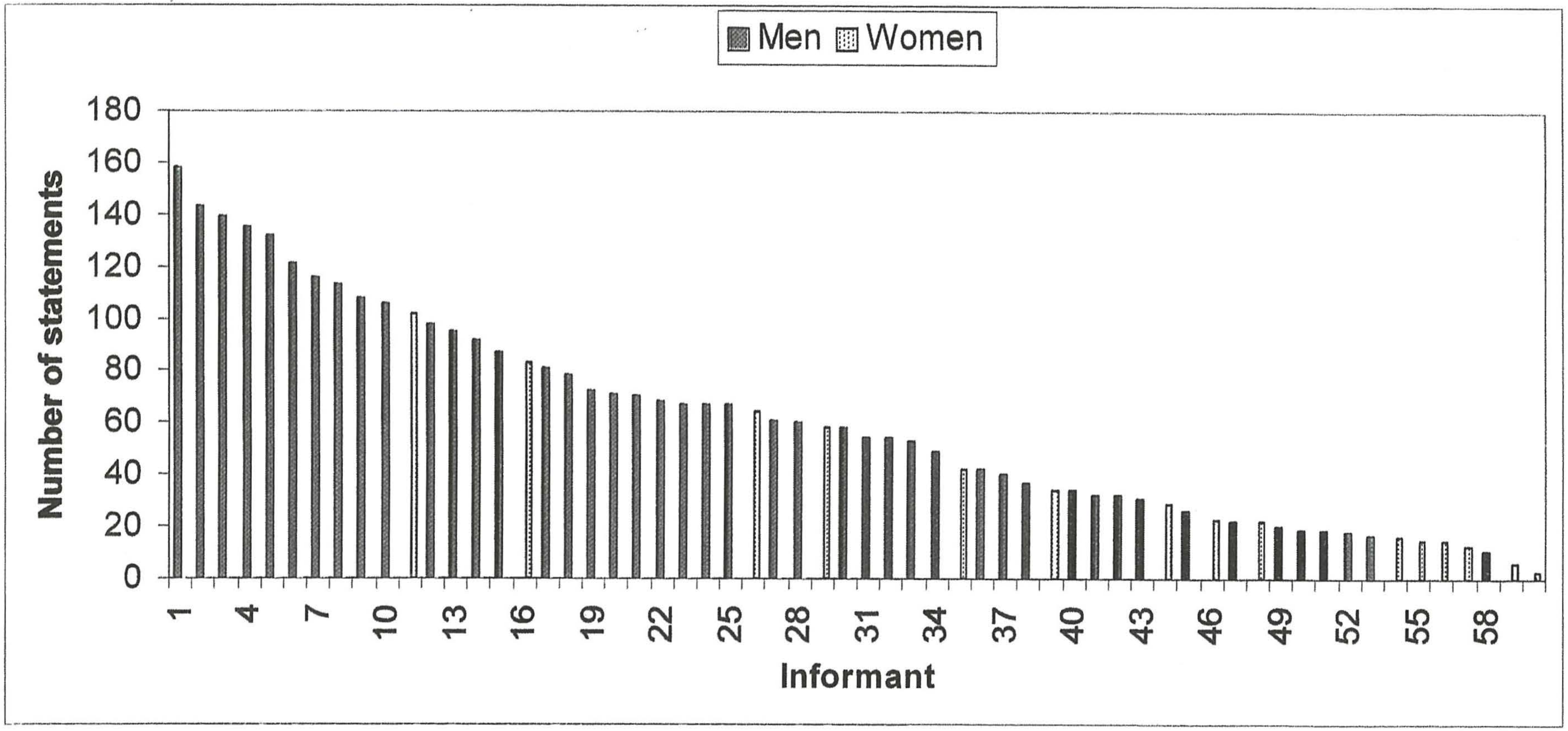

Figure 3.4 Distribution of statements by different informants according to gender

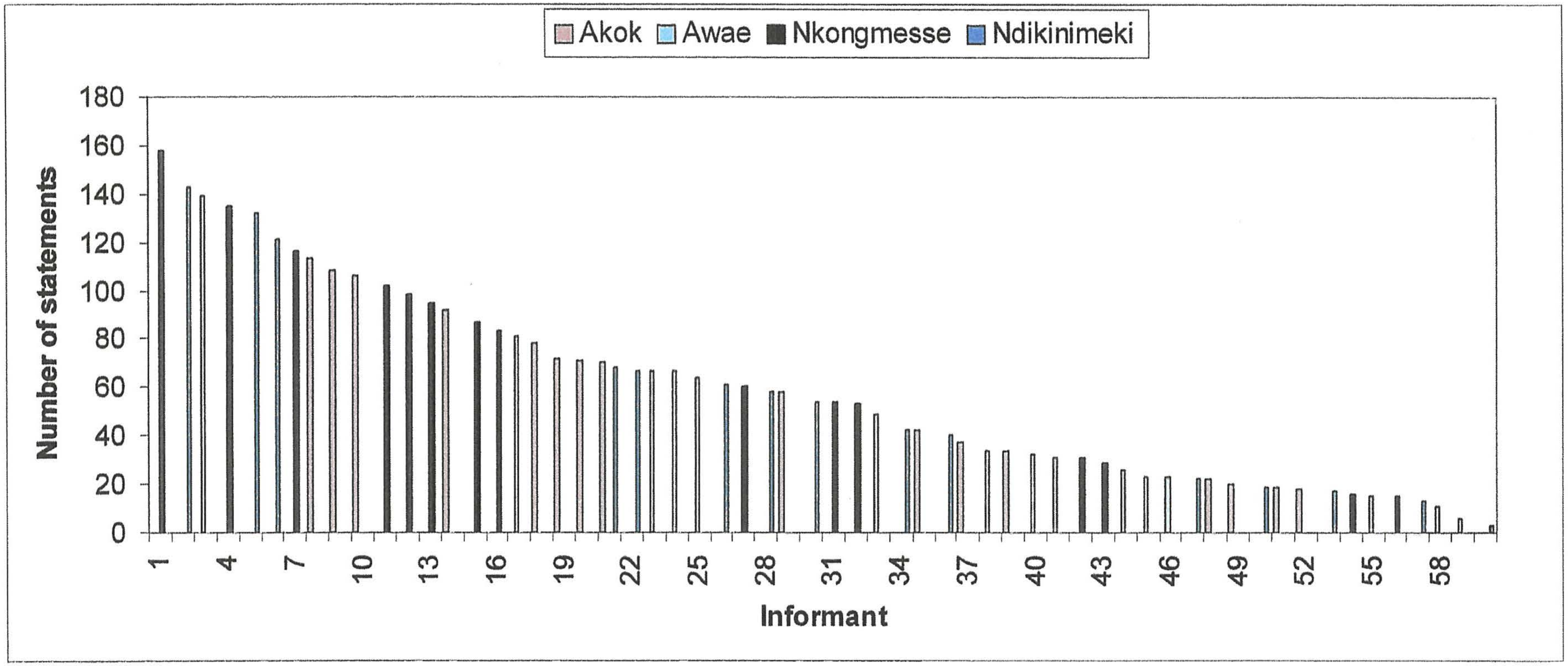

Figure 3.5 Distribution of statements by different informants according to location

3.4 CONCLUSION

The chapter presented the methodological approach used to acquire farmers' knowledge about interactions in their multistrata cocoa systems in southern Cameroon. The interactions amongst plant species, mostly trees, and between trees and soil above and below ground and their impact on system productivity and sustainability appeared to be the key aspects on which they built their knowledge. How they used this knowledge in conjunction with other considerations to make decisions about the management options of their farms is explored in more detail in Chapters 4 and 5.

Intensification of land use systems in the multistrata cocoa areas in southern Cameroon is inevitable, as socio-economic conditions change and the system evolves towards a more intensive cocoa-species of interest model. One danger associated with the mixing of species is competition for natural resources, especially soil resources. There is, therefore, a need for researchers and extension workers to reduce this by proposing relevant strategies to address constraints attached to this new situation.

Analysis of the numbers of statements provided by individual informants shows a fairly continuous distribution, with about half of the informants providing less than 60 statements (25%) out of 239. This points to a need to document existing knowledge, as there is a fear that relevant aspects of farmers' knowledge may be lost as socio-economic and environmental circumstances change.

CHAPTER 4

FARMERS' KNOWLEDGE ABOUT COCOA PESTS AND DISEASES

ABSTRACT

Farmers' knowledge about cocoa pests and diseases and management strategies to control them were surveyed in four study locations in southern Cameroon.

The findings of the research indicated that farmers were aware of several factors that affected the onset and spread of pests and disease. These were: i) the planting material; ii) the microenvironmental conditions in the farm, and iii) inappropriate use of agrochemicals. Farmers' management strategies for the control of pests and diseases were related to causal factors. However, more emphasis was put on the control of microenvironmental conditions and the use of plant extracts as alternatives to expensive manufactured agrochemicals.

It is argued that a judicious incorporation of relevant aspects of this local knowledge into scientific research may produce innovations adapted to farmers' circumstances.

4.1 INTRODUCTION

Cocoa production in Cameroon is greatly affected by pests and diseases, with the two most important problems being mirids and black pod disease caused by *Phytophthora palmivora* and *Phytophthora megakarya.* The latter species of *Phytophthora* has become dominant in Cameroon and, if left untreated, results in near complete crop failure (Lass, 1987; Bakala and Koné, 1998; Nyasse 1997; Duguma et al., 2001). Crop losses occur when the disease attacks the cocoa pod, engulfing it completely with mycelium in a matter of a few days and thereby preventing the pod from reaching a harvestable maturity. Mirids are plant-sucking bugs (Heteroptera: Miridae) with two species, *Sahlbergella singularis* and *Distantiella theobroma*, causing the largest losses in Cameroon (see Section 2.2.4.3). Mirids attack cocoa pods but the effect is mostly cosmetic; the real damage is due to foliar and twig attacks, which often lead to secondary infections, wilting and in some cases tree death.

Since the 1960s chemical control of pests and diseases has been increasing in importance. Up until the liberalization of the cocoa sector in the early 1990s, producers received fungicides either at a heavily subsidized price or for no cost. The government marketing board was able to finance this distribution out of the surplus of the stabilization fund. In southern Cameroon the cocoa sector development parastatal SODECAO (Société de Développement du Cacao) also organized spraying campaigns against mirids whereby all the cocoa farms in a given locality were sprayed simultaneously (Duguma et al., 2001). In today's liberalised market, producers purchase a range of agrochemicals from private traders.

With fluctuating world prices for cocoa, farmers rationally seek to reduce the use of agrochemicals when cocoa prices are low but the neglect of mirids and black pod disease can result in yield declines and damage to the household's tree stock asset base (Duguma et al. 2001). Farmers and policy makers are also concerned about health and environmental issues associated with the use of chemical controls. In recent years efforts at developing integrated pest management control of black pod disease and mirids have received increasing public and donor attention and these techniques are now being incorporated into national extension programs. To assist in the development of these programs it is important to take stock of farmers' ecological knowledge of these problems. This research explores and describes that local knowledge as a contribution to the development of better and more focused integrated pest management efforts, which build upon the knowledge already possessed by farmers.

4.2 MATERIAL AND METHODS

4.2.1 The study area

The biophysical context of the study area including the ecology of cocoa, and the socio-economic context of the four study communities of Akok, Awae, Nkongmesse and Ndikinimeki, has been discussed in Chapter 2 (Sections 2.2.3 and 2.3).

4.2.2 Methods

The methodological approach used to acquire and document farmers' knowledge was the same as the one described in Chapter 3 (Section 3.2) except for the checklist prompts. This was because a specific checklist of prompts (Table 4.1) was necessary to enable an in-depth exploration of farmers' knowledge about pest and disease issues, particularly their occurrence and control aspects. Information on pests and diseases contained in the knowledge base was accessed via the Boolean search facility (Section 3.2.4) that enabled to create topics to that effect.

Table 4.1 Checklist prompts for semi-structured interviews about cocoa pests and diseases.

Research topic	Checklist prompts
Knowledge about cocoa pests and diseases	List of pests and diseases that affect cocoa? What organs of the plant does every pest or disease mostly affect? Classify pests or diseases in terms of harmfulness to cocoa organs Mode of action of every pest or disease Impacts of cocoa pests or diseases on cocoa production
Knowledge about favouring factors	List of factors favouring the occurrence of cocoa pests and diseases Implication of every factor for the severity of the attacks of pests and diseases Response of cocoa cultivars to pests and diseases
Control	How do farmers control cocoa pests and diseases

4.2.2.1 Validation

This stage aimed to quantify the extent to which the knowledge about cocoa pests and diseases acquired from a limited sample of 15 key informants per location (60 for the study area) and presented in the "Cocoa Cameroon" knowledge base was representative of the knowledge held by the farming community at each site. In this respect, a random sample of 60 farmers per study community, not consulted in the creation of the original knowledge base, were interviewed, using open-ended questions bared on the original knowledge base. Their responses were then compared with the knowledge base. In general, when at least 75% farmers agree with a knowledge item represented in the knowledge base, then it is reasonable to regard it as common knowledge (Dixon et al., 2001).

4.3 RESULTS

4.3.1 General

Statements directly related to farmers' knowledge about pests and diseases occurrence represented nearly 30% (71 statements out of 239) of the statements provided by different informants, with further statements explaining the consequences of their attacks. In total, farmers in southern Cameroon have identified four pests and two diseases that affect cocoa (Table 4.2), and some favouring factors for their dissemination have been stated. Mirids, weeds and black pods disease were the most common pests and diseases farmers mentioned (100% of informants), meanwhile, some pests such as mealybugs and termites, as well as cocoa flower disease were mentioned by less than 50% of informants (15%, 35% and 45% respectively).

Table 4.2 Cocoa pests and diseases identified and proportion of farmers aware of these. BPD = black pod disease; FD = flower disease

Pests		Diseases	
Common name	Proportion of farmers aware n = 240	Common name	Proportion of farmers aware n = 240
Mirids	100%	BPD	100%
Weeds	100%	FD	45%
Termites	35%		
Mealybugs	15%		

4.3.2 Pest and disease occurrence

Farmers in the study locations unanimously recognised that the development and the dissemination of mirids and cocoa black pod disease, the most important cocoa pest and disease in the area, was mainly favoured by the microenvironmental conditions in farms (Table 4.3), and factors influencing these were stated. Other favouring factors mentioned were the cocoa cultivars used, the non-availability of manufactured agrochemicals leading to their inappropriate use and the presence of host trees for mirids in or around the cocoa fields (Figures 4.1 and 4.2).

Table 4.3 Validation data on farmers' knowledge about factors favouring the occurrence of cocoa pests and disease

Factors	Akok n = 60	Awae n =60	Nkongmesse n = 60	Ndikinimeki n = 60	Total n = 240
climate v mirids	45 (75%)	55 (92%)	58 (96%)	55 (92%)	213 (88%)
climate v diseases	60 (100%)	60 (100%)	60 (100%)	60 (100%)	240 (100%)
humidity v mirids	20 (33%)	32 (53%)	43 (71%)	40 (66%)	135 (56%)
humidity v diseases	55 (92%)	56 (93%)	56 (93%)	45 (75%)	212 (88%)
shade v humidity	58 (96%)	55 (92%)	59 (98%)	55 (92%)	227 (94%)
canopy v shade	58 (96%)	55 (92%)	59 (98%)	55 (92%)	227 (94%)
crown v shade	58 (96%)	55 (92%)	59 (98%)	55 (92%)	227 (94%)
tree height v humidity	50 (83%)	48 (80%)	55 (92%)	40 (66%)	193 (80%)
tree density v humidity	59 (98%)	60 (100%)	60 (100%)	49 (81%)	228 (95%)
leaf size v canopy	45 (75%)	48 (80%)	45 (75%)	40 (66%)	178 (74%)
hybrid v mirids	55 (92%)	58 (96%)	59 (98%)	45 (75%)	217 (90%)
hybrid v diseases	55 (92%)	58 (96%)	59 (98%)	45 (75%)	217 (90%)
local v mirids	57 (95%)	59 (98%)	55 (92%)	50 (83%)	221 (92%)
local v diseases	57 (95%)	59 (98%)	55 (92%)	50 (83%)	221 (92%)
know about host trees for mirids	25 (41%)	23 (38%)	33 (55%)	15 (25%)	96 (40%)

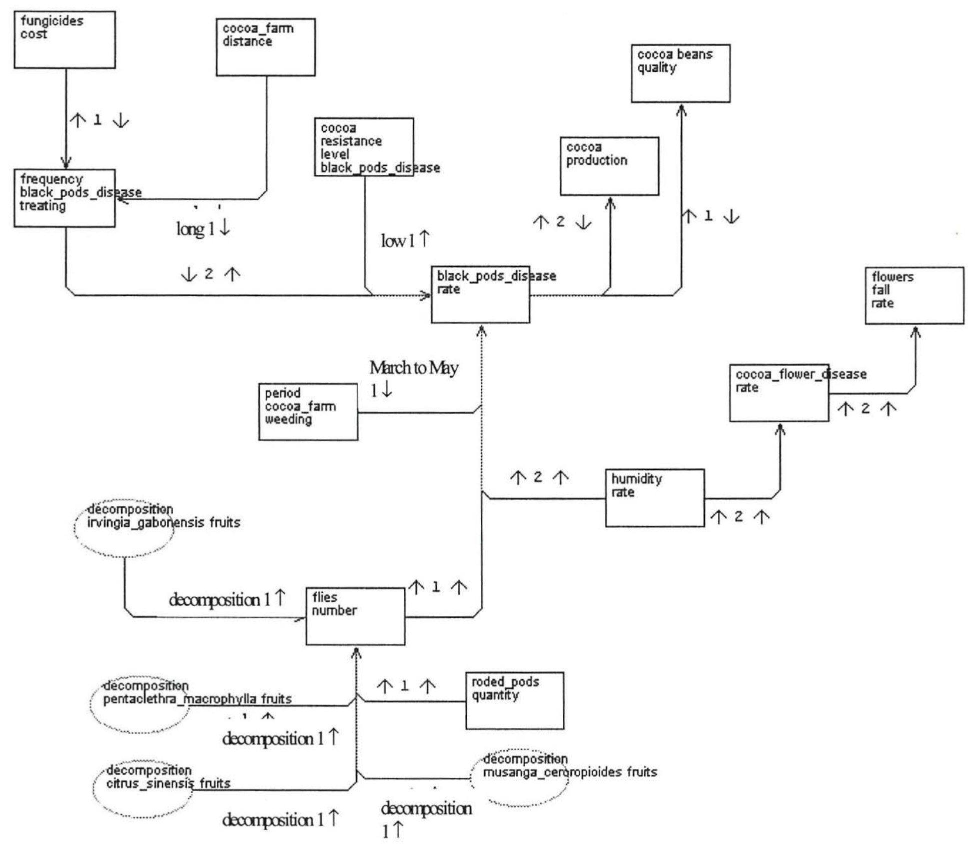

Figure 4.1 Diagrammatic representation of farmers' causal knowledge about cocoa diseases occurrence in southern Cameroon. Nodes represent attributes, actions or processes of components of the system. Arrows indicate the causal node from which the arrow emanates has an influence on the "effect" node to which arrow points, or indicate an increase or a decrease. "1" or "2" beside the link indicates whether the link is a "causes1way" or "causes2way". "↑" indicates an increase of the value and "↓" indicates a decrease of the value. Information about the nature of the relationship is also held within the knowledge base.

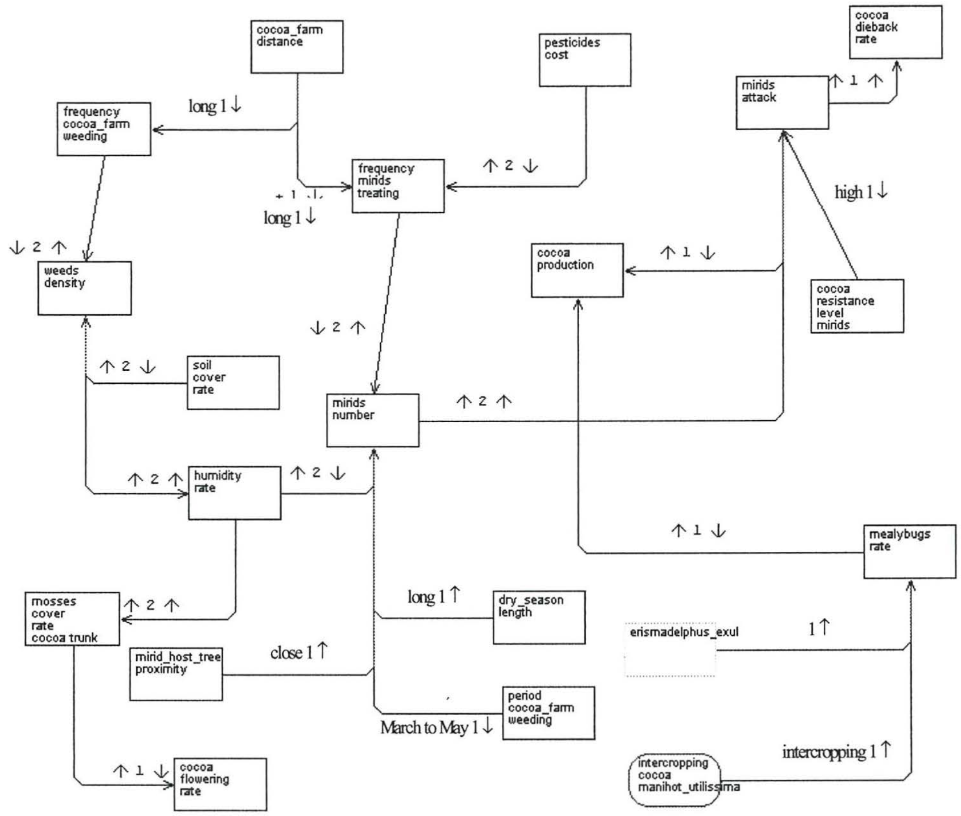

Figure 4.2 Diagrammatic representation of farmers' causal knowledge about cocoa pests occurrence in southern Cameroon. Oval node represents actions. The rest of legend as for Figure 4.1

4.3.2.1 Effect of cocoa cultivars

Local classification of cocoa cultivars used in the area identified two varieties; the local cocoa landraces locally called "german variety" and mostly constituted of forastero-amazonian or upper amazon varieties and a considerable population of trinitario, and the improved varieties or hybrids locally called "SODECAO" (from the name of the parastatal in charge of the distribution of the cultivars of that variety) that have been developed by scientists. Farmers had specific knowledge of the behavioural characteristics of both cultivars as regards the occurrence of black pod disease and mirid attacks. They considered local cocoa landraces to be more resistant to pests and diseases than the improved varieties whatever the prevailing environmental conditions (Photo plates 2.1 and 2.2). However, farmers often preferred the improved varieties because of their precocity and productivity, but were confronted with the difficulty of affording agrochemicals for pest and disease control.

More than 90% of producers of the study area applied manufactured fungicides and around 28% applied manufactured insecticides to control black pods and mirids (Sustainable Tree Crops baseline survey, 2001). These figures only gave indications of the proportion of farmers applying manufactured agrochemicals in their farms, but not on the way these were applied. In the majority of cases, the recommendations for a standard application were not implemented because of insufficient or non-availability of manufactured agrochemicals. The long distances from settlements to cocoa farms in some locations as is the case in Akok and Ndikinimeki (sometimes beyond 6 km) were also consistently cited as an obstacle to a thorough implementation of the recommendations on the use of agrochemicals even when they were available. In most cases, farmers, many of whom are no longer young, have to walk these distances with heavy loads in a hilly landscape.

Photo plate 2.1 Local cocoa stand at Akok showing pest and disease free pod*s*.

Photo plate 2.2 Hybrid cocoa stand at Akok showing susceptibility to black pod disease.

4.3.2.2 Host trees

Farmers repeatedly observed that more serious pest outbreaks, especially mirids, used to occur in certain areas on their farms and had linked the phenomenon to the presence of certain tree species most often found in or around such areas. Eight of such species identified by farmers were: the Douma or Doum or Nioum (*Ceiba pentandra*), the Abel (*Cola acuminata*), the Elon or Etom (*Erythrophloeum ivorense*), the Ekoa (*Lannea welwitschii*), the Fia or Pia or Puopi (*Persea americana*), the Ayous or Hilel (*Triplochiton scleroxylon*), Akol *(Ficus exasperata)* and the Assam (*Uapaca guineensis*).

Little information about why these species were host species was given. However, farmers said that the presence of *Cola acuminata* amongst the mirid host trees was not surprising because both cola and cocoa belong to the same family and mirids also attack cola pods. Moreover, in contrast to cocoa, farmers usually maintain cola pods on trees long after they have reached maturity, thus providing mirids with an alternative source on which to feed and survive.

4.3.2.2.1 Mode of action of mirids

When active on cocoa, mirids were reported to attack by piercing cocoa twigs or shoots to feed, and further by injecting what farmers referred to as "a poisonous liquid" into the young tissue which caused their death, thus weakening the plant as a whole (Photo plate 2.4). The phenomenon is scientifically known as twig or shoot wilting (Vos et al., 2003) that was followed by terminal death of the parts attacked allowing entry of wound fungi. This was considered to be the most harmful effect of mirid attacks on cocoa. Farmers reported that these insects also attacked cocoa pods, but the impact on cocoa production was not very important and mostly cosmetic

(Photo plate 2.3), because this usually happened when the pods had reached harvestable maturity. However, when pods were attacked at earlier stages of development, farmers said the lesions caused by insect bites caused the pods to become hard, thus compromising their development.

Photo plate 2.3 Effects of mirid attacks on a mature cocoa pod at Esse location.

Photo plate 2.4 Effects of mirid attacks on cocoa twigs at Esse location; dieback may occur

4.3.2.3 Effect of microenvironment

The major microenvironmental inducement factor to cocoa pest and disease occurrence at farm level as identified by cocoa farmers appeared to be the humidity in the farm (Figures 4.1 and 4.2). Farmers said that a higher rate of humidity favoured the development and the dissemination of cocoa black pod disease, whilst pest numbers were lower under these conditions and vice versa. Farm components that influence humidity (Figure 4.3) as stated by farmers included: i) weed pressure, as a high biomass of weeds has as a consequence reduced airflow and increased humidity, and vice versa; ii) densities of both cocoa and non-cocoa tree species, as a high density of cocoa and non-cocoa tree species reduces the rate of air circulating within the farm, thus maintaining a high rate of humidity in the farm, and most importantly iii) the shading level via the canopy cover, as a high shading level reduces the amount of solar radiation getting to the understorey layer, thus maintaining a high rate of humidity within the farm. As described previously in Chapter 3 (Section 3.3.2) farmers clearly identified tree species attributes influencing the shading level such as height, crown shape and leaf size. Other factors influencing the rate of humidity mentioned by farmers were the weather via the rainfall regime and the position of farm in the landscape.

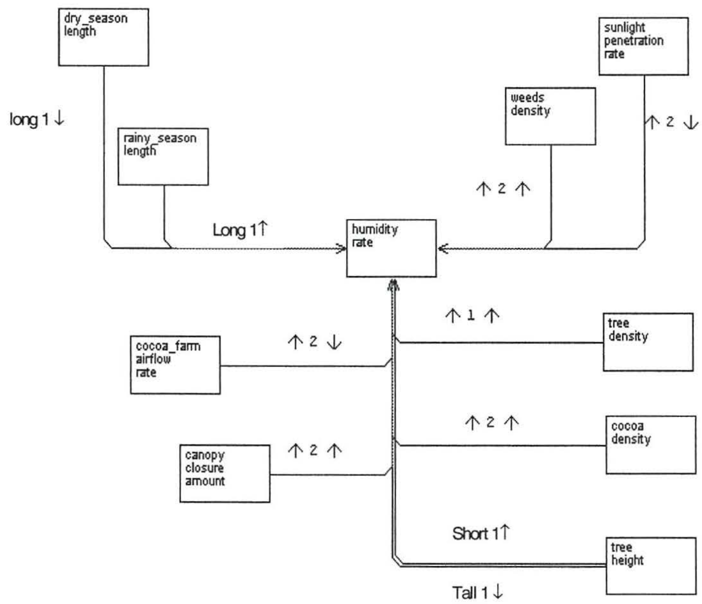

Figure 4.3 Diagrammatic representation of farmers' causal knowledge about factors affecting humidity in their multistrata cocoa fields. Legend as for Figure 4.1.

4.3.2.3.1 Species height and crown shape

Tree species height and crown shape were identified as having a significant effect on the level of canopy closure, thus on solar radiation reaching the cocoa tree stratum. Farmers reported that short trees (15 to 25 m in height) with wide crown shape were highly competitive with cocoa for light. This was due to the fact that the gap between the cocoa and such species' canopies was narrow, leading to a more closed canopy cover. Farmers said that areas with a relatively high density of such species were characterised by a higher level of humidity and a poorer rate of airflow. In contrast, tall tree species (above 30 m in height) were generally accepted, because their aboveground competition with cocoa was reduced. This was because the gap between the cocoa and tree canopy was big enough to enable both adequate airflow and allow sufficient solar radiation to penetrate.

Farmers also pointed out that the intensification of cocoa systems by introduction of exotic fruit tree species was significantly influencing the environmental conditions in farms. Fruit trees were said to be generally short and their crowns described as dense, usually occupying almost the same level as that of cocoa. This increased the amount of canopy cover and caused a reduction of airflow of the stand, leading to an increased humidity in the farm. Fruit trees such as Assa (*Dacryodes edulis*), Andogo Ntangani (*Mangifera indica*) and Fia (*Persea americana*) were particularly mentioned in this respect.

4.3.2.3.2 Species leaf size

Farmers mentioned non-cocoa tree species leaf size as shaping the species crown density. The bigger the tree leaf size, the more dense is the canopy, the less solar radiation getting to the cocoa tree layer, and the higher is the humidity in the farm. Farmers also said big leaves usually retained water droplets hours after rainfall, and thus maintaining wet conditions in the farm.

4.3.2.4 Weeds

As mentioned earlier (Section 4.3.2.3), farmers unanimously identified weeds as playing a significant role in influencing the microenvironmental conditions in farm (Figure 4.4), but also as negatively influencing the growth rate and thus, the productivity of cocoa via competition for natural resources. In this regard, farmers remarked that some weed species grew rapidly if not suppressed, and were reported to be requiring important quantities of soil water and solar radiation to develop. Amongst the species commonly cited were *Chromolaena odorata*, a naturalised plant species locally called "apari bikodgo" that literally means "fallow invader" mostly found in the locations of Akok, Awae and Nkongmesse and, *Pennisetum purpureum* and *Imperata cylindrica* mostly found in Ndikinimeki location.

Mosses were increasingly mentioned by farmers as a new species of weed affecting cocoa trees productivity mostly at the locations of Akok, Awae and Nkongmesse. Farmers said they usually covered cocoa trunks, including the flower clusters, thus leading to an important decrease in the rate of flowering of trees. The phenomenon was said to be mostly common to old cocoa tree stands under permanent humidity conditions.

Some tree species seedlings that often regenerate spontaneously in very large numbers from seeds produced by parent trees were also reported to be importantly invading their surroundings, and competing with cocoa trees for soil water. Farmers said the growth and vigour of cocoa trees, and consequently, their productivity were negatively affected. The dispersal of seeds, thus the rate of invasiveness of seedlings, were said to be more important where the parent stand was uphill in the toposequence. In such cases, seeds could travel relatively long distances via the water runoff. Species commonly mentioned were *Bosqueiopsis angolensis, Antiaris welwitschii* and *Beilschmiedia obscura*.

Another invasive plant species mostly mentioned by farmers of Awae and Nkongmesse locations was mistletoe, a semi-parasite. Farmers said mistletoe seeds were spread mostly by birds, and usually developed on and at the expense of cocoa branches, especially the younger branches. A major favouring microenvironmental condition for its development was said to be lack of shade or low shade. Farmers usually linked cocoa tree dieback to the invasiveness rate of mistletoe.

Farmers reported that the weeds pressure was more important in situation where: i) the soil surface was not adequately covered by leaf litter, ii) the leaf litter decomposed rapidly and, iii) the density of both cocoa and non-cocoa trees was too sparse, thus allowing more canopy gaps. This situation was more common at the forest-savanna transition zone (Ndikinimeki location), but also in cocoa farms created on *Chromolaena odorata* fallow lands in the Awae and Nkongmesse locations.

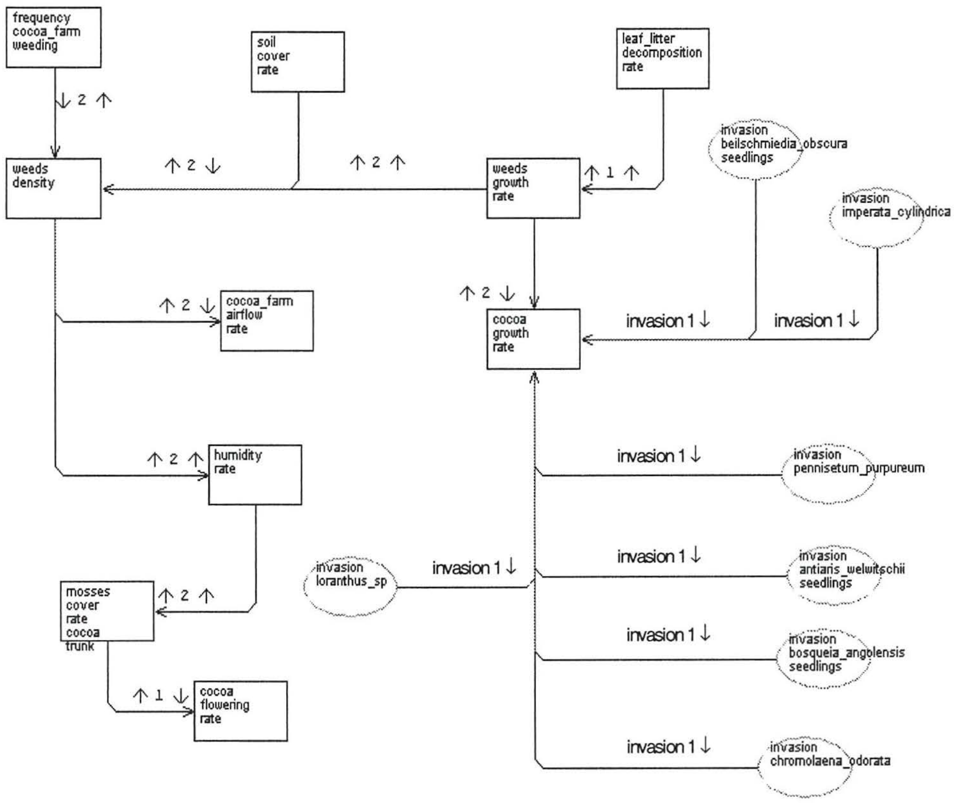

Figure 4.4 Diagrammatic representation of farmers' causal knowledge about weeds. Oval nodes represent processes. The legend as for Figure 4.1

4.3.3 Control strategies

4.3.3.1 Farm management

The investigations revealed that farmers of the study area related management strategies of pests and diseases to the causal factors, but were more specifically focussed on the factors they could handle at relatively low labour and cash costs. In this respect, the regulation of farm humidity through shade management and weed control appeared to be the central concept of their management strategies (Figure 4.5). Out of 27 statements about the management of cocoa farms, 63% (17) dealt with the regulation of relative humidity in the farm. Terms such as: weeding, light pruning of cocoa and non-cocoa trees, suppression of redundant trees and shrubs, or spacing of cocoa trees were common in farmers' glossary to illustrate the management practices that they operate.

As mentioned earlier (Section 4.3.1.3), farmers knew that weedy and/or excessively shaded farms maintained a high rate of humidity. They usually reduced the weed pressure through frequent clearing of the farm if there was sufficient labour (at least twice a year). To control the shading level in the farm, they usually pruned both cocoa and non-cocoa tree species, especially the introduced fruiting trees. They also sometimes suppressed or introduced indigenous tree species as necessary to create a uniform shade level across the farm.

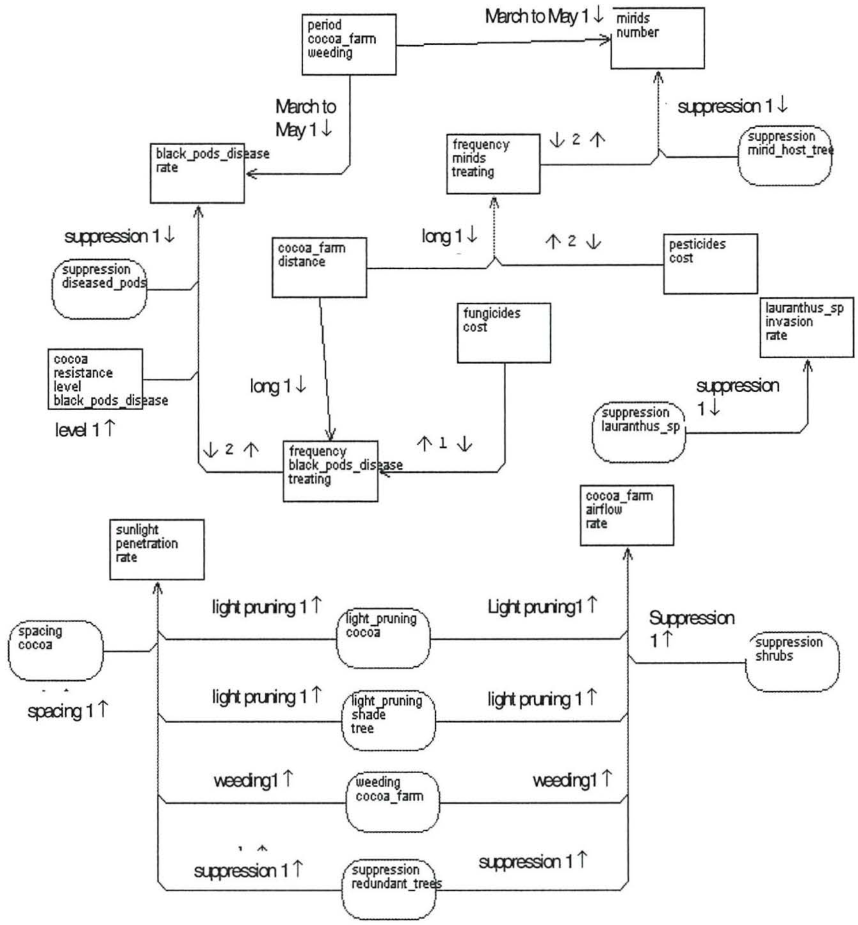

Figure 4.5 Diagrammatic representation of farmers' knowledge of farm management practices to control pests and diseases. Oval nodes represent action. The rest of legend as for Figure 4.1

Farmers considered that excessive pruning of cocoa and non cocoa-trees or excessive suppression of non-cocoa trees could create a lot of open areas in the farm, thus favouring an increase in pest numbers. That is why they preferred the terminology "light pruning" as opposed to "pruning" which according to their understanding, referred to systematic removal of redundant branches and side shoots. They consider "pruning" may not only affect the equilibrium of the system by increasing canopy gaps due to the uneven distribution of non-cocoa trees, but may also reduce the productivity of cocoa trees by reducing potentially productive organs, whereas the concept of "light pruning" calls for more flexibility when selecting cocoa or non-cocoa tree organs to remove. However, farmers mentioned that the appropriateness of these practices could vary according to the age of cocoa trees, the diversity and distribution of non-cocoa trees, and the weather. For example, in areas with abundant rainfall and old cocoa farms, as is the case at the Ebolowa block, more pronounced "light pruning" could be practised without compromising the sustainability of the system, whilst this may be risky in areas with pronounced periods of drought as is the case in the Mbalmayo and Yaoundé blocks.

Cocoa systems of some locations, especially Nkongmesse and Ndikinimeki, were enriched with the introduction of fruit trees such as: Assa (*Dacryodes edulis),* Andogo Ntangani *(Mangifera indica),* Fia *(Persea americana),* and more importantly Afumbi *(Citrus sinensis)* and Mandarin *(Citrus reticulata).* The number of the introduced fruit tree species usually depended on the density of retained species and the mortality of cocoa trees. Because of their height, which is generally short and in some cases their wide and dense crowns, the introduced fruit trees were known to shade and sometimes to suffocate the cocoa trees (especially *Dacryodes edulis* and *Mangifera indica*). This has led to farmers developing a strategy, which consists of a systematic removal of tree branches below the heights occupied by cocoa crowns. This enhances the air circulation of the stand and the amount of solar radiation getting to the understorey layer.

Another strategy to control mirids mentioned by farmers was the removal of suspected mirids host trees in or around cocoa fields. This strategy was however difficult to implement because of the socio-economic or agronomic values of some of those species (see Annexe 3.1). For example, a farmer at Awae location regretted that the suppression of a *Ceiba pentandra* stem, a suspected mirids host, from his cocoa farm resulted in a rapid depreciation of soil conditions around the stem, especially soil moisture, and subsequent depreciation of cocoa trees' health and productivity. Farmers also said that the only means they used to control mistletoe was by suppression; but this was difficult to achieve as the cocoa branches invaded were usually out of their reach. That is why they considered mistletoe as a major threat for their farm tree stock.

4.3.3.2 Use of local plant extracts as agrochemicals

Obtaining manufactured agrochemicals for the control of pests and diseases was a critical issue at farmer level, because they were expensive and not always available when needed. This had led to their inappropriate use and subsequently ineffective control of cocoa pests and diseases. Local solutions to circumvent this at low cost were the development of pesticides and fungicides from local botanical knowledge, which included local plant extracts, used alone or in combination with agrochemicals. Some plant species used to that effect were: essingan *(Guibourtia tessmannii)*, elon *(Erythrophloeum ivorense)*, eyeck *(Pachyelasma tesssmannii)*, popo (*Carica papaya)*, adjab *(Baillonella toxisperma)* and taga (*Nicotiana tabacum)*.

The process consists of extracting and fermenting species' bark, leaves or roots (Table 4.4) for a number of days depending on the concentration needed, but usually for not less than 7 days. About 100 cm^3 of the fermented liquid is added to a one-third or half dose of the manufactured fungicide or pesticide (Table 4.5), depending on their availability, and mixed in 15 l of water. In the absence of manufactured agrochemicals, farmers usually associate the solution of plant extracts with some locally available products such as fuel wood ash or human urine to enhance the adhesiveness and the efficiency of the solution on pods. Farmers reported that one of the main constraints in the use of plant extracts was the scarcity of species used in this regard.

Table 4.4 Use of plant extract to control cocoa pests and diseases.

Scientific name	Part of the plant used	Mode of use	Pests and diseases controlled
Guibourtia tessmannii	bark	mixed with fungicide or pesticide	black pod disease; mirids
Erythrophloeum ivorense	bark	mixed with fungicide or pesticide	black pod disease; mirids
Pachyelasma tessmannii	bark	mixed with fungicide or pesticide	black pod disease
Carica papaya	Leaves; roots	alone	mirids
Baillonella toxisperma	Bark; leaves	alone	black pod disease; mirids
Nicotiana tabacum	leaves	mixed with fungicide or pesticide	mirids

Table 4.5 Pesticides and fungicides usually mixed with solution of plant extracts

Agrochemichal name	Nature	Active ingredient
Ridomil plus	Fungicide	Metalaxyl (12%) Cuprous oxide (60%)
Nordox	Fungicide	Cuprous oxide (75%)
Kocide	Fungicide	Cuprous oxide (50%)
Caocobre	Fungicide	Cuprous oxide (50%)
Dursban 4EC	Insecticide	Chlorpyrifosethyl (240g/l)
DDT	Insecticide	

4.4 DISCUSSION

4.4.1 Pest and disease occurrence

The population dynamics of plant-infecting pathogens, and thus the spread of disease, are influenced by two main factors: by the way the organism is dispersed and by the landscape patterns (Krauss, 2004). Whereas the former is largely intrinsic to the pathogen, the latter can be influenced by agroforestry techniques. Principally, canopy stratification and climatic conditions govern the movement of infectious propagules in the landscape.

Cocoa farmers in Southern Cameroon have a tradition of maintaining non-cocoa trees in their cocoa farms and have developed knowledge about their effects on the cocoa farm agroecosystem. Depending on their densities, spatial arrangement and canopy cover, the non-cocoa trees influence the microenvironmental conditions experienced by cocoa, particularly the humidity, which in turn has a major impact on cocoa pest and disease pressure. Similar knowledge was also developed by farmers in Ghana who reported that the amount of light reaching below the cocoa canopy was considerably reduced under closed canopy of the overstorey species and had effects on the microenvironmental conditions there. The humidity rate was very important and the airflow low, and this had important effects on cocoa pests and diseases, and subsequent effects on cocoa yields (Saunders, 2002). It is well established about plant disease dynamics in agroforestry landscapes (Schroth et al., 2000; Krauss, 2004) that microclimate alterations such as increase humidity and prolonged leaf wetness, usually lead to higher disease incidence at the interface.

Indeed, the most severe problem faced by cocoa farmers in the study area is pests and diseases. Farmers estimated yield loss due to diseases; mainly cocoa black pod disease, at about 80-90% of total production in locations where prevailing climatic and microenvironmental conditions in the farm were favourable to the development and the spreading of the pathogen agent, and adequate means of control were not applied. These figures were fairly consistent with the estimations of scientists, which stand at 50-80% in Cameroon as a whole under similar conditions (Lass, 1987; Nyasse 1997; Bakala and Kone, 1998; Duguma et al., 2001). Yield loss due to black pod disease is estimated at 21% of potential production on a world scale (Mossu, 1990). Of climatic and environmental conditions, rainfall regime, and especially high humidity are factors that mostly favour disease development. Indeed, a microenvironment with high humidity encourages pathogen sporulation and rainfall acts as a disease vector (Blaha, 1983; Ndoumbé, 2002). Such conditions are mostly found in farms where shade level is high as mentioned by farmers earlier in this chapter (Section 4.3.1.3).

Farmers have reported that mirid attacks have a negative impact on cocoa production, and that their pressure was more important in a situation of low shade level or no shade. Scientists do agree that these species are the most important and widely represented insect pests of cocoa in Cameroon (Entwistle, 1987; Bakala and Kone 1998; Duguma 2003). The impact on potential yield is difficult to assess because of the complexity of losses from other related causes such as opportunistic fungal and viral diseases and physiological dieback but most loss estimates range from 15-25% annually (Entwistle, 1987; Bakala and Kone, 1988). However, Padi (personal communication) observed that mirid attacks, if left unattended on a farm for three consecutive years, can reduce yield by as much as 75%. Of the climatic and environmental conditions that favour mirid outbreak in cocoa farms, excessive exposure of cocoa trees to the solar radiation is the most important. Ahenkorah et al (1987) found a shade-insect relationship in a shade and fertiliser trial on Amazon cocoa in Ghana. Three shade regimes were compared. Mirid damage was less severe under shade conditions, moderately severe in areas of broken shade but most severe under the no shade conditions.

4.4.2 Management strategies

4.4.2.1 Shade management

The environmental circumstances leading to outbreaks of cocoa pests and diseases, especially mirids and black pod disease, are almost the same everywhere and solutions to reduce their impact on system productivity and sustainability should be expected to be similar for all the partners. In this regard, Brodt (2001) pointed out that "in the field of plant cultivation, practices and concept that are generally applicable to many different species are more likely to persist in the community than those that are narrowly applicable to only few species. Unless, of course, those species happen to carry special economic or social importance."

Cocoa is a case in point. Both farmers and scientists recognised the positive impact of an appropriate management of shade level in reducing cocoa pest and disease pressure at low cost, whilst providing important biodiversity services. According to Wessel (1987) and Duguma (2003), the role of shade in the management of cocoa agroforests is rather complex as it affects a number of different things at the same time. It reduces light intensity, temperature and air movement, and influences humidity that indirectly affect photosynthesis and pest and disease management. Brenner (1996) remarked that pruning, companion species selection, planting density and arrangement allow the agroforester to increase or reduce crop shading and shelter, which in turn influence the temperature and humidity at farm level. This is in line with what farmers know and try to implement, but are limited in practice by lack of resources.

However, if scientists and farmers do agree on the need of having a properly managed shade, opinions differ on the optimal levels of shade and those trees that are compatible or incompatible with the various shade options. Several scientific reports suggest that a level of shade that allows 25 to 50% of sunlight (i.e. 75% to 50% shade) through to the young cocoa trees for 1 to 5 or 7 years depending on the agroecology of the area where they are grown[19] and 70 to 80% of sunlight (i.e. 30 to 20% shade) when the trees are fully developed will provide an optimum growth and productivity of cocoa (Owusu, 1975; Mossu, 1990; SODECAO, 1982; MINAGRI, 1987, Duguma, 2003).

The implementation of such recommendations presupposes that there is an even distribution of both cocoa and non-cocoa trees in the farm, or that there is a strategy to introduce trees where relevant. This is not always the case for most cocoa farms of the study area, because trees were usually allowed to regenerate spontaneously, with less attention usually given to their spatial arrangement within stands. In this regard, the model of shade management as practised by farmers to regulate the microenvironmental conditions in their farms appears to be effective if well conducted and adapted to their circumstances.

The Cocoa and Coffee Seedlings Project (CCSP), in a joint program with ONADEF (1987), came out with a list of eight shade tree species to be intercropped with cocoa at a density of 83 ha^{-1}. The selection criteria of these species were similar to those described by farmers and included: species height, crown shape and density, and less belowground competition. These species were: *Ficus mucuso, Antrocaryon klaineanum, Terminalia superba,*

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[19] In the south-west basin where both soils and climatic conditions are excellent for cocoa development, trees reach the mature stage four to five years after planting. In Southern Cameroon where soils and climatic conditions are marginal to good, the maturity stage of cocoa trees is reached seven years after planting at the earliest.

Pycnanthus angolensis, Albizia glaberrina, Alstonia congensis, Spathodea campanulata, and *Canarium schweinfurthii.* In this regard, farmers have described the shade value of 65 tree species (Annex 4.1), and this could contribute to increase the possibilities of selection.

4.4.2.2 Trees as pest hosts

Many authors (Mossu, 1990; SODECAO, 1982; CCSP, 1987; Padi, 2003) have reported that some trees can serve as alternative hosts for cocoa pests, especially mirids. Species of the family of cocoa such as *Cola spp.* are often cited to that effect, alongside other species such as *Ceiba pentandra* or *Triplochiton scleroxylon.* Recent studies in Ghana (Saunders 2002) have documented cocoa farmers' awareness of the existence of trees such as *Cola spp., Triplochiton scleroxylon, Ficus exasperata, Glyphaea brevis* or *Carapa procera* that often served as hosts for cocoa pests. The presence of such trees within or in the proximity of cocoa farms has, as a major effect, a rapid increase in mirid numbers during their pullulating phase. Farmers are usually advised to remove such trees from or around their farms, as an integrated pest management strategy to control the incidence of pests, and replace them with species of socio-economic interest.

Farmers in southern Cameroon were fully aware of the pertinence of this strategy (Figure 4.3), but were often constrained by lack of adequate means for its implementation. Some species such as *Ceiba pentandra* or *Triplochiton scleroxylon* are too large and removing them requires equipment like chain saws that farmers do not usually have. Moreover, when they succeed in removing them, they lack seedlings of species of interest to replant vacant spaces, and thus they were confined to use fruiting trees in replacement. Meanwhile, they have expressed their interest in species such as *Terminalia superba, Ricinodendron heudelotii, Pygnanthus angolensis, Coula edulis,* *Milicia excelsa* or *Baillonella toxisperma*. This points to a need to support farmers with seedlings of trees of interest, or to train them in domestication procedures of such species.

4.4.2.3 Local agrochemicals

Farmers exhibited considerable knowledge and skills in fabricating agrochemicals with local plant extracts in a perspective of gradual replacement of the expensive manufactured agrochemicals. The strategy has developed since SODECAO discontinued its assistance services towards cocoa growers some twenty years ago, abandoning farmers who were used to the gratuity of those services.

To date, these concoctions have not been subject to a scientific evaluation to assess their efficacy and effects on both human beings and environment. Meanwhile, similar strategies have been applied in South Africa in relation to plant protection, using extracts of *Guibourtia tessmannii* (Nyemba et al., 1995) or *Warburgia salutaris* (pepper-bark tree) (Drewes et al., 2001). Further laboratory analysis revealed the presence of anti-fungal phytochemicals in roots, bark or leaves of those species. Recent investigations carried out in southern Cameroon on the use of plant extracts to control pests and diseases on cocoa (Coulibaly et al., 2002; Sonwa et al., 2002) mentioned farmers' awareness of possible harmful effects on human health.

Therefore, it is important that farmers' initiatives in southern Cameroon be supported with an effective implication of Government, Research Institutions, and Non Governmental Organisations, as this may allow an environmentally more sensitive exploration of local resources. It is feared that an excessive or uncontrolled exploitation of the limited resources of local plant species involved in the production of such agrochemicals may endanger biodiversity, especially when the part extracted is vital to the plant. The species involved are not usually common, especially in degraded landscapes as is the case in Nkongmesse and Awae locations (Zapfack, personal communication) where their use is gaining ground and local communities critically lack knowledge about their domestication. Support actions may include among others, i) the in situ conservation of the identified species, ii) their domestication at a larger scale, and iii) more laboratory research work to find out more about the active ingredient for a sustainable usage.

There is also a need to regulate the exploration and use of specific aspects of local knowledge by setting mechanisms to protect local intellectual property rights over knowledge about activity and genetic material. This would enhance farmers' determination to put their local botanical knowledge to good use and encourage them to collaborate more with scientists.

4.4.2.4 Reliable cocoa cultivars

The issue of producing reliable cocoa cultivars in terms of productivity, resistance to the various cocoa pests and diseases and adaptability to local ecologies is also a valuable part of integrated pest management strategies and needs to be paid due attention. It is anticipated that such planting material could contribute to considerably slow down the propagation of endemic cocoa pests and diseases, thus reducing the reliance of farmers on expensive manufactured agrochemicals and increasing the productivity of cocoa trees. The issue has been of a major concern in Cameroon for the past decades. Breeding programs were launched at the then Agronomic Research Institute (ARI) of Cameroon in the early seventies (Mossu, 1990). Nowadays, more research programs at the Institute of Agricultural Research for Development (IARD), co-sponsored by CIRAD, CFC and STCP, having as an objective the creation of cocoa cultivars resistant to pests and diseases, and adapted to local environmental conditions are ongoing. It is expected that the findings would reduce the pressure of cocoa pests and diseases.

4.5 CONCLUSION

The present investigations have revealed that cocoa farmers in Southern Cameroon have developed a substantial body of understanding of cocoa pest and disease occurrence in their cocoa systems and management strategies to deal with these over time. Their management strategies were centred on the regulation of the rate of air humidity in farms via the management of shade, which is a critical issue to address at farm level when considering their complexity. These strategies appeared to be ecologically sound, cost effective and adapted to farmers' circumstances.

It is important to note that scientists do not challenge the farmers' approach to pest and disease occurrence and their management. This is probably because the farmers' approach comes as a result of long-term observations accumulated over many years and the "trial and error" test, which is generally experienced by local communities to transform their observations and, "useful" and "no longer useful" practices into knowledge. However, the plant extracts used as local agrochemicals need to be evaluated. Besides the fact that their effectiveness as cocoa pest and disease management agents has not yet been assessed, their possible side effects on human health are also a subject of concern. Moreover, the increasing use of plant extracts as observed in some locations may inevitably lead to a higher rate of extraction of plant organs, thus threatening species' survival in the long run. This points to a need to build a strong partnership among scientists, farmers, Non Governmental Organisations and decision makers to explore and value this technology and incorporate it in global integrated pest management strategies.

CHAPTER 5

LOCAL KNOWLEDGE ABOUT SOILS AND SOIL-TREE INTERACTIONS

ABSTRACT

Farmers' local knowledge about soils and soil-tree interrelationships, and the implications of this for selection of land for growing cocoa, were investigated in four locations in southern Cameroon: Akok, Awae, Nkongmesse and Ndikinimeki.

The findings revealed that farmers distinguished soils on the basis of their colour, texture, drainage, depth, and position in the landscape. Based on these characteristics, ten classes of soils were identified and their effects on growth of cocoa trees described. Farmers also described how trees affect soil conditions, with particular emphasis on attributes of some native species used as shade trees for cocoa. Farmers combined their knowledge of soil characteristics with attributes of the vegetation present to determine suitable farmland to grow cocoa. It is anticipated that understanding of farmers' systems of soil classification and land evaluation could lead to more effective communication between research scientists and farmers and so more practically relevant and cost effective interventions to improve productivity and sustainability of cocoa production.

5.1 INTRODUCTION

The problems faced by small-scale cocoa farmers in southern Cameroon in identifying suitable farmland to establish new cocoa farms or to maintain the productivity of existing farms are many. Concerns have come from the realisation that cocoa productivity has been decreasing, partly because of the establishment of cocoa on marginal farmland and the depletion of soil fertility in existing cocoa plantations. Low and declining soil fertility are recognised by many tropical farmers as major constraints to agricultural production (Smaling et al., 1997, Schroth and Sinclair, 2003). This situation is aggravated in the context of the complex multistrata cocoa systems of southern Cameroon, because they harbour numerous plant components that have differing ecological requirements. It can be anticipated that increased pressure on land as a result of rapid population growth combined with unsustainable management of available soil resources, as is the case in the study locations, may further aggravate this situation. In this respect, farmers were aware of the necessity for a judicious allocation of available farmland to specific crops according to their ecological requirements as a means to sustain the use of soil resources. One of the main constraints in identifying suitable farmland to grow cocoa at small-scale farmer level is that unlike large estate owners, they do not have access to professional means to assess the suitability of farmland.

However, because cocoa has long been regarded as the main source of household income of local communities in the study area (Duguma et al., 2001; Ruf and Schroth, 2004), farmers have endeavoured to identify the most suitable farmland available and allocated this to cocoa cultivation in the hope of maintaining productivity at a reasonable level with as few inputs as possible for as long as possible. In this regard, they have developed local methods for identification of the most suitable farmland. These methods involve consideration of two components, the soil and the vegetation growing in it, with specific attention to some native trees that are used as indicator species. These two components are either used separately or in combination.

- The soil component because farmers have developed a strong understanding of the links between the type of soil and its ability to grow different crops.

- Indigenous plant species, because farmers hold that there are strong relationships between the type of tree species present on a land and its soil conditions.

The working hypothesis is that the locally developed methods used by farmers for assessing soil ability to serve as a substrate for growing cocoa have a coherent rationale, which needs to be understood for there to be effective communication between research and extension staff and farmers, and for opportunities for improvement to be identified. Farmers have been using these methods for a long time and are still using them nowadays to allocate limited farmland to specific uses. The specific objectives of the study were therefore to:

1. acquire farmers' knowledge about their soil classification systems and response of cocoa growth to soil classes,
2. acquire farmers' knowledge about the relationships between soils and trees, and,
3. explore the relevance of the implications of that knowledge for selection of farmland suitable for the establishment of cocoa.

5.2 MATERIAL AND METHODS

5.2.1 The study area

The biophysical context of the study area, including topography and soils, was discussed in Chapter 2 (Section 2.2.3).

5.2.2 Methods

The methodological approach used to acquire farmers' knowledge was the same as described in Chapter 3 (Section 3.2) except for the checklist prompts.

The complexity of soil resources management in farming systems in southern Cameroon in general, and in the multistrata cocoa systems context in particular, required specific checklist prompts (Table 5.1) to have an in-depth exploration of farmers' systems of soil classification and their local methods of assessing soil resource availability. The checklist prompts were established on the basis of information gathered during the scoping phase, during which farmers gave an overview of some methods they use for these assessments. Information on soils contained in the knowledge base was accessed via the Boolean search facility (Section 3.2.4) that enabled the creation of topics to that effect.

Table 5.1 Checklist prompts for semi-structured interviews about soils and soil-tree interactions.

Research topic	Checklist prompts
Soils	List of soil types Effects of each soil type on cocoa growth, productivity and durability of trees List of soil conditions Factors affecting soil conditions Effects of soil conditions on cocoa growth, productivity and durability of the trees
Soil-tree interactions	Contribution of tree species to their knowledge about soil types and soil conditions Tree species attributes involved Soil characteristics affected by tree species Soil attributes affecting tree species in any way

5.2.2.1 Validation

The validation procedure was the same as used for farmers' knowledge about cocoa pests and diseases in Chapter 4 (Section 4.2.2.1).

5.3 RESULTS

5.3.1 Local knowledge about soil

Statements directly related to farmers' knowledge about soils represented 22% (52 statements out of 239) of the statements provided by different informants. Farmers in southern Cameroon generally classified soil according to colour, depth, texture and position in the landscape (Table 5.2).

Table 5.2 Mean percentages of farmers mentioning effects of soil attributes on cocoa growth.

Soil attributes and cocoa growth	Akok n = 60	Awae n =60	Nkongmesse n = 60	Ndikinimeki n = 60	Totoal n = 240
red soil	47 (78%)	57 (95%)	59 (98%)	60 (100%)	229 (95%)
yellow soil	57 (95%)	46 (76%)	25 ((41%)	15 (25%)	143 (60%)
black soil	57 (95%)	59 (98%)	58 (96%)	55 (92%)	229 (95%)
sandy soil	56 (93%)	54 (90%)	55 (92%)	45 (75%)	210 (87%)
gravel soil	55 (92%)	50 (83%)	58 (96%)	60 (100%)	223 (93%)
swampy land	55 (92%)	50 (83%)	58 (96%)	20 (33%)	183 (76%)
Valley soil	55 (92%)	60 (100%)	60 (100%)	60 (100%)	235 (98%)
steeply sloping land	55 (92%)	50 (83%)	53 (88%)	57 (95%)	115 (48%)
deep soil	55 (92%)	55 (92%)	60 (100%)	60 (100%)	230 (95%)
shallow soil	55 (92%)	60 (100%)	60 (100%)	60 (100%)	235 (97%)
Soil conditions and cocoa growth					
soil erosion v soil fertility	45 (75%)	48 (80%)	55 (92%)	58 (96%)	206 (86%)
soil fertility	60 (100%)	60 (100%)	60 (100%)	60 (100%)	240 (100%)
soil moisture	60 (100%)	60 (100%)	60 (100%)	60 (100%)	240 (100%)
soil organic matter	60 (100%)	60 (100%)	60 (100%)	60 (100%)	240 (100%)
Soil clay content	50 (83%)	45 (75%)	45 (75%)	43 (71%)	183 (76%)
Soil gravel content	45 (75%)	45 (75%)	55 (92%)	60 (100%)	205 (85%)

These soil attributes, farmers said, affected the fertility of soil and/or suitability of land for various farming activities, particularly cocoa cultivation (Figure 5.1). Farmers referred to soil fertility using different terminology based on how crops perform on a given piece of land or the presence of biological indicators on the site (Table 5.3), but their perception of fertility was consistent with the practical scientific definition that fertility is "the ability of soil to serve as a suitable substrate on which plants can grow and develop" (Schroth and Sinclair 2003).

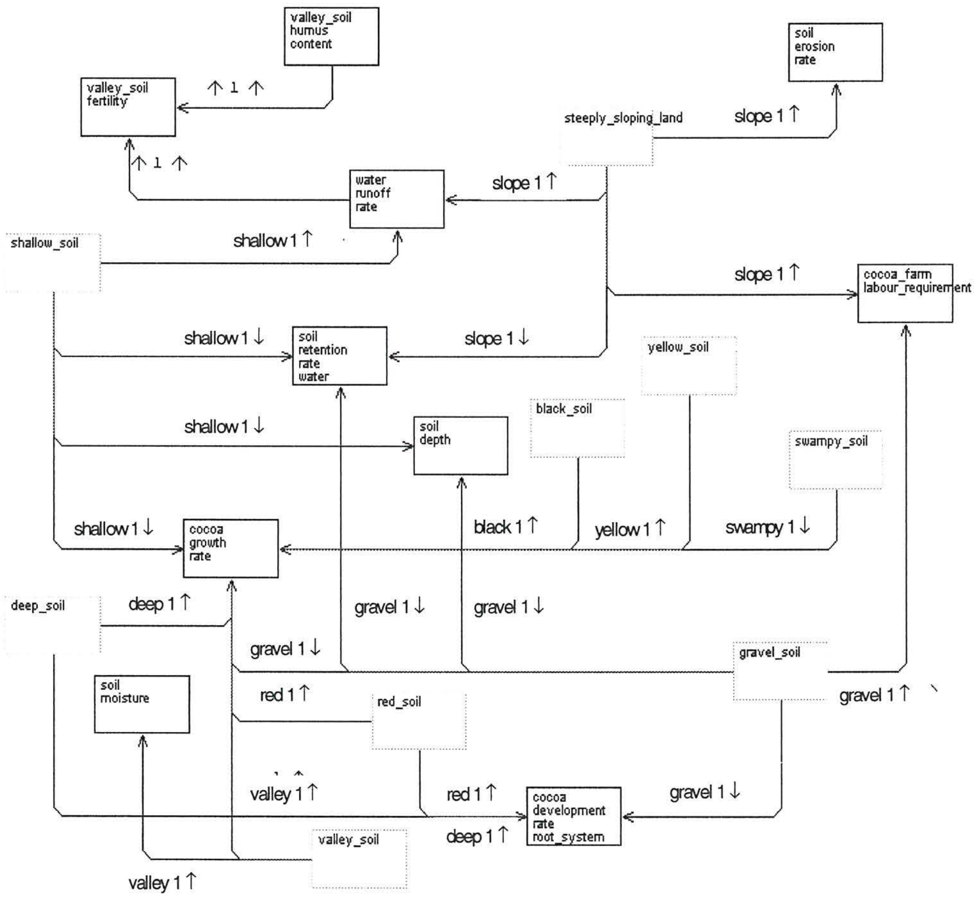


Figure 5.1 Diagrammatic representation of farmers' causal knowledge about the effect of soil type on cocoa growth in southern Cameroon. Nodes represent attributes of components or the system. Arrows indicate the causal node from which the arrow emanates has an influence on the "effect" node to which

arrow points, or indicate an increase or a decrease. "1" or "2" beside the link indicates whether the link is a "causes1way" or "causes2way". "↑" indicates an increase of the value and "↓" indicates a decrease of the value. Information about the nature of the relationship is also held within the knowledge base.

Each of the key soil attributes and their impacts on land suitability are explained in sections 5.3.1.1 to 5.3.1.4.

Table 5.3 Terminology used by farmers in southern Cameroon to describe soil fertility

Local term	Literal meaning	Fertility status
Si avonn	"Soil that has fat"	Fertile soil
Eboubout si	"Soft" or "Cool-soil"	Fertile soil
Allet si	"Hard-soil"	Unfertile soil
Si ekodogo	"Fallow soil"	Fertile soil
Si bidi	"Soil for crops"	Fertile soil
Si apan	"Bush-soil"	Fertile soil
Bidi bi si	" Food from soil"	Nutrients status

5.3.1.1 Soil colour

Farmers' classification of soils according to their colours pertained to three major colour groups, which were yellow, red and dark.

Yellow soils

Yellow soils were mostly identified by farmers of Akok in the southernmost part of the study area. They were rather rare in the rest of the study area, and even when indicated by farmers, the distinction in colour was not pronounced to an external observer. Cocoa tree growth and productivity of these soils varied a great deal from one site to another. Farmers observed that where their clay content was high, growth and productivity of cocoa trees were poor. They attributed this to changes in some characteristics of these soils such as increase in compaction, which was amplified by the movement of people in the farm, especially during periods of intense activity (spraying against pests and diseases or harvesting). As a consequence, the water infiltration and the development of cocoa root systems were reduced. In contrast, in situations where the clay content of the soil was lower, cocoa growth was normal.

Red soil

Red soils were mostly identified by farmers of Awae, Nkongmesse and Ndikinimeki locations in the central and northernmost parts of the study area. The characteristics and the response of cocoa growth and productivity to these soils were similar to those of yellow soils. However, where both red and yellow soils were common, as was the case in the southernmost part of Awae location, farmers observed that cocoa growth was generally better on yellow soils than on red soils.

Black soils

Black soils were represented in the four study locations. They were mostly found under forest cover or long fallows with no systematically defined boundary in the landscape. Their proportion grew steadily from the northernmost part of the study area (Ndikinimeki) to the southernmost part (Akok). There was a common recognition among farmers that cocoa growth and productivity were high in black soils, provided the soil depth (absence of concrete layer) was sufficient to enable the vertical development of cocoa roots. This was because the clay content of black soils was said to be low, and water infiltration, as well as soil water holding capacity were high. Farmers also associated the black colour of soil with its organic matter content.

5.3.1.2 Soil depth

Farmers' classification of soils according to depth simply refers to soils that are either shallow or deep.

Shallow soils

Farmers described shallow soils as soils having laterite concretions or any other form of continuous natural barrier close to the upper layers of their profile. Such soils were classified as unsuitable for cocoa growth because they did not allow the vertical development of cocoa tree roots. Farmers reported that when roots get to banes, their growth is considerably slowed or even stopped, depending on the consistency of the concretion, thus limiting their access to potential resources that were located below that level. Cases of acute water deficiency were reported in the layers above the concretion during periods of drought. Farmers could not clearly indicate the depth at which the presence of concretions was critical for the growth of cocoa. However, they mentioned that young cocoa trees of three to four years could successfully develop in soils with concretions within fifty to eighty centimetres of the surface, while this would not likely happen with older cocoa trees.

Deep soils

Farmers described deep soils as soils presenting no physical barrier that could obstruct the vertical development of plant roots. Farmers reported that everything else being equal, cocoa tree development and productivity were better under deeper rather than shallower soil conditions. This was because the volume of soil that could be explored by cocoa tree roots to capture the resources needed for their development was larger. Deep soils were also cited as having a better water holding capacity than shallow soils, and because of this, they could serve as habitat to the wide range of plant species that develop in multistrata cocoa systems.

5.3.1.3 Soil texture and drainage

Farmers' knowledge about soil texture and drainage across the four study locations was most related to suitability to grow a wide range of crops as well as workability. However, farmers articulated details about unsuitable soil texture for agricultural practices in general rather than in relation to specific crops. Three classes of soils based on their texture, together with their effects on cocoa growth and productivity, were identified across the four locations, they were: gravel, sandy soils and poorly drained soils.

Farmers used two methods to assess soil texture; these involved visual and tactile methods. The visual method was used when the size of the soil particles or aggregates were large enough to be identified by the naked eye, as was the case with gravel soil; meanwhile the method by touch was used when the size of the particles or aggregates were too small to be easily perceptible. In this case, farmers pressed or rubbed soil between two fingers and depending on its roughness, its consistency or its adhesiveness, they could determine whether it belonged to a sandy or clayey soil class.

Gravel soils

Gravel soils were found in the four study locations, but their presence was more pronounced in Nkongmesse and Ndikinimeki. Farmers reported that these soils were very susceptible to drought because the cohesion between individual soil particles was loose and water infiltrated and percolated very rapidly after the rain. Gravels were also identified as obstacles to cocoa tree root development, thus reducing their capacity to explore the soil solution for the uptake of water and nutrients. Consequently, cocoa growth was reported to be critically low under such circumstances. This usually occurred when the gravel formed concretions around the surface soil layers. Weeding of understorey vegetation of a cocoa farm on gravel soil was also reported to be labour demanding and farmers could easily risk injuring themselves. Indeed, cases of injuries were usually recorded as a consequence of bounce of cutlasses off gravels.

However, farmers mentioned that the presence of gravel alone was not enough to classify a soil as marginal for cocoa development, but rather it depended on the particle size and quantity. Moreover, in situations where the clay content of the soil was high, farmers reported that a reasonable amount of gravel of small size was necessary in the soil profile to improve the soil physical properties.

Sandy soils

Sandy soils were usually found along river banks or ancient river terraces and were most common in Akok, Awae and Nkongmesse. In contrast, they were almost absent in Ndikinimeki. Farmers reported that these soils had a low water holding capacity because of the large size of their particles and the absence of clay to join particles together. Water infiltrates and percolates rapidly after rainfall and soil surface layers usually remain dry for most of the year, especially during periods of drought. Many cases of cocoa tree dieback were reported as a result of soil water deficits when the cocoa root system had reached sandy soil. Sandy soils were, therefore, classified as inappropriate for the cultivation of cocoa because of their extremely poor physical properties.

Poorly drained soils

Likely sandy soils, poorly drained soils were reported to be mostly found along river banks, ancient river terraces and inland valleys and were common to the four study locations. Farmers distinguished two types of poorly drained soils: soils under permanent flooding and soils with periodic flooding.

Farmers reported that in the case of soils with permanent flooding, the development of cocoa roots and growth was inhibited because of the absence of aeration. The exploration of soil solution to capture soil resources was therefore restricted, leading to slow growth and low productivity of trees. Farmers also mentioned that root diseases, especially fungal diseases, were favoured by such environments, and tree dieback was frequently recorded.

In contrast, farmers' perceptions of the effects of periodically flooded soils on cocoa growth and productivity were different. In Ndikinimeki, cocoa farms were mostly established along river banks, which were usually periodically flooded especially during the rainy season. Tree growth and productivity were not negatively affected in that case. They rather exhibited good performance when the farm was well managed. In contrast, at Akok, Awae and Nkongmesse, such soils were said to be heavy and permanently congested with water during the rainy season, and extremely dry during periods of drought. In both cases, cocoa tree growth was critically compromised.

5.3.1.4 Position in the landscape

The position of soils in the landscape was one of the criteria commonly used by farmers in southern Cameroon to allocate farmland to various farming activities. This was probably because the landscape of the study area was hilly and it was rare to come across homogeneous surfaces except in valleys. This may be the reason why farmers' classification of soils according to their position in the landscape usually pertained to two positions, which were soils on steeply sloping lands and valley soils.

Soil on steeply sloping land

Cocoa farms on steeply sloping lands were found across the four locations of the study area, but more commonly in Ndikinimeki. Soils on steeply sloping land were reported to sustain high runoff during the rainy season despite the presence of cocoa and other tree species on the slopes. As a consequence, fertile topsoils were usually removed during this process and carried down to the valleys or to the rivers as a result of soil erosion. Both the fertility and the structure of such soils were negatively affected. Working on sloping lands was also reported to be difficult and risky, especially during the harvesting and the processing phases. Farmers in the four locations unanimously classified steeply sloping land as marginal for cocoa growth. However, in situations where farmland scarcity was acute, they would establish cocoa farms on such soils, as was the case at Ndikinimeki.

Valley soils

Similar to black soils, valley soils were unanimously classified by farmers as appropriate for the growth and productivity of cocoa. Due to their position in the landscape, they were considered to be the reservoir for the majority of organic and inorganic soil components removed from the upper parts of the landscape as a result of water runoff and soil erosion. Moreover, farmers unanimously recognised that there was no risk of massive export of some soil components due to runoff as was the case for steeply sloping lands. The risks of leaching were reduced as well, because the infiltration of water was not pronounced and the majority of soil particles were kept in the upper layers of the soil. Their texture was described as balanced, thus favouring exploration of the soil solution by cocoa roots for the uptake of water and nutrients.

Summary of farmers' classification of soils in their area and effects on cocoa growth and productivity is presented in Table 5.4.

Table 5.4 Local soil attributes and their effects on cocoa growth

Soil attribute	Local terms	Explanatory comments	Effects on cocoa growth
Colour	Si Avie	Red soils	Cocoa grows well if the clay content is low and concrete layer beyond 1m in depth.
	Si Avin	Black soils	Cocoa grows well provided soil depth is adequate.
	Si Essouk	Yellow soils	Cocoa grows well if the clay content is low and concrete layer beyond 1m in depth.
Depth	Si Edip	Deep soils	Cocoa grows well if the clay content is low
	Si Bikogo	Shallow soils/laterite	Drought susceptible, low water holding capacity, low root development and poor tree growth.
Texture and drainage	Si Ngok	Gravel soils	Drought susceptible, low root development and poor growth, high labour requirement.
	Si Ntchelegui	Sandy soils	Low water holding capacity, drought susceptible and dieback may occur.
	Si Elobi	Poorly drained soils	Wet soils that inhibit cocoa root development and growth, favour root diseases.
Position in landscape	Si Nkol	Soil on steep slopes	Soil erosion, low fertility value, high labour requirement.
	Si Edok	Valley soils	Cocoa grows well.

5.3.2 Relationships between soil and trees

In total, farmers in the study locations provided 24 statements (10% of the statements of the knowledge base) related to interactions between soil and tree species, with further statements about other living organisms that interact with soil. With respect to tree species, farmers unambiguously mentioned that, in addition to the fact that they gave indications about soil characteristics, such as depth or texture, they could also improve soil conditions, through nutrient cycling locally referred to as "food from soil", soil water management or soil structure (Table 5.5). The attributes of tree species involved in these processes included root system habit, and quantity of leaf litter produced and its decomposition rate (See Annex 5.1).

Table 5.5 Mean percentages of farmers mentioning effects of some tree attributes on soils.

Tree attributes v soil attributes	Akok n = 60	Awae n = 60	Nkongmesse n = 60	Ndikinimeki n = 60	Total n = 240
Deep rooting v soil moisture	50 (83%)	55 (92%)	57 (95%)	45 (75%)	207 (86%)
Shallow rooting v soil moisture	45 (75%)	55 (92%)	55 (92%)	45 (75%)	200 (83%)
Deep rooting v soil fertility	45 (75%)	50 (83%)	55 (92%)	40 (66%)	190 (79%)
Shallow rooting v soil fertility	50 (83%)	55 (92%)	57 (95%)	40 (66%)	202 (84%)
Leaf litter v soil organic matter	55 (92%)	57 (95%)	58 (96%)	45 (75%)	215 (89%)

Other living organisms such as earthworms and termites have been mentioned as indicators of soil fertility status. Farmers said that earthworm activities had a positive effect on the restoration of soil fertility through speeding up the decomposition of leaf litter, which is a component of their feeding, and on soil texture through disintegration of soil particles. In contrast, farmers said that termite activities had a negative effect on soil conditions in general because of the galleries they create below ground, thus reducing the volume of soil that could be explored by crops, and their activities were associated with deficit in soil moisture.

5.3.2.1 Effects of roots on soil conditions

From a conventional scientific standpoint, the main functions of plant roots are to support plants in the soil and to capture water and nutrients from the soil and make them available to plants to perform various functions (Noordwijk, 1996; Schroth et al., 2003; Schroth and Lehmann, 2003; Akinnifesi et al., 2004). Farmers gave less importance to the function of plant support, possibly because this did not pose a constraint to cocoa productivity in their context. They were more interested in the effects of root distribution on the uptake of soil water and nutrients, especially in locations where these resources were limiting.

Cocoa, as mentioned in previous chapters, is grown in association with other tree species. This tree-tree association inevitably includes important belowground interactions because species may have similar or different rooting habit and ecological requirements, thus leading to competition or complementarity. Farmers in southern Cameroon were fully aware of those processes and sometimes their management decisions were based upon them. They identified two classes of tree root systems and stated their effects on soil conditions and subsequently on cocoa growth; these were shallow rooting habit and deep rooting habit (Figure 5.2).

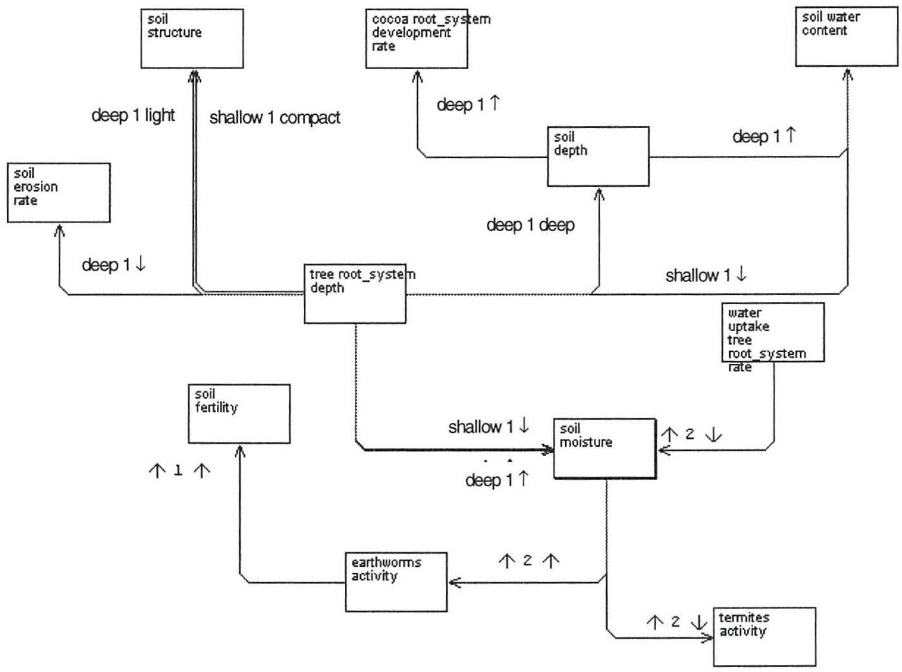


Figure 5. 2 Diagrammatic representation of farmers' knowledge about effects of root systems on soil conditions. Legend as for Figure 5.1.

5.3.2.1.1 Trees with shallow root systems

There was a common recognition among farmers in the study locations that non-cocoa tree species having shallow root systems generally had negative effects on soil structure and were highly competitive with other species for soil water and nutrients. This was because the zones mostly explored by these species were the surface layers of the soil. These soil layers were considered by farmers to contain the essential soil nutrients and as being more exposed to water stress during part of the year, especially during periods of drought. The presence of such species was, therefore, considered to compromise the access of cocoa trees to soil resources in these strategic soil layers due to severe competition. Farmers were aware of the fact that cocoa could not efficiently compete with these naturally regenerating species because they lived in their natural environment, whilst cocoa, that was an introduced species, needed to be placed in a situation of less or no competition to develop adequately.

Cases of degradation of soil structure, especially of the surface layers under trees with shallow rooting habit, have been also reported. Farmers have observed that the excessive uptake of water from the surface layers because of the presence of species with shallow rooting habit has led these soil layers to become more compact and harder as a result of water stress, thus compromising the development of cocoa roots. The cases of Sayeme (*Albizia adianthifolia*), Essak (*Albizia glaberrima*), Eyem (*Albizia zygia*) and Zolebi (*Beilschmiedia obscura*) were usually cited in this regard. Farmers also said that tree species with shallow rooting habits usually grew on marginal soils such as gravel or shallow soils, usually with low fertility, and so were indicators that land was not very suitable for cocoa.

For these reasons, in areas with abundant land resources, sites with such species were allocated to non-agricultural activities, whereas in areas with limited land resources where marginal soils were sometimes used to grow cocoa, these species were removed ahead of the establishment of cocoa, and were usually replaced by fruit trees or banana and plantain. However, contrary to these observations, some tree species with shallow rooting habit were pointed out by farmers as having beneficial effects on both soil moisture and soil nutrient budgets, thus indicating suitable sites for agricultural activities in general and cocoa growth in particular. Doum (*Ceiba pentandra*) or Asseng (*Musanga cecropioides*) are cases in point. Both species have shallow rooting habit, however, farmers reported that these species' roots usually "oozed out" water that moistened surrounding soils. The soil organic matter content at their surroundings was also reported to be relatively high, as a result of the important quantity of biomass they produce and its high rate of decomposition.

5.3.2.1.2 Trees with deep root systems

Unlike species with shallow rooting habit, farmers developed a great interest in species with deep rooting habits because they were said to improve soil conditions and had limited risk of direct competition with cocoa. They unanimously recognised that the association of cocoa with deep-rooted non-cocoa tree species was beneficial to cocoa in many respects, including soil water management, soil structure and nutrient cycling.

Deep-rooting trees were said to regulate the level of soil moisture around their stand. Farmers strongly believed that their roots were capable of pumping water from deeper layers of the soil to the surface layers. This was particularly notable during periods of drought. Farmers observed that in spots with deep-rooted trees, the level of soil moisture was usually high as compared to spots with shallow-rooted trees. Cases of cocoa tree water stress, which they could appraise by the change in cocoa foliage colour from green to yellowish, were not common around deep-rooted trees.

Farmers also mentioned that as a result of the relatively high level of soil moisture around deep-rooted species, the soil aggregates were less compact, making the structure permanently "light" and more friable even during periods of drought, thus maintaining root system activities at a reasonable level. The infiltration of rainwater was said to be improved in sites that had deep-rooted tree species, thus making rainwater available to the deeper soil layers. Another beneficial effect of deep-rooted tree species on soil, as reported by farmers, was a reduction in the rate of erosion on slopes.

However, farmers mentioned that the development of the root system of deep-rooting trees was compromised by shallow soil, especially when roots reach mechanical soil restrictions such as concrete layers, or by insufficient soil resources. Under such conditions, the tree could not develop properly. That is the major reason why farmers strongly linked the distribution of indigenous tree species via their rooting habit to the soil depth in the landscape. However, they recognised that shallow rooting trees also developed well on deep soils.

5.3.2.2 Effects of leaf litter on soil conditions

Farmers used the organic matter content of the soil among other indicators to evaluate its fertility status. The amount of organic matter was visually estimated by the colour of the soil of the surface layers that ranged from dark brown for soil with moderately high amounts of organic matter to black for soil with a high amount of organic matter. The main source of organic matter was identified to be tree leaf litter via its decomposition process, and the amount of organic matter was related to the amount of leaf litter produced.

The amount of undecomposed leaf litter through its mulching effect on soil was unanimously recognised to be an important factor affecting soil erosion because it considerably reduced the impact of rainfall drops on the soil, thus reducing the alteration of the surface layers. Cases of total absence of direct contact of rainfall with soil were reported where the amount of leaf litter was sufficient to cover completely the soil surface as often happened in cocoa systems (Figure 5.3). Farmers recognised that such situations were also detrimental to soil water content because the amount of infiltrated water was considerably reduced. On sloping surfaces, leaf litter was known to considerably reduce the velocity of runoff, thus reducing soil erosion rate.

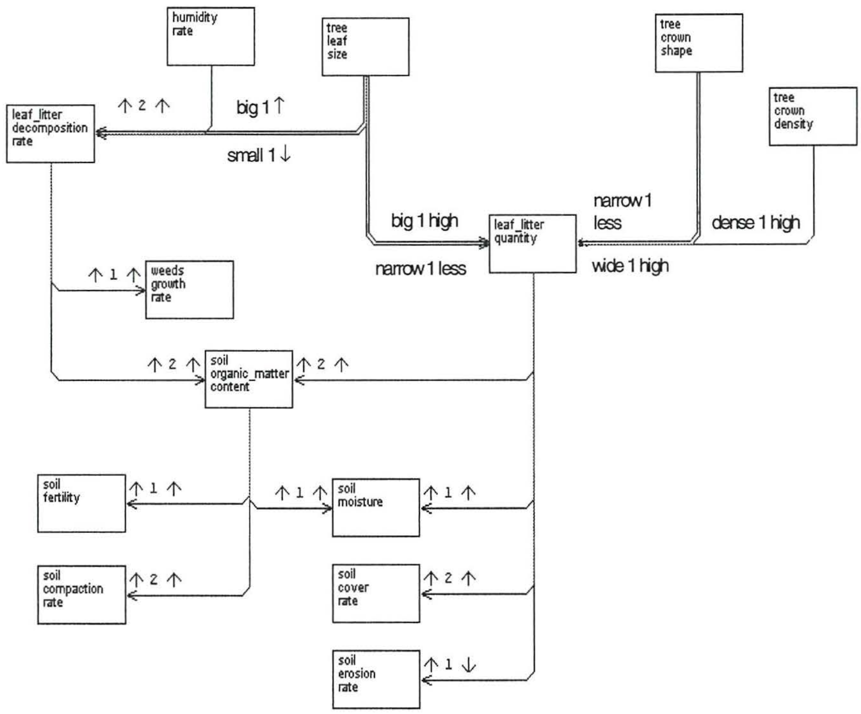


Figure 5.3 Diagrammatic representation of farmers' knowledge about leaf litter and effects on soil. Legend as for Figure 5.1

5.3.2.2.1 Factors affecting the amount of leaf litter

The amount of leaf litter produced was reported to depend mainly on three factors, namely tree density, leaf size and crown density.

Tree density

Plant species density was indicative of the amount of leaf litter produced in the sense that the higher the density, the greater amount of leaf litter produced.

Given the fact that the densities of various species were not homogeneous in farms, the amount of leaf litter produced also was not homogeneous. This was more perceptible around the strongly degraded secondary forests of the central part and the forest-savanna transition zone of the northern part of the study area.

Leaf size

Leaf size was thought by farmers to affect the amount of leaf litter, and especially its capacity to cover the soil surface. The larger the leaf size, the more abundant was the leaf litter produced. For this reason, sites harbouring tree species with large leaf size were usually pointed out as suitable for a wide range of crops, including cocoa. In contrast, sites harbouring species with small leaf size were considered marginal for sustainable agriculture.

Crown shape density

Another criterion used by farmers for the estimation of the potential amount of leaf litter that could be produced by a tree was the tree crown shape. The wider and thicker that a tree crown was, the higher the amount of leaf litter expected.

5.3.2.2.2 Factors affecting the rate of leaf litter decomposition

Farmers identified two main factors that affected the rate of decomposition of leaf litter and these were the microenvironmental conditions in the farm and leaf consistency.

Microenvironmental conditions in the farm

Environmental conditions in the farm were thought to play an important role in the process of leaf litter decomposition. Farmers observed that the rate of decomposition was higher where the prevailing humidity was permanently high, and little solar radiation reached the soil surface. They also remarked that there was an active interaction between soil moisture and leaf litter decomposition rate. The higher the soil moisture was, the higher the rate of leaf litter decomposition. They believed that there were microorganisms living in the soil that were responsible for the process and that these microorganisms could perform only under moist soil conditions. To substantiate their assertions, they pointed out that little or no leaf litter decomposition occurred under some environmental circumstances such as: prolonged periods of drought, on steeply sloping lands, in gravel soils and soil with laterite concretions around the surface layers.

Leaf consistency

Though not directly perceptible, farmers recognised that leaf consistency was an important component of the litter decomposition process. Leaves of some tree species, especially those with bigger leaves, were said to be less consistent, and decomposed faster than those from trees with smaller leaves that were said to be more consistent, irrespective of environmental conditions. Species with small leaves were, therefore, contributing less to the organic matter content of the soil, thus indicating less fertile soils. In contrast, species with large leaves were credited with both abundant leaf litter and faster decomposition rate because their leaves presumably contained much water; therefore they contributed more to the organic matter content of the soil whilst ensuring an adequate protection of the soil surface against erosion.

5.4 DISCUSSION

Local soil classification has recently received attention from scientists as a means of understanding farmers' knowledge about soil properties and soil processes (Marten and Vityakon, 1986; Pawluk et al., 1992; Talawar and Rhoades, 1998; Joshi et al., 2004). It has become more and more apparent that the knowledge of people who have been interacting with their soils for a very long time can offer many insights about sustainable management (Hecht, 1990; Osunade, 1992b).

One of the most important objectives of every farmer when cultivating is to obtain as much production as possible with limited inputs. Soil being the reservoir for an important portion of natural resources that contribute to reach that objective, it becomes crucial to set observation tools and methods that allow a rapid assessment of these resources and the identification of soil properties and processes that may influence the availability of these resources and their sustainable management. In this regard, local farmers in southern Cameroon have developed a detailed explanatory knowledge about the variety of soils of their area and the response of cocoa growth to these soils.

Farmers' perceptions of suitable farmland for cocoa are clearly oriented towards system productivity and sustainability, thus to the long-term fertility of farmland soils. The characteristics of fertile soils, as defined by Schroth and Sinclair (2003) are "to facilitate root development, supply water, air and nutrients to plants, and do not have pest and disease burdens that result in catastrophic impacts on the plants that are being grown". One of the key soil properties involved in these processes is the soil structure, which comprises the arrangement of individual particles in the soil and is especially concerned with their aggregation, the resulting pore size distribution and the stability of the aggregated state (Payne, 1988; Grimaldi et al., 2003). Considering the local assessment of soil characteristics (Table 5.4), and the diagrammatic representation of causal knowledge about soil types and effects on cocoa growth (Figure 5.1), it can be observed that this definition matches with farmers' perceptions of factors determining fertile soil for suitable farmland for cocoa.

Nutrient supply

Soil nutrients are an important component for cocoa tree growth and productivity, though it is known that cocoa can grow successfully under poor soil nutrient conditions, provided that other soil characteristics are not limiting, especially the organic matter content (Wood and Lass, 1985; Van Rants, 1983; MINAGRI, 1987; Mossu 1990). The organic matter content of soil influences a wide range of soil properties and processes and is considered one of the most important components of soil fertility (Gregorich et al., 1994; Schroth et al., 2003). The soil properties and processes concerned include, among others, the ability of soil to retain nutrients against leaching in soils with low cation exchange capacity and the regulation of nutrient availability, the stabilisation of soil structure, and the enhancement of the ability to store soil water.

The organic matter content of soil in turn is most importantly influenced by the amount of leaf litter produced and root turnover, that is a specific aspect of root dynamics referring to the fraction of root system that is renovated during a certain time period (commonly a year) through the death of some roots and their replacement by new root growth (Schroth, 2004). In fact, tree leaf litter, through the process of its decomposition, is one of the main providers of soil organic matter. In this regard, some authors (Salonius. 1972; Gill and Lavender, 1983; Prescott et al., 1992) have reported that plants on infertile sites have leaves that generally decompose more slowly than those of plants growing on more fertile sites.

Contrary to leaf litter, Ostertag and Hobbie (1999) reported that roots decomposed faster than leaves at more infertile sites, in part because of lower lignin-to-nitrogen ratios in roots than in leaf litter. However, decomposing roots immobilised more nutrients than did decomposing leaves, and may serve an important role in recycling nutrients, especially in a multistrata cocoa system context. Other sources of soil organic matter such as living organisms (soil biomass) do exist, but their contribution to soil organic matter amounts to less than 5% of the total of soil organic matter (Jenkinson 1988b, Schroth et al. 2003).

Farmers considered leaf litter as being the main provider of soil organic matter through the process of its decomposition, and similar to scientists, they linked the rate of decomposition to the fertility status of the soil via the leaf size and consistency (Section 5.3.2.2.2). In contrast, they did not mention the contribution of root turnover to the soil organic matter content, probably because as a process occurring belowground, it was not easily perceptible.

The majority of soils in the study area belong to the ferralitic soils group, and their characteristics as discussed earlier in Chapter 2 (Section 2.2.3.2) can be considerably improved by the addition of organic matter. The implication of the quantity of leaf litter produced for shaping the fertility status of soil is therefore obvious. In the absence of organic fertilisers, soil fertility can be maintained or restored through a reasonable production of organic matter via the leaf litter. In this respect, a higher quantity of leaf litter will lead to a higher quantity of organic matter being processed and subsequently, soil properties and soil processes will be importantly improved. The importance farmers attach to soil colour to predict its fertility status is clearly related to organic matter content.

Water availability

Water is essential for plants because it has pronounced influence on nutrient uptake from the soil complex because it affects root growth and the transport of nutrients to the roots (Sinclair, 2003). Soil, through its water budget, is the main water supplier to plants. The availability and mobility of water in aggregated soils depend on the amount of rainfall, but also on pore distribution and pore size and hence on soil structure and texture (Cadisch et al., 2004).

It is therefore obvious that soils with large particles or large aggregates, such as sandy soils or gravel soils, will have high infiltration rates because of the abundance of macropores, allowing percolating water to pass rapidly through the soil. The result may be increased water drainage, with related possible reduced soil water content of the upper layers to the benefit of the lower layers or the ground water. In contrast, when the pores are very narrow in a way that compromises water infiltration, as is the case in compact soils, or when there is a physical barrier in the soil profile, as is the case in gravel soils or lateritic soils, the deeper layers may suffer permanent water deficiency. In situations where the slope is steep enough to encourage water runoff at the expense of infiltration, soil water content may also be critically reduced, thus making it unavailable to plants. Farmers had a good understanding of these processes, and had identified the type of soils that may be affected. These were gravel soils, sandy soils and lateritic soils.

The important role of soil organic matter in stabilising soil structure becomes essential, especially on sandy soils where the stabilising effect of clay on soil structure is limited by low clay content (Pieri, 1989) and on compact soils, where the reduced pore size critically compromises the infiltration of water. Experimental work has also clearly shown that continuous cover of the soil surface by leaf litter offers an adequate protection against evaporation and surface runoff by acting as a semipermeable barrier that slows the velocity of surface runoff and hence increase its infiltration (McDonald et al., 2003). It therefore contributes to enhance the conservation and mobility of soil water, whilst constituting a potential reservoir for organic matter.

These beneficial effects of leaf litter, be they direct, through the protection of soil surface against erosion and evaporation, or indirect, via the positive effects of soil organic matter on soil structure, are essential in the sense that the content and availability of soil water is improved, even in some marginal soil conditions. In these respects, the approach of farmers to associate plant species, essentially trees, to the assessment of soil properties and soil processes appears to be sensible, practical and adapted to farmer circumstances. Howver, farmers' knowledge of the effects of leaf litter on soil conditions appeared to be superficial and limited to apparent processes, with some belowground effects such as the conservation and mobility of soil water not clearly stated.

Root development

Farmers perceived the tree root system component as essential in the process of water and nutrient uptake from the soil complex. Roots are, therefore, at the interface between soil and plants. To perform those vital functions, roots should grow and develop adequately. The more extensive the root system is, the higher the nutrient and water uptake efficiency may be (Van Noordwijk and De Willigen, 1991). However, Van Noordwijk et al. (1996) remarked that the possibility of obtaining higher resource uptake efficiency could only be realised if total supply of nutrients and water is regulated in accordance with crop demands and the resource use efficiency attainable.

Soil structure strongly influences the growth of plant roots, which is generally reduced in compact, dry and poorly aerated soils (Grimaldi, 2003). Such soils, according to local classification, encompass a wide range of soil types including: shallow soils, gravel soils, if the amount of gravel is high, sandy soils, swampy soils with permanent floods, and to a certain extent, soils on steeply sloping lands. Farmers can easily identify such soil types across the landscape by using plant species as indicators when the physical elements of the soils are not apparent, and their decision to allocate available farmland basically considers this.

In addition to their functions of capturing water and nutrients from the soil and making them available to plants, or pumping water and nutrients from deeper soil layers to surface layers, farmers said that plant roots had also contributed to improve soil structure in many ways (see Section 5.3.2.1). Scientists have confirmed some of these ways. Indeed, research work has shown that plant root systems stabilise soil structure by enmeshing aggregates, releasing binding materials (mucilage) into the rhizosphere and increasing soil microbial activity (Morel et al., 1991; Miller and Jastrow, 1990). Schroth (2003) found that when roots grow through the soil, they enlarge existing pores and create new ones, but also remarked that their radial pressure may, at the same time, compress the soil round these pores. This effect of creating new pores and/or enlarging existing ones enhances the process of water getting to the deeper soil layers mentioned by farmers. The essential role that tree roots, mostly deep roots, play in the capture and redistribution of soil resources through the process of "hydraulic lift" (Caldwell et al., 1998) or the function of "root safety net" for intercepting leaching nutrients (Cadisch et al., 2004) is well established. It is therefore sensible to link some aspects of soil structure or management of soil resources to the tree species found on particular sites according to their root system habit.

Soilborne pests and diseases

Soilborne organisms such as plant parasitic nematodes, fungi, bacteria, phytoplasma, protozoa and viruses are amongst the most underestimated of factors that affect plant health and productivity in tropical regions (Desaeger, 2004). Their occurrence and development are mostly influenced by the microenvironmental conditions, especially the soil climate, and the cropping practices used. Because of their usually non-specific symptoms of an infection, these organisms live out of sight and, generally, out of mind of farmers and extension workers.

Yet, the present study revealed farmers' awareness of the fact that the soil substrate was not always pest and disease free. They reported that cocoa grown on farmland previously planted to cassava, as well as cocoa grown on swampy soils, was likely to suffer significant root rot disease pressure. They also reported that cocoa root diseases were important in plots with decaying large tree stumps that had not been extracted during land preparation. Termites were also reported as having destructive actions on the cocoa roots, thus limiting their efficiency with regard to soil resources uptake. However, in the case of cocoa root rot disease that was said to be common in swampy soils, it was difficult to determine whether the symptoms on the roots were related to disease or to other causes. For example, swampy soils also provoke the death of cocoa roots because of insufficient aeration that characterises that environment. The visual symptoms on the roots in both cases were similar (personal observation). In each case however, both farmers and scientists considered that there was evidence that this category of soils was not suitable for growing cocoa.

Soil depth

The importance of soil depth in an agroforestry system, as is the case with cocoa systems, as well as in the allocation of available farmland to various crops, cannot be overemphasised. Indeed, soil depth determines the volume of soil that can be explored by crop roots to capture water and nutrients necessary to their growth (Van Ranst, 1983) as well as the development of crop roots.

However, estimating soil depth is not always easy, even for soil scientists, in the absence of professional equipment. During rapid soil surveys, pedologists often use plant species to give insights about some soil characteristics, including soil depth (Ambassa-Kiki, personal communication). This is a clear indication of the relevance of farmers' methods that actively value their knowledge of soil-plant interrelationships to predict some soil properties, including soil depth. In this respect, tall trees and/or trees with deep rooting habit are mostly indicative of deep soils and vice versa.

In summary, it was apparent that farmers in southern Cameroon possessed a detailed explanatory knowledge about their soils and were able to classify them in terms of soil characteristics and their effects on cocoa growth. In general, many soil characteristics involved in farmers' soil classification were visible to the eyes, and could be broadly grouped into two main determinants, which were texture and colour. The other soil characteristics used were considered to be less important as they were predictable to a major extent by soil colour and texture. This is because farmers highly associate texture and colour with other soil qualities, such as organic matter content, suitability classes for different crops, sensitivity classes to certain agricultural problems, water retention and flooding and, workability and position in the landscape. The fact that texture and colour were the main characteristics of farmers' classification of farmland soils with other relevant characteristics being predictable from soil colour and texture, reflects a classification system oriented towards what Furbee (1989) and Ettema (1994) describe as functional soil classification systems, which is characteristic of local soil classifications.

The active use of farmers' knowledge of soil-plant interrelationships to explain soil properties and soil processes is common to many local communities' soil classification systems (William and Ortiz-Solorio, 1981; Hecht, 1990). In investigating farmers' knowledge of the role of trees in cocoa farms in Ghana, Saunders (2002) found that farmers had a good knowledge of the beneficial effects of some tree species on soil properties such as soil moisture, and based on that maintained such species in their cocoa farms. The same study also revealed similarities between farmers' perceptions of the effects of organic matter and non-cocoa root system habit on the availability and management of soil nutrients and soil water in southern Cameroon and Ghana. Onguéné and Kuyper (2001) compared farmers' ranking of some tree species according to their fertility value and their mycorrhizal associations, and found that farmers' ranking of the species and the mycorrhizal associations of these species were positively correlated. Audrey Richards (1939) describes how Chitimene shifting cultivators of northern Zambia selected new fields using a combination of vegetation and soil indicators.

In summary, the farmers' system of soil classification, though complex because it involves many processes, appeared to be credible and well adapted to their circumstances. However, farmer knowledge about soils and effects on cocoa growth or soil-tree interrelationships is essentially based on personal or local experience derived from long term interactions with soils, thus may be limited or specific to their ecological environment. In this regard, differences and inconsistencies in the content of knowledge may occur. The study has revealed that farmers' knowledge about a number of belowground interactions was not well developed. For example, their appreciation of soil moisture and soil fertility through the tree root system habit interface proved to be not always effective; their knowledge about the leaching of soil nutrients as well as the functions of organic matter in the soil was limited to generalities; they were not aware of the contribution of root turnover to the soil organic matter content. However, these restrictions do not put to question the pertinence of farmers' knowledge about soils; they rather call for more collaboration with scientists for a better understanding of those processes.

5.5. CONCLUSION

Soil resources availability and management is a major aspect of agroforestry systems (Ettema, 1994; Brenner, 1996). Attempts by development agents to bring about adapted solutions to issues related to declining cocoa yields due to poor soil fertility or soil fertility depletion in the cocoa agroforest systems of southern Cameroon have yielded no pertinent results.

Although farmers in southern Cameroon claim that they are critically limited in addressing these issues, it is apparent that their knowledge about soils and their effects on cocoa growth as described in this study was credible in many respects, and can offer many insights about sustainable management of soil resources of their cocoa systems. This points to a need to bring together local soils classification and land evaluation systems of the study area and scientific methods, and to come to a synthesis that provides practical tools for effective farmland evaluation at low cost. It is anticipated that if soil surveys would start with local soil classification, research and development efforts would gain time and insight, and communication between farmers and scientists and extension agents will be greatly improved if local soil nomenclature is used.

CHAPTER 6

FARMERS' PERCEPTIONS OF THE EFFECTS OF TREE DIVERSITY ON PRODUCTIVITY AND SUSTAINABILITY

ABSTRACT

Investigations to test the consistency of farmers' perceptions of the implications of non-cocoa tree species diversity for the sustainability and productivity of the cocoa systems, together with the socio-economic assessment of these species, were carried out amongst thirty farmers at three locations in southern Cameroon: Akok, Awae and Nkongmesse. Eight tree species common across and within sites and displaying a range of ecological traits and use functions were selected and farmers' perceptions of some of their characteristics were investigated. These included: i) their value as indicators of site suitability for cocoa, ii) their soil water uptake characteristics and, iii) their competitiveness with cocoa for soil water. A socio-economic assessment explored their uses and the intensity at which they were used. Finally, an inventory of non-cocoa trees was carried out in 20 cocoa farms in each location to assess trees richness and composition.

The findings about ecological characteristics revealed that farmers had a coherent understanding of these, and that they made no clear distinction between water uptake characteristics and competitiveness for soil water. The socio-economic assessment suggested that non-cocoa trees' products were contributing to subsistence needs and sale in some local markets. 165 non-cocoa tree species were inventoried, of which farmers had previously

identified 129. The number of shared species amongst locations was relatively high (54 to 74%). Frequency distribution of the number of species classified by the number of farms where they were found showed that most species were fairly rare. Tree species richness varied widely between cocoa farms within locations.

6.1 INTRODUCTION

A large number of farmers in Southern Cameroon have a long tradition of maintaining tree biodiversity in their cocoa farms. This ranks cocoa systems in southern Cameroon amongst the best examples in Africa of seemingly permanent agriculture that preserves a forest environment and some of its biodiversity (Ruf and Schroth, 2004). Farmers have used this biodiversity for longer than agricultural and forest scientists have had an interest. Therefore, their knowledge on the ecological functions of trees is a potent resource (Sinclair, 1999). As mentioned in Chapter 5 (Section 5.4), vegetation in general and tree species in particular are key elements that contribute to farmers' decisions to allocate the available farmland to specific uses. In the case of cocoa, farmers are aware of the fact that, system sustainability and productivity are partly related to the interactions between the cocoa and non-cocoa components. In this respect, concepts such as soil water resource management, soil nutrient cycling and shading management are common in their folk language. A critical issue is to assess farmers' perceptions of the effects of these interactions on system sustainability and productivity. In other words, could farmers on the basis of their long-term experience of the interactions occurring amongst the various tree components of their cocoa farms classify a set of tree species in a hierarchy of importance with regards to some ecological characteristics?

6.1.1 Ecological characteristics

In order to assess farmers' perceptions of ecological compatibility of tree species for cocoa farms, investigations on some of their ecological characteristics were carried out with a sample of farmers and in some cocoa farms of the study locations. The aim of these investigations was to test whether farmers could rank non-cocoa tree species in terms of specific ecological characteristics, and if rankings were consistent within and across locations. The domains investigated were:

- value as site suitability indicators for cocoa,
- water uptake characteristics,
- competitiveness with cocoa for soil water.

6.1.2 Species composition and socio-economic assessment

Rapid rural population growth in the study locations is accompanied by a wide scale conversion of forestland to agricultural uses, especially for food crop production (see Section 1.2.1 of Chapter 1), and increasing contribution of forest products to local communities' livelihoods. The ensuing environmental degradation, due mostly to the slash and burn techniques that are common to the study communities, puts this development process into question (Gockwoski et al., 2004). The cocoa systems of southern Cameroon, which are presented as being a reservoir for biodiversity conservation as compared to other agricultural systems, should therefore be paid due attention, especially by enhancing the environmental services for the sustainability of the systems. In this respect, a socio-economic and ecological assessment of non-cocoa tree species is an important step at local level to reach that goal.

The objectives of the investigation were, therefore: i) to assess the non-cocoa tree species uses and the intensity at which they were used and, ii) to assess representation of non-cocoa tree species in the cocoa systems of the study locations.

6.2 MATERIALS AND METHODS

6.2.1 Farmers' perceptions of ecological characteristics of non-cocoa trees

6.2.1.1 General

Surveys on the ranking of eight non-cocoa tree species commonly found in cocoa systems in southern Cameroon as regards some of their agronomic characteristics and use frequency were carried out in three locations: Akok, Awae and Nkongmesse. Unlike farmers in Ndikinimeki, most farmers in the three surveyed locations are indigenous forest dwellers, who have been living in this forest environment for the past 300-400 years (Assoumou 1977) and so could be expected to have developed a good understanding of forest diversity and interactions among its various components.

6.2.1.2 Data collection

A survey questionnaire (Appendix 4) was prepared on the ranking of eight selected non-cocoa tree species (Table 6.1) according to three ecological characteristics which were: i) site suitability prediction status, ii) water uptake characteristics and, iii) level of competitiveness with cocoa for soil water. The selected species were chosen from the knowledge base, and because they were common to cocoa fields within and across sites, and displayed a range of ecological characteristics and use functions. Farmers were also asked to classify the trees in relation to the frequency with which some of their products were harvested for local uses (timber for local construction and furniture, medicinal, nuts, fruits, spices), and whether they were sold in local or urban markets. The questionnaire was distributed to 30 randomly sampled farmers per location. The objective was to find out whether farmers could identify specific tree species for particular ecological and agronomic purposes. This might then be useful within a collaborative research approach aimed at enhancing system sustainability and productivity, through introduction or suppression of some tree species based on their agro-ecological traits.

Prior to the distribution of the questionnaire, group meetings were held with farmers at each location to explain what the exercise was all about. Every presentation of the questionnaire was followed by a collaborative question-answer session during which farmers' willingness to have a deep understanding of the exercise and to share their approach was obvious. The questions were commonly reformulated where relevant to ease the understanding of informants. The questions were drawn from statements provided by key informants during phase 1 of the study (Sections 3.2.2.3 and 5.2.2) and contained in the knowledge base and from secondary information.

Table 6.1 Selected non-cocoa tree species used in ranking study

Botanical names	Local names	Farmers' descriptions.
Milicia excelsa	Abang, Pokombe	Deep rooting habit, abundant leaf litter and high leaf litter decomposition rate, soil fertility value
Irvingia gabonensis	Andok, Azanga	Deep rooting habit, abundant leaf litter and high leaf litter decomposition rate, fertility value.

Musanga cecropioides	Asseng, Pokomba	Shallow rooting habit, abundant leaf litter and high leaf litter decomposition rate, fertility value.
Triplochiton scleroxylon	Ayous, Hilel	Shallow rooting habit, abundant leaf litter and high leaf litter decomposition rate.
Ceiba pentandra	Doum, Hilel	Shallow rooting habit, abundant leaf litter and high leaf litter decomposition rate, fertility value.
Erythrophloeum ivorense	Elon, Etom	Deep rooting habit, low leaf decomposition rate, low fertility value.
Distemonanthus benthamianus	Eyen	Shallow rooting habits, low leaf litter decomposition rate, low fertility value
Ricinidendron heudelotii	Njangsang, Ndangsang	Deep rooting habits, abundant leaf litter and high leaf litter decomposition rate.

6.2.1.2.1 Ranking for ecological characteristics

Farmland suitability status

The effects of trees on soil fertility, and thus in indicating farmland suitability status for various crops, has been established and described (Schroth and Sinclair, 2003). In southern Cameroon, in the absence of professional equipment to identify the most appropriate land for growing cocoa, farmers actively use, among other ecological indicators, tree species present at a the site to predict suitability for farming (see Section 5.3.2 of Chapter 5). Farmers were asked to rank the selected non-cocoa trees in order of importance as indicators of suitable sites for cocoa. The species considered to have the highest farmland suitability status was ranked 1 whilst the species with the lowest suitability status or with negative effect on cocoa growth was ranked 8.

Soil water uptake characteristics and level of competitiveness with cocoa for soil water

The same exercise was repeated considering the eight species as regards their soil water uptake characteristics and level of competitiveness with cocoa for soil water. On the one hand, the species with the highest soil water uptake amount was ranked 1, whilst the species with the lowest amount was ranked 8; on the other hand, the species with the highest level of competitiveness with cocoa for soil water was ranked 1 whilst the species with the lowest level was ranked 8. The distinction between the concepts of "soil water uptake" and "competitiveness with cocoa for soil water" was made because, as mentioned by Smith et al. (2004), quantification of water uptake is important for studies of competition and complementarity in mixed-species agroecosystems, as is the case with cocoa systems in southern Cameroon. It was therefore important to test whether farmers could recognise species that take up a lot of water without competing with cocoa.

6.2.1.2.2 Uses and classification of different tree species in terms of their use intensity

Another household level survey (Appendix 4) gathered information on what farmers said they know about the uses and what they do with the tree species found in their cocoa systems. This survey was complemented with farmers' opinions on the possibility of introducing specific tree species to their cocoa fields and what should be the selection criteria for such species. To achieve this, some indicators were applied. They included the hierarchy of importance with regards to species uses or products of the tree that were harvested and the type and the intensity at which they were used, and the desirability of conservation or introduction of some species to the system. Three levels of use intensity were retained in common agreement with farmers:

1. level 1: low use intensity or not used at all: products of the species not commonly used or not known;
2. level 2: moderate use intensity: product of the species used occasionally;
3. level 3: high use intensity: species products constitute important inputs in the livelihoods of the household.

Farmers were also asked to evaluate the number of individuals of each of the selected species in their farms as well.

6.2.1.3 Data compilation and analysis for ecological characteristics

The individual rankings by each farmer of the eight species per location for each agronomic characteristic were entered in a table and used to establish an overall ranking of the species for the location, which corresponded to the mean rank of individual rankings. Further analysis involved pairwise comparisons among individual farmers' rankings within locations on the one hand, and between individual farmers' rankings and the overall ranking of the location on the other hand. Correlations between the various rankings within and across locations were measured by using the Spearman rank correlation coefficient. These analyses aimed at testing how close the various rankings were to one another.

6.2.1.4 Species composition assessment

An inventory of the non-cocoa tree species was done in twenty cocoa farms in each of the four locations in Southern Cameroon: Akok, Awae, Nkongmesse and Ndikinimeki. The inventory was carried out over 25% of each farmland area following a gradient directed transect method. Given the median cocoa farm size in the study area of 1.4 ha, 25% surface area was generally above the 40 m x 5 m area proposed by Gillison and Brewer (1985), for estimating the diversity of the study milieu whatever the ecosystem. Within a cocoa farm, only indigenous tree species and shrubs with the capacity of transforming into tree species if not suppressed during farm maintenance activities were considered. Common exotic species were not recorded because the purpose of the study was to assess the value of multistrata cocoa systems for conservation of indigenous tree species.

Nkamo Aboubakar, a taxonomist with the Institute of Agricultural Research for Development in Cameroon recorded the entire tree species counted in the inventory, with the assistance of the farm owner for identification of the species' local names. References from various authors (Vivien and Faure, 1985, 1996; Souane Thicakul, 1985 and Lebrun and Stork, 1991, 1992, 1995, 1997) were also used to consolidate the identification.

Species accumulation curves for each study location were established using EstimateS, version 6.0b1 (Colwell, 1997). This was complemented by frequency distributions of species occurrence and numbers of species on farms.

Estimation of the percentage of tree species coincidence between the study locations was done by calculating the Sorensen Index (CCs, Equation 1) of floristic similarity (Brower and Zar, 1977).

$$CCs = \frac{2c}{a + b}$$

With a = species number in location 1, b = species number in location 2, and c = number of shared species in both locations.

The results multiplied by 100 correspond to the percentage of tree species coincidence.

These estimations were important as information gained could provide more insight into the potential of tree diversity conservation of the cocoa systems of southern Cameroon.

6.3 RESULTS

6.3.1 Assessment of ecological characteristics of selected trees

6.3.1.1 Trees as farmland suitability indicators

Pairwise comparisons of farmers' rankings of the extent to which various tree species were indicators of land suitable for cocoa, within locations, were generally highly and positively correlated ($0.7 < r_s < 1$), with a modal value of 0.9. This demonstrates consistency in farmers' perceptions of the value of tree species as farmland suitability indicators within each location. While across locations, the overall rankings for Akok and Awae were similar ($r_s = 0.904$), Nkongmesse was different from both Akok ($r_s = 0.523$) and even more so from Awae ($r_s = 0.333$).

The means of the rankings of selected species according to their farmland suitability for cocoa within and across locations (Figure 6.2) show that, despite differences amongst sites in which species were indicative of high suitability for cocoa, farmers at all three locations unanimously identified

Erythrophloeum ivorense and *Distemonanthus benthamianus* as indicators of low suitability of land for cocoa.

Table 6.2 Ranking of the selected species according to their indication of farmland suitability for cocoa within and across locations.

Akok			Awae			Nkongmesse		
Species	Mean rank	SE	Species	Mean rank	SE	Species	Mean rank	SE
Sp4	1.76	0.14	Sp5	1.50	0.13	Sp1	1.66	0.13
Sp5	2.03	0.20	Sp4	2.33	0.13	Sp8	1.73	0.12
Sp8	2.70	0.17	Sp8	2.90	0.27	Sp2	2.80	0.12
Sp1	3.70	0.17	Sp3	3.80	0.18	Sp4	4.30	0.18
Sp2	5.63	0.16	Sp1	4.90	0.13	Sp3	4.96	0.15
Sp3	5.76	0.12	Sp2	5.60	0.03	Sp5	5.60	0.04
Sp7	6.63	0.17	Sp7	7.00	0.04	Sp7	7.00	0.06
Sp6	7.66	0.19	Sp6	7.96	0.16	Sp6	7.93	0.14

Sp1 = *Milicia excelsa*; Sp2 = *Irvingia gabonensis*; Sp3 = *Musanga cecropioides*; Sp4 = *Triplochiton ecleroxylon*; Sp5 = *Ceiba pentandra*; Sp6 = *Erythroploeum ivorense*; Sp7 = *Distemonanthus benthamianus*; Sp8 = *Ricinodendron heudelotii*

6.3.1.2 Tree water uptake characteristics

Unlike rankings of tree species as land suitability indicators, pairwise comparisons of farmers' individual rankings of tree species soil water uptake amount were highly variable, with r_s ranging from 0.1 to 1.0, with a mode of 0.6. Comparison of the overall rankings amongst locations showed that they were positively and strongly correlated ($0.8 < r_s < 1$), indicating a fairly clear agreement across locations for all selected species (Table 6.3).

Table 6.3 Ranking of the selected species according to their rate of soil water uptake.

Akok			Awae			Nkongmesse		
Species	Mean rank	SE	Species	Mean rank	SE	Species	Mean rank	SE
Sp6	1.83	0.19	Sp6	1.93	0.21	Sp6	1.80	0.20
Sp7	2.53	0.24	Sp7	2.00	0.32	Sp7	2.60	0.28
Sp3	2.90	0.24	Sp1	4.23	0.43	Sp1	3.20	0.41
Sp1	3.20	0.15	Sp2	4.46	0.26	Sp3	3.80	0.21
Sp2	5.00	0.17	Sp3	5.03	0.33	Sp2	5.26	0.22
Sp4	6.13	0.22	Sp4	5.26	0.35	Sp4	5.60	0.23
Sp5	7.03	0.22	Sp8	6.23	0.23	Sp8	6.63	0.22
Sp8	7.23	0.17	Sp5	6.46	0.26	Sp5	6.90	0.24

Sp1 = *Milicia excelsa*; Sp2 = *Irvingia gabonensis*; Sp3 = *Musanga cecropioides*; Sp4 = *Triplochiton ecleroxylon*; Sp5 = *Ceiba pentandra*; Sp6 = *Erythroploeum ivorense*; Sp7 = *Distemonanthus benthamianus*; Sp8 = *Ricinodendron heudelotii*

The means of the rankings showed that, despite the variability in farmers' individual rankings, *Erythrophloeum ivorense* and *Distemonanthus benthamianus* were thought to take up most water, whilst *Ricinodendron heuelotii* and *Ceiba pentandra* were taking less.

6.3.1.3 Competitiveness with cocoa for soil water

Like the rankings of tree species for water uptake rate, pairwise comparisons of farmers' individual rankings of the tree species' competitiveness with cocoa for soil water were highly variable, with r_s ranging from 0.1 to 1.0 with a mode of 0.6. Comparison of the overall rankings amongst locations showed that they were positively and strongly correlated ($0.8 < r_s < 1$). This demonstrates consistency in farmers' perceptions of the competitiveness of tree species with cocoa for soil water amongst locations (Table 6.4). The rankings for soil water uptake and competitiveness with cocoa for soil water were almost identical, suggesting that farmers made no clear distinction between these attributes for the selected species.

Table 6.4 Ranking of the selected species according to their competitiveness with cocoa for soil water within and across locations. Legend as in Table 6.2.

Akok			Awae			Nkongmesse		
Species	Mean rank	SE	Species	Mean rank	SE	Species	Mean rank	SE
Sp6	1.40	0.21	Sp6	1.43	0.24	Sp6	1.43	0.21
Sp7	2.26	0.19	Sp7	2.40	0.23	Sp7	2.26	0.23
Sp3	3.23	0.20	Sp2	3.70	0.39	Sp1	3.56	0.31
Sp1	3.50	0.16	Sp1	4.50	0.26	Sp2	4.13	0.20
Sp2	4.50	0.17	Sp3	4.83	0.18	Sp3	4.23	0.13
Sp4	6.50	0.17	Sp4	5.63	0.17	Sp4	6.03	0.19
Sp5	6.53	0.17	Sp8	6.33	0.25	Sp8	6.53	0.23
Sp8	6.73	0.18	Sp5	7.30	0.25	Sp5	7.50	0.25

Sp1 = *Milicia excelsa*; Sp2 = *Irvingia gabonensis*; Sp3 = *Musanga cecropioides*; Sp4 = *Triplochiton ecleroxylon*; Sp5 = *Ceiba pentandra*; Sp6 = *Erythroploeum ivorense*; Sp7 = *Distemonanthus benthamianus*; Sp8 = *Ricinodendron heudelotii*

6.3.2 Socio-economic assessment and species composition

6.3.2.1 Socio-economic assessment

The results of the investigations about how frequently the selected tree species were used and their mean number per farm (Table 6.5) show that some species that appear rare, such as *Erythrophloeum ivorense* and *Milicia excelsa,* are most frequently used. Concerning what the selected species were used for, findings (Table 6.6) indicated that the main types of local uses were contribution to subsistence needs and some locally marketable products.

Table 6.5 Selected species use intensity (level 1 = no or low use; level 2 = moderate use; level 3 = high use) and average number per farm

Use frequency	Akok		Awae		Nkongmesse	
	Species	Average number per farm	Species	Average number per farm	Species	Average number per farm
Level 1.	*Milicia excelsa*	2	*Erythrophloeum ivorense*	0.1	*Milicia excelsa*	2
	Ceiba pentandra	4	*Distemonanthus benthamianus*	2	*Ceiba pentandra*	4
			Ceiba pentandra	3	*Erythrophloeum ivorense*	1.2
Level 2.	*Musanga cecropioides*	7	*Musanga cecropioides*	8	*Triplochiton scleroxylon*	3
	Triplochiton scleroxylon	3	*Milicia excelsa*	4	*Musanga cecropioides*	10
	Erythrophloeum ivorense	0.2	*Triplochiton scleroxylon*	3		
	Distemonanthus benthamianus	1				
Level 3.	*Irvingia gabonensis*	0.7	*Irvingia gabonensis*	0.5	*Irvingia gabonensis*	2
	Ricinodendron heudelotii	0.1	*Ricinodendron heudelotii*	0.7	*Ricinodendron heudelotii*	3
					Distemonanthus benthamianus	2

Table 6.6 Uses of selected species.

Species	Timber	Poles	Fuel wood	Medicinal	Fruits	Spices	Vegetable	Nuts
Milicia excelsa	X	X	X	X				
Irvingia gabonense			X	X	X	X		
Musanga cercroopioides			X	X				
Triplochiton scleroxylon	X		X				X	
Ceiba pentandra	X			X			X	
Erythrophloeum ivorense	X			X				
Ditsemonanthus benthamianus	X	X	X	X				
Ricinodendron heudelotii			X	X		X		X

6.3.2.2 Species diversity assessment

6.3.2.2.1 Species diversity

The results of the inventory of non-cocoa tree species diversity showed that there were in total 165 different non-cocoa trees in the cocoa systems of the study locations. This compares with 129 species recognised by farmers, and the 65 species for which farmers could list functional attributes that were consistent across locations, during the knowledge survey and reported in Chapter 3 (see Section 3.3.3.2). At location level, 108 species were found on cocoa farms at Akok and Awae, 109 species at Nkongmesse, and 55 species at Ndikinimeki.

Considering the Sorensen Index (CCs) (Table 6.7), the proportion of non-cocoa tree species coincidence was relatively high amongst the locations of Akok, Awae and Nkongmesse (70 to 74% of the species recorded). The highest similarities in species comparison occurred between Nkongmesse and Awae, and Nkongmesse and Akok (74%). In contrast, the similarities were less between these locations and Ndikinimeki (54 to 62%). A list of shared non-cocoa tree species recorded in the cocoa systems of the study locations is presented in Annex 6.1.

Table 6.7 Number of shared species and Sorensen Index (CCs) between locations.

CCs	Akok	Awae	Nkongmesse
Awae	**73 (70.8%)**		
Nkongmesse	**77 (74.4%)**	**77 (74.4%)**	
Ndikinimeki	44 (54.0%)	51 (62.5%)	46 (56.1%)

6.3.2.2.2 Variability in species composition

The figures on the variability in species richness (Table 6.8) indicated that the tree species number per farm was higher at Nkongmesse and ranged from 15 to 46 species, with a mean value of 28.20, as compared to Akok and Awae locations, which belong to similar eco-zones, and where they ranged from 7 to 33 species with a mean value of 19.30, and 7 to 35 species with a mean value of 20.15, respectively. The lowest number of tree species was observed at Ndikinimeki (mean value estimated at 15 with a range of 9 to 27 species). This was expected due to its ecological environment. The difference in variability of species richness amongst locations was not large (standard error ranging from 1.29 to 1.93). The species accumulation curves (Figure 6.1) confirmed the generally higher species richness of Nkongmesse farms and the lower number of species at Ndikinimeki.

Table 6.8 Variability in tree species number in cocoa farms in southern Cameroon n = 20 per location.

Variable	Akok	Awae	Nkongmesse	Ndikinimeki
Mean	19.30	20.15	28.20	15.05
SE Mean	1.29	1.93	1.66	1.37

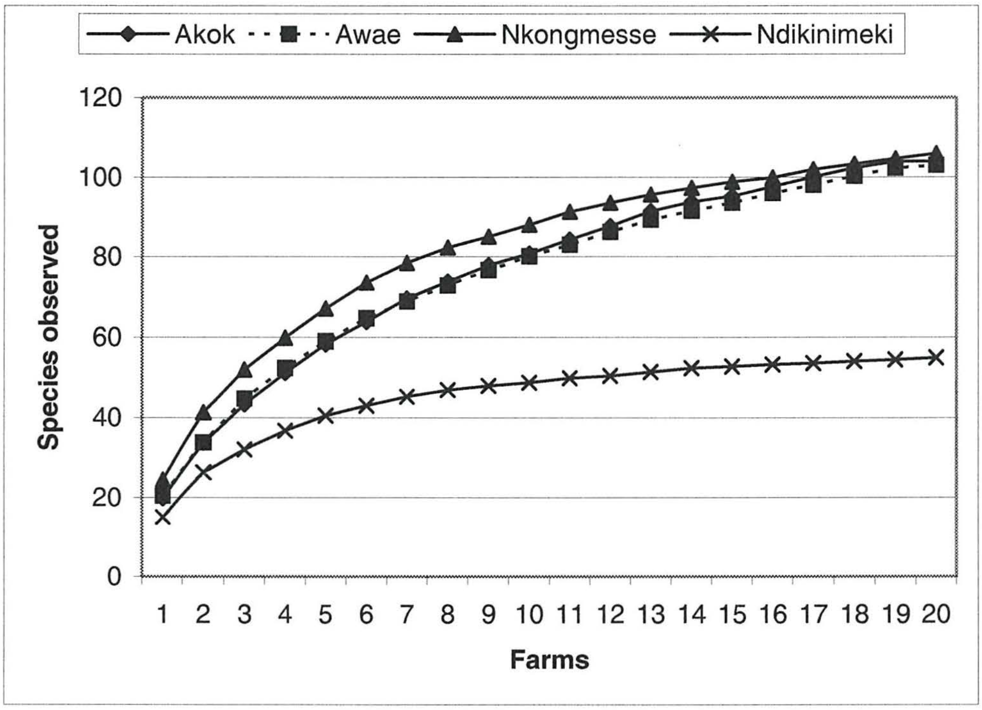


Figure 6.1 Tree species accumulation curves of 20 cocoa farms for each study location.

6.3.2.2.3 Species abundance on farms and numbers of specie per farm

The frequency distribution of the number of species classified by the number of farms where they were found showed that most species were fairly rare (found on few farms). Indeed, 29 to 73 of the non-cocoa tree species inventoried in the cocoa systems of southern Cameroon, representing 53% to 67% of the trees according to location, were found on less than five farms.. More species were found on more cocoa farms at Nkongmesse, thus indicating a more important degree of biodiversity conservation in that location, as compared to Akok, Awae and Ndikinimeki.

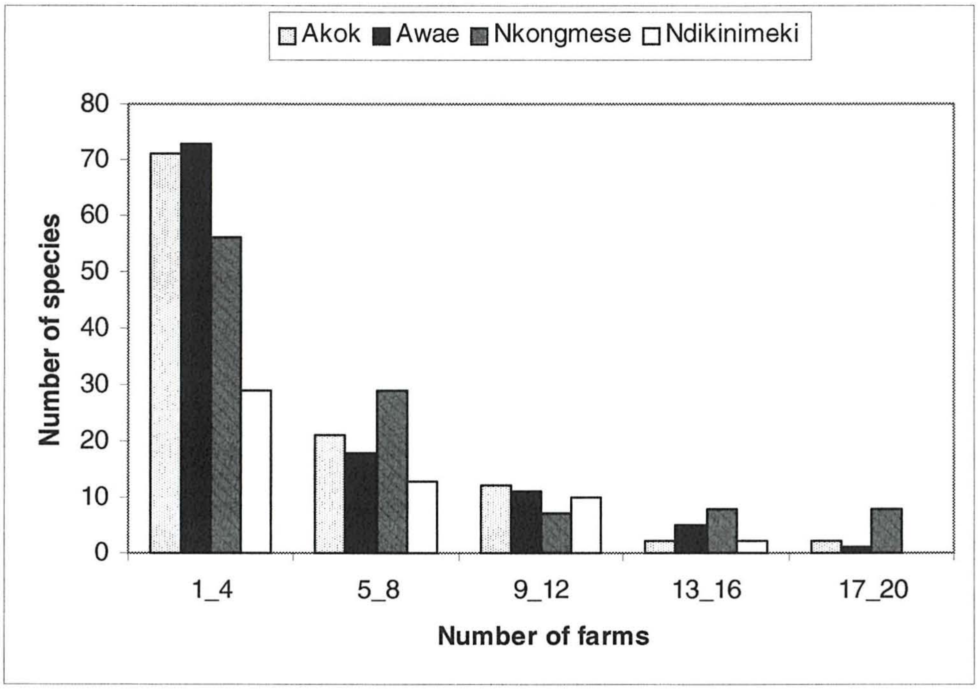
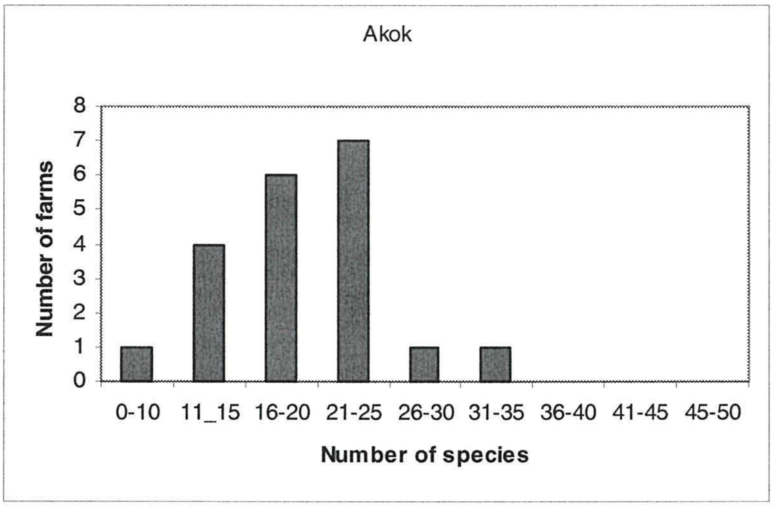
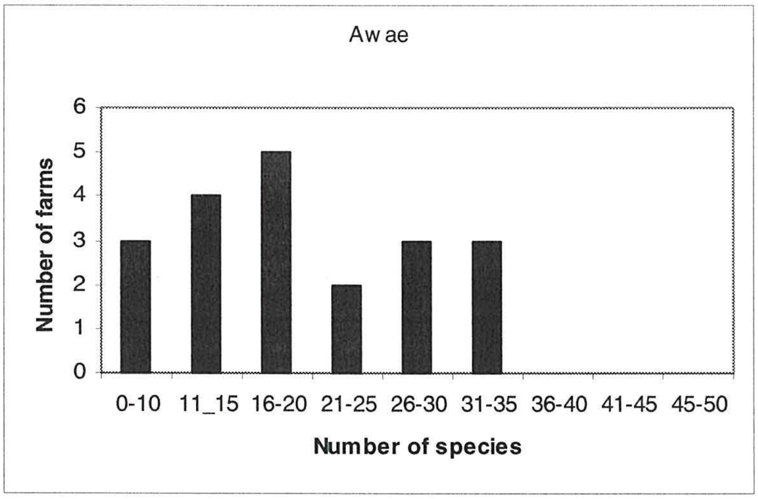


Figure 6.2 Distribution of the number of tree species classified by the number of farm on which they were found

The frequency distributions of farms classified by number of species found on them show that, except for Nkongmesse where the distribution is fairly normal, most cocoa farms in the other study locations have a low number of species (Figure 6.3). This is an indication that despite the apparent importance of tree diversity in the cocoa systems of southern Cameroon as a whole, the proportion of farms having a high level of species' diversity is low within locations. This tendency may even worsen in the years ahead due to the increasing disinterest that farmers develop towards cocoa because of a continuous decline in yields and unpredictable market prices. It is therefore feared that the tendency of introducing species of economic interest may be at the expense of indigenous species.


Akok
Number of farms
8
7
6
5
4
3
2
1
0
0-10
11_15
16-20
21-25
26-30
31-35
36-40
41-45
45-50
Number of species


Aw ae
Number of farms
6
5
4
3
2
1
0
0-10
11_15
16-20
21-25
26-30
31-35
36-40
41-45
45-50
Number of species

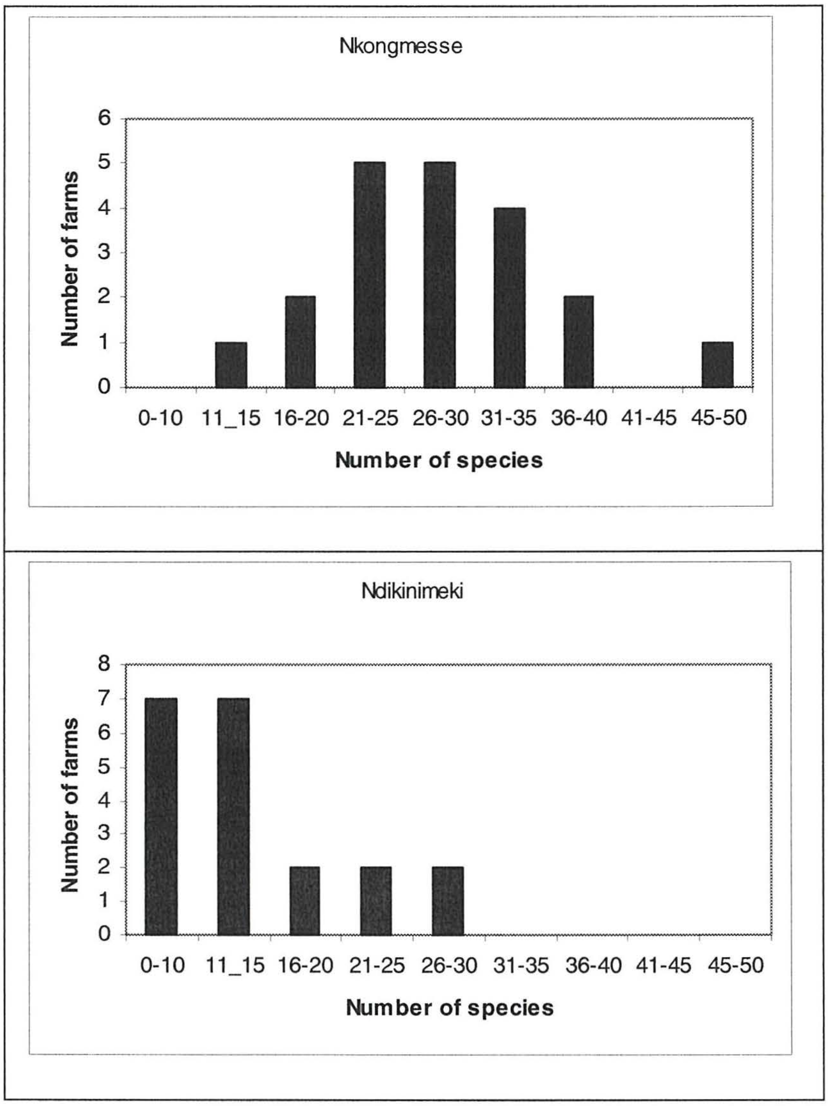


Figure 6.3 Distribution of the number of farms by the number of species found on them.

6.4 Discussion

6.4.1 Understanding farmers' rankings

6.4.1.1 Understanding farmers' rankings of species as indicators of farmland suitability

Farmers in Akok and Awae ranked trees similarly in terms of the extent to which they indicated suitability of land for cocoa while the rankings of farmers at Nkongmesse were somewhat different. This is contrary to expectations. Similar rankings would be expected for Awae and Nkongmesse because, unlike Akok, the other two locations belong to the same agroecological zone, though they differ in land use intensity. There are three possible reasons for differences in rankings amongst individual farmers and sites: 1) changes to the cocoa agroecosystems, 2) complexity in the process of knowledge conservation, and 3) lack of focus in evaluating functional attributes of non-cocoa tree species. Each of these is discussed in turn below.

6.4.1.1 1 Changes in cocoa agroecosystems

Changes to the cocoa agroecosystems stemming from the introduction of exotic tree species or enrichment with valued indigenous tree species could partly explain the differences observed in individual rankings. Indeed, the introduction of exotic species increases complexity. This may induce changes in the ecological functioning of some components and lead to a requirement for management strategies to adapt to the new circumstances. This highlights the dynamic nature of local knowledge systems as well as the need for acquiring new knowledge as production systems change. Local knowledge changing in response to technological shifts was evident from the initial knowledge acquisition (Section 3.3.4). The increasing introduction of fruit tree species and oil palm in the cocoa farms in Nkongmesse coupled to the numerous normal alterations that agroecosystems have undergone over time have led to a different approach to management of the system, with even more attention given to the fruit tree components because of their greater economic returns. In this respect, farmers need to consider the effects of non-cocoa trees on the productivity of fruit trees as well as cocoa.

6.4.1.1.2 Complexity in the process of knowledge conservation

The process by which local knowledge is conserved over generations is complex. This is partly because local knowledge is not usually systematically documented. It was noted previously (Section 3.3.5) that statements of knowledge provided by different informants demonstrate considerable erosion of ecological knowledge, with about half of the informants providing more than 60 statements (25%) and half less. This adds to the possibilities of having varied rankings within locations, because the appreciation of the effects of non-cocoa trees by some farmers may reflect the respondents' expectations, rather than their direct observations.

Moreover, the use of tree species as cocoa farmland suitability indicators is possibly an element of culture rather than a result of individual experience. This is because most cocoa farms in the study area have been inherited (Sanctoir, 1985, Diaw, 1997, Oyono, in press), meaning that the present owners did not participate in their creation, and consequently were not involved in the site selection. In addition, the destruction of some key indicator species by logging companies or by the slash and burn farming practice common in the area has reduced farmers' opportunities to use these species for decision making. However, some farmers can deduce among the existing species of their cocoa farms those having positive effects on the farmland suitability status for cocoa through the quality of the cocoa tree foliage and cocoa productivity around them. Here again, other factors not necessarily linked to farmland suitability prediction status of the species such as soil water content, soil structure or farm management may contribute to differences in individual rankings (see below).

6.4.1.1.3 Lack of focus in evaluating functional attributes of non-cocoa trees

During fieldwork, it was noted that sometimes farmers took into account other attributes of tree species, such as their competitiveness or status as a host for cocoa pests, when ranking them as indicators of land suitability. Ayous (*Triplochiton scleroxylon)* and Doum or Douma (*Ceiba pentandra*) were ranked lower in terms of indicating land suitability of cocoa at Nkongmesse than Awae or Acock because they were particularly undesirable at Nkongmesse. This is because they are thought to host capsids, and capsids are more of a problem at Nkongmesse than at the other two sites. Their ranking may be therefore more importantly influenced by that aspect, irrespective of any of other ecologically positive effects that could be attributed to these species.

6.4.1.2 Understanding farmers' rankings of soil water uptake characteristics and competitiveness with cocoa

Farmers' rankings for soil water uptake and competitiveness with cocoa for water were highly and positively correlated ($0.770 < r_s < 0.900$), indicating that the two concepts were not discrete. The initial expectation had been that farmers might recognise that some species that took up a lot of water might not compete so much with cocoa because they obtained the water from deeper than the cocoa roots. The rankings between species' farmland suitability prediction status and both soil water uptake status and competitiveness for soil water, were highly negatively correlated ($r_s < -0.730$), indicating that farmers associate high soil water uptake of trees with low farmland suitability.

Rankings of the uptake of soil water by tree species and competitiveness with cocoa for soil water were fairly similar across locations (Tables 6.3 and 6.4) but the rankings within locations showed many disparities amongst individual farmers. To understand the differences and the commonalities in the rankings within and across locations, the following aspects are considered below: 1) the farmers' ability to observe the process of plant water uptake, 2) variations in landscape position and soil types, 3) variations in tree density, 4) non-cocoa tree root distribution, 5) allelopathic function of species.

6.4.1.2.1 Farmers' observation methods

The process of soil water uptake by plants roots is complex, as are agroforestry systems in general and the cocoa systems of southern Cameroon in particular. Water is essential for plant growth and, as an inevitable consequence of opening their stomata to enable gaseous exchange during photosynthesis, plants transpire water, which they usually have to take up from soil (Sinclair, 2003). The rate of soil water uptake by plants will therefore depend on its content and availability. Many professional methods for estimating soil water content in different contexts and circumstances have been developed (Teixiera and Huwe, 2003), indicating the difficulty of finding simple tools for estimating soil water accessible to plants.

This is more critical at farmer level where, in addition to the complexity that characterises their cocoa systems, they lack adequate tools for assessing the process of soil water uptake by the major plant species components of the system. However, because they have to address issues related to system sustainability and productivity for which soil water management is a key point, they have developed methods adapted to their circumstances. Basically, these methods have to do with easily observable characteristics such as tree foliage shape or abundance of sap.

Generally, farmers hold that trees harbouring evergreen foliage throughout the year or for most of the year have a high soil water uptake rate. They also consider that the quantity of sap exuded by trees when stems or roots are cut is an indication of their rate of soil water uptake. The more sap exuded by a species, the higher its soil water uptake rate. To test this, they wound the tested tree (or cut a portion of its root if the species has a shallow rooting habit as is the case with Asseng (*Musanga cecropioides)* or Elon (*Erythrophloeum ivorense*)) and monitor the quantity of sap exuded.

One of the limitations of this test lies in the fact that all farmers do not base the assessment of the quantity of sap exuded on a rigorous method of quantification applicable by all. This may explain the disparities noticed among the individual rankings.

Another limitation of the two tests is that they do not reflect the physiological or biological processes occurring in the specific life cycle of the species concerned, which farmers do not usually consider, probably because they are not aware of them. Indeed, some species such as Andogo Ntangani (*Mangifera indica)* and Andok or Azanga (*Irvingia gabonensis)* will always harbour evergreen foliage for most of the year and sometimes throughout the year, irrespective of the amount of soil water absorbed. Ndamba (*Funtumia elastica)* will always exude abundant sap if wounded whatever the circumstances.

6.4.1.2.2 Landscape position and soil structure

It is obvious that to be used by plants, soil water has to be available. In this respect, landscape position and soil structure affect soil water content and availability, and, therefore, soil water uptake patterns. The water content of the soil represents the balance between processes that add water to the soil, such as infiltration of rainfall, and processes through which water is lost from the soil, such as plant water use (transpiration), evaporation, runoff and drainage (Sinclair, 2003). Among the above processes describing water dynamics in the soil, at least three are directly influenced by the landscape and soil structure, namely, infiltration of rainfall, runoff and drainage.

Sloping land may often lead to an unbalanced distribution of the content of soil water along its gradient because of runoff. The upper sections may have limited amounts of soil water for part of the year whilst in the lower parts or valleys, soil water may likely be available throughout the year. The water uptake of plants may reflect the soil water budget more than species differences in water uptake.

In applying the farmers' approach to testing soil water uptake rate by plant species through the amount of sap exuded from their roots at Akok, contrasting results were obtained in two stands of Asseng (*Musanga cecropioides)* at two different points of the landscape. More sap, which even formed drops, was exuded from the section of root of the stand in the lower part of the landscape, whilst the section of root from the upper part of the landscape only produced a film of sap on the section. These two situations explain how the content of soil water can influence a species rate of water uptake. Consequently, farmers at different positions in the landscape may have different classifications of species as regards soil water uptake. While this indicates the pertinence of the farmers' approach to observing plant water uptake, it also points to a need to get more insight into the complexity of resource management in an agroforestry system context where interactions amongst components may vary depending upon their landscape context.

The central role occupied by soil structure in the storage, availability, and mobility of soil water has been highlighted by many authors (Schroth 2003, Van Ranst 1983), and is well understood by farmers (see Section 5.3.1 of Chapter 5). Soil structure comprises the arrangement of individual particles of soil and is especially concerned with their aggregation, the resulting pore size distribution and the stability of the aggregated state (Payne 1988, Schroth 2003). For example, compact soils, because of the small pore size, will considerably reduce the infiltration rate of rainfall water, thus limiting the water content of lower soil layers and encouraging runoff. In contrast, sandy soils, because of their macro pores due to the larger size of their aggregates, will encourage rapid infiltration of water. The development of plant species organs in these two soil conditions is obviously different from those in balanced soil structure conditions because the availability of water to plants is not the same. Farmers with limited land resources who have to farm on such marginal land may appreciate the rate of water uptake by a species differently compared with farmers in areas with good soil structure and similar climatic conditions.

6.4.1.2.3 Non-cocoa tree density

The cocoa systems at the study locations are characterised by variations in tree densities within the farm (Section 3.3.2). Given the fact that all the various components of the system exploit resources from the same substrate at different rates, competition is inevitable, particularly where resources are limiting (Ong et al. 1996). This raises the issue of inter-specific competition for limiting resources where generally, some species may not fully meet their demands. In such cases farmers' classification, which is based on external signs, may reflect the environmental circumstance of his observations. In other words, in farms where non-cocoa trees are not abundant, the effect of the competition with cocoa for soil water will be less pronounced as compared to farms where the density of non-cocoa trees is higher.

6.4.1.2.4 Non-cocoa tree roots distribution

The spatial arrangement of plants, and the resulting segregation of root systems have been viewed as an indication of belowground competition (Nobel, 1997; Brisson and Reynolds, 1994). In Chapter 5 (Section 5.3.2.1), farmers portrayed the prominent position held by the non-cocoa tree root system architecture and distribution in the process of soil water management. One of the key conclusions they arrived at was that everything else being equal, species root architecture and distribution had an influence on the rate of soil water uptake, thus on the level of competitiveness with other species of the system for soil water.

How farmers could determine that level of competitiveness was a critical issue because they lacked appropriate tools and/or common methodology to arrive at that. As mentioned in Section 6.3.2.2.1, because farmers had to understand the process of soil water management in their farm, they had developed local assessment methods. These methods were based on an evaluation of cocoa growth rate, foliage colour and productivity of trees in different niches of the farm. This approach, though reliable, presents some important limitations. The process of water uptake by trees is complex and involves other considerations (see Sections 6.4.1.2.2 and 6.4.1.2.3) and each consideration may have its specificities. Furthermore, growth rate or the foliage colour may be influenced by other considerations such as cocoa tree age and health.

6.4.1.2.5 Allelopathic functions of species

Farmers identified some species of the system as having allelopathic attributes, thus leading to negative impact on cocoa growth. However, they could not substantiate this because in their perception, the boundary between competition for soil water and allelopathy was difficult to establish. Elon (*Erythrophloeum ivorense*) is a case in point. In cocoa farms where this species was found, there were few cocoa trees around, and when they did exist, their foliage was of low quality and their productivity almost zero. The soil moisture around the tree was also critically low. Farmers strongly held the view that the roots of this species were exuding a "poisonous ingredient" that inhibited the growth of other tree components around. To support their argument, they referred to the use of the bark of that species for the production of local agrochemicals and other cultural uses.

In summary, farmers' perceptions of factors affecting soil water content, and hence farmers' rankings of tree species soil water uptake are presented in Figure 6.3 below.

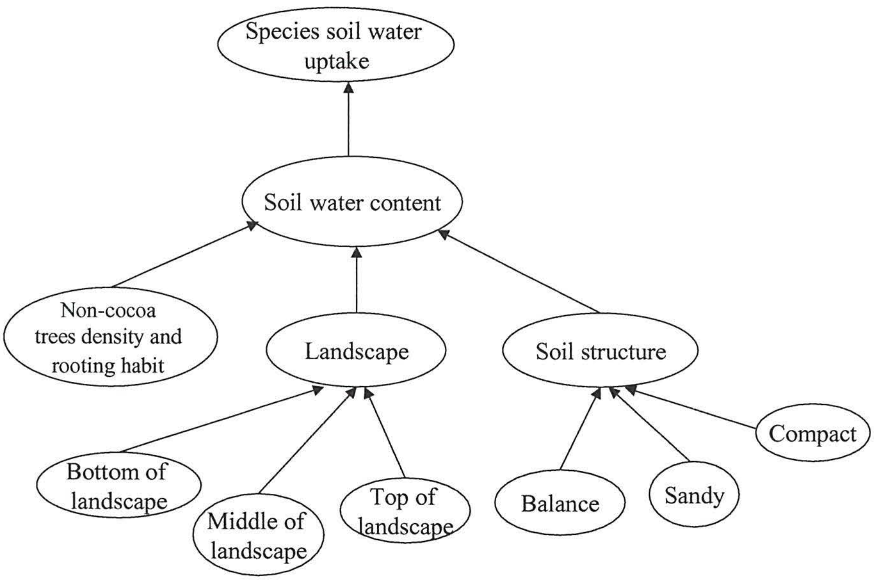


Figure 6.4 Diagrammatic representation of farmers' knowledge of the process of water uptake by trees.

6.4.2 Socio-economic assessment and species composition

6.4.2.1 Socio-economic assessment

Findings of the investigations on what non-cocoa tree species found on cocoa farms of the study area were used for, as well as their intensity of use (Tables 6.6 and 6.7), indicated that the main types of uses were contribution to subsistence needs and some locally marketable products. In this regard, the major products harvested or collected were timber, fuelwood, fruits, nuts, spices or poles. Tree products used for medicinal purposes also importantly contributed to ensuring first health care, especially in remote areas or for households with limited resources. Farmers said that the intensity of use of trees for timber or poles would have been more important than it is if the timber species were abundant. Indeed, as opposed to fruits, nuts, spices or oil, once harvested, the tree is lost, which affects availability. Therefore, trees destroyed by harvest have an extra pressure and would deserve special attention for conservation and/or domestication. In many cases, farmers expressed their willingness to acquire seedlings of such species or to be trained in how to produce them.

6.4.2.2 Species composition

In total, 165 non-cocoa tree species were inventoried in the cocoa systems of southern Cameroon. These figures are far less than those registered from both primary or secondary forests of the area, which range from 400 to 472 species, depending on the source[20]. Other studies (Zapfack et al., 2002) ranked cocoa systems fourth amongst the major land use systems displaying an important

[20] The figures presented have been compiled by the author of the thesis from results of inventories published by van Djik (1999), Vivien and Faure (1989, 1996) and ONADEF (1983, 1985).

proportion of the trees in southern Cameroon, after the primary forest, the secondary forest and old fallows. They also noted that, despite their low diversity indices, the cocoa farms were the most protected land use systems.

Species composition was more similar between the locations of Akok, Awae and Nkongmesse, in contrast, the similarities were lower between these locations and Ndikinimeki. These results were expected because the three locations showing similarities in term of species diversity belong to the same eco-region, and the majority of the cocoa farms were established long before the increased population density threats to the forest domain became a reality. In addition, the communities in the three locations have almost the same elements of culture and the agricultural practices are the same as well.

In contrast Ndikinimeki, which is situated at the forest-savanna transition zone, has a different ecology, characterised by a considerable limitation in species diversity. Moreover, farms in the area are relatively young and are generally managed by migrants mostly originating from the savanna zones of the high lands of western Cameroon, who do not usually perceive the value of tree species, as a forest dweller would do. This has led to more influence of those outsiders over the management options of these systems and subsequent negative impact on non-cocoa species diversity. They usually grow cocoa in the absence of shade and because of that, they have introduced various techniques of killing large trees with less damage to cocoa trees, while natives do not cut down the larger trees, at least not all of them. Similar cases have been reported in the Côte d'Ivoire where the strong Baoulé migrants moved from the savanna into the forest zone and determined not only the speed with which cocoa spread but also the way in which cocoa was grown (Ruf and Schroth, 2004).

Cocoa farms at Akok and Ndikinimeki locations appeared to be more homogeneous in term of species number (standard error of 1.29 and 1.37) than Nkongmesse and Awae (standard error of 1.66 and 1.93). The farm management practices recommended by the cocoa development parastatal SODECAO, which had great influence over cocoa farmers' management options in Akok, could partly explain this. Farmers in this location reported that SODECAO agents recommended a standard typology for cocoa farms, which consisted of considerably reducing shade in farms by suppressing as many non-cocoa trees as possible and applying fertilizer, in order to optimise cocoa trees resource use efficiency. This was not far from management techniques applied by migrants at Ndikinimeki location and discussed above. However, farmers at Akok diversely implemented the SODECAO recommendations because they were not supported with technical itineraries and material support for their application.

6.5 CONCLUSION

The use of tree species in the process of suitable farmland identification in general and cocoa farm establishment in particular is a long tradition among forest dwellers, which has survived over generations. Even though not all impacts of trees on soil fertility and soil water management are beneficial (competition, allelopathy), several studies have shown benefits (Woomer and Swift 1994, Schroth and Sinclair 2003, Teixeira et al. 2003). For example, recent studies on mycorrhizal associations with a reduced sample of tree species of the rain forest of southern Cameroon (Onguéné and Kuyper 2001) revealed positive correlations between farmers' preference for some species, soil conditions and the rate of their association with mycorrhizas. This suggests that there may be an underlying basis for farmer preferences.

Quantification of water uptake by plant species is important for understanding the processes of competition and complementarity in an agroforestry context. The methods used by farmers to address this issue are limited by challenges in adequately considering the environmental factors affecting the availability of soil water. This points to a need for more involvement of scientists in the selection of compatible species to maintain or introduce to the system.

Tree products harvested from non-cocoa tree species in the cocoa systems contribute an important portion to the livelihoods of local communities (Gockowski et al., 2004; Ngobo, 2002; Duguma et al., 2001; Aulong, 1998) They provide a wide range of products such as medicines, fruits, spices and vegetables, which poor farmers could not easily access if they had to pay for. However, some types of uses that require the removal of vital parts of the tree may be a threat to species survival. The low representation of some species in cocoa farms of the study area is also a matter of concern, as it may lead to a gradual loss of the species concerned. This calls for an urgent need to set up appropriate measures for the conservation or domestication of such species.

The similarities noticed in farmers' overall perceptions of ecological interactions between cocoa and non-cocoa species point to a possibility to establish a strong partnership between scientists and local communities to enhance the sustainability and productivity of cocoa systems in southern Cameroon, while fulfilling their immediate needs and rending environmental services. This can be achieved by adopting a selection procedure of species ecologically friendly to cocoa and economically attractive to local communities based on farmers' knowledge.

CHAPTER 7

GENERAL DISCUSSION AND CONCLUSION

7.1 GENERAL

The present study was about investigating and evaluating farmers' ecological knowledge and management of multistrata cocoa systems in southern Cameroon, and exploring possible grounds for effective partnership between farmers and scientists aimed at enhancing system sustainability and productivity. In this concluding chapter, key lessons that can be drawn from an appreciation of farmers' understanding of the processes taking place in their cocoa systems, as well as the implications of this understanding for targeting research and extension, are addressed.

One of the most important challenges reported by cocoa farmers in southern Cameroon is the continuous decline in cocoa farm yields over the past two to three decades. Farmers and scientists generally attributed this to increasing pressure from cocoa pests and diseases, especially mirids and black pod disease, and to soil fertility depletion. Other constraints were mentioned, including inappropriate planting material, inadequate farm management and inadequate socio-economic infrastructures and institutions.

7.2 IMPLICATIONS OF FARMERS' KNOWLEDGE FOR RESEARCH AND EXTENSION

A growing number of case studies conducted in recent years have suggested that farmers' knowledge could enhance the sustainability and productivity of agricultural systems in developing countries, if judiciously integrated with global science (Warren and Rajasekaran, 1993; Thrupp, 1989; Ettema, 1994; Sinclair and Walker, 1999). The relevance of this interest lies in the assumption that farmers' knowledge systems are generally based on trial-and-error problem-solving approaches by community members or individuals with the objective of meeting the challenges they face in their local environments and circumstances. In this respect, farmers in southern Cameroon have a long tradition of farming cocoa and have maintained their cocoa farms in continuous production over generations; therefore, their knowledge could be considered as a potent resource that could be tapped if participatory research strategies were followed.

7.2.1 Implications of farmers' knowledge for research on pests and diseases

The study provided insights into farmers' current knowledge about cocoa pests and diseases. Farmers articulated a substantial body of knowledge about factors influencing the occurrence and spread of cocoa pests and diseases, especially black pod disease and mirids, and the strategies they use for their control. Their approach to control can be broadly grouped into the following two management strategies

1. Management of microenvironmental conditions in the farm. Especially the humidity level that farmers said was linked to shade and weather.
2. Choice of cocoa cultivars. Local cocoa landraces were found to be pest and disease resistant but low yielding, whilst hybrid cultivars, though high yielding, were reported to be vulnerable to pests and diseases.

In this regard, farmers' knowledge of factors favouring the outbreak of cocoa pests and diseases is likely to be similar to what is known scientifically. Much more interesting was the nature of the descriptions and explanations provided by farmers about the attributes of associative trees and how these affect microenvironmental conditions in farm (see Section 4.3.2.3 of Chapter 4), indicating what Sinclair and Walker (1999) described as "explanatory aspects" of local knowledge. These explanations could significantly contribute to refining research and extension programmes. Possible research areas could be: i) developing selection criteria for associated non-cocoa tree species, ii) designing a lay out for rational arrangement of associated trees, iii) targeting breeding programmes on relevant cocoa cultivars and, iv) validating the use of plant extract-based pesticides and fungicides that farmers currently use.

7.2.1.1 Non-cocoa tree species selection

Most of the tree species (including fruit trees) maintained or introduced in the cocoa systems in southern Cameroon were not selected on the basis of their ability to display positive interactions with the cocoa component. Rather, many proved to contribute significantly to increasing shade level in the farm. In order to control shade level, research should develop selection criteria for tree ideotypes to be associated with cocoa, whose architecture should permit adequate air circulation in the farm and sufficient solar radiation getting to the understorey. Attributes of trees such as open crown architecture, sparse leaf area and tall tree height should be considered as they have proved to have considerable implications for shade level. This builds on the concept of associative tree ideotypes, much talked about in agroforestry (Wood and Burley, 1991) but rarely apparent in research and development efforts (Simons and Leakey, 2004). In this regard, farmers' knowledge of tree species commonly found in their cocoa farms could be used to complement scientific research by developing a local specification of associative tree ideotypes for cocoa.

7.2.1.2 Rationalisation and optimisation of tree spacing

Farmers in southern Cameroon adopted the structure of their cocoa systems with little or no input from global science. As mentioned in Chapter 4 (Section 4.4.2.1), cocoa systems in the study area are characterised by an uneven distribution of associated trees, leading to uneven shade levels across cocoa farms. In such conditions, heavily shaded patches of cocoa farms are likely to serve as reservoirs for development of cocoa pests or diseases and point sources for their spread. This points to a need to develop more even shade conditions. A possible practical way to achieve this could be through designing rational and optimal arrangements of both cocoa and associated trees in the farm to ensure appropriate level and distribution of shade across the farm.

The rationale of such research initiatives is supported by the fact that the existing literature on shade management in a cocoa system context is still to be clearly expressed; with some authors advising leaving the ultimate decision to farmers (Wood and Lass, 1985; Mossu, 1990; Brenner, 1996). However, given a specific set of conditions and objectives it is possible, with a full involvement of farmers in the research process, to make relatively accurate decisions as to how non-cocoa tree species can be efficiently managed along side cocoa trees.

7.2.1.3 Targeting breeding programmes on relevant cocoa cultivars

Farmers have identified one of the major reasons for the increased pressure of cocoa pests and diseases in southern Cameroon to be the susceptibility of the so-called "improved cocoa varieties" to these endemics. Indeed, scientists seem to have oriented their research programmes essentially towards developing high yielding cocoa varieties, whilst ignoring the crop protection aspects (Blaha, 1974). This was probably because the effects of pest and disease attacks were not as devastating as they are in current economical circumstances and possibly a mindset that expected that pest and disease problems could be addressed by chemical control. This points to a need to reorient research on breeding programmes towards the development of shade tolerant cocoa varieties, with high yield and pest and disease resistance. The outcomes of such research can help to considerably reduce management and maintenance costs of cocoa farms, thus encouraging farmers to be even more interested in cocoa farming activities.

7.2.1.4 Validation of the use of local plant extracts

An increasing number of farmers reported the use of local plant extracts to control cocoa pests and diseases in replacement of expensive manufactured agrochemicals. As mentioned in Chapter 4 (Section 4.4.2.3), besides the cost-effectiveness of this approach, their efficiency or possible toxicity to both human health and environment have not yet been scientifically assessed. Sonwa et al. (2002) reported that some farmers in southern Cameroon, who have used these, indicated possible harmful effects on human health. This points to a need for scientific assessment of the plant extracts used by farmers and to determine the context for their use. Similar studies have been carried out in South Africa in relation to plant protection, using extracts of *Guibourtia tessmannii* (Nyemba et al., 1995) or *Warburgia salutaris* (Drewes et al., 2001). This is an effective method of using available knowledge to target research. Such initiatives should consider how the original group providing the knowledge benefit from it by setting mechanisms to protect ethics and local intellectual property rights (IPR).

7.2.2 Enhancing system sustainability and productivity

Enhancing system sustainability and productivity requires an understanding of both above and belowground interactions occurring between the various components of cocoa production systems. The relevance of this approach lies in the fact that plants growing close together are subject to competition, complementarity[21] or facilitation[22] (Schroth et al., 2003). These types of interaction, especially competition, are particularly pronounced in a complex tropical context where resources (light, water and nutrients) are usually limiting factors to production and opportunities to manipulate the environment using agrochemicals are constrained by high cost and lack of availability.

This study revealed farmers' awareness of the fact that understanding and managing interactions between the various plant species was critical for enhancing system sustainability and productivity. However, farmers articulated more comprehensive knowledge about aboveground than belowground interactions (see Chapter 3, Sections 3.3.2 and 3.3.3). This may be attributed to the fact that aboveground interactions can be more easily observed and so farmers can more readily develop and test various management strategies. In contrast, belowground interactions are more complex and less visible, leading to both farmers and scientists having less well developed understanding of their function and consequently a less well developed suite of management interventions.

[21] Complementarity between two interacting species means that the use of a resource by one species is not at the expense of the use of this resource by the other species (Schroth, 2003).
[22] Facilitation means that one species actually improves the growth conditions of the other species (Schroth, 2003).

Given the central role of soil resources in subsistence production, it becomes imperative for research to thoroughly understand belowground interactions, mainly in terms of soil water and nutrient management. The need for research to urgently address issues related to facilitative belowground interactions and complementarity in resource use among the major plant species in a system without incurring a lot of competition has been expressed by many authors (Anderson and Sinclair, 1993; Sinclair et al., 1994; Ettema, 1994; Teixeira et al., 2003). Some of the research areas having potential for enhancing cocoa system sustainability and productivity are: i) species rooting patterns, ii) studies on allelopathic interactions and, iii) introduction of livestock to cocoa systems.

7.2.2.1 Species rooting patterns

A key component to understanding the belowground interactions that occur in a cropping system is the species root systems, because root growth and distribution determine the extent of soil resource capture, and thus the sustainability and productivity of the system (Van Ranst, 1983; van Noordwijk and De Willigen, 1991; Akinnifesi, 2004; Buresh, 2004). Therefore, the use of soil resources can be optimised and belowground interactions minimised, through the combination of species that exploit different soil layers via their root systems. In this regard, farmers distinguished between tree species with a shallow rooting habit as potentially highly competitive with other crop components for soil resources, and tree species with a deep rooting habit as generally not only being less competitive, but also possibly facilitating the uptake of available soil resources by other plant species in the system.

This is consistent with what has been suggested by many scientists (Laycock and Wood, 1963; Schroth et al., 1996; Jama et al., 1998). According to these authors, tree species selection according to root characteristics may consider criteria such as the ability to rapidly develop a deep root system for nutrient recycling from subsoil, restricted lateral root development to reduce competition with other crop components, or a large root mass for physical improvement of compact subsoil.

However, such simplification of the implications of species root system distribution for soil resource management cannot be systematically generalised. Farmers have reported cases of species with well developed lateral roots such as, *Ceiba pentandra, Musanga cecropioides and Uapaca guineensis,* but with positive impacts on soil fertility and soil moisture around them, as well as deep rooting trees such as *Treculia africana* and *Erythrophloeum ivorens* that have negative impacts on soil fertility. Also, basing selection of tree species to maintain or introduce in a cocoa system, only on their rooting habit may not necessarily meet the expectations of the majority of farmers as this may lead to rejecting some species of interest such as *Dacryodes edulis* or *Mangifera indica*, which although shallow rooting are of extremely high importance for household livelihood. Therefore, other species selection criteria such as socio-economic features of the species should be considered.

As Sanchez remarked (in Franzel et al., 1996), the relatively small scientific knowledge base on indigenous multipurpose trees makes estimation of the possible effects of research efforts more difficult than for agricultural commodities. Given trade-offs that farmers are presently making when integrating trees with cocoa suggests that research could usefully focus on addressing the following key constraints.

- Assessment of impacts of the most common tree species root systems on the uptake of water and nutrients from the soil, and their plasticity in response to management interventions such as shoot and root pruning. This research is especially important for fruit trees or other high value tree species that farmers may be interested in domesticating because they can derive income from them or because the tree contributes to meet their subsistence needs (timber, medicinal, fuel or wood).
- Effects of root systems on soil properties, including physical properties (desegregation of compact horizons to facilitate soil aeration and water movement) or chemical properties (nutrient recycling, beneficial association with living organisms as is the case with mycorrhizal associations).
- Development of breeding programmes for producing associative tree species of interest with root system structures that favour complementarity or facilitation processes, or reduce competition for soil resources, whilst maintaining their productivity potential.

7.2.2.2 Studies on allelopathic interactions

Farmers mentioned the existence of some plant species that inhibit the growth of other species in their immediate surroundings. *Pachypodanthium stautii* or *Antiaris welwitshchii* are some examples reported. However, it was not clear whether this "exclusion" of other crop components happened as a result of competition, or through the release of toxic compounds from these plants. Therefore, it seems sensible that the allelopathic compatibility of trees, or crops with trees should be checked before they are introduced to cocoa systems. Some recent findings have indicated that allelopathic effects of trees may be selective and may positively or negatively influence growth, behaviour, productivity and survival of associated species (Bhatt and Todaria, 1990; Kim et al., 1999).

Research to investigate allelopathic influences of controversial non-cocoa plant species on cocoa or associated components of interest, particularly those to be introduced to the system, is therefore essential. Such research should not only focus on species that stimulate or inhibit the growth of neighbouring components of the system, but also on species having selective suppressive effects on weeds. It can be anticipated that biocontrol of weeds could contribute to significantly reducing labour required to control weeds in cocoa. Farmers' knowledge of plant species interactions could constitute a potent source of information for developing such research activities.

7.2.2.3 Domestication of indigenous tree species of interest and their integration into the cocoa production system

Opting for rationalisation and optimisation of tree spacing inevitably leads to removal and replacement of undesired species or introduction of species of interest. Farmers should, therefore, be provided with planting material to that effect. At present, farmers do not generally possess the technical ability to propagate seedlings of desired species and usually rely on natural regeneration. Proceeding in this manner leads to restrictions on the number of trees present, their species richness and their distribution across the farm. Yet, farmers at the study area expressed interest in introducing multifunctional indigenous non-cocoa species to their farms to enhance sustainability, provide an alternative source of income and maximize biodiversity. Such species include: Adjad *(Baillonella toxisperma),* Abang *(Milicia excelsa),* Eyen

(Distemonanthus benthamianus), Asse *(Entandrophragma cylindrical),* Eteng *(Pygnanthus angolensis),* Akom *(Terminalia superba)* and Ayous *(Triplochiton scleroxylon).*

ICRAF and other research institutions have developed numerous techniques for propagation of species with potential for domestication and inclusion in the cocoa systems of the region (Duguma et al., 1990; Okafor and Lamp, 1994; Franzel et al., 1996). This points to a need to re-evaluate and adapt these propagation techniques to farmers' circumstances in a way to develop a self-reliance amongst farmers for the domestication of desired tree species, rather than depending on research institutions or external providers. Such an approach has been successfully developed with rubber farmers in Jambi, Indonesia to produce rubber seedlings for gap replanting in their jungle rubber agroforests (Joshi, 2001[23]).

7.2.2.4 Introduction of livestock to cocoa systems

Farmers have always raised the issue of low cocoa yields due to low soil fertility or soil fertility depletion across the study locations. Given farmers' limited access to manufactured fertilisers, it becomes essential to find cost-effective ways to improve on the fertility status of soils under cocoa. As mentioned in Chapter 2 (Section 2.2.3.5), the interactions amongst crops, livestock and environment are underdeveloped in the study area; meanwhile animal manure could contribute a great deal to the recycling of soil nutrients, while controlling weeds. Introducing livestock to cocoa farms, especially herbivores may, therefore, significantly enhance both their productivity and

[23] Field visit demonstration during a workshop organised in Muara Bungo, Jambi, Indonesia, 3-6 September 2001 on the theme: "Complex agroforests: Farmer knowledge, Profitability and Conservation".

profitability. Such managerial schemes are being successfully applied to other cash crop systems with oil palm (*Elaeis guineensis*) and rubber (*Hevea brasiliensis*) in Cameroon (CDC, SOCAPALM) and elsewhere in the world at either individual farm or company estate levels (Joshi 2001, personal communication).

Research activities to be initiated for the introduction of livestock to cocoa systems may amongst others consider the following aspects:

- selection or development of shade-tolerant fodder that would not interact negatively with other components of the cocoa system;
- assessment of impacts of grazing cattle on soil physical properties such as compaction, water infiltration, and root development;
- assessment of the effects of the application of fungicides and insecticides to cattle health;
- timing of the grazing period to avoid the destruction of cocoa production organs by livestock

In conclusion to this section, it should be noted that research programmes on cocoa in Cameroon, and even in many specialised research institutions elsewhere, have been developed around particular disciplines such as phytopathology, entomology or agronomy, rather than considering a broader approach encompassing associated domains to solving a particular problem or constraint. As a consequence, this has usually led to contradictory messages being delivered to farmers, reinforcing their scepticism towards innovations and complicating the task of extension workers. For example, whilst cocoa phytopathology specialists recommend a considerable reduction of the shade level in the farm to avoid severe outbreaks of black pod disease, entomologists warn against possible large increases in pest numbers as a result of low shading.

This points to an urgent need to take a holistic approach to research on issues related to cocoa systems sustainability and productivity, which integrates contributions from existing research units and extension workers, rather than addressing them separately as is the case currently. This does not necessarily mean undermining the activities of existing specialised research units, but rather bringing them together in a way to come out with a coherent package of innovations.

7.3 KEY LESSONS LEARNED AND RECOMMENDATIONS

7.3.1 Farmers' knowledge of tree species and biodiversity conservation perspectives

The fact that farmers exhibited a good understanding of the ecological functions and socio-economic uses of tree species may explain their strong attachment to conservation of tree diversity. In this regard, farmers generally consider cocoa systems as the most secure area for endangered tree species or species of interest, especially in locations with land pressure. This is probably one of the reasons why cocoa systems of southern Cameroon are considered as a reservoir for tree diversity conservation as compared to other farming systems.

However, the analysis of Figures 6.3 and 6.4 (see Chapter 6 – Section 6.3.2.2.3) raises concerns. Indeed, the majority of non-cocoa tree species inventoried (53 to 67% according to locations) are represented in less than 20% of cocoa farms, indicating their low representation at farm level. In the long run, there is a fear that poorly represented species may no longer be found in cocoa system habitats. Among the species concerned are mostly those of high socio-economic interest such as *Terminalia superba, Tetrapleura tetraptera, Entandrophragma cylindrica, Piptadeniastrum africanum, Lophira alata, Erythroxylon manii, Cola acuminata,* and *Distemonanthus benthamianus*.

The attachment of farmers to tree diversity does not necessarily imply their commitment to conserving those species. Because of their low resource status, farmers often carry out destructive actions even on endangered species to fulfil immediate household needs. This calls for an urgent setting up of appropriate initiatives aiming at:

- re-enforcing farmers' conservation capacities by developing participatory conservation strategies adapted to a cocoa agroforest context;
- enlarging the list of protected plant species that is presently limited to a few timber species, to endangered species still found in some cocoa farms;
- reducing the risk of having the henceforth "protected plant species" destroyed by farmers through the creation of an incentive for protection of those; this may increase farmers' commitment to biodiversity conservation.

7.3.2 Local knowledge erosion

Local knowledge systems have often been communicated through "oral traditions" and learned from family or community members over generations (Warren, 1987, 1991; Thrupp, 1989). As a consequence, local knowledge has not been stored in a systematic way, with the implicit danger it may become degraded over time. In the case of cocoa farmers in southern Cameroon, this is noticeable in the uneveness in the amount of knowledge contributed by various informants (about half of the informants contributed less than 25% of the statements in the documented local knowledge base).

In this regard, there is an urgent need for effective mechanisms for recording and documenting farmers' knowledge not only on cocoa systems, but also on any specified plant species, so that it can be accessible to farmers who do not have this information, the development community and to global science. The AKT5 system approach used in the present study is a valuable tool to achieve that. The methodology has been used successfully in a number of projects in Asia, Africa and Latin America and has been adopted globally by the World Agroforestry Centre (ICRAF) (Dixon et al, 2001). Other initiatives such as establishing regional and/or national farmers' knowledge resource centres within the existing research structures can be envisaged. Their mandate could include the following functions.

- Provision of a regional and/or national data management pool where information on local knowledge systems are systematically recorded and documented for use by researchers and the development community. This would necessitate training targeted staff of the national research institutes and universities, or of any relevant structure.

- Comparison of local knowledge systems about any crop across the various regions and identification of the reasons for existing differences. Generalisation of knowledge acquired from different sources or regions and its dissemination. This may contribute to facilitate effective communication amongst stakeholders.
- Comparison of local knowledge systems with global science to identify possible gaps in knowledge between the two systems, and define research and extension priorities based on analyses of these.
- Establishment of links with other existing similar institutions, research institutes and universities for effective exchange of information and programmes.

7.4 GENERAL CONCLUSION

The present study has shown that farmers in southern Cameroon possess detailed knowledge of ecological processes occurring in their cocoa farms and have developed coherent and valuable management strategies adapted to their circumstances. Most of the findings of the present study demonstrate that farmers' knowledge of the process investigated was similar to what is known scientifically. Much more remarkable was their understanding of cocoa pest and disease occurrence and the cost-effective management strategies developed, as well as their approach to the selection of suitable farmland sites for establishing cocoa farms. The study also demonstrated that farmers were using their cocoa systems as a reservoir of tree diversity conservation in the absence of any assistance from specialised institutions. This is because they have developed good knowledge of the ecological functions of non-cocoa tree species, and domestic uses of their products, and have integrated this in making management decisions for their farm.

How could local and global scientific knowledge be linked to improve the success of co-operation in developing and implementing sustainable and productive cocoa systems in southern Cameroon? On the basis of this study, it may be anticipated that global science, especially research institutions and extension services, would gain from an explicit evaluation, validation and incorporation of pertinent portions of farmers' knowledge into their research programmes. In this respect, Thrupp (1989) suggests that in order to validate farmers' knowledge, it should not be necessary to measure and "scientise" it in terms of formal Western methods and scientific principles, since the value of such knowledge has been proved over centuries and scientific systematisation may misinterpret the cultural value and subtle complex nuances of these knowledge systems. A more productive way forward is to seek to share knowledge amongst local and scientific traditions. This requires effective means of communication that respect both knowledge systems and that allow farmers access to science, but on their own terms, so that they can draw down and integrate only those elements of scientific knowledge that they want into their production systems.

There is much to be learned from local knowledge of farmers in southern Cameroon about ecology and management of cocoa systems, if we are to move from the conventional delivery of innovation packages towards interactive technology development. The hope for sustainable and productive cocoa systems in southern Cameroon rests on the effectiveness of the integration of global science and local knowledge rather than reliance on one tradition at the expense of the other. As local knowledge is being eroded, knowledge-based systems appear to be a valuable tool in providing a framework to document this valuable area of knowledge and make it accessible to many users.

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Appendix 1 Farmers' perceptions of the uses of some non-cocoa tree species of their cocoa systems. Key to codes use: Ft = fertility value; Fr = fruit value; Dr = drink value; Nu = nuts value; Tb = timber value; Fw = fuel wood value; Sp = spices value; Sh = shade value; Ol = oil value; Me = medicinal value.

Botanical names	Local names	Uses	Botanical names	Local names	Uses
Afzelia pachiloba	Mbanga afum	Tb, Fw, Sh.	*Ficus mucuso*	Toll, posses	Tb, Fw, Sh, Ft, Me.
Albizia adianthifolia	Sayeme	Fw, Sh, Me.	*Funtumia africana*	Metondo	Sh
Albizia ferruginea	evouvous	Tb, Sh, Ft	*Funtumia elastica*	Ndamba	Fw, Sh
Albizia glaberrima	Essak	Fw, Sh, Ft	*Grewia brevis*	Evie	Fw, Sh, Ft
Albizia zygia	Eyem Hypok	Tb, Fw, Sh	*Hylodendron gabunense*	Mvanda	Tb, Fw, Sh
Alstonia congensis	Akouk	Fw, Sh, Ft, Me	*Irvingia gabonensis*	Andok, Azanga	Fr, Fw, Sp, Sh, Ft, Me.
Antiaris welwitschii	Alogo, Aloa	Sh	*Lophira alata*	Okoga, Bongossi	Fw, Sh, Ft, Me
Antrocaryon klaineanum	Otengui, Agongi, Etambale	Fr, Tb, Fw, Sh, Ft	*Maesopsis eminii*	Nkanga	Tb, Fw, Sh, Fr.
Baillonella toxisperma	Adjab	Tb, Fw, Sh, Ft, Ol	*Mangifera indica*	Andogo ntangani, Poungol	Fr, Fw, Sh, Me
Beilschmiedia obscura	Zolebi, Zoule	Fw, Sh	*Margaritaria discoidea*	Ebeng, Ebebeng	Fw, Sh
Bosqueiopsis angolensis	Otomba afum	Fw, Sh	*Microberlinia bisulcata*	Alen Ele, Zingana	Tb, Fw, Sh, Ft
Carica papaya	Popo, Fofo	Fr, Me	*Morinda lucida*	Akeng	Fw, Sh, Ft, Me
Carpolobia lutea	Onong	Fw, Sh, Me	*Musanga cecropioides*	Asseng, Esseng, Pokomba	Fw, Sh, Ft, Me
Ceiba pentandra	Doum, Douma, Nioum	Tb, Fw, Sh, Ft, Me	*Musa paradisiaca*	Ekoan	Fr, Ft, Me
Citrus reticulata	Mandarin	Fr, Dr, Fw	*Myrianthus arboreus*	Angekong	Fw, Sh, Ft
Citrus sinensis	Afoumbi, Opouma, Pofoma	Fr, Dr, Fw	*Pachypodanthium staudtii*	Ipilemess	Sh, Me
Coelocaryon preussii	Ekoman, Nom Eteng	Fw, Sh, Ft	*Parinari chrysophylla*	Iloloponi	Fw, Sh, Ft
Cola acuminata	Abel	Fr, Me	*Pentaclethra macrophylla*	Ebai, Ebaye	Fw, Sh, Me.

Cordia platythyrsa	Ebe	Tb, Sh, Ft, Fr	*Persea americana*	Fia, Pia, Puopi	Fr, Fw, Sh, Me.
Coula edulis	Kome, Ewome	Fr, Nu, Fw, Sh, Ft, Me	*Piptadeniastrum africanum*	Atui	Tb, Fw, Sh,
Dacryodes edulis	Assa, Pouti	Fr, Sh, Me	*Pycnanthus angolensis*	Eteng	Tb, Fw, Sh, Ft, Me.
Desbordesia glaucescens	Omang	Tb, Fw, Sh	*Ricinodendron heudelotii*	Njangsang, Ezezang, Ndangsang	Fr, Nu, Fw, Sp, Sh, Ft, Me
Distemonanthus benthamianus	Eyen	Tb, Fw, Sh	*Schrebera arborea*	Obang	Fw, Sh
Elaeis guineensis	Alen, Elen, Nipile	Fr, Dr, Nu, Ol, Me.	*Spathodea campanulata*	Evovone	Sh, Ft
Entandrophragma cylindrica	Asse, Possa	Tb, Fw, Sh, Ft	*Lannea welwitschii*	Ekoa	Tb, Fw, Sh
Eribroma oblongum	Edjong, Eyong	Tb, Fw, Sh, Ft,	*Symphonia globulifera*	Osse	Tb, Sh
Erismadelphus exsul	Itieti, Afobilobi	Sh, Ft	*Terminalia superba*	Akom, Pouledi	Tb, Fw, Sh, Ft, Me.
Erythrophloeum ivorense	Elon, Etom	Tb, Sh, Me	*Tetrapleura tetraptera.*	Possakssak, Akpa	Tb, Fw, Sh, Sp
Erythroxylum mannii	Landa	Tb, Fw, Sh, Ft	*Treculia africana*	Etoup	Fr, Fw, Sh
Ficus exasperata	Akol	Tb, Fw, Sh, Ft, Me.	*Triplochiton scleroxylon*	Ayous, Adjos, Hilel	Tb, Fw, Sh
Milicia excelsa	Abang, Pookombe	Tb, Fw, Sh, Ft	*Voacanga sp*	Mviekam, Pondong	Sh
Zanthoxylum heitzii	Opong, Olon	Tb, Fw, Sh, Ft	*Musa sapientum*	Ekoan	Fr, Ft, Me
Zanthoxylum tessmannii	Bongo	Tb, Fw, Sh	*Uapaca guineensis*	Assam	Tb, Fr, Fw, Ft
			Vitex ciliata	Ewolo, Poneng	Fw, Sh

Appendix 2 Farmers' ranking of 65 tree species commonly found in their cocoa systems according to their shade value for cocoa. Ad = Adequate; Md = Moderate; UAd = Unadequate.

Botanical names	**Local names**	**Shade value**
Albizia ferruginea	Evouvous	Ad
Albizia glaberrima	Essak	Ad
Antrocaryon klaineanum	Otengui, Etambale	Ad
Baillonella toxisperma	Adjab	Ad
Ceiba pentandra	Doum, Douma, Nioum	Ad
Coelocaryon preussii	Ekoman	Ad
Cordia platythyrsa	Ebe	Ad
Coula edulis	Kome	Ad
Entandrophragma cylindrica	Asse, Possa	Ad
Eribroma oblongum	Edjong	Ad
Erismadelphus exsul	Itieti	Ad
Erythroxylum mannii	Landa	Ad
Ficus exasperata	Akol	Ad
Ficus mucuso	Toili, posses	Ad
Irvingia gabonensis	Andok, Azanga	Ad
Lophira alata	Okoa	Ad
Maesopsis eminii	Nkanga	Ad
Maranthes chrysophylla	Iloloponi	Ad
Microberlinia bisulcata	Alan	Ad
Milicia excelsa	Abang, Pookombe	Ad
Morinda lucida	Akeng	Ad
Musanga cecropioides	Asseng, Esseng, Pokomba	Ad
Myrianthus arboreus	Angekong	Ad
Parinari chrysophylla	Iloloponi	Ad
Pentaclethra macrophylla	Ebai	Ad
Piptadeniastrum africana	Atui	Ad
Pycnanthus angolensis	Eteng	Ad
Ricinodendron heudelotii	Njangsang, Ezezang, Ndangsang	Ad
Spathodea campanulata	Evovone	Ad
Symphonia globulifera	Osse	Ad
Terminalia superba	Akom, Pouledi	Ad
Treculia africana	Etoup	Ad
Zanthoxylon heitzii	Opong	Ad
Afzelia pachiloba	Mbanga afum	Mo
Albizia zygia	Eyem Hypok	Mo
Alstonia congensis	Akouk	Mo

Beilschmiedia obscura	Zolebi	Mo
Bosqueiopsis angolensis	Otomba afan	Mo
Desbordesia glaucescens	Omang	Mo
Distemonanthus benthamianus	Eyen	Mo
Erythrophleum ivorense	Elon, Etom	Mo
Funtumia africana	Metondo	Mo
Funtumia elastica	Ndamba	Mo
Lannea welwitschii	Ekoa	Mo
Nesogordonia papaverifera	Ewoua	Mo
Persea americana	Fia, Pia, Puopi	Mo
Schrebera arborea	Obang	Mo
Triplochiton scleroxylon	Ayos, Adjos, Hilel	Mo
Uapaca guineensis	Assam	Mo
Vitex ciliata	Ewolo, Poneng	Mo
Voacanga sp	Mviekam, Pondong	Mo
Zanthoxylum tessmannii	Bongo	Mo
Albizia adianthifolia	Sayeme	UAd
Antiaris welwitschii	Aloa	UAd
Carpolobia lutea	Onong	UAd
Citrus reticulata	Mandarin	UAd
Citrus sinensis	Afoumbi, Opouma, Pofoma	UAd
Cola acuminata	Abel	UAd
Elaeis guineensis	Alen, Elen, Nipile	UAd
Hylodendron gabunense	Mvanda	UAd
Mangifera indica	Andogo ntangani, Poungol.	UAd
Margaritaria discoidea	Ebeng	UAd
Pachypodanthium staudtii	Ipilemess	UAd
Tetrapleura tetraptera.	Possakssak	UAd

Appendix 3 Farmers' knowledge about ecological attributes of some tree species commonly found in the cocoa systems.

Botanical name	Local names	Functional attributes
Afzelia pachylloba	Mbanga afum	Shallow rooting habit, tall tree, small leaf area, wide and open crown, low leaf litter decomposition rate, high rate of water absorption, low fertility value.
Albizia adianthifolia	Sayeme	Shallow rooting habit, short tree, open crown, small leaf area, low leaf litter decomposition rate, and high rate of water absorption, low fertility value.
Albizia ferruginea	Evouvous	Deep rooting habit, tall tree, wide and thick crown shape, big leaf area, abundant leaf litter with high leaf decomposition rate, high fertility value.
Albizia glaberrima	Essak	Deep rooting habit, tall tree, wide and thick crown shape, big leaf area, abundant leaf litter with high leaf decomposition rate, high fertility value.
Albizia zygia	Eyem Hypok	Shallow rooting habit, short tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, branches susceptible to damage, low fertility value.
Alstonia congensis	Akouk	Deep rooting habit, tall tree, wide and open crown, intermediate leaf area, abundant leaf litter with high decomposition rate, fertility value.
Antiaris welwitschii	Alogo, Aloa	Shallow rooting habit, wide and thick crown, small leaf area, abundant leaf litter with low decomposition rate, allelopathic function, high water absorption rate, low fertility value.
Baillonella toxisperma	Adjab	Deep rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, fertility value.
Beilschmiedia obscura	Zolebi, Zoule	Shallow rooting habit, narrow and open crown, small leaf area, low leaf litter decomposition rate, allelopathic function, high water absorption rate, low fertility value.
Bosqueia angolensis	Otomba afum	Shallow rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with low decomposition rate, high water absorption rate, low fertility value.
Carica papaya	Popo, Fofo	Shallow rooting habit, short tree, parasol leaf shape, narrow and open crown shape, low leaf decomposition rate, high rate of water absorption, low fertility value.
Carpolobia lutea	Onong	Shallow rooting habit, tall tree, wide and open crown, small leaf area, low leaf litter decomposition rate, high rate of water absorption, low fertility value.
Ceiba pentandra	Doum, Douma, Nioum	Shallow rooting habit, very tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, branches susceptible to damage, high fertility value. Host for cocoa pests.
Citrus reticulata	Mandarin	Shallow rooting habit, short tree, open crown, small

		leaf area, low rate of leaf litter decomposition, high rate of water absorption, low fertility value.
Citrus sinensis	Afoumbi, Opouma, Pofoma	Shallow rooting habit, short tree, open crown, small leaf area, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Coelocaryon preussii	Ekoman, Nom Eteng	Deep rooting habit, tall tree, big leaf area, wide and thick crown shape, abundant leaf litter and high decomposition rate, high fertility value.
Cola acuminata	Abel	Shallow rooting habit, short tree, big leaf are, narrow and thick crown shape, low leaf litter decomposition rate. Host for cocoa pests.
Cordia platythyrsa	Ebe	Deep rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high fertility value.
Coula edulis	Kome, Ewome	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high leaf decomposition rate, high fertility value.
Dacryodes edulis	Assa, Pouti	Shallow rooting habit, short tree, intermediate leaf area, wide and thick crown abundant leaf litter with low rate of decomposition, low fertility value.
Desbordesia glaucescens	Omang	Shallow rooting habit, tall tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, and low fertility value.
Distemonanthus benthamianus	Eyen	Shallow rooting habit, tall tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, low fertility value, allelopathic function.
Elaeis guineensis	Alen, Elen, Nipile	Shallow rooting habit, short tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Entandrophragma cylindrica	Asse, Possa	Deep rooting habit, tall tree, big leaf area, wide and thick crown, high leaf litter decomposition rate, high timber value, high fertility value.
Entrocaryon klaineanum	Otengui, Agongi, Etambale	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, high fertility value.
Eribloma oblongum	Edjong, Eyong	Deep rooting habit, short tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high fertility value.
Erismadelphus exul	Itieti, Afobilobi	Deep rooting habit, tall tree, small leaf area, open crown, alternative host for mirids, abundant leaf litter with high rate of decomposition, high fertility value.
Erythrophloeum ivorense	Elon, Etom	Deep rooting habit, very tall tree, open crown, small leaf area, low leaf litter decomposition rate, high rate of water absorption, low fertility value. Host for cocoa pests.
Erythroxylum mannii	Landa	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, fertility value.
Ficus exasperata	Akol	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate
Ficus mucuso	Toll, posses	Deep rooting habit, tall tree, wide and open crown, big leaf area with high leaf litter decomposition rate,

		high fertility value.
Funtumia africana	Metondo	Shallow rooting habit, tall tree, wide and open crown, big leaf area, low leaf litter decomposition rate, low fertility value.
Funtumia elastica	Ndamba	Shallow rooting habit, tall tree, open crown, small leaf area, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Grewia brevis	Evie	Deep rooting habit, tall tree, small leaf area, wide and thick crown, abundant leaf litter with low decomposition rate, fertility value.
Hylodendron gabonnense	Mvanda	Shallow rooting habit, short tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Irvingia gabonensis	Andok, Azanga	Deep rooting habit, tall tree, intermediate leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high fruit value, high fertility value.
Lannea welwitschii	Ekoa	Deep rooting habit, short tree, wide and open crown, big leaf area, abundant leaf litter with high leaf decomposition rate, fertility value, host for cocoa pests.
Lophira alata	Okoga, Bongossi	Deep rooting habit, very tall tree, wide and open crown, big leaf area, abundant leaf litter and high decomposition rate, high fertility value
Maesopsis emanii	Nkanga	Deep rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high fertility value.
Mangifera indica	Andogo ntangani, Poungol	Shallow rooting habit, big leaf area, wide and thick crown, abundant leaf litter with low decomposition rate, high water absorption rate, low fertility value.
Margaritana discordea	Ebeng, Ebebeng	Shallow rooting habit, short tree, small leaf area, open crown, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Microberlinia bisulcata	Alen Ele, Zingana	Deep rooting habit, very tall tree, wide and open crown, big leaf area, abundant leaf litter and high decomposition rate, high fertility value
Milicia excelsa	Abang, Pookombe	Deep rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, fertility value.
Morinda lucida	Akeng	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, medicinal value, high fertility value.
Musa paradisiaca	Ekoan	Shallow rooting habit. Short tree, big leaf area, narrow crown shape, low leaf decomposition rate, high fertility value.
Musa sapientum	Ekoan	Shallow rooting habit. Short tree, big leaf area, narrow crown shape, low leaf decomposition rate, high fertility value.
Musanga cecropioides	Asseng, Esseng, Pokomba	Shallow rooting habit, short tree, big leaf area, wide and open crown shape, abundant leaf litter with high decomposition rate, branches susceptible to damage, medicinal value, high fertility value.
Myrianthus	Angekong	Deep rooting habit, tall tree, thick crown, big leaf

arboreus		area, abundant leaf litter with high decomposition rate, high fertility value.
Pachypodanthium staudtii	Ipilemess	Shallow rooting habit, short tree, open crown, small leaf area, low leaf litter decomposition rate, low fertility value, allelopathic function, low fertility value.
Parinari chrysophylla	Iloloponi	Deep rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high fertility value.
Pentaclethra macrophylla	Ebai, Ebaye	Deep rooting habit, tall tree, wide and open crown, big leaf area with high leaf decomposition rate, high fertility value.
Persea americana	Fia, Pia, Puopi	Shallow rooting habit, short tree, big leaf area, low leaf litter decomposition rate, branch susceptible to damage, host for mirids, high water absorption rate, low fertility value.
Piptadeniastrum africanum	Atui	Shallow rooting habit, tall tree, wide and open crown, small leaf area, abundant leaf litter with low decomposition rate, high rate of water absorption, low fertility value.
Pycnanthus angolensis	Eteng	Deep rooting habit, tall tree, open crown, big leaf area, abundant leaf litter and high decomposition rate, high fertility value.
Ricinodendron heudelotii	Njangsang, Ezezang, Ndangsang	Deep rooting habit, very tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, branch susceptible to damage, high fertility value.
Schrebera arborea	Obang	Shallow rooting habit, very tall tree, small leaf area, wide and open crown, low leaf litter decomposition rate, high rate of water absorption, low fertility value.
Spathodea campanulata	Evovone	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, high fertility value.
Symphonia globulifera	Osse	Shallow rooting habit, tall tree, small leaf area, wide and open crown, low leaf litter decomposition rate, high water absorption rate, low fertility value.
Terminalia superba	Akom, Pouledi	Deep rooting habit, very tall tree, wide and open crown, big leaf area, abundant leaf litter and high decomposition rate, high fertility value.
Tetrapleura tetraptera.	Possakssak, Akpa	Shallow rooting habit, short tree, small leaf area, open crown, low leaf litter decomposition rate, low fertility value.
Treculia africana	Etoup	Deep rooting habit, short tree, wide and thick crown, big leaf area, abundant leaf litter with high leaf decomposition rate, low fertility value.
Triplochiton scleroxylon	Ayous, Adjos, Hilel	Shallow rooting habit, tall tree, thick crown, big leaf area, abundant leaf litter with high decomposition rate, high rate of water absorption, low fertility value, host for cocoa pests, low fertility value.
Uapaca guineensis	Assam	Shallow rooting habit, short tree, open crown, small leaf area, low leaf litter decomposition rate, low fertility value, host for cocoa pests, high fertility value.
Vitex ciliata	Ewolo,	Shallow rooting habit, short tree, small leaf area, open

	Poneng	crown, low leaf decomposition rate, high water absorption rate, low fertility value.
Voacanga sp	Mviekam, Pondong	Shallow rooting habit, short tree, big leaf area, wide and dense crown, abundant leaf litter with low decomposition rate, high water absorption rate, low fertility value.
Zanthoxylum heitzii	Opong, Olon	Deep rooting habit, tall tree, wide and thick crown, big leaf area, abundant leaf litter with high decomposition rate, fertility value.
Zanthoxylum tessmannii	Bongo	Shallow rooting habit, tall tree, big leaf area, wide and thick crown, abundant leaf litter with high decomposition rate, high water absorption rate, low fertility value.

Appendix 4 Distribution of non-cocoa tree species across locations. Ak = Akok; Aw = Awae; Nk = Nkongmesse; Nd = Ndikinimeki; * = Species contained in the data base

Tree species	Local Names	Locations
Afrosersalisia afzelii	?	Aw
Afzelia bipindensis	?	Aw, Nd.
*Afzelia pachiloba**	Mbanga afum	Ak, Nk
*Albizia adianthifolia**	Sayeme	Ak, Aw, Nk, Nd
*Albizia ferruginea**	Evouvous	Aw, Nk, Nd
*Albizia glaberrima**	Essak	Ak, Aw
Albizia spp.	Angoa	Ak
*Albizia zygia**	Eyem, Hypok	Ak, Nk, Nd
Allanblackia floribunda		Ak, Aw, Nk
*Alstonia congensis**	Akouk	Aw, Nk.
Amphimas ferrugineus	?	Nk
Amphimas pterocarpoides	?	Ak, Aw, Nk
Angylocalyx oligophyllus	?	Ak, Aw, Nd
Anonidium mannii	Ebom	Nk
Anthocleista schweinfurthii	?	Aw
Anthonotha fragans	?	Nk, Nd
Anthostema aubryanum	?	Ak
*Antiaris welwitschii**	Alogo, Aloa	Aw
*Antrocaryon klaineanum**	Otengui, Agongi, Etambele	Ak, Nk, Nd
Artocarpus communis	Mbelfut	Ak
*Baillonela toxisperma**	Adjab	Ak, Nk
*Beilschmiedia obscura**.	Zolebi, Zoule	Ak, Nk
Berlinia grandiflora	Abem	Ak, Nk
Bombax buonopozense	?	Aw, Nk
Bombax sessile	Alen okpwe	Ak, Aw
*Bosqueiopsis angolensis**	Otomba afan	Ak, Aw
Bridelia micrantha	Ewolot	Ak, Aw, Nk, Nd
Britiera utilis	Eyong	Ak, Aw, Nk
Canarium schweinfurthii	Abel beti	Ak, Nk
Carapa procera	Ngan, Engang	Nk
Carica papaya	Popo, Fofo	Ak, Aw, Nk, Nd
Carpolobia alba	?	Ak, Aw, Nk, Nd
*Carpolobia lutea**	Onong	Nk
Cassia spp.	Cassia	Ak
*Ceiba pentandra**	Doum, Douma, Nioum	Nk, Aw, Nk, Nd
Celtis africana	?	Ak, Aw, Nk
Celtis spp.	?	Ak, Aw, Nk
Celtis tessmannii	?	Ak, Nk
*Milicia excelsa**	Abang, Pokombe	Ak, Aw, Nk, Nd
Cleistopholis glauca	Avoe	Aw, Nk, Nd
*Coelocaryon preussiii**	Ekoman, Nom eteng	Aw, Nk
*Cola acuminata**	Abel	Ak, Aw, Nk, Nd
Cola lateritia	Efok	Ak, Aw, Nk

Cola pachycarpa	Endoum	Aw, Nd
Cordia aurantiaca	Otolban	Nd
*Cordia platythyrsa**	Ebe	Ak
*Coula edulis**	Kome, Ewome	Ak, Nk
Cylicodiscus gabunensis	Adoum	Ak, Aw, Nk, Nd
Cynometra hankei	?	Ak
*Desbordesia glaucescens**	Omang	Ak, Aw, Nk, Nd
Dialium pachyllum	?	Nk
Dialium zenkeri	?	Ak
Discoglypremna caloneura	?	Ak, Aw, Nk
*Distemonanthus benthamianus**	Eyen	Aw, Nk
Duboscia macrocarpa	Akak	Ak, Aw, Nk
Diospyros paviflora	?	Nk
Enantia chlorantha	Mfol, Mfo	Ak, Aw, Nk, Nd
Entandrophragma angolense	Edoussie, Ebeba	Ak, Nd
Entandrophragma candollei	Assie	Ak, Aw, Nd
*Entandrophragma cylindricum**	Asse, Possa	Ak, Nk
*Eribroma oblongum**	Edjong, Eyong	Ak, Aw, Nk
*Erismadelphus exsul**	Afobilobi, Itieti	Ak, Aw, Nk, Nd
Erythrina milbraedi	?	Ak, Nk
*Erythrophleum ivorense**	Elon, Etom	Ak, Nk
*Erythroxylum mannii**	Landa	Nk
*Zanthoxylum heitzii**	Opong, Olon	Ak, Aw, Nk, Nd
*Zanthoxylum tessmannii**	Bongo	Aw, Nk
*Ficus exasperata**	Akol	Nd
*Ficus mucuso**	Toll, Posses	Ak, Aw, Nk, Nd
Ficus spp.	Ekekam	Ak
*Funtumia africana**	Metondo	Aw
*Funtumia elastica**	Ndamba	Ak, Aw, Nk
Gambeya africana	Abam	Aw, Nk
Garcinia kola	Onie	Ak, Aw, Nk
Garcinia mannii	Ebam	Ak, Nk
Gossweilerodendron balsamiferum	Sinedon	Ak, Aw, Nk
*Grewia brevis**	Evie	Ak, Aw, Nk
Guarea cedrata	Ebangbemva	Aw
Harungana madagascariensis	?	Aw, Nd
Homalium spp.	?	Nk
*Hylodendron gabunensis**	Mvanda	Aw, Nk
Hymenocardia hyrate	Okekele	Nk
*Irvingia gabonensis**	Andok, Azanga	Ak, Nk, Nd
Irvingia grandifolia	Andongwe	Ak, Aw, Nk, Nd
Irvingia robur	Nom andok	Ak, Aw, Nk, Nd
Khaya ivorensis	N'gollon	Aw, Nk, Nd
Klainedoxa gabonensis	Ngon	Ak, Aw, Nk
*Lannea welwitschii**	Ekoa	Ak, Nk
*Lophira alata**	Bongossi, Okoga	Ak, Aw, Nk

Lovea trichiloides	Bibolo	Ak
*Maesopsis eminiii**	Nkanga	Ak, Aw, Nk, Nd
Mallotus appositifolius	Opess	Nd
Mammea africana	Ebot, Ebodzok	Ak, Aw, Nk
Mansonia altissima	Bambanja	Nk, Nd
Maranthus chrysophylla	Asila oman	Aw
*Margaritaria discoidea**	Ebebeng, Ebeng	Nk
Markhamia lutea	Osse, Angossa	Ak, Aw, Nk, Nd
Markhamia spp.	?	Aw, Nd
Massularia acuminata	?	Ak, Aw, Nk, Nd
*Microberlinia bisulcata**	Alen ele, Zingana	Ak, Aw, Nk
Milicia excelsa	Abang, Pokombe	Ak, Aw, Nk, Nd
Milletia mannii	Awong	Ak, Aw, Nk, Nd
Mitragyna ciliata	Afopzam, Elolom	Ak, Nk
Monopetalanthus microphyllus	Ngang	Aw, Nk
*Morinda lucida**	Akeng	Nk
Morus mesozygia	Ossel	Ak, Aw, Nk
Musa paradisiaca	Odjoe	Ak, Aw, Nk, Nd
Musa sapientum	Ekoan, Neconge	Ak, Aw, Nk, Nd
*Musanga cecropioides**	Asseng, Esseng, Pokomba	Ak, Aw, Nk, Nd
*Myrianthus arboreus**	Angakong	Ak
Mytragina ciliata	Elolom	Ak, Aw, Nk, Nd
Nauclea diderrichii	?	Nd
Omphalocarpum lecomteanum	?	Nk, Nd
Pachyelasma tessmannii	Eyek	Ak, Aw, Nd
*Pachypodanthium staudtii**	Ipilemess	Nk
*Parinari chrysophylla**	Iloloponi	Aw, Nd
Parkia bicolor	Esang, Eseng	Ak, Aw, Nk, Nd
Paullinia pinnata	Eback, Evuna	Aw, Nk, Nd
Pausinystalia johimbe	Adjeck	Aw, Nk
*Pentaclethra macrophylla**	Ebai, Ebaye	Ak, Aw
Pericopsis alata	Nom eyen	Nd
Peterscanthus macrocarpus	?	Ak, Aw
Petersianthus macrocarpus	Nom abing, Abing	Ak, Aw, Nk, Nd
*Piptadeniastrum africana**	Atui	Ak, Aw
Polyalthia maveoleus	?	Aw
Polyscia fulva	?	Aw, Nk
Pseudospondias microcarpa	?	Nd
Pteleopsis hylodendron	Sikon	Ak, Aw, Nk, Nd
Pterocarpus mildbraedii	Mbel afum	Aw
Pterocarpus soyauxii	Mbe, Mbel	Ak
Pterygota macrocarpa	Efok ayus	Ak, Nk
*Pycnanthus angolensis**	Eteng	Ak, Aw
Rauvolfia macrophylla	Essombo	Aw, Nk, Nd
Rauvolfia spp.	Atto	Aw
Rauvolfia vomitoria	Mezan meza	Aw, Nd
*Ricinodendron heudelotii**	Njangsang, Ndangsang,	Ak, Aw, Nk, Nd

	Ezezang	
Rothmannia hispida	Endon	Aw, Nk
Sapium ellipticum	Osiemvot	Ak, Aw, Nk
*Schrebera arborea**	Obang	Ak, Aw, Nk
*Spathodea campanulata**	Evovone	Ak, Aw, Nk, Nd
Spondias cytherea	Cassamanga	Ak, Aw
Staudtia kamerunensis	Ovos, Mbonda	Ak, Aw, Nk, Nd
Sterculia rhinopetala	Nkanang	Ak, Aw, Nk
Sterculia subviolacea	Efok afum	Ak, Aw, Nk
Sterculia tragacantha	Ipock	Ak, Aw, Nk, Nd
Strombosia glaucescen	?	Aw, Nk
Strombosia grandifolia	Bibolo afum	Ak, Aw, Nk, Nd
Syzygium guineensis	?	Aw
Tabernaemontana crassa	?	Ak, Aw, Nk
*Terminalia superba**	Akom, Pouledi	Ak, Aw, Nk
*Tetrapleura tetraptera**	Possakssak, Akpa	Ak, Aw, Nk
Tetrorchidium didymostemon	Efoublo	Ak, Aw, Nk, Nd
*Treculia africana**	Etoup	Ak, Aw, Nk
Trichilia spp.	Nom oswe	Ak
Tricoscypha acuminata	Anvout	Nk
Trilepisium madagascariense	?	Nd
*Triplochiton scleroxylon**	Ayous, Adjos, Hilel	Ak, Aw, Nk, Nd
*Uapaca guineensis**	Assam	Ak, Aw, Nk, Nd
Vernonia conferta	Abanyack	Nk
Vitex ciliata.*	Ewolo, Poneng	Ak, Aw, Nd
*Voacanga africana**	Mviekam, Pondong	Ak, Aw, Nk, Nd
Xylopia aethiopica	Nom akui	Nd
Xylopia staudtii	?	Nk

APPENDIX. 5 Farmers ecological and socio-economic assessment of commonly found tree species of their cocoa systems

The botanical name, local name and uses are given, together with a key to code use and to simplified value rating.

Key to the codes use

Fr = Fruit
Dr = Drink
Nu = Nuts
Tb = Timber
Fw = Fuel wood
Sp = Spices
Sh = Shade
Oi = Oil
Ft = Fertility
Me = Medicinal

Key to simplified value rating

Fruit value
Hi = High fruit quality for human consumption
It = Intermediate fruit quality for human consumption
Lw = Low fruit quality for human consumption.
Nt = not producing fruit

Drink value:
Hi = High drink value
Lw = Low drink value
Nt = not producing drink

Nuts value:
Hi = High nuts value
It = Intermediate nut value
Lw = Low nut value
Nt = Not producing nuts

Timber value:
Hi = High timber value; very strong and durable
It = Intermediate timber value
Lw = Low timber value; not strong and durable
Nt = not a timber

Fuel wood value:
Hi = High fuel wood value (fiercely burning and heat producing)
It = Intermediate fuel wood value
Lw = low fuel wood value

Spices value:
Hi = High spice value
Lw = low spice value
Nt = Not producing spices

Shade characteristics:
Ex = Excellent canopy cover (adequate for cocoa growth and farm management)
It = Intermediate canopy cover
Lw = low or excessively dense canopy cover

*In farmers opinion in general, Shade provided by short trees with big leaf area is too dense, but that provided by taller tree is adequate for cocoa growth and farm management.

Oil value:
Hi = High oil value
Lw = low oil value
Nt = Not producing oil

Fertility value:
Hi = high fertility value
Lw = low fertility value

Medicinal value:

Appendix 5 continued

Botanical names	Local names	Fruits	Drink	Nuts	Timber	Fuel wood	Spices	Oil	Fertility	Medicine	Shade
Afzelia pachiloba	Mbanga afum	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		It
Albizia adianthifolia	Sayeme	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		Lw
Albizia ferruginea	Evouvous	Nt	Nt	Nt	It	It	Nt	Nt	Hi		Ex
Albizia glaberrima	Essak	Nt	Nt	Nt	It	Hi	Nt	Nt	Hi		Ex
Albizia zygia	Eyem Hypok	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		It
Alstonia congensis	Akouk	Nt	Nt	Nt	Nt	Lw	Nt	Nt	Hi		It
Antandrophragma cylindrica	Asse, Possa	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Entandrophragma cylindrica.	Possa	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Antiaris welwitschii	Aloa	Nt	Nt	Nt	Nt	Hi	Nt	Nt	Lw		Lw
Antrocaryon klaineanum	Otengui, Etambale	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Baillonella tosusperma	Adjab	Nt	Nt	It	Hi	Hi	Nt	Lw	Hi		Ex
Beilschmiedia obscura	Zolebi	Nt	Nt	Nt	Lw	Lw	Nt	Nt	Lw		It
Bosqueiopsis angolensis	Otomba afan	Nt	Nt	Nt	It	It	Nt	Nt	Lw		It
Carpolobia lutea	Onong	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Carpolobia lutea	Onong	Nt	Nt	Nt	Lw	Lw	Nt	Nt	Lw		Lw
Ceiba pentandra	Doum, Douma, Nioum	Nt	Nt	Nt	Lw	Lw	Nt	Nt	Hi		Ex
Milicia excelsa	Abang, Pookombe	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Citrus reticulata	Mandarin	Hi	Hi	Nt	Nt	Hi	Nt	Nt	Lw		Lw
Citrus sinensis	Afoumbi, Opouma, Pofoma	Hi	Hi	Nt	Nt	Hi	Nt	Nt	Lw		Lw
Coelocaryon preussii	Ekoman	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Hi		Ex
Cola acuminata	Abel	Hi	Nt	Nt	Nt	Lw	Nt	Nt	Lw		Lw
Cordia platythyrsa	Ebe	Nt	Nt	Nt	Lw	It	Nt	Nt	Hi		Ex
Coula edulis	Kome	Hi	Nt	Hi	Nt	Lw	Nt	Nt	Hi		Ex
Dacryodes edulis	Assa, Pouti	Hi	Nt	Nt	Nt	Nt	Nt	Nt	Lw		*
Desbordesia glaucescens	Omang	Nt	Nt	Nt	It	It	Nt	Nt	Lw		It
Distemonanthus benthamianus	Eyen	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		It
Elaeis guineensis	Alen, Elen, Nipile	Hi	Hi	Hi	Nt	Lw	Nt	Hi	Lw		Lw
Entandrophragma cylindricum	Asse	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Eribroma oblongum	Edjong	Nt	Nt	Nt	It	Hi	Nt	Nt	Hi		Ex
Erismadelphus exsul	Itieti	Nt	Nt	Nt	Lw	It	Nt	Nt	Hi		Ex
Erythrophleum ivorense	Elon, Etom	Nt	Nt	Nt	Hi	Nt	Nt	Nt	Lw		It
Erythroxylum mannii	Landa	Nt	Nt	Nt	Hi	Hi	Nt	Nt	It		Ex

Botanical names	Local names	Fruits	Drink	Nuts	Timber	Fuel wood	Spices	Oil	Fertility	Medicine	Shade
Xanthoxylumheitzii	Opong	Nt	Nt	Nt	It	Hi	Nt	Nt	It		Ex
Xanthoxylumtessmannii	Bongo	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Lw		It
Ficus exasperata	Akol	Nt	Nt	Nt	Lw	It	Nt	Nt	Hi		Ex
Ficus mucuso	Toili, posses	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Hi		Ex
Funtumia africana	Metondo	Nt	Nt	Nt	Lw	It	Nt	Nt	Lw		It
Funtumia elastica	Ndamba	Nt	Nt	Nt	Nt	Hi	Nt	Nt	Lw		It
Hylodendron gabunense	Mvanda	Nt	Nt	Nt	It	Hi	Nt	Nt	Lw		Lw
Irvingia gabonensis	Andok, Azanga	It	Nt	Nt	Nt	Hi	Hi	Nt	Hi		Ex
Lannea welwitschii	Ekoa	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		It
Lophira alata	Okoa	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Maesopsis eminii	Nkanga	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Mangifera indica	Andogo ntangani, Poungol.	Hi	Nt	Nt	Nt	Lw	Nt	Nt	Lw		Lw
Maranthes chrysophylla	Iloloponi	Nt	Nt	Nt	It	Hi	Nt	Nt	Hi		Ex
Margaritaria discoidea	Ebeng	Nt	Nt	Nt	Lw	Lw	Nt	Nt	Lw		Lw
Microberlinia bisulcata	Alan	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Morinda lucida	Akeng	Nt	Nt	Nt	Nt	It	Nt	Nt	Hi		Ex
Musanga cecropioides	Asseng, Esseng, Pokomba	Nt	Nt	Nt	Nt	Lw	Nt	Nt	Hi		Ex
Myrianthus arboreus	Angekong	Nt	Nt	Nt	Lw	It	Nt	Nt	Hi		Ex
Nesogordonia papaverifera	Ewoua	Nt	Nt	Nt	Lw	Lw	Nt	Nt	It		It
Pachypodanthium staudtii	Ipilemess	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		Lw
Parinari chrysophylla	Iloloponi	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Pentaclethra macrophylla	Ebai	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Persea americana	Fia, Pia, Puopi	Hi	Nt	Nt	Nt	Lw	Nt	Nt	Lw		It
Piptadeniastrum africana	Atui	Nt	Nt	Nt	It	Hi	Nt	Nt	Hi		Ex
Pycnanthus angolensis	Eteng	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Ricinodendron heudelotii	Njangsang, Ezezang, Ndangsang	Hi	Nt	Hi	Nt	Lw	Hi	Lw	Hi		Ex
Schrebera arborea	Obang	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Lw		It
Spathodea campanulata	Evovone	Nt	Nt	Nt	Nt	Lw	Nt	Nt	Hi		Ex
Symphonia globulifera	Osse	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Lw		Ex
Terminalia superba	Akom, Pouledi	Nt	Nt	Nt	Hi	Hi	Nt	Nt	Hi		Ex
Tetrapleura tetraptera.	Possakssak	Nt	Nt	Nt	Lw	Hi	Nt	Nt	Lw		Lw
Treculia africana	Etoup	It	Nt	Nt	Lw	Hi	Nt	Nt	Hi		Ex

Botanical names	Local names	Fruits	Drink	Nuts	Timber	Fuel wood	Spices	Oil	Fertility	Medicine	Shade
Triplochiton scleroxylon	Ayos, Adjos, Hilel	Nt	Nt	Nt	It	It	Nt	Nt	Lw		It
Uapaca guineensis	Assam	It	Nt	Nt	Lw	Hi	Nt	Nt	Hi		It
Vitex ciliata	Ewolo, Poneng	Nt	Nt	Nt	Lw	It	Nt	Nt	Lw		It
Voacanga sp	Mviekam, Pondong	Nt	Nt	Nt	Nt	Lw	Nt	Nt	Lw		It

Appendix 6 Grouping of non-cocoa tree species according to their representation frequency in 20 inventoried cocoa farms per location

Appendix 6-1 Species frequency at Akok location

Species	Frequency	Species	Frequency
Albizia glaberrima	1	*Funtumia elastica*	2
Allanblackia floribunda	1	*Garcinia mannii*	2
Alstonia boonei	1	*Hallea stipulosa*	2
Anonidium mannii	1	*Harungana madagascariensis*	2
Artocarpus communis	1	*Maesopsis eminiii*	2
Baillonela toxisperma	1	*Markhamia lutea*	2
Bombax buonopozense	1	*Nauclea diderrichii*	2
Bosqueiopsis angolensis	1	*Olax staudtii*	2
Brachystegia mildbraedii	1	*Solanum spp.*	2
Caloncoba welwitschii	1	*Trichilia spp.*	2
Carpolobia alba	1	*Xanthoxylumtessmannii*	2
Celtis spp.	1	*Ficus spp.*	2
Cleistopholis glauca	1	*Crinum zeylanicum*	3
Cola acuminata	1	*Cylicodiscus gabunensis*	3
Coloncoba welwitchi	1	*Markhamia spp.*	3
Macaranga sp	1	*Milletia mannii*	3
Dacryodes macrophylla	1	*Morinda lucida*	3
Duparquetia orchidacea	1	*Sterculia subviolacea*	3
Ficus exasperata	1	*Vernonia conferta*	3
Grewia brevis	1	*Vitex ciliata.*	3
Klainedoxa gabonensis	1	*Albizia spp.*	3
Lophira alata	1	*Albizia zygia*	3
Margaritaria discoidea	1	*Carpolobia lutea*	4
Myrianthus arboreus	1	*Erythrophloeum ivorense*	4
Pentaclethra macrophylla	1	*Dacryodes igaganga*	4
Piptadeniastrum africanum	1	*Entandrophragma cylindricum*	4
Pseudospondias microcarpa	1	*Petersianthus macrocarpus*	4
Pseudospondias microcarpa	1	*Britiera utilis*	4
Pycnanthus angolensis	1	*Carapa procera*	4
Rauvolfia macrophylla	1	*Glyphaea brevis*	5
Symphonia globulifera	1	*Schrebera arborea*	5
Terminalia superba	1	*Spathandra blakeoides*	5
Tetrapleura tetraptera	1	*Tabernaemontana crassa*	5
Treculia africana	1	*Tricoscypha acuminata*	5
Tricalysia spp.	1	*Alsodeiopsis africana*	5
Antidesma membranacum	2	*Canarium schweinfurthii*	5
Barteria fistulosa	2	*Sapium ellipticum*	6
Beilschmiedia obscura.	2	*Spathodea campanulata*	6
Bombax sessile	2	*Vernonia amygdalina*	6
Brenania brieyi	2	*Coula edulis*	6
Coelocaryon preussiii	2	*Mallotus appositifolius*	6
Duboscia macrocarpa	2	*Irvingia gabonensis*	7

Appendix 6-1 continued

Species	Frequency	Species	Frequency
Afzelia pachilloba	7	*Enantia chlorantha*	10
Cordia aurantiaca	7	*Ficus mucuso*	10
Pterocarpus soyauxii	7	*Pausinystalia johimbe*	10
Tetrorchidium didymostemon	7	*Trilepisium madagascariense*	10
Uapaca guineensis	7	*Eribroma oblongum*	11
Xylopia staudtii	7	*Distemonanthus benthamianus*	12
Albizia adianthifolia	8	*Triplochiton scleroxylon*	12
Entandrophragma candollei	8	*Hylodendron gabunense*	12
Homalium spp.	9	*Ricinodendron heudelotii*	13
Erythroxylum mannii	9	*Ceiba pentandra*	15
Parkia bicolor	9	*Milicia excelsa*	17
Xylopia aethiopica	9	*Musanga cecropioides*	17

Appendix 6-2 Species frequency at Awae location

Species' name	Frequency	Species' name	Frequency
Afrosersalisia afzelii	1	*Paullinia pinnata*	1
Albizia ferruginea	1	*Polyscias fulva*	1
Allanblackia floribunda	1	*Pseudospondias microcarpa*	1
Amphimas ferrugineus	1	*Pseudospondias microcarpa*	1
Anonidium mannii	1	*Pteleopsis hylodendron*	1
Anthonotha fragans	1	*Rauvolfia spp.*	1
Anthostema aubryanum	1	*Sorindeia spp.*	1
Artocarpus communis	1	*Spathandra blakeoides*	1
Cola pachycarpa	1	*Spondias cytherea*	1
Cordia aurantiaca	1	*Staudtia kamerunensis*	1
Cordia platythyrsa	1	*Sterculia rhinopetala*	1
Dacryodes spp.	1	*Uapaca guineensis*	1
Desbordesia glaucescens	1	*Vernonia amygdalina*	1
Diospyros crassiflora	1	*Voacanga africana*	1
Duparquetia orchidacea	1	*Xylopia aethiopica*	1
Dyospyros paviflora	1	*Pterocarpus mildbraedii*	2
Enantia chlorantha	1	*Sterculia tragacantha*	2
Gambeya africana	1	*Strombosia grandifolia*	2
und 15 (ntil-moro)	1	*Tabernaemontana crassa*	2
Khaya grandifolia	1	*Tetrapleura tetraptera*	2
Lannea welwitschii	1	*Treculia africana*	2
Lendackeria dentata	1	*Vitex ciliata.*	2
Morus mesozygia	1	*Afzelia bipindensis*	2
Nauclea diderrichii	1	*Bertiera laxa*	2

Appendix 6-2 continued

Species' name	Frequency	Species' name	Frequency
Bombax buonopozense	2	*Rauvolfia macrophylla*	5
Grewia barombiensis	2	*Tetrorchidium didymostemon*	5
Guarea thompsonii	2	*Trichilia spp.*	5
Hallea stipulosa	2	*Trilepisium madagascariense*	5
Klainedoxa gabonensis	2	*Vernonia conferta*	5
Parkia bicolor	2	*Albizia glaberrima*	6
Maesopsis eminiii	3	*Bridelia micrantha*	6
Morinda lucida	3	*Duboscia macrocarpa*	6
Pterocarpus soyauxii	3	*Piptadeniastrum africanum*	6
Caloncoba welwitschii	3	*Cola lateritia*	8
Carapa procera	3	*Irvingia gabonensis*	8
Ricinodendron heudelotii	3	*Markhamia lutea*	8
Rothmannia hispida	3	*Myrianthus arboreus*	9
Cleistopholis glauca	3	*Pycnanthus angolensis*	9
Diospyros barteri	3	*Pentaclethra macrophylla*	10
Lovoa trichilioides	3	*Spathodea campanulata*	10
Antrocaryon klaineanum	4	*Alstonia boonei*	11
Britiera utilis	4	*Funtumia elastica*	11
Canarium schweinfurthii	4	*Terminalia superba*	11
Erythrophloeum ivorense	4	*Albizia adianthifolia*	12
Cola acuminata	4	*Distemonanthus benthamianus*	12
Entandrophragma angolense	4	*Grewia brevis*	12
Milletia mannii	4	*Margaritaria discoidea*	12
Tricoscypha acuminata	4	*Milicia excelsa*	13
Carpolobia alba	5	*Ceiba pentandra*	14
Discoglypremna caloneura	5	*Rauvolfia vomitoria*	14
Entandrophragma cylindricum	5	*Ficus mucuso*	15
Erythroxylum mannii	5	*Triplochiton scleroxylon*	16
Massularia acuminata	5	*Musanga cecropioides*	18
Petersianthus macrocarpus	5		

Appendix 6-3 Species frequency at Nkongmesse location

Species	Frequency	Species	Frequency
Albizia zygia	1	*Cordia aurantiaca*	3
Alchornea africana	1	*Pachyelasma tessmannii*	3
Alstonia boonei	1	*Parinari chrysophylla*	3
Anthocleista schweinfurthii	1	*Vernonia amygdalina*	3
Celtis africana	1	*Trichilia sp*	4
Cleistopholis glauca	1	*Trichoscypha arborea*	4
Cylicodiscus gabunensis	1	*Trilepisium madagascariense*	4
Dacryodes macrophylla	1	*Amphimas ferrugineus*	4
Diospyros crassiflora	1	*Beilshmiedia obscura*	4
Duboscia macrocarpa	1	*Ficus spp.*	4
Enantia chlorantha	1	*Treculia africana*	4
Entandrophragma candollei	1	*Pycnanthus angolensis*	5
Ficus exasperata	1	*Sterculia tragacantha*	5
Ficus mucuso	1	*Symphonia globulifera*	5
Guarea cedrata	1	*Terminalia superba*	5
Harungana madagascariensis	1	*Tricoscypha acuminata*	5
Leptactina involucrata	1	*Hylodendron gabunensis*	5
Lophira alata	1	*Mallotus appositifolius*	5
Maesopsis eminiii	1	*Milletia mannii*	5
Markhamia lutea	1	*Polyalthia maveoleus*	5
Massularia acuminata	1	*Xanthoxylumheitzii*	6
Myrianthus arboreus	1	*Hymenocardia hyrate*	6
Nauclea diderrichii	1	*Mansonia altissima*	6
Paullinia pinnata	1	*Rauvolfia vomitoria*	6
Petersianthus macrocarpus	1	*Pterocarpus mildbraedii*	7
Tetrapleura tetraptera	1	*Spathodea campanulata*	7
Alstonia congensis	2	*Sterculia rhinopetala*	7
Carapa procera	2	*Vitex ciliata*	7
Celtis tessmannii	2	*Voacanga africana*	7
Coelocaryon preussiii	2	*Bosqueiopsis angolensis*	7
Cola pachycarpa	2	*Entandrophragma cylindricum*	7
Duparquetia orchidacea	2	*Funtumia africana*	7
Erythroxylon mannii	2	*Lendackeria dentata*	7
Xanthoxylumtessmannii	2	*Desbordesia glaucescens*	8
Grewia brevis	2	*Schrebera arborea*	8
Lovoa trichilioides	2	*Vernonia conferta*	8
Margaritaria discoidea	2	*Albizia adianthifolia*	8
Monopetalanthus microphyllus	2	*Baillonella toxisperma*	8
Morinda lucida	2	*Canarium schweinfurthii*	8
Pentaclethra macrophylla	2	*Cola lateritia*	8
Pteleopsis hylodendron	2	*Afzelia pachilloba*	9
Voacanga spp	2	*Lasianthera africana*	9
Xylopia aethiopica	2	*Microberlinia bisulcata*	9
Antiaris welwitschii	3	*Parkia bicolor*	9
Bombax buonopozense	3	*Angycolyx oligophyllus*	10

Appendix 6-3 continued

Species	Frequency	Species	Frequency
Bridelia micrantha	10	*Distemonanthus benthamianus*	16
Mitragyna ciliata	11	*Carpolobia alba*	17
Albizia ferruginea	13	*Irvingia gabonensis*	17
Allanblackia floribunda	13	*Milicia excelsa*	18
Cassia spp.	14	*Cola acuminata*	18
Ricinodendron heudelotii	14	*Ceiba pentandra*	19
Mammea africana	14	*Uapaca guineensis*	19
Carpolobia lutea	15	*Musanga cecropioides*	20
Triplochiton scleroxylon	15	*Dacryodes buettneri*	20

Appendix 6-4 Species frequency at Ndikinimeki location

Species	Frequency	Species	Frequency
Petersianthus macrocarpus	1	*Cola latiera*	5
Rauwolfia macrophylla	1	*Mitragyna ciliata*	5
Ricinodendron heudulis	1	*Nauclea diderrichii*	5
Spathodea campanulata	1	*Piptadeniastrum africana*	5
Staudtia kamerunensis	1	*Pterygota macrocarpa*	5
Sterculia rhinopetala	1	*Antiaris welwitschii*	6
Terminalia superba	1	*Erythrophleum ivorense*	6
Canarium schweinfurthii	2	*Ficus mucuso*	6
Ceiba pentandra	2	*Garcinia kola*	6
Cordia platythyrsia	2	*Baillonella toxisperma*	7
Microberlinia bisulcata	2	*Milicia excelsa*	7
Cprdia platythirsa	3	*Pygnanthus angolensis*	7
Entandrophragma cylindricum	3	*Lovea trichiloides*	8
Erismadelphus exsul	3	*Afzelia bipindensis*	9
Funtunia elastica	3	*Albizia adiantifolia*	9
Mansonia altissima	3	*Pentaclethra macrophylla*	9
Morus mezozygia	3	*Antandrophragma cylindrica*	10
Musanga cecropioides	3	*Eribroma oblongum*	11
Mytragina ciliata	3	*Erythroxylum mannii*	11
Pericopsis alata	3	*Morinda lucidia*	11
Pteleopsis hylodendron	3	*Uapaca guineensis*	11
Albizia ferruginea	4	*Voacanga africana*	11
Alstonia bonei	4	*Duboscia macrocarpa*	12
Anonodium mannii	4	*Triplochiton scleroxylon*	12
Distemonanthus benthamianus	4	*Albizia zygia*	14
Lannea welwitschii	4	*Tetrapleura tetrapteura*	16
Lophira alata	4		
Pachypodanthium staudtii	4		
Polyscia fulva	4		

Appendix 7

Questionnaire about the ranking of some non-cocoa tree species found in the cocoa systems according to site suitability predictions, usage frequency, the type of usage and the number of stands of the species.

Location:

Name of the farmer:

Gender:

1. Rank the following 8 non-cocoa tree species of your cocoa farm, which you consider as being site suitability indicators by order of importance. The species that, according to you has the highest impact on site selection will be ranked 1, whilst the species, which has the lowest impact, will be ranked 8.

2. For each non-cocoa tree species, give a score indicating the frequency of usage.

- Less often or not at all: 1.
- Often: 2.
- Very often: 3.

3. For each species, state the use category (fruits or nuts, building material, fuel wood, handicraft material, medicinal, ...) and the number of stands of that species in your farm. (Only one farm is considered)

Species name	Ranking according to site suitability indicator	Usage frequency	Usage category and number of stands in your farm
Milicia excelsa			
Irvingia gabonensis			
Musanga cecropioides			
Triplochiton scleroxylon			
Ceiba pentandra			
Erythrophloeum ivorense			
Distemonanthus bentamianus			
Ricinodendron heudelotii			

Questionnaire about the ranking of non-cocoa tree species according to their of competing with cocoa for soil water.

Rank the following 8 non cocoa tree species of your cocoa farm which you consider as competing most with cocoa for soil water (The highest will be ranked 1 and the lowest will be ranked 8).

Species	*Milicia excelsa*	*Irvingia gabonensis*	*Musanga cecropioides*	*Triplochiton scleroxylon*
Rank				
Species	*Ceiba pentandra*	*Erythrophloeum ivorense*	*Distemonanthus benthamianus*	*Ricinodendron heudelotii*
Rank				

Finally, is there any non-ocoa tree species of your cocoa farm which you have not identified, but which have positive or negative interactions with your cocoa trees?

/__________/

If your answer is yes, what is their number and how do they interact with your cocoa trees?

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Appendix 8 List of statements abstracted from farmers' knowledge about cocoa multi-strata systems in southern Cameroon.

1: weeding of cocoa farm frequency is twice a year
2: the value of elaeis guineensis oil is high
3: the value of elaeis guineensis fermented juice is high
4: the value of coula edulis nuts is high
5: harvesting of cocoa pods period is appropriate if cocoa pods colour is yellow
6: planting of cocoa period is in the range may to July
7: the value of ricinodendron heudelotii nuts is high
8: the value of funtumia elastica rubber is high
9: cocoa pods life cycle is in the range 4 months to 6 months
10: the value of baillonella toxisperma oil is high
11: growth of cola acuminata rate is slow
12: light pruning of cocoa period is in the range January to march
13: the value of manihot utilissima tubers is high
14: the value of vegetables is high
15: treating of black pods disease period is appropriate if pods stage is cherel
16: treating of black pods disease frequency is twice a month if the frequency of rainfall is high
17: valley soil soil structure is light
18: gravel soil structure is compact
19: lateritic soil structure is compact
20: treating of mirids period is appropriate if pods stage is mature
21: tree root system profile is shallow if soil structure is compact
22: tree root system profile is deep if soil profile is deep
23: the level of sodecao resistance drought is low
24: the level of sodecao resistance mirids is low
25: the level of local cocoa resistance mirids is high
26: the level of sodecao resistance black pods disease is low
27: the level of local cocoa resistance black pods disease is high
28: the level of local cocoa resistance drought is high
29: an increase in quantity of leaf litter causes an increase in rate of cover of soil
30: the value of tree medicinal is high causes an increase in revenue of household
31: the value of tree fruits is high causes an increase in revenue of household
32: tree leaf size is small causes tree crown density is sparse
33: tree crown density is sparse causes an increase in rate of penetration of sunlight
34: the value of tree timber is high causes an increase in revenue of household
35: tree leaf size is big causes an increase in rate of decomposition of leaf litter
36: tree leaf size is small causes a decrease in rate of decomposition of leaf litter
37: tree root system profile is shallow causes a decrease in moisture of soil
38: tree crown shape is narrow causes leaf litter quantity is less
39: tree height is tall causes an increase in rate of airflow of cocoa farm
40: tree height is tall causes a decrease in rate of humidity
41: tree height is short causes an increase in rate of humidity
42: tree leaf size is small causes leaf_litter quantity is less
43: tree leaf size is small causes an increase in rate of penetration of sunlight

44: an increase in production of cocoa causes an increase in revenue of household
45: an increase in fertility of soil causes an increase in rate of growth of cocoa
46: an increase in number of flies causes an increase in rate of black pods disease
47: an increase in quantity of roded pods causes an increase in rate of flies
48: weeding of cocoa farm period is in the range march to may causes a decrease in number of mirids
49: weeding of cocoa farm period is in the range march to may causes a decrease in rate of black pods disease
50: gravel soil causes an increase in labour requirement of cocoa farm
51: an increase in rate of humidity causes an increase in rate of black pods disease
52: swampy soil causes an increase in rate of humidity
53: an increase in fertility of soil causes a decrease in rate of competition of system components
54: an increase in number of mirids causes an increase in attack of mirids
55: steeply sloping land causes an increase in rate of runoff of water
56: an increase in rate of runoff of water causes an increase in rate of erosion of soil
57: an increase in rate of erosion of soil causes a decrease in fertility of soil
58: steeply sloping land causes an increase in labour requirement of cocoa farm
59: an increase in moisture of soil causes a decrease in rate of competition of system components
60: an increase in content of soil clay causes a decrease in rate of development of cocoa root system
61: weeding of cocoa farm causes an increase in rate of penetration of sunlight
62: decomposition of fruits causes an increase in content of soil organic matter
63: an increase in attack of mirids causes an increase in rate of dieback of cocoa
64: an increase in rate of flowering of cocoa causes an increase in production of cocoa
65: lauranthus sp invasion cocoa branches causes an increase in rate of dieback of cocoa
66: light pruning of cocoa causes an increase in rate of airflow of cocoa farm
67: an increase in content of soil organic matter causes an increase in fertility of soil
68: weeding of cocoa farm causes an increase in rate of airflow of cocoa farm
69: an increase in rate of airflow of cocoa farm causes an increase in rate of flowering of cocoa
70: an increase in rate of dieback of cocoa causes a decrease in production of cocoa
71: suppression of redundant trees causes an increase in rate of airflow of cocoa farm
72: suppression of diseased pods causes a decrease in rate of black pods disease
73: light pruning shade tree causes an increase in rate of airflow of cocoa farm
74: an increase in rate of airflow of cocoa farm causes a decrease in rate of humidity
75: tree leaf size is big causes an increase in amount of closure of canopy

76: tree leaf size is big causes an increase in rate of leaf retention water
77: an increase in quantity of leaf litter causes an increase in moisture of soil
78: weeding of cocoa farm period is in the range march to may causes an increase in rate of flowering of cocoa
79: an increase in density of cocoa causes a decrease in rate of airflow of cocoa farm
80: spacing of cocoa causes an increase in rate of penetration of sunlight
81: an increase in density of tree causes a decrease in rate of airflow of cocoa farm
82: an increase in rate of erosion of soil causes a decrease in moisture of soil
83: tree leaf size is big causes the quantity of leaf_litter is high
84: cocoa farm distance is long causes a decrease in frequency of treating of black pods disease
85: cocoa farm distance is long causes a decrease in frequency of weeding of cocoa farm
86: cocoa farm distance is long causes an increase in labour of carying of cocoa beans
87: an increase in rate of humidity causes an increase in rate of decomposition of leaf litter
88: an increase in rate of decomposition of leaf litter causes an increase in rate of growth of weeds
89: an increase in rate of decomposition of leaf litter causes an increase in content of soil organic matter
90: light pruning shade tree causes an increase in rate of penetration of sunlight
91: an increase in density of tree causes an increase in rate of humidity
92: tree root system profile is deep causes an increase in moisture of soil
93: cocoa farmland suitability is suitable causes an increase in rate of growth of cocoa
94: sandy soil soil causes a decrease in rate of retention of soil water
95: gravel soil causes a decrease in rate of retention of soil water
96: invasion of Bosqueiopsis angolensis seedlings causes a decrease in rate of growth of cocoa
97: an increase in rate of black pods disease causes a decrease in production of cocoa
98: invasion of lauranthus sp causes a decrease in rate of growth of cocoa
99: lauranthus sp invasion cocoa branches causes dry up of cocoa branches
100: invasion of antiaris welwitschii seedlings causes a decrease in rate of growth of cocoa
101: an increase in age of cocoa causes a decrease in production on trunk of cocoa pods
102: an increase in age of cocoa tree causes an increase in production on branches of cocoa pods
103: an increase in amount of closure of canopy causes a decrease in rate of penetration of sunlight
104: decomposition of irvingia gabonensis fruits causes an increase in rate of flies
105: decomposition of Musanga cecropioides fruits causes an increase in rate of flies
106: dry up of cocoa branches causes dieback of cocoa
107: cocoa flowering branches causes an increase in rate of downfall of cocoa flowers

108: an increase in rate of downfall of cocoa flowers causes a decrease in production of cocoa
109: intercropping cocoa musa sapientum causes an increase in rate of growth of cocoa
110: intercropping cocoa manihot utilissima causes a decrease in rate of growth of cocoa
111: deep soil causes an increase in content of soil water
112: redeem soil causes an increase in rate of development of cocoa root system if the content of soil clay is low
113: red soil causes an increase in rate of growth of cocoa if the content of soil clay is low and soil profile is deep
114: a decrease in vigour of cocoa tree causes a decrease in production of cocoa
115: termites galeries causes a decrease in rate of development of cocoa root system
116: decomposition of citrus sinensis fruits causes an increase in rate of flies
117: an increase in rate of water uptake tree root system causes a decrease in moisture of soil
118: cocoa farmland suitability is unsuitable causes a decrease in rate of growth of cocoa
119: tree crown density is sparse causes a decrease in amount of closure of canopy
120: earthworms causes soil structure is light
121: an increase in moisture of soil causes an increase in activity of earthworms
122: an increase in amount of closure of canopy causes an increase in rate of humidity
123: an increase in activity of earthworms causes an increase in fertility of soil
124: an increase in rate of leaf retention water causes an increase in rate of humidity
125: the level of cocoa resistance black pods disease is low causes an increase in rate of black pods disease
126: biting of mirids causes cocoa pods content is hard if development of cocoa pods stage is in the range 1 month to 2 months
127: an increase in density of weeds causes an increase in rate of humidity
128: an increase in density of shrubs causes a decrease in rate of airflow of cocoa farm
129: dry season length is longer causes an increase in rate of wilted pods
130: an increase in rate of mosses cover cocoa trunk causes a decrease in rate of flowering of cocoa
131: an increase in rate of humidity causes an increase in rate of mosses cover cocoa trunk
132: decomposition of pentaclethra_macrophylla fruits causes an increase in rate of flies
133: invasion of beilschmiedia obscura seedlings causes a decrease in rate of growth of cocoa
134: an increase in attack of mirids causes a decrease in quality of cocoa pods
135: a decrease in quality of cocoa pods causes a decrease in quality of cocoa beans
136: a decrease in quality of cocoa beans causes a decrease in production of cocoa
137: a decrease in rate of growth of cocoa causes a decrease in precocity of cocoa
138: light pruning of cocoa causes an increase in rate of penetration of sunlight

139: an increase in amount of closure of canopy causes a decrease in rate of dieback of cocoa
140: rainy season length is longer causes an increase in rate of humidity
141: an increase in fertility of soil causes an increase in rate of development of cocoa root system
142: an increase in moisture of soil causes a decrease in activity of termites
143: manihot utilissima causes a decrease in fertility of soil
144: suppression of redundant trees causes an increase in rate of penetration of sunlight
145: tree crown shape is narrow causes a decrease in amount of closure of canopy
146: tree height is short causes a decrease in rate of airflow of cocoa farm
147: an increase in rate of humidity causes a decrease in number of mirids
148: intercropping cocoa xanthosoma sagitifolium causes an increase in rate of growth of cocoa
149: dry season length is longer causes a decrease in rate of flowering of cocoa
150: dry season length is longer causes an increase in number of mirids
151: deep soil causes an increase in rate of development of cocoa root system
152: an increase in rate of runoff of water causes an increase in fertility of valley soil
153: valley soil causes an increase in moisture of soil
154: an increase in rate of cover of soil causes a decrease in density of weeds
155: gravel soil causes a decrease in depth of soil
156: steeply sloping land causes a decrease in rate of retention of soil water
157: an increase in density of cocoa causes an increase in rate of humidity
158: an increase in content of valley soil humus causes an increase in fertility of valley_soil
159: a decrease in rate of growth of cocoa causes a decrease in vigour of cocoa
160: an increase in cost of pesticides causes a decrease in frequency of treating of mirids
161: an increase in cost of fungicides causes a decrease in frequency of treating of black pods disease
162: a decrease in depth of soil causes a decrease in rate of growth of cocoa
163: invasion of chromolaena odorata causes a decrease in rate of growth of cocoa
164: lateritic soil causes a decrease in rate of retention of soil water
165: lateritic soil causes an increase in rate of runoff of water
166: a decrease in rate of development of cocoa root system causes an increase in rate of dieback of cocoa
167: intercropping cocoa musa paradisiaca causes an increase in rate of growth of cocoa
168: tree crown shape is wide causes the quantity of leaflitter is high
169: cocoa farm distance is long causes a decrease in frequency of treating of mirids
170: intercropping cocoa manihot utilissima causes an increase in rate of mealybugs
171: erismadelphus exsul causes an increase in rate of mealybugs
172: an increase in content of soil organic matter causes an increase in moisture of soil

173: steeply sloping land causes an increase in rate of erosion of soil
174: a decrease in depth of soil causes a decrease in moisture of soil
175: an increase in rate of development of cocoa root system causes an increase in rate of growth of cocoa
176: an increase in rate of growth of cocoa causes an increase in production of cocoa
177: tree root system profile is shallow causes a decrease in content of soil water
178: an increase in rate of wilted pods causes a decrease in production of cocoa
179: an increase in rate of retention of soil water causes an increase in moisture of soil
180: an increase in rate of mealybugs causes a decrease in production of cocoa
181: a decrease in frequency of treating of mirids causes an increase in number of mirids
182: an increase in rate of penetration of sunlight causes a decrease in rate of humidity
183: suppression of shrubs causes an increase in rate of airflow of cocoa farm
184: an increase in area of cocoa farm causes an increase in production of cocoa
185: an increase in labour of household causes an increase in area of cocoa farm
186: tree crown shape is wide causes an increase in amount of closure of canopy
187: an increase in rate of black pods disease causes a decrease in quality of cocoa beans
188: gravel soil causes a decrease in rate of development of cocoa root system
189: sandy soil causes a decrease in rate of development of cocoa root system
190: an increase in density of weeds causes a decrease in rate of airflow of cocoa farm
191: a decrease in frequency of treating of black pods disease causes an increase in rate of black pods disease
192: an increase in rate of growth of weeds causes a decrease in rate of growth of cocoa
193: valley soil causes an increase in rate of growth of cocoa
194: mired host tree proximity is close causes an increase in number of mirids
195: black soil causes an increase in rate of growth of cocoa if soil profile is deep
196: deep soil causes an increase in rate of growth of cocoa
197: swampy soil causes a decrease in rate of growth of cocoa
198: activities of earthworms causes farmland site is suitable
199: yellow soil causes an increase in rate of growth of cocoa if the content of soil clay is low and soil profile is deep
200: an increase in content of soil organic matter causes an increase in rate of compaction of soil
201: lateritic soil causes a decrease in rate of growth of cocoa
202: activities of termites causes farmland site is unsuitable
203: lateritic soil causes a decrease in depth of soil
204: tree root system profile is deep causes soil profile is deep
205: soil structure is light causes an increase in rate of development of cocoa root system
206: an increase in moisture of soil causes an increase in rate of development of cocoa root system
207: tree root system profile is deep causes a decrease in rate of erosion of soil

208: an increase in quantity of leaf litter causes a decrease in rate of erosion of soil
209: an increase in quantity of leaf litter causes an increase in content of soil organic matter
210: an increase in frequency of rainfall causes an increase in content of soil water
211: dry season length is longer causes a decrease in rate of humidity
212: a decrease in frequency of weeding of cocoa farm causes an increase in density of weeds
213: an increase in density of tree causes an increase in amount of closure of canopy
214: an increase in amount of closure of canopy causes a decrease in rate of airflow of cocoa farm
215: tree crown density is thick causes an increase in amount of closure of canopy
216: tree crown density is thick causes the quantity of leaf litter is high
217: gravel soil causes a decrease in rate of growth of cocoa if the content of gravel is high
218: an increase in rate of humidity causes an increase in rate of cocoa flower disease
219: suppression of mired host tree causes a decrease in number of mirids
220: an increase in rate of fall of flowers causes a decrease in production of cocoa
221: an increase in attack of mirids causes a decrease in production of cocoa
222: the level of cocoa resistance mirids is low causes an increase in attack of mirids
223: cocoa pods content is hard causes a decrease in production of cocoa
224: cocoa flower disease causes an increase in rate of fall of flowers
225: tree height is tall causes tree root system depth is deep
226: tree height is short causes tree root system depth is shallow
227: the labour requirement of direct seeded seedlings is less than nursed seedlings
228: the capital requirement of seed beded seedlings is less than nursed seedlings
229: the capital requirement of direct beded seedlings is less than nursed seedlings
230: the labour requirement of seed beded seedlings is less than nursed seedlings
231: the resistance to drought of direct seeded seedlings is greater than nursed seedlings
232: the resistance to dieback of direct seeded seedlings is greater than nursed seedlings
233: the vigour of local cocoa is greater than sodecao
234: the resistance to drought of local cocoa is greater than sodecao
235: the bean index of sodecao is greater than local cocoa
236: the productivity of sodecao is greater than local cocoa
237: the resistance to mirids of local cocoa is greater than sodecao
238: the resistance to dieback of local cocoa is greater than sodecao
239: the precocity of sodecao is greater than local cocoa