Report for the Thematic Course

"Land Use in Developing Countries"

Alternatives to Shifting Cultivation in the Humid Lowlands of Southern Cameroon

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ABSTRACT

Large forest areas are still to be found in southern Cameroon. However, the forest is subject to an increasing pressure, the scale of deforestation estimated to be between 80,000 and 150,000 ha per year, mainly as a result of shifting cultivation practices. Southern Cameroon has been identified as a conservation priority area demanding special conservation attention on the basis of high biodiversity, high endemism of plant and animal species, and conversion of forests to other uses.

In this paper, the general and underlying causes of deforestation are described in connection to the Cameroon rain forest. The concept of shifting cultivation is described, and agroforestry systems assessed as alternatives. Two agroforestry systems seem to be of specific interest as alternatives to shifting cultivation in the humid lowlands of southern Cameroon: the boundary plantings/litter banks, and the home garden/multi-strata system.

The litter bank system may function as a food crop production system where cassava, maize and groundnut are cultivated surrounded by litter banks of the nitrogen fixing *Calliandra calothyrsus*. The two main advantages of this system are improvement of soil fertility and production of firewood. The multi-strata system may be defined as a cocoa-agroforest in which the production of cocoa is the main objective, using *Albizia spp* as a nitrogen fixing tree, *Irvingia spp.* as a source of additional income, and both as shade trees. The most important advantages of the system are the ability to provide a diversified source of income and to maintain biodiversity.

The project has been conducted as a literature study, supported by interviews with 17 Cameroonian citizens.

Key words: Shifting cultivation, deforestation, multi-strata system, litter bank system

PREFACE

The present project ‘Alternatives to shifting cultivation in the humid lowlands of southern Cameroon’ is conducted as a fulfilment of the Thematic Course *Land Use in Developing Countries* at the Royal Veterinary and Agricultural University, Denmark. The Thematic course is a partial fulfilment of the degree of Master of Science in land use in developing countries. The project was written in the period February to May 2000.

The purpose of the study is to decrease the ongoing deforestation by identifying possible alternatives to slash and burn practices. The issues connected to deforestation are complex, and solutions may be difficult to see. However, the idea behind the study is that on a global scale, as well as for the small-scale farmer, every contribution counts in conserving the natural resources and providing subsistence needs for the poor.

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ABBREVIATIONS

ASB: Alternative to Slash and Burn

CED : Centre pour l'Environnement et le Développement

CEC: Cation Exchange Capacity

CGIAR: Consultative Group for International Agriculture Research

FAO: Food and Agriculture Organisation of the United Nations

FCFA: Franc Communauté Financière Africaine

GDP: Gross Domestic Product

GNP: Gross National Product

ICRA: International Course for Development oriented Research in Agriculture

ICRAF: International Centre for Research in Agroforestry

IITA: International Institute for Tropical Agriculture

LAC: Low Activity Clays

MPT: Multi Purpose Tree

PRA: Participatory Rural Appraisal

RRA: Rapid Rural Appraisal

SOM: Soil Organic Matter

UNDP: United Nation Development Program

UNESCO: United Nations Educational, Scientific and Cultural Organisation

USDA: United States Department of Agriculture

VAM: Vesicular-Arbuscular Mycorrhiza

UNITS

°: degree

°C: Celsius degree

mm: millimeter

cm: centimeter

m: metre

km : kilometer

km² : square kilometer

ha: hectare

m^3: cubic meter

%: percent

ppm: parts per million

t: ton

U.S. $: United States dollar

ELEMENTS

C: Carbon

Ca: Calcium

CO_2: Carbon dioxide

K: Potassium

Mg: Magnesium

N: Nitrogen

NO_X: Nitrogen oxides

P: Phosphorus

S : Sulfur

SO_x : Sulfur oxides

Contents

1 INTRODUCTION

In this first chapter, the problem addressed will be analysed and formulated, the objectives will be described, the limitations presented, and the methods explained. A literature review has been conducted as a basis for the problem to be identified and the objectives and limitations to be formulated.

1.1 Background

Shifting cultivation, in the humid tropical countries, is the greatest obstacle not only to the immediate increase of agricultural production, but also to the conservation of the production potential for the future, in the form of soils and forest (FAO, 2000a).

Shifting cultivation is a rotational farming system in which a shorter cultivation phase on slash and burn cleared land is followed by a longer fallow where soil fertility is restored by natural vegetation. It is the oldest land use system, fully sustainable with adequate lengths of fallow (Young, 1997).

Shifting cultivation is still regarded as the main traditional farming system in the tropics and subtropics, covering Asia, the Americas, and Africa (Nair, 1993). After the adoption of agriculture as a pattern of subsistence, man has transformed an estimated 1,000 million hectares, or an area equal to the Amazon basin in size, into semi-desert (Bene et al. 1977 c.f. FAO, 1991). According to Grainger (1993), deforestation is mainly happening due to transformation to other land uses, and is now happening in such a scale that the forest could disappear within one or two centuries if continuing at the current speed.

Population pressure and slow growth in agricultural production are now threatening the security of the rural population and the environmental balance in Cameroon. There is a need for a sustainable alternative that increases agricultural productivity and maintains the environment, especially in the humid forest areas (IITA, 2000).

1.2 Problem Analysis

In a bio-diversity context, Cameroon is one of the most important countries in the world (Blakie, 1996). The World Bank has identified Cameroon as a conservation priority area demanding special conservation attention on the basis of high biodiversity, high endemism and conversion of forests for other uses (World Bank, 2000b). Thus, an increasing problem identified in the Cameroon lowlands is the ongoing deforestation and forest degradation, much due to shifting cultivation practices. This issue has several different aspects: political, economic, and cultural, all leading to a continuous depletion of the forest resources. The main factors are discussed in the following analysis.

Deforestation and Degradation

During the late 1970's and early 1980's, Cameroon experienced a short-term boom from petroleum and mineral exports. Thereafter, the country reverted to exporting mostly cocoa and coffee, and began to export a growing amount of timber. Due to falling international petroleum, cocoa and coffee prices, declining oil reserves, the deprivation of the US dollar and poor economic policies, Cameroon entered an economic crisis in 1986, causing the GDP to decrease continuously the following years. As a result, its currency became increasingly overvalued until 1994 when it was finally devalued (Kaimowitz et al., 1998).

In the four-year period (1989-1993) preceding the devaluation, the government greatly reduced official cocoa and coffee prices, causing farmers income to fall. By 1993, the GDP had fallen with 50% since the crisis began, small-scale coffee and cocoa farmers being most acutely affected (World bank, 2000a). Thus, farmers were forced into shifting cultivation practices and extraction of forest products for subsistence and income generation. This resulted in greater deforestation and degradation, as, on average, families clear more land for commercial shifting cultivation than for coffee and cocoa farming. Further, certain non-timber forest products and fuelwood harvesting practices degrade the resource base (Kaimowitz et al. 1998)

After the devaluation in 1994, the forest clearing and degradation in Cameroon continued to increase. The production of logs increased by 34% as the devaluation greatly encouraged forest product exports. Forest clearing for food crop cultivation and forest degradation, through unmanaged extraction of forest products, are also reported to have increased (Kaimowitz et al.. 1998).

During this period, the Cameroonian Government also eliminated subsidies for fertiliser and fungicides. This led to a shift from coffee and cocoa production to food crop production using shifting cultivation, as fertiliser and fungicides were used mainly for the production of cocoa and coffee (Kaimowitz et al. 1998).

The population growth (the population having increased from 4 to nearly 16 million since 1950, giving a yearly population growth rate of almost 3 %) (World bank, 2000a and b) creates an increasing demand for forestland both for cultivation purposes and as a source of fuelwood and non-wood forest products. In the northern parts of Cameroon, the fuelwood harvest is already well over the maximum sustainable level. In the southern forest areas, the sustainability of the forest is expected to become a dominant issue, fuelwood being estimated to become the major forest product (Blaikie, 1996). The scale of deforestation is estimated to be between 80,000 and 150,000 ha per year mainly as the result of shifting cultivation, commercial and small-scale logging and fuelwood collection. In contrast, the increase in land dedicated to permanent agriculture is about 8,000 ha per year (Egbe, 1998; Tchoungui, 1995).

The World Bank (Worldbank, 2000b) has identified the humid forest areas in Cameroon as a region of global priority in terms of biodiversity and ecosystem services. Being a part of the Congo basin, these forest areas represent the second largest tropical forest block in the world, and thus a unique reservoir of plant and animal species.

Ndoye et al., (1998) mentions that certain non-wood forest products (e.g. *Garcinia kola)* already might be endangered by overexploitation in southern Cameroon. Thus, Ndoye et al. (1998) conclude that due to the difficult trade-offs between improving the livelihood of forest-depending people and forest conservation, research should contribute in *finding a balance for achieving livelihood improvement through non-wood forest products and forest conservation goals.*

The International Centre for Research in Agroforestry (ICRAF) has initiated a special 'ASB programme' (alternatives to slash and burn programme) looking at the consequences of shifting cultivation practices. They state that *high population growth rates in the tropics and the increasing demand for land to produce food and raw materials, is resulting in high rates of deforestation at the forest margins in the tropics. Traditional shifting cultivation systems that previously sustained people without degradation of the natural resource base, are rapidly being replaced by unsustainable slash and burn agriculture.* ICRAF has identified the humid forest areas in Cameroon as a benchmark area, being *a zone of rapid demographic, social and environmental change* (ICRAF, 2000).

Centre pour l'environnement et le développement (CED, 1999) in Cameroon states that *shifting cultivation, the predominant farming system practiced in the area* (southern Cameroon), *is a major cause of forest degradation.* Further, they claim that *intensification of farming to diminish the area used is essential. Experiments with biological agriculture must be supported, and extension of such practices should be promoted.*

Blaikie (1996) concludes that *sustainability of the forest estate in Cameroon is not being achieved.* He states that, despite all research, training and data collection done, *they are dwarfed by rapid and largely unchecked deforestation and by primitive and wasteful logging.*

Thus, the human impact on the forest as a resource seems to create degradation and deforestation due to the increased need for opportunities for cash income generation. Research seems to be needed to find alternative farming systems or income opportunities to prevent further forest degradation and depletion.

Whitmore (1990) argues that an important requirement for sustainable utilization of rain forest resources without degradation is to work within the ecosystem nutrient budgets and cycles, and then not to disrupt them by excessive damage. Regarding fuelwood and non-wood forest products, the rain forest ecosystem should not be depleted by successive harvests. Shifting cultivation is sustainable if practiced by traditional experienced farmers. However, it has the limitation that it can only sustain 10 – 20 persons per km^2. Approximately 90% of the area is constantly under fallow, demanding large areas for few people. If the fallow period is excessively shortened, or the period of cultivation extended too long, the system breaks down.

This seems likely to occur in Cameroon, experiencing a considerable population increase with a following land scarcity in the densely populated areas. People from these areas are forced into practicing shifting cultivation in the forest zone (Tchoungui, 1995; Bahuchet, 1996). This has another impact, which according to Whitmore (1990) is totally destructive. Farmers having no prior experience in forest farming often slash and burn the forest and grow crops on the released nutrients for several years in succession. Continuing until the coppicing ability of the trees and the soil seed bank are exhausted, soil nutrients are seriously depleted and weeds invade the area, preventing the wanted forest succession. Thus, the forest may be transferred to wasteland, the forest boundaries being pushed further and further with time.

Due to the identified problems associated with shifting cultivation this study is based on the following hypothesis:

Shifting cultivation is not sustainable long-term in a context of a fast growing population

Large forest areas are still to be found in Cameroon. However, the forest is being pressured by human activities as shifting cultivation practices. Thus, according to the World Bank (World bank, 2000b), there is still time for an approach to the deforestation and forest degradation problems to be made, where strategic long term planning can be functional. The scenario of saving species or habitats from extinction is thus facilitated, and a planning of biodiversity protection within the framework of social and economic development of the region is possible. Further, the World Bank (2000b) argues that the Cameroon rain forest, being a part of the Congo basin, represents *a rare and perhaps unique opportunity to build on the experience of others, to put theory into practice, and to benefit from the cost-effectiveness of prevention rather than cure.*

In the humid lowlands of Cameroon, there seems to be possibilities for social and political solutions to the deforestation problem. An improvement of the national economy could probably lead to improved employment in the urban and dense populated areas. The migrations of people to the forested areas could then be diminished, with a smaller part of the population doing shifting cultivation for subsistence reasons. Further, with improved prices on cocoa and coffee, farmers could return to the cultivation of cash crops as before the crisis, the pressure from shifting cultivation on the rain forest being lowered. However, as an estimated 80% of the population in

Cameroon is involved in agriculture, it seems that the optimal solution would be sustainable sedentary agricultural systems for the small-scale farmers. Thus, if sustainable and continuous sedentary agriculture is practiced, the large land requirements may decrease, leading to a lowered migration to the forest areas with the following shifting cultivation practices.

Soil Fertility

To achieve sustainable annual cropping, input and recycling of nutrients is essential. In large areas of sub-Saharan Africa, where population pressure is high, the soil fertility has declined due to shorter fallow periods. The loss of nutrients from the soil is one of the fundamental problems in the area (Rao et al., 1998). Annual cropping systems require a constant input of nutrients due to continuing crop harvests and losses (e.g. leaching) (Sanchez and Palm, 2000).

Constant annual cropping may be obtained by the use of fertiliser and pesticides. However, these external inputs are sold at high prices, limiting the ability of small-scale farmers to purchase them. Further, the distribution of fertiliser and pesticides is often of a limited extent, caused by a poor infrastructure. Thus, the access for the small-scale farmer to the external inputs is often limited (Rao et al., 1998).

Agroforestry systems are possible alternatives to shifting cultivation, which is being implemented in many humid areas (Kerkhof, 1990). The trees provide browse for domestic animals, fuelwood and lumber for buildings, and fruits and other edible products for the people. Further, the concept of agroforestry is based on the belief of the trees being able to keep the soil fertile (Whitmore, 1990). It is a wide concept including many different land use systems where livestock and/or crops exist together with trees (Nair, 1993). Shifting cultivation practices are defined as a part of the agroforestry paradigm. However, agroforestry systems facilitating sedentary cropping have been considered valid alternatives to shifting cultivation (Okigbo, 1984). Around the tropics there are local examples that strongly suggest that agroforestry have the potential to address the problems connected to increasing human welfare and environmental degradation (Leakey, 1998).

1.3 Literature Review

To get a thorough picture of the agricultural situation, and an understanding of the research and experiments carried out for the improvement of the land use practices in southern Cameroon, a literature review was conducted.

Lodoen (1998) describes the Cameroon cocoa agroforests as options to reduce shifting cultivation in Cameroon. Juo and Manu (1996) mention shifting cultivation as a major cause of deforestation and land degradation, the recycling of mineral nutrients being stated as an important factor in replenishing soil fertility. Harwood (1996) states that alternatives to shifting cultivation due to lack of land is needed in humid West Africa. Agroforestry is claimed to be a suitable cropping system in Africa by Paludan (1985). Further, Alegre and Cassel (1996) argue that well managed agroforestry alternatives to shifting cultivation can reduce soil deterioration, maintain soil fertility, and promote long term productivity. Alternatives to shifting cultivation practices in the humid forest of Cameroon are further recommended by Kotto-Same et al. (1997). Agroforestry systems are also assessed by Leakey (1998) to support needs for both the urban and the rural population in humid West Africa. The advantages of home gardens reducing exploitation of natural forests are highlighted by Perera and Rajapakse (1991). Socioeconomic issues to be considered before the implementation of new agricultural systems are assessed by Boehnert (1988). Kormawa et al. (1999) are addressing the land and labour scarcity problem in connection to the introduction of multi-purpose trees. Regarding soil fertility enhancement, Kanmegne et al. (1999) are discussing the use of shrub- and tree species. The different species are compared as to their beneficial effects on the soil quality. Giller and Wilson (1991) present the opportunities for improving soil nitrogen content when nitrogen fixing tree and crop species are introduced in tropical cropping system. Tonye et al (1994) is discussing alley cropping as a solution to the soil fertility problem of the forest zone of Cameroon. Residue management for improved yields has been assessed by Tonye et al (1997). The result being that labour is an important requirement for a successful improvement of soil fertility. Ayuk et al. (1999) address the *Irvingia gabonensis* tree as to its economic importance, uses, management and farmers´ improvement objectives. For these properties, Mollet et al. (1995) report the *Irvingia gabonensis* tree to be preferred by farmers in the humid lowlands of Cameroon. The potential of *Albizia zygia* tree in cocoa plantation systems has been assessed by Anim-Kwapong and Teklehaimanot (1997). Further, Jha (1997b) has assessed the performance of *Albizia* species in different soil and ecological conditions in India. Duguma et al. (1994) have tested ten different multipurpose tree species, mentioning *Calliandra calothyrsus* as the preferred tree species in agroforestry on acid soils. Further, Duguma and Mollet (1998) assessed *Calliandra calothyrsus* as an acid tolerant species, recommending it for the humid southern Cameroon. Duguma and Tonye (1994) conducted a screening of multipurpose trees and shrubs for agroforestry in the humid lowlands of Cameroon, recommending the implementation of several agroforestry systems, with the *Calliandra calothyrsus* as one of the preferred tree species. Roshetko et al. (1997) evaluated the establishment methods of *Calliandra calothyrsus*. Finally, the vegetative propagation of *Calliandra calothyrsus* is assessed by Tchigio and Duguma (1998) and provenance evaluation by Duguma and Mollet (1997).

1.4 Objectives

Deforestation and forest degradation are considered world environmental problems, with large forest areas being cleared continuously (Bene et al., 1977 c.f. FAO, 1991; Young, 1997). This project is written based on the analysis in section 1.2, indicating that deforestation and forest degradation is a problem of increasing importance in Cameroon. Thus, the following **overall objective** has been identified:
To prevent deforestation in Cameroon

Shifting cultivation practices are important factors in the deforestation process. Thus, a need for alternative land use practices seems to exist. Based on the above analysis, the literature review, and the below limitations, three **specific objectives** have been identified:

1. To describe the general causes of deforestation in connection to the current situation in the Cameroon rain forest
2. To describe and understand the concept of shifting cultivation, and its problems connected to sustainability.
3. To assess agroforestry systems as alternatives to shifting cultivation, determine which agroforestry system(s) that may be of interest for the humid lowlands of southern Cameroon, and describe these systems as regarding their functions and possibilities.

1.5 Limitations

The project was formulated considering the extent of the deforestation problem, the need for alternative or improved land use systems, and the limited information available. For the necessary coverage to be made (on technical issues, economics, legal rights, ownership rights, implementation, etc), considerable time and research is needed. As the time and resources available for this project have been limited, and for the necessary depth to be obtained when considering the different issues, this project should be regarded as covering parts of the total picture only. Other projects should be made, regarding issues not covered by this report, before a total evaluation of the problems should be conducted. Thus, mainly **technical** and **biological** issues are emphasised and investigated in connection to our objectives. Further, for a proper framework for this project to be provided, the following limitations have been identified:

The project is limited **geographically**, the choice of study area being based on considerations mentioned in section 1.2. The humid lowlands of southern Cameroon are chosen due to the large forest resource the area still possess, the forest being under constant pressure from external factors, slowly degrading and depleting the resource. Further, the densely populated areas experience a lack of available land due to population growth. Deforestation and population growth are interlinked, as the first suffer from shifting cultivation, and the other may induce shifting cultivation.

A further limitation has been on **methods**, as this study has been based mainly on literature reviews. Interviews with Cameroonians have been conducted, using structured questionnaires. These interviews are however not of significant importance to the project. The methods used are more thoroughly described in section 1.6.

Political aspects have not been considered. The alternatives to shifting cultivation practices are issues of great importance also politically. However, the extent of the issue implies a need for a thorough investigation before an analysis can be conducted. Thus, political issues and policy making have not been considered, nor have issues regarding natural resource management or land tenure, or rules or legislation controlling or affecting land use practices. Political questions connected to development, poverty, or income generation have neither been considered. Stakeholder analyses have not been conducted, even though this may be of major importance for sustainable long-term solutions to be obtained, as they depend on the will of the people to engage in or adopt the project suggestions.

Economic and socioeconomic issues have been considered only to a limited extent, and only as regarding the chosen agroforestry systems. Issues as gender and impact of social status (casts etc.) have not been investigated.

The issues connected to **implementation** of new systems are of significant importance. The implementation of new land use systems has however been addressed only briefly, and as a part of the perspectives. The issues considered are mainly regarding the possibilities of education in agroforestry disciplines.

In section 1.2, the shifting cultivation practices were identified as the main reason for deforestation in the humid lowlands of Cameroon. As shifting cultivation is mainly practiced for subsistence or small-scale commercial reasons, only the impact of **small-scale farmers** on the forest has been addressed. Further, the project has been limited considering **two agroforestry practices** as possible alternatives to shifting cultivation, one concerning the subsistence farmer, the other concerning the small-scale cash-crop producer. Other alternatives, as the use of fertiliser and pesticides, livestock ranging, or wet rice production, have not been considered.

Finally, due to the limited literature available, one of the group members have been used as a reference. As Acha Atam Jackson is from southern Cameroon, his knowledge has been assumed valid when considering local issues. The assumption has been done based on recognition from the project's methods supervisor, professor Jørgen Madsen.

1.6 Methods

The project is based on a review of available literature. The review has been conducted using the Royal Veterinary and Agricultural library, as well as other libraries and institutions (Centre for Development research) in Copenhagen. Danish, French and English literature has been used, as each language is understood by at least one group member. In addition to books and articles, the Internet has been consulted to gather information, mainly from larger organisations as FAO, CGIAR, and the World Bank. Maps are mainly taken from the Microsoft *Encarta 2000.* Further, the project has benefited from one of the authors being born and raised in the study area, providing insight and information about the area not possible to obtain through literature. Some interviews have been made with Cameroonian citizens living in Denmark or Europe. Here, structured questionnaires were made and sent to the interviewees by mail or email. The questionnaires returned were analysed, and are put in chapter 7. However, these interviews are considered only a supplement to the literature studies, as the information has been gained from people currently living abroad. The value of the information is thus not considered to have the same viability as the research found in literature. The information from the questionnaires is as such considered only as guidelines or supportive additions to the literature reviewed, however suggesting Cameroonian preferences, and thus leading us on the way to our conclusions.

Being based on literature, the study will mainly have a descriptive nature. Discussions and assessments are made on the agroforestry systems identified as suitable for the humid tropics, which components to be used in these systems, and the advantages and disadvantages of the two systems chosen for further investigation. All however based upon the literature consulted.

2 CAMEROON

In this chapter we wish to present the characteristics of Cameroon. The country in general is shortly addressed, followed by a more detailed description of the humid lowlands of southern Cameroon.

Map 1: Cameroon (Encarta, 1999).

2.1 General Characteristics of Cameroon

The Republic of Cameroon lies between latitude 2° and 13° north and between longitudes 8° and 16° East in West Central Africa (Map 1). It covers an area of 475.000 km^2, of which 8.536 km^2 is water, and has a 400 km coastline on the Gulf of Guinea (Tchoungui et al. 1995). Cameroon covers a wide range of climates and vegetation, ranging from dense, humid evergreen forest in the South to dry Sahel and Sudan savannah in the north (Karmilof, 1989; Tchoungui et al., 1995). The country as a whole has an exceptionally high biological diversity and high levels of endemism, with some 260 species of mammals, 848 species of birds, 542 species of fresh and brackish water fish (17% endemic) and 9,000 species of plants (156 species endemic) recorded. The plant and mammal endemism is highest in the moist evergreen forest in the south, especially along the coast (Tchoungui et al. 1995).

Cameroon has three major ecological zones, identified based on vegetation and climate (ICRA, 1990):

1. The humid lowland zone, with equatorial rain forest, stretching from 2° N – 6° N, covering 60% of the total land area
2. Wooded savannah and open woodland, stretching from 6° N - 10° N, covering 32% of the total land area
3. The Sudan-Sahelian zone, stretching from 10° N – 13° N, covering 8% of the total land area

2.2 The Humid Lowlands of Southern Cameroon

The humid lowlands are the areas below 1000 m altitude. This comprises the littoral plain and the southern plateau.

The littoral plain stretches from Rio del Rey, close to the Nigerian border, south to Equatorial Guinea. It covers 50.000 km^2 or 10% of the national territory. Having favourable climate and soil conditions, the area possesses a high agricultural potential, as well as an easy access to transportation and distribution networks. Industrial plantations growing banana, tea, rubber and oil palms characterise the northern parts of the area, together with farms growing food crops as maize, root crops, cowpeas and pineapple as well as vegetable gardens. Rubber plantations dominate in the south. The vegetation of the littoral plain is the Atlantic coastal forest, one of the most biologically diverse in Africa (Tchoungui, 1995).

The southern plateau is located inland, east of the sedimentary littoral plain and covers all of the south and southeast of Cameroon. Covering 165.000 km^2, being 35% of the national territory, it is bounded to the north by the western highlands and the Adamawa plateau and extends to the eastern and southern borders of the country. Intensive agricultural activities are taking place in the area, with food crops as maize, tubers, plantains, and groundnuts as cash crops like coffee, cocoa, palm oil, citrus fruits and avocado. There are no cattle rearing, and little industrialisation taking place. The southern plateau is covered with dense, humid evergreen forest; the most important commercial forest resource in Cameroon (Tchoungui, 1995).

2.3 Climate

Southern Cameroon is characterised by an equatorial climate, with high relative humidity, low insolation and relatively constant annual temperatures above 18°C (Blaikie, 1996). There is an equatorial bimodal pattern of precipitation, with one long and one short rainy season. The rainfall generally decreases towards the north and the interior of the country (Blaikie, 1996). The annual precipitation in the humid lowlands ranges from 1,650 mm in Haut Nyong (East Province) to 1860 mm in Mvila (South Province). The two rainy seasons are occurring during mid-March – mid-July and mid-August – mid-November. During the rest of the year, the monthly rainfall hardly exceeds 50 mm (Ayuk et al. 1999).

2.4 Soils

According to FAO-UNESCO's soil map of Africa, Cameroon soils are mostly Ferralsols and to some extend Nitosols and Acrisols (FAO & UNESCO, 1977). When using the more common USDA soil taxonomy system Ferralsols is found to be equal to Oxisols, while Nitosols and Acrisols are equal to Ultisols (Kang & Tripathi, 2000). Oxisols and Ultisols are 2 major tropical soil types found in the humid rainforest zones and derived savannas, 22% of the tropics has Oxisols while 11% has Ultisols (Ahn, 1993).

Oxisols and Ultisols are relatively similar. Their major differences are due to the time the soils have been weathered under the hot and wet climate in the humid tropics. Oxisols are considered the most weathered soil in the tropics followed by Ultisols (Ahn, 1993).

Oxisols are defined as soils containing an oxic horizon, which is a horizon that is enriched with clay. This horizon has a low cation exchange capacity (CEC), which is even lower if the soils are acidic. Ultisols have an argillic horizon, which is an underlying horizon that has received clay particles from the above horizon (Borggaard, 1998). Ultisols are acidic with a quite low pH in the deeper part of the argillic horizon. CEC is low but not as low as in Oxisols (Møberg & Borggaard, 1998). The low CEC in both soils are caused by a high content of low activity clays (LAC soils) in the clay fraction and low content of soil organic matter (SOM) (Borggaard, 1998). This means that Oxisols contain very little or no reserves of unweathered minerals, that can be released as plant nutrients (Ahn, 1993). Furthermore, nutrients applied to the soil from decomposing plant material cannot be retained in the soil profile for later plant use (Borggaard, 1998). The Ultisols also have a low content of nutrients, but the content is a little higher than the Oxisols (Møberg & Borgaard, 1998).

Kaolinitic minerals (which is a LAC) and iron and aluminium oxides dominate the clay fraction of both soils. If the content of aluminium oxides is high, aluminium toxicity can be a problem. The reddish or reddish brown colour of the soils is due to the different iron oxides forms (Borggaard, 1998).

The physical properties (e.g. infiltration rate, soil structure) of both soils are normally good (Ahn, 1993), and the land use system practiced will to a greater extent depend on the chemical properties of the soils (Møberg and Borggaard, 1998).

Phosphate is often retained quite strongly in both soils and sulphate can also be retained in subsurface of the Oxisols to some extend, whereas sulphate is often present and can be absorbed in the Ultisols. The dominant processes in both soils are leaching of clay, and thereby also basic cations (plant nutrients), down the soil profile together with enrichment of aluminium and iron (Møberg & Borggaard, 1998).

Under natural conditions Oxisols and Ultisols are covered with forest. Shifting cultivation is the most common land use system practiced on these soils, although more and more soils are being brought under permanent cultivation. Both soils can be cultivated permanently if the right considerations are taken. Regarding Oxisols, very little plant nutrient is released by weathering in the soil and only a small amount of plant nutrients can be stored in the soil. This means that most of the nutrients needed by the crops must be supplied to the soil in form of plant residues, manure and/or fertiliser. When the content of macro- and micronutrients is low in Oxisols there is chance of inducing micronutrient deficiency if only macronutrients are applied as fertiliser. With Ultisols, there are three major characteristics that should be taken into consideration when using these soils for cultivation: Erodibility (when the organic matter content is low in the top horizon and mostly in the highlands), aluminium toxicity and low content of most plant nutrients (Møberg & Borgaard, 1998).

Cultivation of crops that grow well on these low nutrient soils can ensure a higher production from the soils. These crops could be cereal crops (e.g. rice), root and tuber crops (cassava, yam, cocoyam and sweet potato), grain legumes (cowpea, groundnut) and also plantains and banana (Kang & Tripathi, 2000). Some of these crops may on the other hand be affected by aluminium toxicity (Norman et al., 1995) and are thus not suitable for cultivation in the humid lowlands of Cameroon.

2.5 Agriculture

Approximately 83 % of the total population is estimated to be involved in agriculture (FAO, 1989 c.f. ICRA, 1990). The humid lowlands of Cameroon have two cropping seasons, corresponding to the two rainy seasons (March-July and August-November) (Tonye et al., 1994). The main farming systems are shifting cultivation, plantation cash crop production systems, and traditional multi-strata home garden systems (Ayuk et al. 1999). The main food crops are maize, cassava, tubers, plantains, and groundnuts. The main cash crops are rubber, cotton, coffee, cocoa, palm oil, citrus fruits, avocado and bananas (Ayuk et al. 1999; Tchoungui et al. 1995). In home gardens, a diversity of crops is cultivated, ranging from vegetable crops to mango trees (Ayuk et al. 1999).

2.6 Economy

The Cameroonian economy is dominated by production of primary products, agricultural production accounting for about 80% of the country's economy. Small farms, less than 2 ha, occupy 90% of the cultivated area, and supplies 90% of the agricultural production and 80% of the market products, although only 3% of the GDP (Ayuk-Takem, 1989 c.f. ICRA, 1990).

Cocoa is one of the most important cash crops grown, with a considerable export to western countries. Together with Côte d'Ivoire, Ghana, and Nigeria, Cameroon produced 65% of the global output (Lodoen, 1998). The forest sector is also a significant contributor to the national economy, representing the third largest foreign currency earner in the country. Cameroon is the sixth largest exporter of tropical wood in the world, the third largest in Africa (Egbe, 1998; Blaikie, 1996).

2.7 Population

The population in Cameroon has increased from 4 million in 1950 to nearly 16 million inhabitants in 1999, giving a yearly population growth rate of almost 3 % (Worldbank, 2000b). In 1991, the population was approximately 12,5 million people, of which 55% were aged under 20 years old, and 6% over 60 years. Approximately 64% of the population lives in rural areas (Blaikie, 1996).

The population comprises about 234 different ethnic groups. The main groups are Bamileke, Bamoun, Douala, Bassa, Fulani, Fang, Tikars and Maka (Egbe, 1998).

The population density varies significantly with the different geographical areas, the average being $26/km^2$. There are three high population zones: Far north, west and northwest, and the Littoral province in the west and southwest. Due to land-use pressure, the agricultural activity is not possible to extend significantly in these areas (Tchoungui, 1995).

3 THE RAIN FOREST

In this chapter, three important aspects of the rain forest are presented. First, the Cameroon rainforest is presented, followed by a description of the causes and the three schools of deforestation. Then the rain forest ecology is presented, emphasising dynamics, stability and nutrients as important aspects in connection to shifting cultivation practices. The purpose of this chapter is to give an understanding of the importance of the rain forest, and the problems related to deforestation and forest degradation.

3.1 The Cameroon Rain Forest

Cameroon is the only west African country still possessing large reserves of tropical forest.
22 million hectares of dense humid evergreen forest is to be found in Cameroon, being a highly valuable source of timber as well as possessing a high biodiversity characteristic for this forest type. The forest areas cover 269,970 km^2, or more than 50% of the national territory, ranking third in Africa after those of the Republic of Congo and Gabon. In 1990, the forested areas were estimated to have approximately 6.1 million inhabitants, that is about half of the total population (Egbe, 1998; Blaikie, 1996).

Forest and Biodiversity

These dense humid evergreen forest areas can be divided into an evergreen Atlantic zone along the coast which, coincident with the littoral plain, is the most endangered and most diverse area, and an evergreen Cameroon-Congolese zone, coincident with the southern plateau. The Atlantic zone has probably the highest biodiversity in Africa, with high levels of endemism found. Most of this forest have already been degraded or lost, with most large animals eliminated (Tchoungui, 1995). The forest in the Atlantic zone is tropical lowland evergreen rain forest. These are lofty, dense, evergreen forests with a height of at least 45 m. There is a continuous multilayered canopy with abundant undergrowth, and usually no water stress experienced. (Whitmore, 1990; Tchoungui et al. 1995; Blaikie, 1996; Warner, 1991).

The biodiversity and endemism of the Cameroon-Congolesian zone is very high, though lower than in the Atlantic zone (Tchoungui et al. 1995). The forest is here a tropical semi-evergreen rain forest. It is a closed, high forest with a tree height of up to 45 m. It includes both evergreen and, in the top of the canopy, deciduous trees. These forests occur where an annual period of water stress is experienced, due to dry(er) seasons or specific soil conditions. Almost the whole African rain forest block is of the tropical semi-evergreen type, including the Cameroon inland areas as well as the rest of the Zaire basin (Whitmore, 1990).

The forest found in the Cameroon-Congolesian zone is the least disturbed in the country, mainly because of a low population pressure (Tchoungui, 1995). However, these areas also provide land areas for shifting cultivation techniques practiced by the majority of the rural population (Blaikie, 1996).

Economic and Social importance

The contribution from the forest sector to the national economy is substantial. The forest sector represents the third largest contributor to foreign currency income in Cameroon, after oil and agriculture. In 1991, the forest sector represented 4% of the GNP, employing 20,000 workers. Cameroon is the sixth largest exporter of tropical timber in the world, the forest sector contributing with 9% of the industrial production in the country (Egbe, 1998).

In Cameroon, all forestland is owned by the state. However, customary laws tend to recognise local peoples' ownership of land. In spite of official recognition, the local people organise their resource use according to well-defined customary laws, mainly based on traditional knowledge. The forest is used for a variety of purposes: many groups, such as the Baka and Bakola people, derive most of their basic requirements from the forest. They need trunks, branches and leaves for their houses and furniture, they cut cane to make ropes, they hunt, fish and collect forest products as wild yams, honey, wild berries, palm oil, *moabi* nuts, and *ilomba* seeds. Their traditional medicine is essentially based on wild trees and herbs. Firewood is the main source of energy, and is collected in the form of branches and tree trunks. This collection of firewood is so extensive that it in some areas, especially near urban centres, it is a direct threat to the forest (CED, 1999).

Farming in the forest areas are practiced with simple tools and few modern inputs. It is estimated that 60% of the farmers cultivate an area smaller than one hectare (CED, 1999). Even so, the proportion of forest converted into farmland is substantial, as shifting cultivation demands long fallow periods and thus large land areas for cultivation. The fallow periods do however allow an undisturbed regeneration period. Pioneers clearing undisturbed forestlands for plantations constitute another serious threat, vast areas being cleared every year. As regarding logging, the depletion of the forest in the major timber-exporting countries such as Ghana and Côte d'Ivoire led to a shift to Central Africa, having the last extensive amounts of African forest. The Cameroonian government, seeing short-term possibilities for earning hard cash, are allowing large-scale logging activities without consulting the local population. In a press conference in August 1995, the Minister of Environment and Forestry declared that Cameron's forests were under-exploited, and that over the next century five million cubic metres could be extracted annually without altering the national forest potential (CED, 1999).

The perceptions of the impact of logging vary between the different groups. Members of the local elite tend to highlight the benefits of logging as the building of roads, schools, and health facilities. On the other hand, the indigenous farmers tend to dislike the logging activities, as few social and financial benefits are given to the villagers, whereas they are the ones to face the consequences after the logging company has left the area. Even the villagers' farms are sometimes destroyed by road construction or logging activities. The farmers do not receive any compensation, as they are living on government land (CED, 1999).

3.2 Deforestation

As deforestation is central in this report, a background to the issue will be given here. First, the direct and underlying causes of deforestation will be discussed, followed by a description of the three schools of deforestation as presented by Wunder (1998).

3.2.1 Causes of Deforestation

Before the causes and problems of deforestation are discussed, a definition of the concept is necessary. Wunder (1998) distinguish between broad and narrow definitions of deforestation. The broad version includes not only extraction of trees and changes to other land uses, but also different types of forest degradation[1] as reduced biomass, species diversity, gene pool, etc. The narrow definition of deforestation, on the other hand, is exemplified by the FAO definition of deforestation, which is *depletion of tree crown cover to less than 10%.* All other types of tree removal and loss of biomass are termed *forest degradation*.

Martinsen (1999) recognises three direct causes of deforestation; Logging, Fuelwood collection and Alternative land uses. As Wunder (1998) and Grainger (1993), Martinsen mention logging as an exaggerated agent of deforestation, at least when using the narrow FAO definition. All three mention the almost universal use of selected cutting instead of clearfelling as a factor possibly degrading the tropical forest ecosystem, however not causing deforestation. Grainger (1993) states that only between two and ten trees of commercial species are usually extracted per hectare out of a total of several hundred tree species.

Regarding fuelwood collection, it is recognised that over-harvesting of fuelwood is a major cause of forest degradation (FAO, 1997). Considering that only about 6% of the tropical non-coniferous timber production reaches international markets (Barbier et al. 1994), firewood collection may be assumed to have a large impact on the forest. Wunder (1998) describes the *fuelwood trap* as the poor man's energy crisis. The poor are driven by poverty and lack of alternatives to deprive the forest of tree biomass for energy necessities. The fuelwood gap theory suggests that population growth and unsustainable extraction of firewood create an increasing imbalance between demand and supply of fuelwood, leading to deforestation. In Cameroon, fuelwood is the main source of energy, over 50% of the households consuming 10 Kg of fuelwood per day on average (CED, 1999). Centre pour l'Environnement et le Développement (CED, 1999) states that in several areas, particularly on the outskirts of larger towns, exploitation of firewood is a direct threat to the forest. The devaluation in 1994 led to increasing prices on cooking gas used by the urban population,

[1] Degradation may be defined as *temporary or permanent deterioration in the density or structure of vegetation cover or its species composition* (Grainger, 1993).

leading to an increase in firewood demand in the cities. However, Grainger (1993) mentions that firewood collection is not a significant cause of deforestation in tropical rain forests. Further, Wunder (1998) states that fuelwood collection only in exceptional cases lead to deforestation of the narrow definition, as an almost complete removal of the forest cover has to occur. A complete deforestation may happen in areas on city margins, but not in rural areas. A considerable degradation of the forest resource may however occur, making the fuelwood supply an important question to address.

Wunder (1998) mentions clearing of forestland for alternative land uses as a more widespread cause than logging and firewood collection. Grainger (1993) goes as far as stating that tropical deforestation is happening mainly for other land uses to take place. Based on this statement, he defines tropical deforestation as a land use problem more than a forestry problem. This fits well with the land use situation in Cameroon as described in the problem analysis.

In addition to the three above mentioned causes of deforestation, several underlying causes may be identified. These are issues creating the above mentioned direct causes. Underlying causes may be agricultural and population growth, economic development, poverty, accessibility, government policies, and ownership rights (Wunder 1998; Martinsen 1999; Grainger 1993).

Population growth is one of the major forces behind deforestation, due to the simple deduction that more people need more space. A higher average income in the population leads to higher demands for comfort and food consumption. Thus demand for food may increase even with no population growth (Grainger, 1993). However, the wealth in most countries is not evenly distributed. Most small farmers do not have the possibility to invest in more productive farming practices, and then a more sustainable and less degrading use of the forest (Martinsen 1999). Further, as may now be seen in Cameroon, poverty leads to deforestation when urban dwellers or landless people migrate to forest areas, clearing forest to survive (Whitmore, 1990; Bahuchet, 1996).

The difficult access to forest areas is an obstacle to migration, saving the forest in distant areas. However, when roads are built from one area to another, e.g. by loggers, access is provided for poor migrants. Thus, increased access may intensify deforestation, as the forest is replaced by subsistence farming practices. Non-traditional shifting cultivators often practice unsustainable cultivation practices, whereas traditional shifting cultivators are cultivating the forest in a sustainable way, letting the forest regenerate after a period of cultivation (Delphin and Mertz, 1990). Tenure is playing an important role, as the state generally owns all forestlands. Customary laws recognise local people's ownership of land, but as the formal rights belong to the state, exploitation of the forest by outsiders may happen without the agreement of the local people (CED, 1999).

Government policies are important as regarding the state's encouragement of logging activities, promotion or expansion of land uses, building of roads, or other political decisions having an influence on the direct causes of deforestation as mentioned above. Further, underlying causes to deforestation as population growth, economic activities, and the extent of poverty are influenced by government policies (Grainger 1993).

The centralisation of government administration has in many cases resulted in a lack of structure and an administration not being able to control the population. Thus, the effect may be lawlessness, where laws and rules are not important to follow. When lawlessness exist together with the forest being government land, the rural population may loose their incentives to take care of the land, and thus leading to deforestation (CED 1999; Grainger 1993; Martinsen 1999; Jackson, 2000). Martinsen (1999) mentions that when people have no owner rights, the farmer does not have the choice of waiting with a clearing of the forest. There is no opportunity cost, as if the farmer does not make use of the area now, someone else might.

3.2.2 The Three Schools of Deforestation

From the above section, it should be clear that the issue of deforestation is extremely complex, and is depending upon not one but several factors with complex interrelations. Wunder (1998) tried to put these causes and interactions into systems, as he says 'for simplicity's sake'. The causes and line of reasoning to explain deforestation are assumed to be interrelated, and as such grouped in three different schools: the *impoverishment* approach, the *neoclassical* approach, and the *political ecology* approach.

In the impoverishment approach the main factor responsible for deforestation is said to be poverty, or the growing number of poor. The rapid population growth leads to an increasing number of poor, who are driven to an unsustainable exploitation of the natural resources for subsistence necessities (Wunder, 1998).

The neoclassical approach, on the other hand, gives open-access property rights and rational economic behaviour the responsibility for deforestation. The farmers motive for changing forestland into farmland is not subsistence, but possibilities for capital income generation (Wunder, 1998).

In the third school of deforestation, the political ecology approach, the reason for deforestation is claimed to be found outside the country or far from the resource. The main factor responsible is considered to be capitalist investors crowding out peasants. The deforestation may happen through activities of larger companies, or as a result of the same companies forcing small farmers to give up their land, thus having to clear new forest land for their subsistence (Wunder, 1998).

These three schools are not mutually exclusive, and may co-exist within the same region. In Cameroon, some 60% of the farmers cultivate an area smaller than one hectare, practising small-scale farming with rudimentary tools and few modern inputs (CED, 1999). This put together with the ongoing urban-rural migration for subsistence needs fit well into the impoverishment approach. However, following the lower prices on cash crops, several plantation farmers started commercial shifting cultivation of food crops. As these shifting cultivation practices demand more land than sedentary plantation cropping, commercial incentives (the neoclassical approach) may be found as a reason for deforestation (Kaimowitz et al. 1998). Further, CED (1999) mentions farmers clearing vast forest areas each year for industrial plantations as a major problem in parts of the country. As all land is government property, large logging companies are destroying smaller farms for road construction or logging operations. The farmers having to clear new land without having received any compensation, as they have no legal rights to the land (CED, 1999). Thus, also the factors included in the political ecology approach seems to be present in Cameroon, the rain forest being pressured from all sides.

3.3 Ecology

Through the twentieth century, an increasing amount of scientists have been collecting and identifying rain forest plants and animals, and describing forest structure. An understanding of the fragility of the rain forest ecosystem developed, side by side with an increasing and unlimited extraction of forest products for economic profits. To be able to assess the impact of man – here shifting cultivators - on the rain forest environment, a basic knowledge on the dynamics of the rain forest ecology is necessary (Whitmore, 1990; Delphin and Mertz, 1990).

3.3.1 Definition

The term *Tropical Rain Forest (Tropische Regenwalt)* was given by the German botanist A. F. W. Schimper in 1898 for the forests in the permanently wet tropics. These are evergreen or partly evergreen forests, having a constant high temperature, with a mean of 18°C in the coldest month. This, however, excludes some high-altitude rain forests and a difference of 5°C between the mean temperatures of the coldest and warmest month may be used as an alternative definition. Rain forests have a rainfall of 100 mm or more every month, either with a short dry season or none (Whitmore, 1990; Warner, 1991).

3.3.2 Dynamics and Stability

When a tree in the rain forest falls to the ground due to age or disturbances, a canopy opening is created – a forest gap. In such gaps, light is increased, causing microclimatic conditions different from under the forest canopy. The following succession – gap dynamics – begins with a fast germination and growth of pioneer species, the seeds germinating when the gaps are created and the direct sunlight reaches the ground. The pioneer species are thus depending on the increased radiation and on the nutrients released by the fallen tree. Then, the pioneer species create a new canopy, under which seedlings of climax species establish, to take over the space after the pioneer species dies off (Kricher, 1997).

These tree falls are quite frequent, creating a dynamic pattern of regeneration in the rain forest. The pioneer species that are being established in the forest gaps are decided partly by their intern competition, and partly by plant – herbivore relations in the area. Thus a forest mosaic of gaps in different sizes and stages is excisting, having an understory with different stages of growth providing large numbers of spatial and temporal niches. This results in a diversity of plants and animals unique for the tropical rain forest. The rain forest is as such a complex system of patches in various stages of regrowth, with plants and animals intimately linked within the ecosystem (Whitmore, 1990; Warner, 1991).

The high overall stability of the rainforest is a result of several factors: the high complexity, the high biodiversity and the almost closed nutrient cycle. The high biodiversity is closely linked to the high complexity, as a high level of species diversity creates a complex system, e.g. where animals fulfil the role played by wind in temperate forests for pollination and seed dispersal. The high level of plants and animals are due to a long and stable climatic history without episodes of extinction or factors severely limiting the species diversity. Linked with a large variance of niches and intimate species interactions, a highly varied and stable forest ecosystem is created (Whitmore, 1990; Warner, 1991; Kricher, 1997). Further, the tropical soils are generally poor in nutrients, as most of the nutrients in the ecosystem are found in the vegetation.

3.3.3 Nutrients

A rapid decomposition of litter and organic materials is constantly happening in the rain forest. The processes continue throughout the year, providing the extensive root systems of the trees with the nutrients needed. With 65 – 80% of the vegetation's root system found within the topsoil layer, the roots absorb most of the dissolved nutrients before they are leached out. As 10 – 20% of the total biomass dies off each year, the rain forest vegetation is believed to act like a giant sponge, sucking up a substantial amount of the decomposed nutrients, leaving only a small amount of nutrients in the soil (Moran, 1981 c.f. Warner, 1991).

However, Whitmore (1990) argues that this popular belief (the main part of the nutrients being in the biomass) is not necessarily true. Whitmore refers to several studies where 40 – 60% of the nutrients were found in the upper 30 cm of the soil. He states that cations as Magnesium, Calcium and Potassium seems to be stored mainly in the vegetation, whereas Phosphorus and Nitrogen are stored in large levels in the soil. The significance of the recorded levels are though difficult to assess as much probably is stored in forms unavailable to the plants. Jordan (1985 c.f. Delphin and Mertz, 1990) conclude that the high proportion of soluble cations K^+, Ca^{2+}, and Mg^{2+} in the vegetation does not result from a high vegetation storage capacity, but from the cations being leached out from the soil.

Nutrients are added to the forest floor by throughfall and stemflow in addition to litterfall. A further nutrient input to the soil may come from the breakdown of soil minerals. When the litter is decomposed, the nutrients are passed into the mineral soil and taken up by the roots if not leached out.

3.4 Conclusion

The humid lowlands of Cameroon have extensive forest resources. The forest is a major resource for the country, now threatened by deforestation and forest degradation through logging, fuelwood extraction and transformation of the forest to other uses. The resource is still of a considerable size, but is considered an important area to address due to a fast and increasing pressure on the forest.

The transformation of forestland to other uses seems to be the main reason for deforestation and forest degradation. This is created by an increasing demand for land, mainly due to population growth, poverty, and government policies.

The impoverishment approach emphasises poverty and a subsistence-need for resources (firewood) as the main reason for deforestation. The approach thus suggests a need for poverty alleviation. The neoclassical approach underlines the possibilities for non-subsistence income generation as the main reason for deforestation. A sustainable intensification of cash crop production may thus decrease the incentives to exploit forestlands. In the political ecology approach, outside large-scale investors are said to be forcing local people from their lands, and then to clear new land.

The rain forest has a high overall stability due to a high biodiversity, a high complexity, and an almost closed nutrient cycle. A large part of the nutrients are found in the vegetation, creating a severe loss of nutrients if the vegetation is removed.

4 SOIL FERTILITY

In this chapter, a presentation of the tropical soil fertility concept is given. The purpose is to provide the background needed for later considerations to be understood.

"The tropics have the potential to be the most productive cropping environments in the world" (Giller and Wilson, 1991). Plants need heat, light and moisture to grow and all of these are available in abundance in the tropics, and when rainfall is sufficient, cultivation of crops are possible year-round. But the Tropics do not gain the expected high crop yields and the reasons are often unpredictability of the climate and low soil fertility (Giller and Wilson, 1991). "Soil fertility refers to the inherent ability of the soil to supply the nutrients needed by plants" and involves many important aspects like availability of the nutrients and uptake mechanism (Ahn, 1993).

Soil fertility depletion is highly recognised in Western Africa and is mainly because of the change from natural forest systems to unsustainable agricultural systems (Rao et al., 1998). Agricultural systems differ from natural systems in the way that there is a net output of nutrients due to crop harvest and losses. If the nutrients removed from the system is not replaced, the result can be a negative nutrient balance and thereby an overall nutrient depletion of the soil (Sanchez and Palm, 2000). These balances can be gradually restored under natural fallows but land scarcity prohibits this natural fertility restoration. If continuing cultivation is practiced nutrient inputs are needed. These inputs can be obtained from three different sources: mineral inputs, organic inputs and inputs from intercropping with green manures or trees (Giller et al., 1997). Mineral inputs (mineral fertilisers) are not considered a strategy for restoring/improving the nutrient capital for the small-scale farmer, mostly because of high prices and no availability (Rao et al., 1998). Organic inputs (crop residues, N-rich organic material and animal manure) are together with intercropping with green manures and trees indeed considered strategies for replenishing the soil fertility in the tropics (Giller et al., 1997). Improving the cycling of nutrients in the agricultural system is also a very important method for improving the nutrient status of the soils. Nutrient cycling can be explained as the "transfer of nutrients from one component to another already in the soil-plant system" (Sanchez and Palm, 1996). Nutrient cycling is not enough to solve the problem; extra nutrients must be brought into the cropping system if the soil fertility should be improved (Giller et al., 1997).

Nitrogen and phosphorus are the major limiting nutrients for plant growth in Western Africa (Rao et al., 1998). Nitrogen is required in the greatest quantity for plant growth and the capacity of the soil to supply nitrogen to crops is connected to the soil organic matter (SOM). Less or no organic matter inputs result in a low SOM content and together with the faster turnover of SOM under cultivation, the organic matter pool in the soil can quickly be used up. The nitrogen status of the soil can be improved if legumes or leguminous trees are introduced in the agricultural system because of these species ability to fix atmospheric nitrogen. Besides SOM application to the soil and the use of legumes, enhancing the synchronisation of nitrogen release from organic matter with crop demand for nitrogen, can improve the nitrogen status for the crop. Using trees in the systems has another beneficial impact on the nitrogen status of the soil, because the trees can capture some of the nitrogen that otherwise would have been leached out of the system (Giller et al., 1997). Crops growing with trees are often referred to as agroforestry and these systems are recognised for their improving effects on soil fertility. For example, trees promote a more efficient nutrient cycling than agricultural systems, and they produce organic material that can be used to improve soil organic matter content and thereby the nutrient status in the soil (Sanchez and Palm, 2000; Rao et al., 1998; Young, 1997).

Nutrient balances are one way of estimating whether the nutrient outputs are bigger than the inputs resulting in a depletion of the soil nutrient pool (Giller et al., 1997). The nitrogen balance can be estimated by adding all nitrogen inputs and then subtracting all nitrogen outputs (Figure 1):

Nitrogen inputs:		Nitrogen outputs:		
-Mineral fertiliser -Organic inputs -Atmospheric deposition -Biological fixation -Sedimentation	-	-Harvested products -Crop residue removal -Leaching -Gaseous losses -Runoff and erosion	=	Positive or negative result

Figure 1: The nitrogen balance (Smaling et al., 1997).

5 *SHIFTING CULTIVATION*

In this chapter shifting cultivation is defined and presented, and the main advantages and disadvantages discussed. The purpose of the chapter is to give a picture of shifting cultivation, and explain why it is a problem in tropical areas.

Shifting cultivation is a step in agricultural development, which people in various parts of the world have passed, are still passing and are still to arrive (FAO, 1984). In the past, shifting cultivation was practiced in the temperate forest climates on the northern part of the globe but currently it is an agricultural system found in the tropics, and thereby the developing countries. This makes shifting cultivation the most widespread agricultural system in the tropics supporting between 300 and 500 million people. Even though this is not more than approximately 5 percent of the world's population, it cannot be ignored because various types of shifting cultivation are currently practiced on 30% of the world's exploitable soils. Where the population density is low, shifting cultivation is mainly practiced giving the farmers space and land to move around. However, due to the increasing population and the following land scarcity in certain tropical areas, the negative consequences of this practice are increasing (FAO, 1991).

5.1 *History*

In almost all regions of the world, man lived for a long period of time (over 1.5 million years) from hunting, fishing and gathering. Shifting cultivation started about 9,000 years ago (Jha, 1997a). Today, it is largely concentrated in the tropics, especially in the humid and subhumid zones of Southeast Asia, equatorial Africa and Latin America. These areas include a great geographic, climatic and ethnic diversity (Peters and Neuenschwander, 1988).

The tropical forest in Africa was probably occupied after the discovery of fire and iron tools, about 50,000 years ago (Okigbo, 1984). Some 5,000 to 6,000 years ago, when the population density was low, people settled in temporary huts, burning an area of bush and planting crops. When the cleared land had been farmed for some years and the yield of crops, wild plants and animal products declined, the community would move to another site and repeat the cycle (Okigbo, 1984).

5.2 Definition

Shifting cultivation is an agricultural system in which a cultivation phase (often short) alternates with a longer fallow period on land cleared by slash and burn. The land is cleared by slashing down the herbs and trees with simple hand tools. Useful trees and shrubs are selectively left standing though sometimes pruned. Some trees are pruned for later regeneration or to serve as stakes for climbing crops. The dry plant residues are then burnt, and crop seeds are sown. During the 2-3 years of cultivation, crops are grown in mixtures of several varieties and species for subsistence or for sale. In the fallow period, which is usually much longer (often 10-20 years or more) the land is allowed to revert to more or less wild vegetation (Okigbo, 1984; FAO, 1984; MacDicken, 1990; Nair, 1993). Usually, the fallow period is long enough to restore soil fertility sufficiently for a new cropping season (Figure 2) (Okigbo, 1984).

Figure 2: The theorical relation between length of fallow and soil productivity in shifting cultivation (Andreae, 1980 c.f. Boehnert, 1988).

5.3 Different Shifting Cultivation Systems

The different methods used can be categorised as traditional and non-traditional and further in the following three types. The traditional is considered sustainable whereas the non traditional is not (El Moursi, 1984; Delphin and Mertz, 1990):

Traditional

- **The truly shifting type:** The farmer shifts frequently to other areas and does not intend to re-utilise the abandoned field. After two or three years, and in some cases up to five years or more of cultivation, he abandons the field and looks for other forestland to clear. The farmers often possess substantial traditional knowledge of how to practice the discipline without damaging or degrading the forest ecosystem (see appendix 1).

Non-traditional

- **Semi-permanent type:** This kind of farmer builds his house near the area he has cleared. When, after two to five years of cultivation, the yield is decreasing, the farmer enlarges the clearing or looks for an additional area not far from his house. Thus, shorter fallows are often the result, with a continuous degradation of the soil being the result.
- **Permanent type:** The farmer as an entrepreneur rent cheap labour to clear a forest area and plant it with permanent commercial crops (coconut or coffee). It is seldom that this type of farmer and his family live in the forest community.

Besides shifting cultivation, the term slash and burn agriculture has been used to describe the cropping system, due to the clearing and burning involved. Even if this term describes quite well the practice in most areas, it has fallen out of general use. Today, anthropologists prefer to use the neutral term "swidden farming". Swidden is an old English word for a burned clearing (Peters and Neuenschwander, 1988).

5.4 Who are the Shifting Cultivators

In Africa, shifting cultivation is usually practiced all over the humid zone. However, more and more often, fallow in shifting cultivation is not left a sufficient length of time because of economic and social constraints (Adedipe, 1985). Although there are some variations, this intensification, resulting in shorter fallow periods, is occurring throughout the region (FAO, 2000b).

As we have seen before, there is a difference between farmers practising truly shifting cultivation (integral) and those practising semi-permanent shifting cultivation (partial). The integral shifting cultivation is a land use system based on *a more traditional year-round, community-wide, largely self-contained, and ritually sanctioned way of life*. At the beginning of the integral system, large amounts of forestland may be cleared every year. Once the community is well established, the clearing decreases. This form of shifting cultivation does not destroy the forest forever, but replaces it with a successional series of regrowth, which is more productive than the original forest (Conklin, 1957 c.f. FAO, 2000b).

On the other hand, some farmers are practising the partial system, which, rather than being based on a way of life, reflects *only the economic interest of its participants*. Instead of having historical and cultural links to the area, these farmers may be there only to cultivate the land for a year or two. Another partial system occurs when the cultivators migrate into the forest, often with little prior knowledge of the traditional techniques, and not being able to develop a system that can be sustainable (Conklin, 1957 c.f. FAO, 2000b).

Unfortunately, many governments and agronomists do not make any distinction between these two systems, but, since they have very different impacts on the environment, this distinction should be made. When destruction of the forest occurs, it is the partial cultivator, not the integral, who is usually the cause (Bahuchet, 1996).

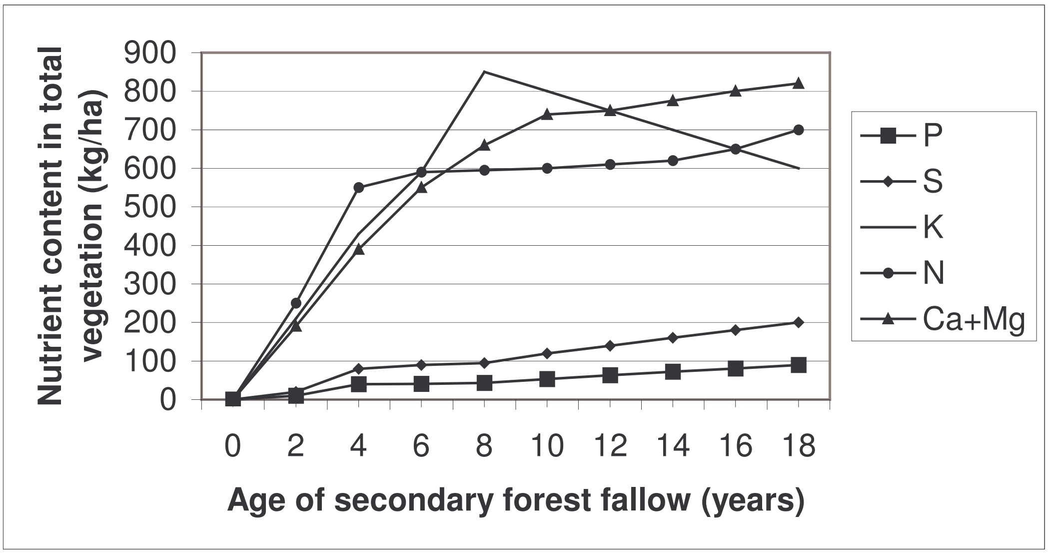
5.5 Steps in Shifting Cultivation

There is a variation of shifting cultivation systems all over the world, but they all follow the same seven stages (FAO, 1984):

1 Site selection
2 Clearing to open a field
3 Burning to eliminate vegetation
4 Planting of crops
5 Weeding during the growing season
6 Harvesting the crop
7 Fallowing of the field

During the fallow period, nutrients accumulate in the biomass of vegetation, as well as in the topsoil through mineralization of leaf and timber (Figure 3) (Peters and Neuenschwander, 1988).

Figure 3: Nutrient accumulation pattern in a secondary forest fallow following slash and burn cultivation in Yanmgambi, Zaire (Sanchez, 1976 c.f. Peters and Neuenschwander, 1988).



5.6 *Beneficial Aspects of Shifting Cultivation*

The advantages of shifting cultivation are related to the burning process. Fire is practically the only means available for clearing the fields to create a larger planting area. The positive points of this practice are:

1 **Clearance of unwanted vegetation from the field**

2 **Alteration of soil structure, making planting easier**

The heat of the fire changes the texture of the earth and makes it more friable. This loose texture is easy to plant in and provides a good seed-bed.

3 **Enhancement of soil fertility**

When the vegetation is burned, large quantities of nutrient rich ashes are deposited on the soil surface, providing easy access to the nutrients for the following crops. This increase in fertility usually last more than one harvest (Table 1).

Table 1: Properties of the surface horizon of forest soil during the shifting cultivation cycle (Adapted from Sabhasri, 1978; Brinkman and Nascimento, 1973 and Sanchez, 1976, cf Peters and Neuenschwander, 1988).

Properties	Before burning	After burning	After one harvest
Phosphorus (ppm)	3.97	32.5	18.5

Potassium (ppm)	208	296	177
Calcium (ME %)	0.3	1.4	1.4
Magnesium (ME %)	0.3	1.4	1.4
Aluminium (ME %)	1.6	0.6	0.7
PH	4.7	6.5	5.6

4 **Decrease in soil acidity**

Since plant ashes are generally alkaline, burning results in an increase in soil pH (Table 1). More over, this also helps in solving one of the more serious problems of tropical soils, aluminium toxicity, since an increase in soil pH reduces the exchangeable aluminium.

5 **Increase in availability of soil nutrients**

The heating of the soil makes a part of the stored nutrient pool easily available to the plants.

6 **Sterilisation of soil and reduction of the microbial, insect and weed population**

The heating of the soil controls weeds and reduces insect, nematodes and various pathogen populations. The elimination of weed seeds means less weeding in the following cropping seasons (FAO, 1991).

5.7 Major Constraints of Shifting Cultivation

The different problems in connection to shifting cultivation are listed below.

5.7.1 Problems Occurring During Normal Cycle

FAO (2000a) states the following consequences of shifting cultivation practices:

1. The fallow, which restores the soil fertility, is identical with natural vegetation which remains outside human control, **outside the possibility of improvement**.
2. **Soil and forest resources are being wasted** by bush fires, erosion and other factors.
3. **Man is never induced to intensify his agriculture**, nor to proceed with long-term improvements of his land.

4. Having to move away periodically, **he does not accumulate any permanent material wealth.**
5. **Beyond a certain critical limit, the density of population cannot increase** as, at the approach to this limit, all the soil becomes degraded.
6. **No concentration or *agglomeration* of the population can, therefore, take place** and no urbanisation is possible, which means that the cultivators have to remain economically at a subsistence level, without professional differentiation, without exchange or specialisation, i.e., without any possibility of progress.
7. **Where cash crops have been introduced**, in an attempt to raise the standard of living of the cultivators, without altering the methods of cultivation, experience has shown that **the destructive effects of shifting cultivation have become even greater.**

5.7.2 Problems Occurring with an Overexploitation of the Land

There are many problems with shifting cultivation because of the shortening of the fallow period: Global warming, deforestation, loss of biodiversity, erosion, loss of soil organic matter, and decreasing soil fertility.

Global Warming

From an environmental point of view the biggest problem is the global warming due to burning of vegetation in the shifting cultivation cycle. It is estimated that more than 50% of the nutrients from the system is stored in the above ground vegetation (Palm et al., 1996). By burning the vegetation, CO_2, NO_X and SO_X gases are released. The biggest problem is the greenhouse gases CO_2 and NO_X, which are released into the atmosphere. It is estimated that 15% to 25% of the global warming is due to the clearing of tropical rainforests (Sanchez, 1993).

Deforestation

Deforestation is mostly due to the population growth in the third world and government policies which are forcing the rural population to migrate into the rainforests. This is resulting in loss of “reserve capital” for the country, because the trees that are cut down have a higher value than the crops harvested in the 3 to 5 year period before the site is abandoned (Kotto-Same et al., 1997).

Loss of Biodiversity

The loss of biodiversity is a problem that is recently often discussed. When deforestation is occurring with a high intensity, there is no longer any primary forest surrounding the cleared areas. This results in a secondary forest with fewer species of both plants and animals when plots are abandoned. For the farmer this loss in biodiversity can lead to a smaller amount of predators for pests and quick growing and spreading of weeds as these have much less competition from other species (Kotto-Same et al., 1997). More over, from a scientific point of view a loss of genetic pool is not desirable as it represents a large value for future uses in the fields of medicine, industrial products and better farming products (Palm et al., 1996).

Erosion

Soil erosion is one of the most serious problems faced by man in relation to shifting cultivation in the tropics. Erosion can destroy good agricultural land by removal of nutrients and organic matter and destroy the soil structure in a very short time if the necessary soil conservation steps are not taken. There are two kinds of erosion: Wind and water erosion. Wind erosion can especially be a great problem when the ashes from the burning, which are a very important source of nutrients, are blown away by winds (Møberg, 1997).

Loss of soil organic matter

Soil organic matter (SOM) is an accumulation of dead, undecayed organic matter originating from crop residues, weeds, grasses, tree leaves and roots but also from soil animals and micro-organisms together with humus (Borggaard, 1998). The SOM is very important, not only is it providing nutrients for plant uptake but it is also improving the quality of the soil in many ways. The SOM has an important role in water retention capacity, soil structure, and physical properties (Palm et al., 1996). SOM is crucial for soil productivity especially in tropic farming, where soils are very old and strongly weathered and have a low cation exchange capacity (CEC) (Møberg, 1997).

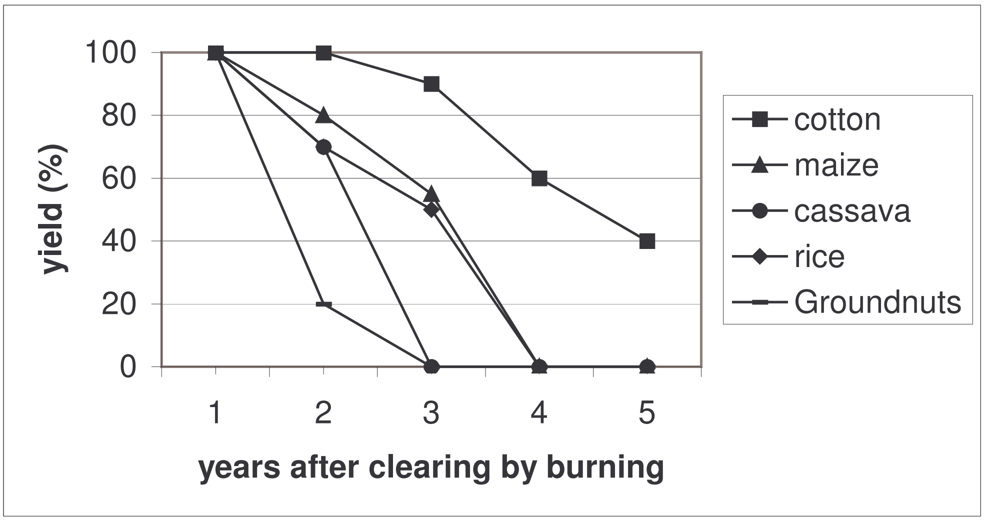
In shifting cultivation it is estimated that there is a decrease in soil organic matter on 17-27% during the first cropping season corresponding to 3-5 months. This rapid decline in SOM is decreasing in the following cropping seasons, because the easy degradable organic compounds are decomposed in this first few months (Juo & Manu, 1996). Plot experiments have shown that it will take approximately 35 years of fallow to re-establish the amount of organic matter lost in the first cropping season (Palm et al., 1996).

Decrease in soil fertility

Cutting down and burning the vegetation to release nutrients for crop production is an integrated part of shifting cultivation. This burning process releases some of the plant nutrients into the air as gases (N, S) and the rest is found in the ashes (Ca, Mg, K, P). This method is preferred because when leaving the cleared material to decompose it takes a longer time to release the same amount of nutrients as a single burn (Peters & Neuenschwander, 1988).

The quality and quantity of the cut plant material is determining the amount of nutrients released for the following cropping season. Therefore, the length of the fallow period is very important for the sustainability of this system (Palm et al., 1996). High amounts of nitrogen and sulphur are lost to the atmosphere as gases, leaving only small amounts in the ashes. The nutrients remaining in the ashes may be quickly lost due to erosion, leaching, and removing of crops and crop residues. This leads to a quick drop in soil fertility and productivity within a few years (Figure 4), resulting in the abandonment of the area, leaving it to fallow. If the fallow period is not long enough, the fertility of the soil is not fully restored (Palm et al., 1996).

Figure 4: Decline in yield under prolonged cropping following slash and burn cultivation without fertiliser in tropical rain forest areas (Ruthenberg, 1971 c.f. Peters and Neuenschwander, 1988).



5.8 *Alternatives to Shifting Cultivation*

The following systems are examples of alternatives to shifting cultivation that have been suggested or implemented by African farmers and agricultural scientists (Okigbo, 1984):

1. Tropical tree/crop plantation (including oil palms, rubber, cocoa, coffee, coconuts, tea). Trees are grown either in a monoculture with closed canopy, or with an open canopy in association with leguminous cover
2. Coconut/Pasture/livestock associations
3. Multistorey systems involving an association of a tree, crop(s) and livestock
4. Asian wet rice and flood land agricultural systems
5. Adequate use of organic mulches and crop residues with no-tillage systems on the alfisols and oxisols of the humid and subhumid tropics
6. Alley cropping and use of fallow shrubs, not only as nitrogen fixers and "nutrients pumps", but also as sources of fuel, staking materials and supplementary food supplies
7. Other agroforestry systems, in which arable crops are grown together with economic trees. Where this is done in the early stages of the establishment of plantations of early maturing timber species of tree crops, it is essentially taungya.

5.9 *Conclusion*

Shifting cultivation has been practiced throughout the humid tropical zone, in millennia. Until now, it is considered one of the most sustainable agricultural systems for this area. The use of fire for the clearing includes numerous advantages like enhancing the soil fertility. On the other hand it has many disadvantages, like keeping the farmers to a subsistence level instead of improving their standard of living. More over, in a context of a fast growing population, a number of other problems occur, leading the practice to be unsustainable. Shifting cultivation can be divided into traditional and non-traditional systems, the traditional one being considered as sustainable, unlike the non-traditional one.

Looking at the alternatives to shifting cultivation, it seems that agroforestry practices do have an important role to play. Thus, agroforestry systems are going to be described more thoroughly in the following chapter.

6 AGROFORESTRY

In this chapter the concept of agroforestry will be presented. Agroforestry will be defined, the systems classified, and systems of interest for the humid tropics will be presented. Finally, positive and negative aspects are mentioned.

Using trees on farms is an ancient art. For millennia, farmers have grown trees on their farms, pasturelands and around their homes. Neither the concept nor the practice of agroforestry is new (ICRAF, 2000).

6.1 Definition

ICRAF (2000) define agroforestry as:

A dynamic ecologically based, natural resources management system that, through the integration of trees on farm and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels.

Thus, agroforestry is a collective name for land use systems that associates trees or shrubs with crops or livestock on the same land (Nair, 1991) including a high level of interaction between woody and non-woody components (Huxley, 1999). Trees can provide many products (timber, food, fruits, nuts, fodder, fuelwood, fibres, medicines, cosmetics, oils, resins) and services (conservation of the soil, enhance soil fertility, improve microclimates, living fences, boundaries, sequester carbon, stabilise watershed, protect biodiversity, control weeds, etc.) (ICRAF, 2000). An emphasis is often put on the use of indigenous multipurpose trees and shrubs as particularly suitable for low-input conditions and fragile environment (Nair, 1991).

There are many agroforestry systems existing, and the research in this area has accelerated rapidly since the early 1980's. This has resulted in a greater understanding of the science of agroforestry. Much of this knowledge came from observation of existing practices and systems, although an increasingly important knowledge is established through designed agroforestry experiments (MacDicken and Vergara, 1990).

6.2 Agroforestry Systems

6.2.1 Classification

There are two basic categories of agroforestry systems: simultaneous and sequential. In a simultaneous system, trees and crops or animals exist together, at the same time and on the same piece of land. These are the systems in which trees and crops compete most for light, water and nutrients. However, competition can be minimised, for example, by spacing. The main simultaneous systems are: boundary plantings, contour hedges, live hedges and fences, hedgerow intercropping (alley cropping), parklands systems, silvopastoral systems, agroforests, shaded perennial crops, multi-strata and windbreaks (ICRAF, 2000).

In sequential systems, crops and trees shift in occupying most of the same space. At certain times in the cycle, trees are the only components, whereas crops or animals only occur in other parts of the cycle, with or without trees. The time sequence should keep competition to a minimum. Trees in a sequential system should grow rapidly when crops are not growing, recycle nutrients from deep layers, fix nitrogen and have a large canopy to help suppress weeds. The main systems are: shifting cultivation, relay intercropping, improved fallows and taungya systems (ICRAF, 2000).

Since there are only three basic components in the system (woody perennials, herbaceous plants, and animals), another classification commonly used is based on the nature of these components (Figure 5):

- Agrisilivicultural (crops with trees or shrubs)
- Silvopastoral (Animals and pasture with trees)
- Agrosilvopastoral (crops, trees and animals and pasture) (Nair, 1993; Nair, 1991; Boehnert 1988).

Figure 5: Classification of the agroforestry systems based on the type of components (Nair, 1985a c.f. Nair, 1993).

6.2.2 Agroforestry systems in the Humid Tropics

The main agroforestry systems used in the humid tropics are going to be introduced in the following part (MacDicken, 1990;Nair, 1993).

Home gardens: In general, these systems are highly diverse, with a high density of both forest and domesticated tree species, and often have a complex and layered vertical structure. The upper story is often composed of tree and palm species that produce timber, fuelwood, fruit, fodder, shade and food. The middle story may produce coffee, cocoa, papaya, bananas, or fruits and spices from shrub or smaller tree species. The understory may consist of beans and pulses, root crops, grasses or legumes for fodder, herbs, etc. The perennial components of these gardens are usually multipurpose trees, which are utilised for fruit production. One of the main advantages of home gardens is the proximity to the farmer's house, which makes the labour more efficient; provide shade, windbreak, and privacy (Nair, 1993).

Field boundary plantings: In these systems, fences of living trees provide protection and privacy, and produce wood and foliage products (Ong and Huxley, 1996). In the humid and subhumid tropics, leguminous species or multipurpose trees are commonly used (MacDicken, 1990).

Animal based systems: These may be trees on rangeland, where provision of shade for the animals is the main use of the trees; plantation crops with pastures, where grazing by the livestock is a secondary source of income; or live fences, where the trees provide shelter for the livestock (MacDicken and Vergara, 1990). Trees can supply protein rich fodder when grass is absent. By reducing grazing pressure, these systems can lead to a better vegetation cover and reduce erosion (Ong and Huxley, 1996).

Shade uses in crop production: Multistoried systems are widely used to provide shade for plantation crops. The use of shade for crops has existed for almost 2,000 years However, this practice is increasingly being replaced by the use of water and fertility management practices.

Permanent shading of plantation crops can be provided by the planting of shade trees or by the selective cutting of the natural forest (MacDicken, 1990).

Taungya: This is a system in which agricultural crops are grown together with tree species in a forest plantation, during the early years of the forestry plantation establishment. The land belongs to the forestry department who allows the farmers to cultivate their crops together with taking care of the plantation trees. After 2-3 years, when the canopy is closing up, the area is left for the plantation trees (Nair, 1993).

6.3 Advantages and Disadvantages of Agroforestry

Given the widespread use of agroforestry by millions of people all over the world, it seems quite safe to assume that this land use has provided enough advantages over systems to be retained. Even if agroforestry research has accelerated in recent years, many of the advantages of agroforestry remain unknown and untested (MacDicken and Vergara, 1990).

6.3.1 Advantages of Agroforestry

Biological advantages

Improvement of the photosynthesis with a mixed canopy: Higher levels of interception of solar radiation by different leave canopies can result in higher photosynthesis production (MacDicken and Vergara, 1990). This is expressed through the dry matter produced per unit of radiation intercepted (Ong et al, 1991).

Improvement of soil chemical, physical and biological characteristics: Nutrient pumping in agroforestry is when tree roots extend into portions of the soil profile that may not be accessible to annual crop root systems, and translocating nutrients to above ground plants parts. However, the main effects of trees on soil properties are a consequence of above-ground organic matter inputs through litter fall or pruning and root system inputs to the soil. Nutrients released through the decomposition of tree litter and roots are perceived a major benefit of agroforestry systems, particularly with nitrogen fixing trees (Steppler, 1990). Physical properties are improved as high soil organic matter is improving the structural stability, and creating a balance between fine and coarse pores (Young, 1997).

Potential reduction in soil erosion: Agroforestry practices help in reducing erosion by:

- Increasing the soil cover by litter and pruning
- Providing partly permeable hedgerow barriers
- Leading to the progressive development of terraces through soil accumulation
- Increasing soil resistance to erosion by maintenance of the soil organic matter
- Stabilising the earth structure by the roots system (Young, 1989).

Reduction in microclimates extremes: It is only recently that the evidence of amelioration of microclimates has been discovered (Ong et al, 1991). Temperature and moisture extremes are modified under tree canopies. The tree canopies protect the soil surface from solar radiations during the day and reduce heat losses during the night, and they narrow the amplitude of daily temperature variations (MacDicken and Vergara, 1990).

Reduced risk of complete crop failure: Plant diversity can reduce the risk of total crop failure because the risk of losses from pest infestation or climatic stress is spread among many species of crops and trees (Huxley, 1999).

Physical support for herbaceous climbers: The tree component can provide support for climbers such as black pepper, vanilla, yams. Therefore, farmers can save money by not using expensive supports that need to be replaced periodically (MacDicken and Vergara, 1990).

Socio-economic advantages

Socio-economic considerations are often more easily understood by farmers compared to the more theoretical biological issues (Mac Dicken and Vergara, 1990).

Variety of products and/or services: A variety of products can be produced from the same piece of land (food, firewood, posts, poles, craft wood, fodder, fertiliser, medicinal products, and services), therefore inducing increased income opportunities (ICRAF, 2000; Huxley 1999, Boehnert, 1988).

Potential for improved human nutrition: The wide diversity of crops and trees in agroforestry systems provide a wide range of edible products for human consumption (Nair, 1993*). Home gardens have been reported capable of producing up to 40 % of the total family calorific requirements* (Terra, 1953, and Michon, 1983 c.f. MacDicken and Vergara, 1990).

Improved distribution of labour: Labour requirements may be more equally distributed over a long period of time. This results in the reduction of high and low periods of labour requirements during the year (MacDicken and Vergara, 1990; Boehmert, 1988).

6.3.2 Disadvantages of Agroforestry

Increased competition: Trees compete with annual crops for nutrients, growing space, solar energy, and soil moisture and may result in reduced yields. This can be minimised, for example, by combining deep rooted tree with shallow rotted crops and spatially zoned systems (ICRAF, 2000; Young 1989).

Allelopathy: Seed germination and plant growth can be inhibited by the release of naturally occurring compounds (allelochems) from roots and aerial tissues of other plants. Allelopathy has injurious or detrimental effects on neighbouring plants through the release of allelochems (Young, 1997). Allelopathic substances produced by tree roots may be a possible problem although there is little evidence (Young, 1989).

Habitat or alternative hosts for pests: Trees can provide a habitat for pests of all sorts, particularly in trees and cereal combinations, where the cereal are attractive food for rodents, birds and insects. Likewise, agroforestry planting can provide an improved habitat for rodents, snakes, mosquitoes, and other insects and disease pests (MacDicken and Vergara, 1990).

Potential for increased erosion: Soil erosion can increase when tree canopies are high above the ground and shading results in reduced ground cover (Young, 1989). More over, raindrops intercepted by leaves can coalesce and form bigger drops that have greater erosivity than unintercepted rainfall (MacDicken and Vergara, 1990).

6.4 Conclusion

Even if the science of agroforestry is relatively new, the practice has existed for millennia all over the world, and are today concentrated in the humid and sub-humid tropics. The systems possess good and bad qualities, however the benefits seem to outweigh the disadvantages. A wide range of systems, including numerous components, can be used in the humid tropics.

The following five systems have been identified as suitable for the humid tropics by Nair (1993) and MacDicken (1990): Home gardens, field boundary planting, animal based systems, shade use systems, and taungya.

7 QUESTIONNAIRE ANALYSIS

To get a clearer picture of shifting cultivation practices and knowledge of agroforestry in Cameroon, 40 questionnaires were prepared and distributed to Cameroonians studying in Europe. The people chosen for the sample were known to one of the authors (see reference list: Jackson, 2000), a Cameroonian by origin. The questionnaires were sent either by mail or given hand to hand. Finally, 17 questionnaires were returned. However, the few questionnaires have only been used as a guideline and support when consulting secondary literature, as most of the interviewees are living in Europe, are not farmers themselves, and thus far from the real situation in Cameroon. However, these qualitative data may help to better understand shifting cultivation in southern Cameroon, since most of the students are of farmer's bred, although the viability of the interviewees, and thus the quality of the questionnaires, may not reflect the real situation. The information obtained can be used as a more "real-life" background than the one that is offered by literature. The questionnaire is found in appendix 3, and the answers are in appendix 4.

The people questioned were mainly men, between 25 and 30 years old. All of them are studying in Europe and have at least a high school diploma, most having BSc's. Twelve people out of the 17 are coming from Southern Cameroon, which is our study area, especially from the southwest province. Finally, 15 are from a farming family and 10 of them have been working as farmers themselves. We can assume from this first part that the interviewees possess a good practical and theoretical knowledge about the subject.

Farming

The second part of the questionnaire has been made in order to learn more about the traditional agricultural practices in Southern Cameroon. Thus, it appears that most of the farms are around 1 to 2 ha, rarely more. The main crops are: beans, coco yams, plantains, vegetables, maize, cassava, potatoes, yams, groundnuts and also cocoa, coffee, pepper and banana. Most of the times, intercropping is practiced together with trees and hedges on the same field. The work is made by a combination of men, women, and children, and labour is sometimes hired. Finally, local tools are usually used for cultivation practices.

Shifting cultivation

Several questions were asked regarding shifting cultivation practices. The clearing and burning is done by the whole family, often just by men. Usually, some of the trees are left standing, if not all. These are often fruit trees, but may however also be huge trees used as shelter against wind and shade, and sometimes because of cultural values. Figure 6 shows that the cultivation period usually last 1 to 3 years and rarely more than 7 years. More important, figure 7 shows that the fallow period is reported by most of the interviewees (53%) usually to last 1 year (never more than 3 years) and the yield start to decline after 3 or 4 years. In all cases, shifting cultivation has been used for a long time (many generations). Most of the interviewees agreed on the fact that shifting cultivation is practiced to increase the yield, and is an efficient and easy way of clearing land. On the other hand, the main problems were recognised as being the destruction of soil organisms such as bacteria, and pollution. Finally, the most cited alternative was the good use of manure and fertilizers.

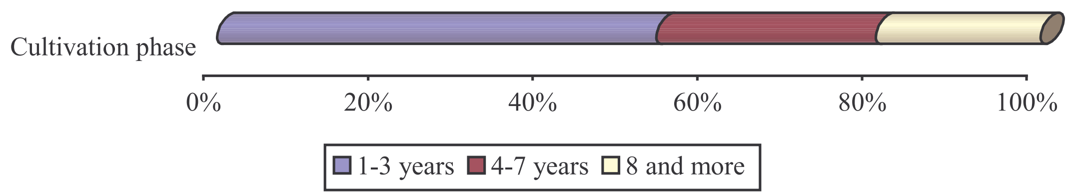


Figure 6: Cultivation period (answers in % of all interviewees)

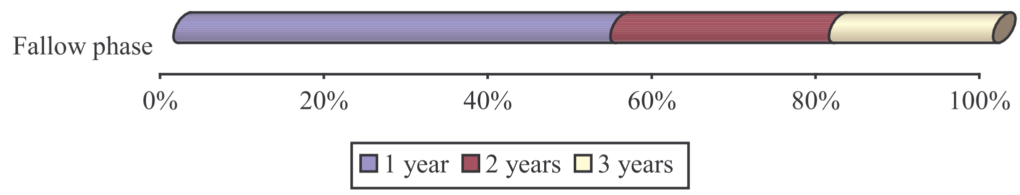


Figure 7: Fallow period (answers in % of all interviewees)

Forest

Concerning the part about trees and forest, the wood is used essentially as firewood (Figure 8) and also as building materials (timber). Then come the other uses such as medicines, forage, fruits, spices, and herbs. The most common tree species are the fruit trees (mango, pear, orange and plum). When asking about the long-term consequences of burning, the first things that come into view are erosion and loss of fertility. Then come the issue of deforestation, pollution, and loss of biodiversity.

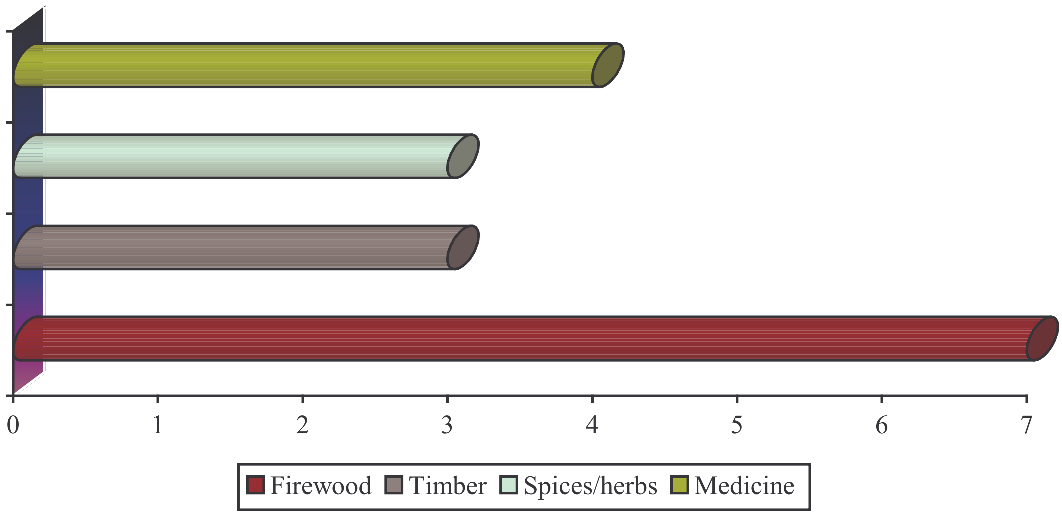


Figure 8: Main uses of forest products (Number of interviewees mentioning the use)

Finally, the last part of the questionnaire concerns the socio-economic aspects. The first question informs us that the crops are used for home consumption and sale. The farmers have to walk at least 3 or 4 km to reach their field, the distance however sometimes being 10 or more. The land is owned by private owners or by the government, and it is obtained either by renting or buying it or by having a special agreement with the government. The last question tells us that conflict between farmers and local NGO's or local power sometimes happens, very few said it never happens.

8 ALTERNATIVES

Two main reasons for shifting cultivation in Cameroon were identified in the problem analysis: shifting cultivation performed by small-scale farmers for subsistence reasons, and shifting cultivation for commercial production of food crops, due to increased prices on fertiliser and fungicides. In the following chapter, agroforestry systems suitable as alternatives both for the subsistence shifting cultivator and the commercial shifting cultivator will be assessed. The systems assessed are those identified in chapter 6 as suitable for the humid tropics. Further, the literature review shows several constraints present for agricultural production in the humid lowlands of Cameroon. First, these constraints will be listed for then to be addressed when considering the possible alternatives.

8.1 Main Constraints

The main constraints identified are (Duguma et al., 1994; Tonye et al., 1994; Kanmegne et al., 1999; Kotto-Same et al., 1997; Duguma and Tonye, 1994; Ayuk et al., 1999; Leakey, 1998; Harwood, 1996; Kormawa et al., 1999):

- Nitrogen and phosphorous deficiency (LAC soils), P is strongly retained
- Low soil organic matter (SOM)
- Firewood collection
- Acid soils (Aluminium toxicity)
- Shade for cash crops
- Land scarcity
- Labour scarcity
- Poverty (people cannot afford fertiliser, lime or other inputs (inoculation))
- Short time horizon (quickly economic return to investments)

Problems connected to acid soils and aluminium toxicity are limiting the choice of trees and crops (Young, 1997). The problems may be addressed by using trees and crops tolerant to these conditions (Norman et al., 1995). Thus, these issues are not considered when discussing the agroforestry systems. They will be addressed when the components of each system are chosen.

8.2 The Alternatives

Animal-based systems

Animal-based systems with livestock production are known to have income generating potentials in the humid tropics (MacDicken, 1990). However, according to MacDicken (1990), livestock production has traditionally been less important in humid areas than in dry areas. Further, MacDicken states that uncontrolled grazing by the animals may cause damage to both trees and crops. For the subsistence farmer, livestock production may be an unreachable alternative, as the required amount of money may be difficult to obtain. For the commercial shifting cultivator, on the other hand, livestock production may be an alternative. However, according to Whitmore (1990), livestock production is one of the main reasons for deforestation in South America, new areas continuously being slashed down to provide grazing areas for the cattle. The intensive grazing by the cattle prevents the forest from regenerating, the areas being transformed to prairies and grasslands. As the main objective for finding alternatives to shifting cultivation is stopping deforestation and forest degradation, this seems not to be a good solution.

Taungya

The main objective of the Taungya system is according to Young (1990) to provide labour for the (re)establishment of forest plantations. The land belongs to the government or large-scale corporations, allowing the small scale farmers to raise their crops during the first years of the establishment. The Taungya system has been tried as an alternative to shifting cultivation, by giving up their practice for obtaining the same possibilities in the forest plantation (Nair, 1993). Nair (1993) mention the *Forest Village Scheme* in Thailand as one of the best known examples. Here, each family in a selected village unit was given a small piece of land to build their houses and establish home gardens. The farmers were also permitted to cultivate crops between the young trees in the plantation. The obligation being that they provided the necessary labour for the establishment and management of the timber plantation. The system has however not been very successful. It has been met with extensive criticism, accused of exploiting cheap labour, and having technical, socioeconomic and institutional shortcomings (Nair, 1993; Young, 1997). Further, problems connected to transport (to and from the village), possible lack of available areas for cultivation with time, and a long time horizon are mentioned. With a time horizon of more than a few years, difficulties may be encountered as to convince the farmers of the economical and biological values of the timber trees (Paludan, 1985). The Taungya system is mostly aimed at the establishment of large timber plantations (Young, 1997; Paludan, 1985), and is depending on large investments and initiatives from the government for implementation (Nair, 1993). The Taungya system seems thus not an optimal alternative for the small-scale shifting cultivator.

Field boundary planting

Field boundary plantings can also be referred to as litter banks or cut and carry systems. One of the systems main advantages include production of plant litter that can be used as mulch in the fields. The application of plant litter from (leguminous) trees to the soils can increase the soil organic matter and especially the nitrogen status of the soils, because of the nitrogen fixed by the trees. The soil improvement results in higher crop yields (Giller and Wilson, 1991). Further, the litter bank system has the ability to reduce the problem induced by firewood collection. A high firewood production is achieved when the trees are allowed to grow bigger than if they were placed in the field with the crops (Young, 1997).

The litter banks in the system does not need to take up much land, since the trees can be planted on the already bare boundaries of the field. Thereby, is the problem with land scarcity not worsened, although you could recommend the litter banks area to expand if the need for firewood and mulch is high.

The litter bank system does not require large economic resources, which is very important for the small-scale farmer. The largest expense is normally buying the tree seeds and establishment of seedlings when starting the system (Roshetko et al., 1997;Huxley, 1999). A short time horizon is possible in the system if fast growing tree species are chosen (Ty et al., 1997). The system seems as such well suited for the subsistence shifting cultivator, as a continuous cropping of food crops and supply of firewood may be facilitated.

Home gardens/agroforests combined with shade uses in crop production

The word "homegarden" has been used rather loosely to describe diverse practices, from growing vegetables behind houses to complex multi-storied (multi-strata) systems (Nair, 1993). Lodoen (1998) states that: *In the southern Cameroon and other parts of West Africa the cocoa agroforest is the main sedentary land use system,* as alternative to shifting cultivation. An agroforest is a plant community that resembles a natural forest, approaching its species diversity more than most other systems. It is generally consisting of multiple strata, and contains large, mature trees and shade-tolerant understorey plants (ICRAF, 2000). Also Young (1997) argues that the multi-strata home gardens are suitable systems for cocoa production in humid zones. He states further that little soil specific experimental work has been done on these gardens, as the system is *so clearly sustainable*. Benefits include erosion control, enhancement of soil organic matter and nutrient recycling as the system has a high production of plant litter, a complete ground cover of litter and an efficient uptake of nutrients due to a multilevel root system (Young, 1997).

The diversity of species in the cocoa agroforest gives room for the production of a variety of products on the same piece of land. The products may include food, fruits, fuelwood, timber, fodder, medicine, and services as shade for cocoa trees farmers and livestock (MacDicken, 1990; Nair, 1993).

According to a study by Perera and Rajapakse (1991) on home gardens in Sri Lanka, home gardens have several advantages mainly in reducing exploitation of natural forest. 62 % of the investigated farmers depended solely on their home garden for firewood collection. Further, they mention that this system is sustainable being able to *conserve basic resources of production in the long term*.

The cocoa agroforest may be a good alternative to commercial shifting cultivation. As mentioned in the problem analysis, the main reason for the increase in commercial shifting cultivation was the government ceasing subsidies for fertiliser and fungicides. By using the cocoa agroforest system, the need for fertiliser input may be reduced. The diversification of species used may further secure the farmers economy, by reducing the risk of great economic losses if one crop species fail (MacDicken, 1990). Leakey (1998) mention further the great potential in complex gardens for production of a wide range of non-timber forest products, enhancing the economic value of the garden.

8.3 Conclusion

Two systems seem to be of specific interest as alternatives to shifting cultivation in the humid lowlands of southern Cameroon. The boundary plantings/litter banks and home garden/multi-strata system have both several advantages as to improve the soil organic matter, to keep the nutrient content in the soil on a sustainable level, and to produce firewood. The litter bank system has low land and economic requirements, making it interesting for the subsistence farmer. The multi-strata system, on the other hand, may make a sustainable cultivation of cash crops possible without extensive additional nutrient inputs or the danger of total crop failure being significant.

9 SUGGESTED SYSTEMS

In this chapter, the two most interesting systems identified in chapter 7 will be further examined. The litter bank system and the multi-strata system will both be presented and assessed as regarding their possibilities as alternatives to subsistence and commercial shifting cultivation in southern Cameroon. First, the main criteria for the choice of components are described: Use of multipurpose trees, use of leguminous trees, use of indigenous practices and the use of already known food and cash crops. The reasons for these criteria being chosen are given below. In section 9.1, the litter bank system is thoroughly described, and the choice of components discussed. A possible design of the system is then suggested, and nutrient balances are estimated. The results are then evaluated for their advantages and disadvantages. In section 9.2, the multi-strata home garden system is described and assessed as for the litter bank system. The purpose of this chapter is to assess the value of these systems, including the chosen components, to the small-scale farmers.

Use of multipurpose trees

Multipurpose trees have, like the word is indicating, many potentials: Soil organic matter augmentation through leaf litter fall, ability to take up nutrients from deep soil horizons through their deep extensive root systems, fix atmospheric nitrogen, timber value, medicinal importance, fodder provision for animals feed, fruit for home consumption etc. Some of the products can be sold by the farmers and give them additional income that will improve their standards of living (Huxley, 1999).

Most trees may be characterised as multipurpose trees as most trees have several potentials. However, the distinction is important for underlining the difference from trees mainly used for wood production. Thus, multipurpose trees are providing the small-scale farmers with a wide range of products and services, making it an important part of the agroforestry systems (Young, 1997; Huxley, 1999; Nair, 1993).

Use of leguminous tree

The use of leguminous tree species address two of the main problems mentioned; nitrogen deficiency and low soil organic matter content. Nitrogen deficiency is a major constraint for cultivation of crops in the humid lowlands of Cameroon (Kanmegne et al., 1999). For tropical crops nitrogen is the nutrient required in the highest amounts compared to other nutrients (Ahn, 1993). Due to high prices and low availability, nitrogen fertiliser is not a good option for improving the nitrogen content in the soil (Rao et al., 1998). Because of this, the natural sources of nitrogen supply to the soil have to be considered for improvement. Nitrates washed down in the rain from the atmosphere only results in small increases in the soil. Nitrogen released from decomposing plant and animal residues or from mineralisation of soil humus is contributing to the nitrogen pool of the soil. However, due to the small amount of plant residues returned to the field and the generally low content of soil organic matter, the increases are often small. The last solution is nitrogen gained from atmospheric nitrogen fixation by biological processes for example in leguminous tree species (Ahn, 1993). Biological nitrogen fixation is where atmospheric di-nitrogen is converted into mineral nitrogen. Including leguminous tree species in an agroforestry system can make a significant contribution to the improvement and maintenance of soil fertility, mostly due to the nitrogen fixation (Giller & Wilson, 1991). The nitrogen fixed meets the trees own requirement besides improving the nitrogen status of the soil. The amount of nitrogen transferred to associated plants, like in agroforestry systems, is very difficult to estimate (Dommergues, 1996). Eventually, the cultivated crops will benefit from the nitrogen fixed if the organic matter from the trees is applied to the fields (Giller & Wilson, 1991). Furthermore, the legume trees are, like other trees, able to capture nutrients (including nitrogen) from soil horizons deep down where crops cannot reach them and thereby enhancing the soil nutrient status (Dommergues, 1996).

Leguminous trees fix very different quantities of nitrogen. This factor is thus one of the important issues to consider before choosing the right tree legume for a specific system. Other important factors are the tree legumes adaptability to grow under specific conditions (e.g. acid soils or drought) and needed tree products like fuelwood, foods or fodder (Giller & Wilson, 1991).

Use of indigenous practices

By using the basis of indigenous practices in improved systems, the adoption of a new or improved system can become easier for the farmers (MacDicken, 1990; Bahuchet, 1996). Alcorn (1990) notes that the management of traditional agroforestry systems is done on the basis of indigenous knowledge. The art having evolved linking development of agroforestry systems with the experience of people. Centre pour l'Environnement et le Dévéloppement (CED, 1999) mention sustainable harvesting of non-timber and farm products in the Cameroon as areas needing attention. In this context, they state that *recognition of traditional knowledge is a precondition for* (this attention) *to be effective.* Thus, the use of components and disciplines known to the local people seems important as a basis for possible improvements.

Use of already known food and cash crops

The use of already known food and cash crops may be seen in connection to the above mentioned indigenous practices. By using already known food and cash crops, the local farmer does not need education in the cultivation methods (Kerkhof, 1990). Djimde and Raintree (1988 c.f. Mollet et al., 1995) defined the land use system in southern Cameroon as a cocoa-food crop-coffee-system. The food and cash crops are grown for local preferences of food, and as they are adapted to the conditions in the area (acid soils, low soil fertility etc.), resulting in increased potentials for higher yields (Norman et al., 1995; Jackson, 2000).

9.1 Litter banks

The litter bank system is a simultaneous agroforestry system belonging to the agrisilvicultural systems (trees with crops). Depending on the purpose of the system it can be called by many other names. "Boundary plantings" is used when referring to the placement of trees along field boundaries or other borders. "Biomass transfer system" (cut-and-carry mulching) is used when the important aspects of the system is plant litter (organic matter) production to the soils, resulting in higher soil fertility. "Litter banks" are basically the same, but this name is used specifically when the trees are just besides the cropping fields, and the need for carrying the plant litter is minimal. Finally, the system can be called a "Fuelwood production system", when considering the systems possibilities for producing fuelwood most important (Young, 1997; Nair, 1991). The addition of mulch to the fields improve the soil fertility and thereby, in most cases, also the crop yields. The trees ability to produce firewood is another important purposes of the system (Giller and Wilson, 1991;Young, 1997). If there is increased need for wood and nutrients, more lines of trees should be included in the fields, e.g. an extra line in the middle of the field, thereby loosing the meaning of boundary plantings.

In the litter bank system the trees (e.g. leguminous trees) are grown as a separate block for example around the field(s) and the leaf matter is cut from the trees and carried to the cropland, where it is added to the soil as mulch. Because the tree-crop-interface is kept to a minimum, this system will minimize the competition between the trees and the crops (Young, 1997).

In addition to the criteria mentioned before, several issues are important to consider when choosing tree and crop species. Synchrony in pruning time, plant nutrient release by decomposition of the plant litter, time of high nutrient requirements by the crops, production of plant litter and production of firewood are all issues to be regarded (Young, 1997).

9.1.1 Calliandra calothyrsus

Several sources mention *Calliandra calothyrsus* as the most suitable tree species in connection to the humid lowlands of Cameroon. These will be further addressed in the section below.

Results of experiments with *Calliandra calothyrsus*

In an experiment on cassava cultivation with adjacent litter banks, Kotto-Same et al. (1997) conclude that *C. calothyrsus* is a promising species for litter bank systems. They also test cassava in alley cropping, however not recommended due to cassava suppressing the growth of the alley trees. Instead, cassava growing next to litter banks of a fast growing multipurpose tree species as *C. calothyrsus* is recommended. This system is lowering the competition between the trees and the cassava, and the prunings from the leguminous tree is improving the soil fertility by organic matter inputs to the fields. In the experiment, *C. calothyrsus* is also recommended due to its well adoption to the acid soils in the area.

In an experiment screening ten different multipurpose tree species in the humid lowlands of Cameroon, Duguma and Tonye (1994) conclude that *Calliandra calothyrsus* is the "best candidate for technologies aimed at improving soil fertility" in this area, and one of the best candidates for agroforestry practices. The conclusion is based on the tree having the highest nitrogen value both in the leaves and in soil samples taken from under the tree. Further , the *C. calothyrsus* has one of the highest biomass and leaf litter yields, and result in the highest percentage of organic matter in the soil. As nitrogen is a major yield-limiting nutrient in southern Cameroon, *C. calothyrsus* seems to be a suitable choice. There are however some important issues to remember. The nitrogen (and phosphorus) content in the leaf litter is different at different months of the year, and mulch application and following decomposition should thus be synchronised with the nutrient need of the crops in the field. Further, a negative aspect of using *C. calothyrsus* is that when direct seeding is performed, the tree has one of the lowest survival rates. Furthermore, plant height and stem diameter of *C. calothyrsus* is significantly reduced when intercropped with maize, indicating that *C. calothyrsus* is more suitable in agroforestry systems that are spatially zoned (Duguma and Tonye, 1994).

In an evaluation of four trees in the humid lowlands of Cameroon, Kanmegne et al. (1999) conclude that *Calliandra calothyrsus*, together with *Cromolaena odorata*, is the best tree specie for improving soil fertility in the area. He base his conclusion on *C. calothyrsus* being suitable for acid soils, having the highest nitrogen content in the biomass, and the leaf biomass having the lowest lignin content. Low lignin content results in fast plant litter decomposition, making the litter suitable as mulch when crop demand for nutrients is high. *C. calothyrsus* has, like the three other species tested, the highest root distribution in the soil depth of 0-20 cm. The tree is thus not good for intercropping, as competition will decrease the yields unless heavy root pruning is carried out.

In a test of ten multipurpose tree species on acid soils in the humid lowlands of southern Cameroon, Duguma et al. (1994) concludes that *Calliandra calothyrsus*, together with *Cassia siamea*, is the most suitable multipurpose tree. The conclusion is here based on *C. calothyrsus* having the production of the greatest coppice biomass (9-13 t/ha), and significant higher nitrogen and organic matter percentage of soils under the trees than the other species tested.

Finally, when conducting a general test of different trees' potential for improving the soil fertility, Tonye et al., (1994). conclude that *C. calothyrsus* is the most promising species, because of its high leaf biomass and its high leaf nitrogen content. Leaf calcium content is in that connection very low. However, the calcium requirement is not very high for species as maize and cassava (Norman et al., 1995) An intercropping of these species should thus be possible, with *C. calothyrsus* as a promising tree species for improving soil fertility,

Description of *Calliandra calothyrsus*

The genus *Calliandra* contains 132 species, where *C. calothyrsus* is the best known and most used. *Calliandra* belongs to the family *Leguminosae*, a family where many of the genus's have the ability to fix nitrogen from the atmosphere. Many of the *Calliandra* species are found in tropical humid lowland forests. *C. calothyrsus* has been used successfully on Java (Indonesia) due to its high potential for production of fuelwood, green manure, animal fodder and pulpwood. *C. calothyrsus* is currently tested in humid tropical areas for its potentials in agroforestry (Powell and Roshetko, 1997). Macqueen (1997) state that *C. calothyrsus* is *unique within the genus in terms of its wide international use as an agroforestry multipurpose tree*.

Calliandra calothyrsus is a small branching tree with a maximum height of 12 m and a stem diameter of approximately 20 cm. It has several deep taproots and many finer roots spreading just beneath the soil surface. *C. calothyrsus* has the ability to form nodules and fungal associations when rhizobia and mycorrhiza is present in the soil (Macqueen, 1997). The tree provides the bacteria with carbohydrates and the bacteria converts atmospheric nitrogen, in the nodules, to a usable N from for the tree. The generation of nitrogen is one of the most important characteristics for the agricultural systems in low fertility soil environments. Only some bacteria strains can lead to symbiotic relationship with *C. calothyrsus*, and when the trees are introduced in new areas, inoculation is often necessary. Besides the symbiosis with rhizobium, the tree can form a symbiotic relationship with vesicular-arbuscular mycorrhiza (VAM). When these fungi grow in connection to the tree roots, the root area is increased resulting in an improved access to water and nutrients (Roshetko et al., 1997). One important factor in humid tropical areas is the increased access to phosphorus in the soil (Ahn, 1993). To insure that *C. calothyrsus* is benefiting from this symbiosis, inoculation with mycorrhiza to the nursery soil can be carried out (Roshetko et al., 1997).

Calliandra calothyrsus is not particular tolerant to shade and can be out-competed when growing under taller trees. It requires a mean annual rainfall of 1,000-4,000 mm and annual minimum temperatures of 18-22 ºC. Slightly acid soils is tolerated with a pH of 4.5 but poorly drained soils will reduce its growth (Macqueen, 1997). *C. calothyrsus* is adapted to many environments, however with best results obtained when using a suitable provenance (seed source) (Roshetko et al., 1997).

C. calothyrsus can be established in several ways. The easiest way is to sow the seeds directly in the field. Unfortunately, when using this method the seeds are more susceptible to climatic extremes and the seeds used should be of highest quality. Another method is to sow the seeds in plastic (polyethylene) bags in a nursery, and then transplant the seedlings in the field at the beginning of the rainy season. *C. calothyrsus* can also be successful propagated by stump sprouts made from 4 to 12 month old seedlings. Vegetative propagation can be used, but the method is difficult and requires additional work (Roshetko et al., 1997).

Regardless of the sowing method used, *C. calothyrsus* has a slow initial growth. This makes it vulnerable to competition from other plants for light, water and nutrients, and all crops should be removed in a distance of approximately 50 cm in the initial growth period. In addition, weeding is often required in the first 6-12 month (Roshetko et al., 1997). Nevertheless, *C. calothyrsus* is a popular multipurpose tree because of its easy establishment, quickly growth (after initial growth) and resprouts after repeated harvests (Ty et al., 1997).

In Indonesia firewood production is a major reason for growing *C. calothyrsus*. The trees are planted at a spacing of 1x1 m. To encourage rapid resprouting, the trees are cut at a height of 30 to 50 cm (50 cm cutting is more favourable for overall coppice development, (Tomaneng, 1990)) at the end of the dry season. The annual firewood production rages from 5 to 20 m^3/ha from one-year-old trees and 30 to 65 m^3/ha from 20-year-old trees. In Sri Lanka, *C. calothyrsus* is often used as mulch and to provide nitrogen to the fields. The mulch conserves soil moisture and suppresses weed growth (Ty et al., 1997).

C. calothyrsus do not suffer serious damage from pest and diseases, either in their place of origin or in places where they have been introduced. This belief should though be considered with some caution since there has been very little study of pest and disease problems in these trees (Boa, 1997).

9.1.2 Crops Involved

Mutsaers (1978) states that groundnut, maize and tubers are normal in intercropping systems in southern Cameroon. Further, Tonye et al. (1994) mention maize, cassava and groundnut as normal in mixed cropping systems in the forest zone of Cameroon. These statements are supported by

Jackson (2000), mentioning maize, cassava and groundnut as the most preferred food crops in southern Cameroon.

Cassava

Cassava (*Manihot esculenta*) is an erect perennial shrub. It is planted vegetatively, and can grow to 1-5 m in high. The plants produce 5-20 storage roots or "tubers" and thus often referred to as a tuber crop. Cassava has deep and well-developed roots that can reach the soil nutrients deep in the soil profile, and can thereby yield rather well on less fertile soils (Ultisols and Oxisols). Cassava can tolerate low calcium, potassium, and nitrogen contents in the root environment better than other species, and especially the low nitrogen tolerance makes it adaptable for food crop cultivation in the humid lowlands of Cameroon. Potassium is required in higher amounts than nitrogen and the low soil content will, to some extend, result in lower yields. Phosphorus (P) can generally also be a limiting factor to high yields mainly because of cassavas inefficiency in taking up the P, but this problem is often reduced due to mycorrhizal associations (Norman et al., 1995). Although cassava can grow on low fertility soils, it can still remove large amounts of soil nutrients, and thus give high yields. Cassava responds well to chemical fertiliser, manure and incorporation of green manure in the soil (mulching) (Howeler, 1996). The growth of cassava is affected by aluminium toxicity, however to a small extent compared to e.g. maize. Further, cassava can tolerate a lower soil pH than other root crops and maize (Norman et al., 1995). Time of harvest is determined not only by planting time and growing environment but also by the small-scale farmer's dietary or financial needs since the individual tubers may be harvested progressively, leaving the rest in the soil for future harvest. In the wet tropics, the tubers are normally harvested between 12-18 month after planting (Norman et al., 1995).

Maize

Maize (*Zea mays*) is an annual tropical cereal. High amounts of water and nutrients, and a soil pH of 5-8 are factors required if high yields should be obtained. Nitrogen is one of the most important nutrients required (Fageria et al., 1997), and especially after the onset of tasselling will the lack of nitrogen reduce the yield. Phosphorus deficiency in acid soils is another limiting factor, maize having high demands for P during early growth. Mycorrhiza fungi can however increase the uptake to some extent. General, nutrient deficiencies often limit maize yields on Oxisols and Ultisols, but if correct amounts of nutrients are applied at the right time, high yields are attainable (Norman et al., 1995). Aluminium toxicity is a problem, especially when growing on acid tropical soils. Further, poor soil structure can restrict root development and thereby reduce the yield. Maize matures in 100-120 days after sowing, depending on temperature and altitude. The precipitation in the humid lowlands of Cameroon is high enough to secure no water deficit in the growing season, but a low nutrient content (especially nitrogen) in the soil may affect the yield. A good physical condition of the soil can reduce the nutrient problem by improving the root development of the maize. In low fertility areas, like the humid lowlands of Cameroon, maize should always be grown in the start of a cropping season to gain a reasonable yield (Norman et al., 1995).

Groundnut

Groundnut *(Arachis hypogaea)* is an annual plant with a creeping growth close to the soil. The stems are 30-50 cm long. As the name indicates, the groundnut is formed below the soil surface (Lötschert and Beese, 1983). Groundnut is not drought resistant and lack of water is the major constraint to yield in many areas (Norman et al., 1995). The groundnut has a deep taproot with well-developed lateral roots. As the fruits ripen below the ground, it prefers light soils (Lötschert and Beese, 1983). The most suitable soil is a well-drained soil with fairly high calcium content and a moderate organic matter content (Fageria et al., 1997). It is tolerant of a high aluminium content in the soil, and very tolerant of acid soils. Low soil nutrient content is not considered a major problem since groundnut is a nitrogen-fixing legume. A lack of calcium can however give reduced yields. Groundnut inoculates effectively with natural occurring Bradyrhizobium bacteria, thus fixating atmospheric nitrogen in most soils (Norman et al., 1995). Groundnuts are cultivated both as a sole crop and as a component of intercrop mixtures. It may have a substantial beneficial effect on immediately following non-legume crops (Norman et al., 1995). Competition between groundnuts and trees grown in the same field is not considered high because of the groundnuts shallow root profile compared to most trees deeper rote profile (Norman et al., 1995).

9.1.3 Design of the System

How the litter bank system should be designed depends on many different factors, where labour and land scarcity, need for plant litter as mulch and need for firewood is considered the most important ones. More litter banks on the field area means a higher plant litter and firewood production, but it also means less land for crop cultivation and higher labour requirements for the small-scale farmer

(Huxley, 1999). It is important to remember that even though only few litter banks are established, the nutrient status of the soil in the field will improve due to the additional mulch applied, and small amounts of firewood is also appreciated. On the other hand, if the nutrient status is only slightly improved and the firewood production is not high enough to support the small-scale farmers needs, the litter bank system will not represent a suitable alternative to the shifting cultivation system. Keeping these factors in mind the best suitable design of the litter bank system is considered in connection to the nutrient requirements (nitrogen) of the food crops produced and the firewood needs of the farmer.

To determine how many tree rows is necessary in the system for producing enough nitrogen and firewood to satisfy the farmer, the following estimations is proposed:

Nitrogen gained from the tree litter (initial pruning after one year):

Total leaf biomass (dry weight) (t/ha/year):	9.10 (Duguma and Tonye, 1994)
Nitrogen content in leaves (litter biomass) (%):	2.92 (Duguma and Tonye, 1994)
Total nitrogen content in litter biomass (t/ha):	0.27
Proportion of nitrogen derived from fixation (%):	44.6 (Purwantari et al., 1996 (II))
Total addition of nitrogen to the system (t/ha):	0.12*
Plant available efficiency (%):	30.0** (Nielsen, 1999)
Nitrogen available (kg/ha):	**36.0**

*Only the nitrogen in the litter biomass that is derived from atmospheric fixation can be considered as an input to the litter bank system. The rest of the nitrogen in the biomass is taken up from the soil.

**This number is quite low due to a high loss of nitrogen for denitrification.

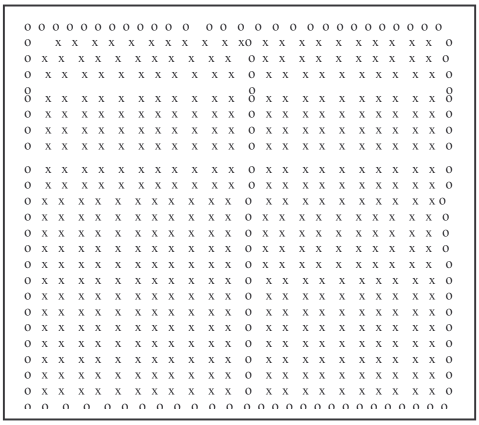
Firewood gained from the trees are estimated as the following:

One year old trees (m^3/ha):	5-20 (Ty et al., 1997)
20 year old trees (m^3/ha):	30-65 (Ty et al., 1997)
Average (mostly based on young trees) (m^3/ha):	15 (Duguma, 1995)
Specific gravity of the Calliandra (t/m^3):	0.65 (Duke, 1983)
Average (t/ha):	**9.75**

The trees can be placed around the field like boundary plantings, with a row of trees placed in the middle of the field, dividing the field into two equally sized fields. The middle row is added to obtain more tree litter and firewood. The middle row may need more frequently pruning if the crops are grown close to the trees. Frequently prunings will result in a lower firewood production, but the tree litter production should remain the same as from the boundary trees. The estimation of nitrogen available to the food crops, and the firewood available to the farmer is made for an area of 1 ha. The trees take up approximately 1/5 of the area, and the estimations should therefore be corrected to:

Nitrogen available (kg) per year:	**7.2**
Average firewood production (t) per year:	**1.95**

The design of litter bank system (1 ha) is illustrated below (Figure 9):



o: *C. calothyrsus*
x: Food crops

Figure 9: Design of the litter bank system.

The design is hypothetical and the proportions are not correct. The biomass production listed above equals approximately 4000 trees/ha (Szott, 1995).

Biomass production from the trees varies with time and number of prunings carried out, and with the tree population in the system. Biomass production at the initial and subsequent prunings increases with the age at which the tree is first pruned (Szott, 1995). This indicates that the older the tree is at the first pruning, the higher biomass production can be expected. Furthermore, it has been reported that production and survival of *C. calothyrsus* is increased with decreasing pruning frequency and increased pruning height and that also the proportion of wood to total biomass yield increases with increasing time between prunings. Normally, it is possible to make many subsequent prunings on *C. calothyrsus* if the initial pruning is carried out when the tree is 12 months old. Finally, biomass production decreases with increasing tree population but, on the other hand, this increases production per hectare. Following the best pruning techniques, higher biomass quantities can be produced (Szott, 1995).

As mentioned earlier, the firewood-need for one household is estimated to be 3.65 t/year. One hectare in the litter banks produce 1.95 t/year equal to 53 % of the amount needed for one household. The firewood produced in this system is therefore not enough to support a small-scale family for one year. This system is of course not the only source of firewood for the small-scale farmer, who often has trees or bushes scattered around the farm area. However, the system should produce the majority of the firewood needed to secure the forest areas from being exploited.

How do the trees and crops fit together

The crop rotation shown below (Table 2) is strictly illustrative, however made to show a possible crop rotation in a cassava-maize-groundnut litter bank system:

Year	1. season	2. season
1	Cassava + Maize	Cassava (continued)
2	Cassava (continued)	Cassava (continued)
3	Maize + groundnut	Maize + groundnut
4	Maize + groundnut	Maize + groundnut

Table 2: Crop rotation for the litter bank system.

The litter bank system has most often spatial zones between the crops and the trees, making competition a minor problem.

More important to consider is the synchronisation of tree pruning time, amount pruned, and the nutrient requirements of the crops cultivated. Frequently pruning including only small amounts of plant litter every time, applied to the field, results in a more equal release of nutrients, and thereby a lower chance of nutrients lost by leaching (Ahn, 1993; Giller et al., 1997). Frequent application of plant litter to the soil surface also protects against soil crusting and weed problems. Generally, nutrients from plant litter application can be better utilised when the crop has a certain size (Nielsen, 2000). Cassava has a slow initial growth and could therefore be expected to benefit more from nutrients released later in the growing season. Maize needs nitrogen in all growing phases but especially after the onset of tasselling will nitrogen release, benefit the yield (Norman et al., 1995). Groundnut does not need the soil nitrogen due to its nitrogen fixing ability (Giller and Wilson, 1991).

9.1.4 Nitrogen balance

The following nitrogen balances have been estimated:

Maize + groundnut intercropped in one season

The balance corresponds to a nitrogen content of 1.5% in the maize seeds (reference states 1.0% but this is too low (Nielsen, 2000)) giving a yield of 3 t/ha (Ofori et al., 1987). And to a nitrogen content of 4% in the groundnut seeds giving a yield 1.5 t/ha (Fageria et al., 1997). N-harvest index for groundnut = 50% (Giller et al., 1994). The balance is made based on the assumption that crop residues are returned to the fields (Figure 10).

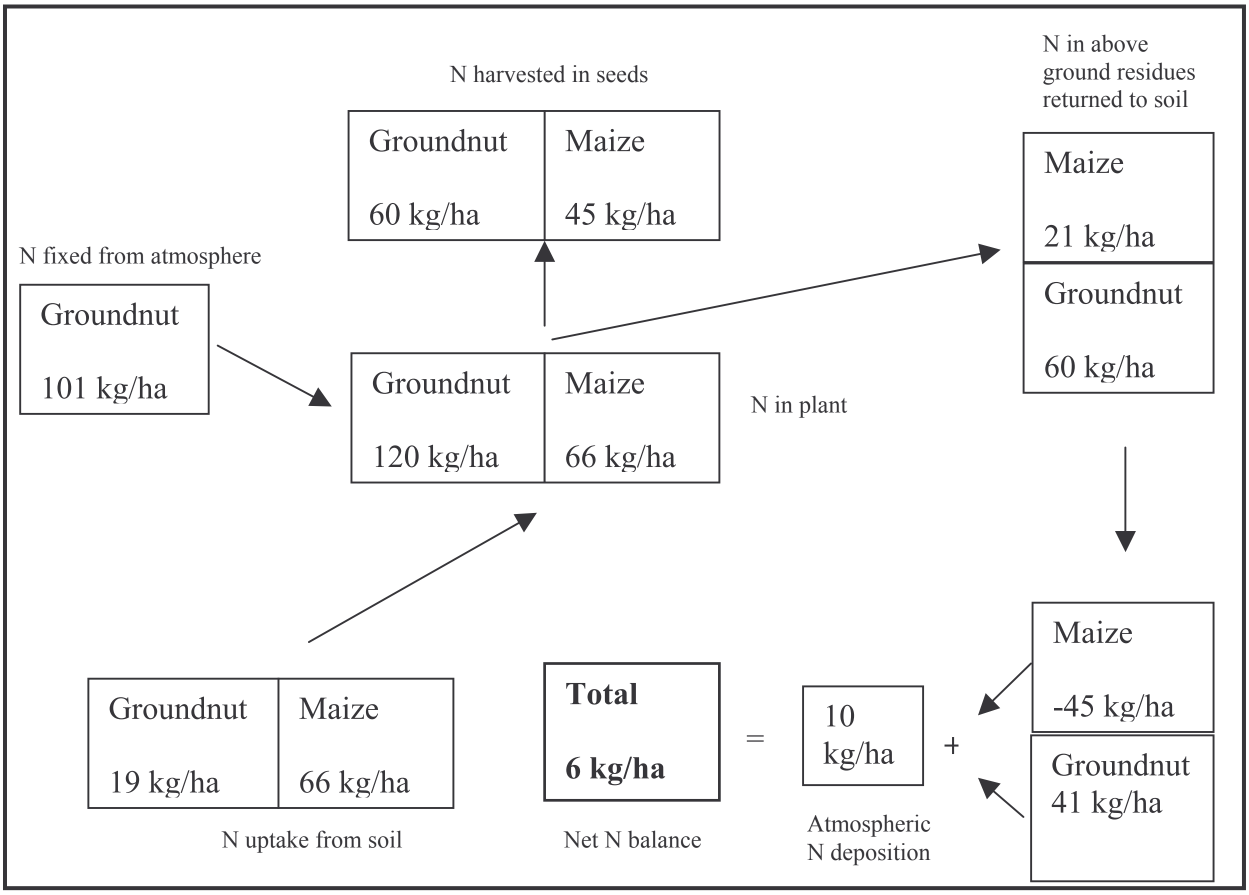


Figure 10: The nitrogen balance for the litter bank system with maize and groundnut intercropped for one season (Giller and Wilson, 1991;Ofori et al., 1987;Nielsen, 2000).

The total net balance result for 2 seasons (1 year), when the available nitrogen from the mulch (litter banks) is included in the calculation is:
(2 x 6 kg/ha) + 7.2 kg/ha = **19.2 kg nitrogen/ha**

The result in the balance figure shows that the total nitrogen balance for the maize + groundnut system is positive, but still close to zero (+6). When the plant litter from the litter banks is applied to the soil, the balance is improved, and thereby more stable if changes in nitrogen fixed or soil nitrogen polls occur. The surplus of nitrogen is not very high but together with the nitrogen pool mineralised natural every year from the soil (3-7%), the nitrogen depletion can be lowered and perhaps even non existing. A high nitrogen balance is preferred but only if the following crop or system can utilise the surplus nitrogen, otherwise it will just be leached out (Nielsen, 2000). A positive nitrogen balance gives the farmers an opportunity to stay on the same piece of land for continuing cultivation without declining yields. Maize yield for this balance is 3 t/ha for one season giving 6 t/ha for one year, and this is a very reasonable yield for the small-scale farmer in the humid lowlands of Cameroon (Nielsen, 2000).

Cassava and Maize Intercropped

The balance corresponds to a cassava yield of 9 t/ha (IFA, 1992) and a maize yield of 3 t/ha (Ofori et al., 1987). Again the balance is made based on the assumption that the crop residues are returned to the field (Figure 11).

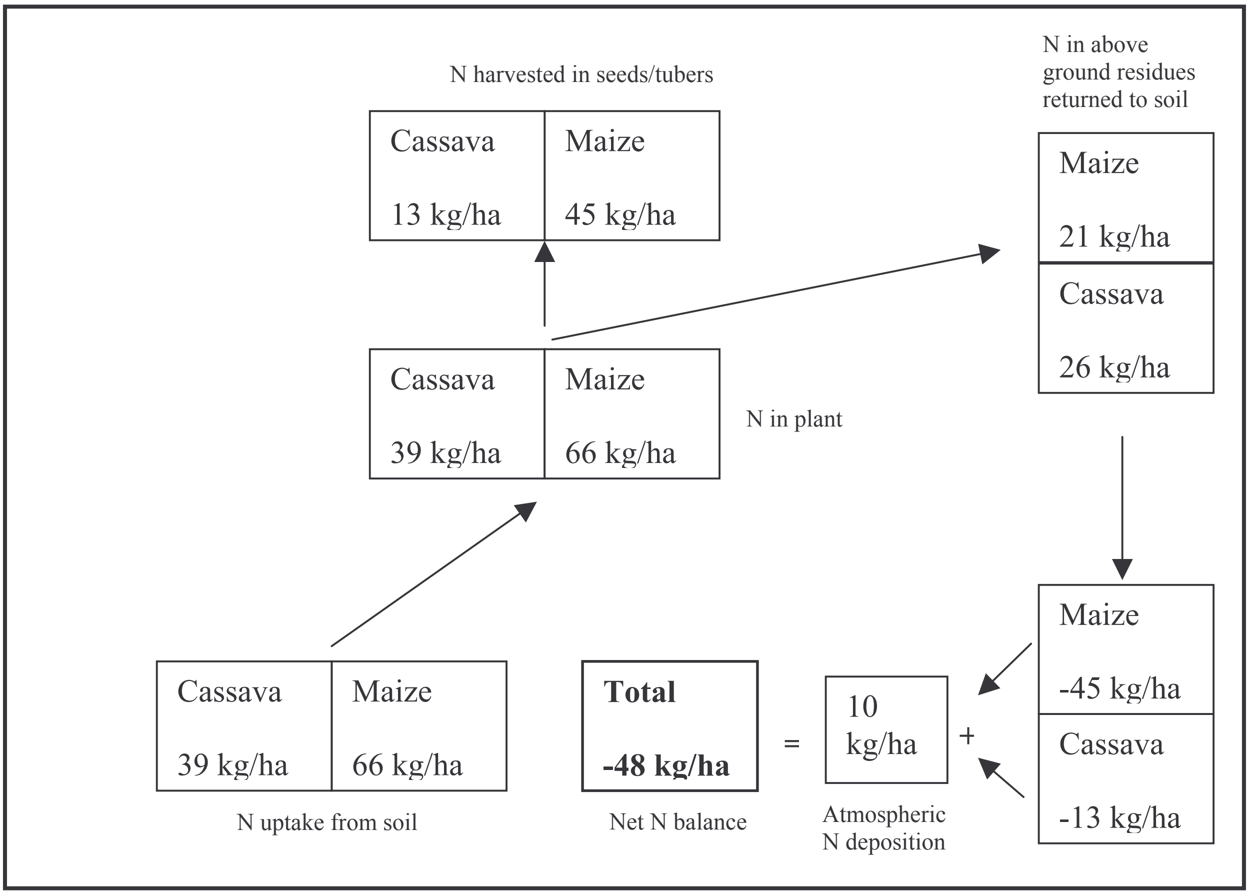


Figure 11: The nitrogen balance for the litter bank system with maize and cassava intercropped (IFA, 1992;Ofori et al., 1987).

The following total net balance has to be calculated for 2 years due to the fact that cassava is cultivated for 2 years. Maize is only part of the system in the first season of the first year is:

-48 kg/ha + (2 x 7.2 kg/ha) = **-33.6 kg nitrogen/ha**

The estimations shows that the total nitrogen balance for the cassava + maize system is negative (-48). When the plant litter from the litter banks is applied to the soil, the balance is improved but still has a negative result. The nitrogen mineralised naturally every year will however improve the balance slightly, and the system can benefit from the surplus nitrogen in the maize and groundnut system.

9.1.5 Advantages of using the litter bank system

The highest valued advantages of the litter bank system in the humid lowlands of southern Cameroon are its potential for improving the soil fertility in the cropping fields and increase the firewood production for the small-scale farmer. This will hopefully result in a decrease in the use of shifting cultivation practices in the area. The litter bank (biomass transfer) system is recognized as a successful system in improving soil fertility through maintenance of organic matter, nitrogen fixation, nutrient uptake from the deep soil horizons and, to some extent, more closed nutrient cycling (Young, 1997). All the crops cultivated in the system can benefit from the higher soil nutrient content, but especially the maize is expected to benefit from this system (given that plant litter application and decomposition is synchronised with the maize's nutrient requirements) (Norman et al., 1995). One experiment stated that the humid lowlands of Cameroon required an application of 8.4 t/ha plant biomass for maintaining the soil organic matter pool and numbers from *Calliandra calothyrsus* shows a yearly production of 9.1 t/ha. Unfortunately, according to our design, the trees only produce what corresponds to 1/5 ha. In spite of that, the nitrogen balance does show positive improvements because of the trees. Furthermore, by choosing *C. calothyrsus*, which is known for its potential as firewood producer and tolerant of acid soils (Ty et al., 1997;Kotto-Same et al., 1997), the system should be very adaptable to the study area.

The trees in the litter bank system can often be grown on poorer soils not used for crop cultivation (Giller and Wilson, 1991;Young, 1997) and this is an important advantages in areas where the small-scale farmer suffer from land scarcity (Blaikie, 1996). More land for tree production can be required if the marginal areas already used do not produce the "needed" organic matter for a crop production. This additional land is often taken from the agricultural field, the litter bank system then worsening the land scarcity problem (Young, 1997). If there are not nutrients enough to sustain the growth of crops in the whole area, tree production might as well be increased (Nielsen, 2000).

The system does have additional labour requirements (see disadvantages), but because the trees can be pruned more or less according to requirements for firewood and plant litter or when the small-scale farmers have the labour resources to use for it, the requirements does not feel high. These occasional prunings can only be used because of the low competition problems between the trees and crops when they are specially zoned (Young, 1997). Of course, there are many experiments showing that some times are more suitable for pruning than others (Szott, 1995).

The "cut and carry system" where plant material from other areas is cut and applied on the cropping fields, is known in some areas in the tropics (Young, 1997). If this is the case for some small-scale farmers in the humid lowlands of Cameroon, the adoption and implementation could go much easier. Due to the relative fast growing of *Calliandra calothyrsus*, the system has a short time horizon before improvements is experienced (Ty et al., 1997) giving it an advantage compared to other potential systems for the area.

Whether or not the litter banks system has any potential for improving the biodiversity is not clear, but the change from shifting cultivation with the following deforestation to a permanent cultivation system may show some improvements for the biodiversity.

The litter bank system also has the potential for reducing soil erosion and the plant litter applied to the soil can protect the soil from physical damage caused by the rain (Young, 1997). Furthermore, the plant material can be used as a high protein source for livestock (Purwantari et al., 1996(I)). These potentials can be very important to some farmers in the humid lowlands of Cameroon, but they are not of highly relevance in connection to our main focus.

9.1.6 Disadvantages of using the litter bank system

An important disadvantage to consider is the small-scale farmer's lack of knowledge about managing the new litter bank system. One difficulty is that the farmer needs to learn about pruning of the trees, at what time in the season and how many times yearly, if the best results of the system should be obtained. The farmer also has to be introduced to the new tree specie, since *Calliandra calothyrsus* is not an indigenous tree specie in the humid lowlands of Cameroon. The introduction of a new specie can result in a low adaptability, if the potentials for using this specific specie is not understood by the farmer (Huxley, 1999).

To secure the best establishment of the tree seedlings, sowing in nurseries and later replanting in the field is regarded as the best method. However, this method is properly new to many farmers and in addition requires higher labour inputs. If direct sowing is used instead of the recommended nursery method, the result can be a poorer tree establishment and thereby properly also a less successful adoption of the system (Tonye et al., 1994; Roshetko et al, 1997). Higher labour demand is also an issue in connection to cutting the tree biomass an adding it to the fields regularly. Even though the trees are placed just around the field, work is required to spread the green material all over the field (Young, 1997).

To improve the growth of the *Calliandra calothyrsus* seedlings in the field, weeding in the first 6-12 month is often recommended. This also requires additional labour inputs for the small-scale farmer (Roshetko et al., 1997).

There are additional costs connected to the litter bank system, but these are mostly in the establishment period. The cost of raising the tree seedlings is normally the highest cost for the small-scale farmers, since he/she has to buy polyethylene bags and seeds (Tonye et al., 1994; Huxley, 1999). Furthermore, funds for inoculation can be required when a new specie is introduced in an area (Giller and Wilson, 1991).

The potential improvement of the nutritional status, especially nitrogen, in the system is recognized. But it should be remembered, that the leaf litter of *Calliandra calothyrsus* has a low potassium content, and potassium is important for cassava growth. The potassium status of the soil can be improved if the ashes from the burnt wood are returned to the soil, since the woody material stores more potassium (Kanmegne et al., 1999). Finally, the benefits from decay of root residues (resulting in nutrient release) cannot be properly utilised in this litter bank system due to the spatially division of trees and crops (Young, 1997).

9.2 Multi-Strata Home Garden System

Almost all farming systems in the humid tropics can to some extent be classified as multi-strata home garden since most of them include palms, trees, bushes, bananas, and various other perennial crops in gardens and fields (Ruthenberg, 1980 c.f. MacDicken, 1990). These gardens may have a complex combination of trees and crops such as timber trees, fruit trees, coconuts, maize, tea, coffee and cocoa in multiple vertical layers (Young, 1997; Nair, 1993).

According to Leakey (1998), at least three things are needed for multi-strata agroforests to be further developed in West Africa. First, he argues that there is a need to develop appropriate systems of commercial importance. The cocoa agroforest has been identified as a system of commercial interest earlier in this paper. Secondly, there is a need to create the *entrepreneurial mentality* among the people, as Leakey claims them mainly to be subsistence farmers. However, Kaimowitz et al. (1998) and Jackson (2000) mention cash crop producers shifting from cash crop production to food crop production for income reasons, mainly due to increasing prises on fertiliser. Thus, the incentive, the knowledge, and the mentality could be assumed already to be present in the Cameroon lowlands. Thirdly, research is needed to determine how the tree species may be combined into agroforests. Three approaches are suggested to answer this question: (i) to test prototype systems (best guess combinations), (ii) to test hypotheses regarding optimal combinations and densities, and (iii) random mixtures. As an answer to these approaches, Leakey suggest *planting in cleared forest land as a tree-based alternative to slash-and-burn agriculture* as the most practical and most relevant way to develop a multi-strata system for a small-scale farmer. When selecting species, Leakey suggests indigenous tree species, and farmer surveys to identify the preferred species. For the multi-strata system, cocoa, *Irvingia gabonensis*, and *Albizzia spp*. were chosen. These three species are described in the following.

9.2.1 Cocoa

According to Lodoen (1998), cocoa is a species well adapted for a multi-strata home garden, being the basis for the local economy in the ASB (Alternatives to Slash and Burn) benchmark area of South Cameroon. Further she argues that the cocoa agroforests remain productive and environmentally sustainable for up to 50 years.

In a study of *Irvingia gabonensis* in the humid lowlands of Cameroon Ayuk et al., (1999) states that coffee and cocoa are the main cash crops in the area. Further, Amin et al., (1996) mention cocoa and coffee as mainly produced for exports, and that the quantity exported is a good approximation of the amounts produced. The World Bank (2000a) specifically mentions cocoa together with fuel and manufactures when estimating Cameroon's total exports. On this basis, as well as, Lodoen (1998) and Jackson (2000) stating that cocoa agroforest is the main sedentary land use system in southern Cameroon, cocoa is identified as the main cash crop in Cameroon.

General characteristics

Cocoa (*Theobroma cacao*) is a perennial crop that grows to the height of 8-10 m. Its height is however kept shorter by pruning (Rehm and Espig, 1991). It has a taproot that reaches about 2 m deep into the soil. From the taproot collar arise the feeding roots that are 5-6 m long and are found in the topsoil. Cocoa is a low altitude crop and can grow from sea level to an altitude of 700 m (Opeke, 1982). The crop flourishes best in the humid tropical climates with temperatures ranging from 25-28 °C (Rehm and Espig, 1991).

Cocoa has low need for sunshine, the optimal rainfall being between 1500-2000 mm/year, evenly distributed. It is sensitive to moisture stress and water logging. Cocoa prefers a deep and well-drained soil with a rich supply of organic matter and a high water holding capacity. The crop is acid tolerant (Rehm and Espig, 1991), the soils should be free from iron concretions, and have a high nutrient content (Opeke, 1982).

Cocoa can be sown directly by seeds if the conditions for germination are suitable. Usually the seeds are sown in plastic bags and then transplanted in the field after 6 months. Cocoa can also be established by vegetative propagation (Rehm and Espig, 1991; Willson, 1999).

Cocoa farming requires labour all year around. Weeding is mainly needed in the first three years of the cocoa cultivation, when the canopy is not yet closed. The pruning of the cacao tree is a necessary practice that is carried out to remove unwanted growth and maintain regularly shaped trees. Mulching is important in cacao cultivation to help conserve the soil moisture and reduce evaporation. Further, mulching helps to limit the losses of the young seedlings, maintain soil fertility, control erosion, and conserve the soil organic matter (Opeke, 1982).

Cocoa is processed and used in a variety of ways. The cocoa bean testa (shell) is an important by-product of the chocolate industry and used as a suitable feed for ruminants and as organic fertiliser (Opeke, 1982). One of the important factors that have favoured the success of the cocoa industry in West Africa is that the cocoa beans can be processed and stored on farms without the use of capital equipment (Wessel, 1992).

9.2.2 Irvingia spp.

The choice of *Irvingia spp.* are based on a study carried out by Mollet et al. (1995) where small farmers in the south humid forest zone of Cameroon ranked *Irvingia spp.* as the most preferred wild tree species. Tree species and rankings are shown in appendix 2. *Irvingia spp* are multipurpose indigenous tree species found in the humid forest zone of Cameroon, and thus well known (Ayuk et al., 1999). Further, the International Centre for Research in Agroforestry (ICRAF) has identified *Irvingia spp.* as a priority wild fruit tree species for domestication. They state that domestication is an opportunity to alleviate poverty using indigenous trees in diversifying land use systems and developing dynamic agro-ecosystems (Ladipo et al, 1996). Thus, *Irvingia spp.* seems to have the potential to improve the already known multi-strata home gardens into more profitable and diversified systems.

General characteristics

Irvingia is a large evergreen fruit tree (with bush mango fruits) reaching 35 m in height and 120 cm in diameter. It has an extensive branching system, and an extensive root system (Ayuk et al., 1999).

Irvingia gabonensis is widely distributed and commonly found in West and Central Africa. The geographical distribution of the species extends from the Casamance region (Senegal) to Angola and it is found in most semi-deciduos forest. The bush mango tree is well adapted to rainfall (Ayuk et al., 1999).

The *Irvingia* is propagated by marcotting, transplantation of wildlings, or propagation of seedlings. Marcotting is when a rooting medium is applied on a debarked section of a detached stem, which is then attached to the tree in a container (a polyethylene bag). Once the wrapped section develops roots, the stem is removed and planted in the field after a weaning period in the nursery (Lodoen, 1998). Transplantation of wildlings is however the most used method by the local farmers (Ayuk et al., 1999). Propagation by seedlings demands a longer growth period before bearing of fruits takes place (10 to 15 years) than when transplanting wildlings. When established by marcotting, the period before fruiting is reduced to 3 to 5 years. When farmers plant seeds, the main seed sources are from on their own farms, from a market place or from neighbours. The criteria for tree selection are large fruits, fruits with good taste, and high yield, regular production and early maturity (Lodoen, 1998).

The bush mango tree is usually preserved on farms to provide shade for crops such as coffee and cocoa and it is reported to restore soil fertility (Shiembo et al., 1996 c.f. Ayuk et al., 1999). Pruning may be conducted to provide the required structure for shade, mulching and fruiting. (Ayuk et al., 1999).

The bush mango kernel is a staple in the diets of many farmers of the humid forest zone in Cameroon. It is used as a condiment for soups. It can also be pound into a paste that is used as a substitute and complement for groundnuts (Lodoen, 1998). Further, the kernel may be used as a source of oil for making soap (Shiembo et al., 1996 c.f. Ayuk et al., 1999). The fresh bark of the tree is a product with several uses: to add flavour to locally made palm wine, as medicine, as a powerful antibiotic for scabby skin, a cure for diarrhoea when mixed with oil, a remedy for toothache, for the treatment of hernia, yellow fever and dysentery and as an anti-poison agent (Lodoen, 1998; Ayuk et al., 1999).

Economic Value and Potential of *Irvingia Gabonensis*

An economic assessment and potential of Irvingia based on production data for the period July 1993-June 1994 (table 3) shows the total production of bush mango on three different locations in Cameroon. The production is divided in products sold, products consumed and other (products used as gifts etc.). The total income from the sale of the products is listed using middle season prices.

Table 3: Production estimates and value of production of bush mango in the humid lowlands of Cameroon (Ayak et al., 1999)

Variables	Division					
	Lekié		Haut Nyong		Mvila	
	Fruits	Seeds	Fruits	Seeds	Fruits	Seeds
Total production (Kg/collector)	112	32	835	27	165	110
Sale (Kg/collector)	23	15	328	12	90	56
Consumption (Kg/collector)	54	17	456	15	73	49
Other (Kg/collector)	35	0	51	0	2	5
Prices, in FCFA (Middle of season)	4480	9600	12525	3645	7425	39050

US$=500FCFA

From the table it is clear that the *Irvingia gabonensis* have an economic potential. It indicates that the bush mango has a significant role in the local diet, contributes in food security and provides additional income for the inhabitants of the humid forest zone. There are variations in prices and consumption between the different districts, indicating the bush mango to have a higher economic potential in certain areas (Ayuk et al., 1999).

9.2.3 Albizia spp.

Anim-Kwapong and Teklehaimanot (1997) mention the use of indigenous tree species as the most suitable strategy for the rehabilitation of degraded cocoa lands. *Albizia zygia* is said to be suitable for this purpose due to tolerance to acid soils and nitrogen fixation. Further, they report the *Albizia* tree as an important shade tree in cocoa plantations in West Africa. *Albizia zygia* is among other tree species mentioned as dominating the south Cameroon forest landscape (Ayak et al., 1999). Escalante (1997) mention *Albizia saman* as playing an important role in several agroforestry systems, supplying shade in coffee and cocoa plantations, and wood. Further *Albizia niopoides* have been tested for their potentials in agroforestry systems in West Africa, the results being positive as for their efficiency for enhancement of crop performance (Okunomo et al., 1997). Thus, *Albizia* *spp.* seems to be well suited for enhancing soil fertility and providing shade in cocoa agroforests in southern Cameroon.

General characteristics

Albizia are among the most widely planted trees in the world (Evans, 1982 c.f. Roshetko, 1997). *Albizia* is a native to Asia, Africa, Northern Australia and India. Some species have been naturalised in Bangladesh, Myanmar, and Pakistan. It is cultivated in the tropical and subtropical regions of North Africa, West Indies, South America and Southeast Asia. The species of Albizzia occur scattered in mixed deciduous, semi evergreen, and evergreen forests with a mean annual rainfall range of 600-2,500 mm and temperature range of 5 to 46 °C. Temperature is more important to the tree than rainfall and humidity affecting leaf fall and leaf initiation (Jha, 1997b). Thus, *Albizia* are adapted to a variety of soils and environments (Mohiuddin, 1997).

Albizia spp. are large deciduous trees with tall, erect or somewhat curved stems. It has a pale yellowish or greenish white bark and light crown. The tree may reach a height of 36 m and a girth of 2-3 m. Usually it is 18 to 24 m in height. *Albizia spp*. are fast growing trees attaining a girth of about 1-1.3 m in 12 years and about up to 2 m in 30 years, giving a mean annual girth increment of 3-4 cm. The leaf fall in *Albizia* takes place in January-February and new leaves formation takes place in April-May. The tree is rarely leafless (Jha, 1997b).

The best method for the propagation of *Albizia* is by seed planting in nurseries (Roshetko, 1997). The germination of seeds is coming after a long exposure to environmental influences. Sun, rain, wind, and animal damage fracture the hard seed coats for the permeability of water to enable germination. Under natural conditions, the seeds may not germinate for years (Roshetko, 1995b c.f. Roshetko, 1997). However, treatment by hot-water soak for 1-3 minutes, followed by 24 hours in cool water, allow a faster and successful germination to take place (Halos and Fabian 1987 c.f Roshetko, 1997). After this treatment, the seeds are allowed to germinate in the nursery, with a following transplanting in the field to be conducted (Roshetko, 1997). Another means of planting is by vegetative propagation (Anim-Kwapong and Teklehaimanot, 1997).

Albizia species prefers well-drained loamy soils. They grow fairly well on clayey, laterite or black cotton soil but fail in heavy clay soils. The species can grow on mild alkaline and saline soils. The trees are acid tolerant and as such do well in acid soils with pH down to 4.5 (Jha, 1997b).

In agroforestry systems, *Albizia spp.* mainly provide shade and improve the soil quality due to a nitrogen fixing ability. The tree produce a large amount of litter through leaves, pods, and small branches. This contributes considerably to the soil organic matter and nutrient pool in the topsoil. The species of *Albizia* have extensive root systems that break up heavy soils and provide channels for drainage and aeration that further enhances soil conditions. The roots of *Albizia spp.* also bear abundant nodules, where *Rhizobia* bacteria fix atmospheric nitrogen (Jha, 1997b).

Because of the soil-improving and shade providing abilities of *Albizia*, the different species have been extensively used and planted in Southeast Asia as shade and nurse crops for coffee, cocoa, and tea plantations (Jha, 1997b).

Albizia are valuable timber trees, used for construction and technical purposes. Another important use of *Albizia* is for fuelwood. The wood burns well, the trees coppice easily, and the wood is particularly prized for veneer. Further, goats, cattles, and sheep eat the leaves of *Albizia spp*. Some species of *Albizia* have been widely used in reclamation of degraded lands (Djogo, 1997).

9.2.4 Design of the System

How the multi-strata system should be designed depend on several factors. Being a cash crop production system, the main components included all have market values, as income generation is the main purpose of the crop cultivation. Cocoa’s need for shade is considered the most important aspect, together with firewood production and the need for nutrients. Further, a diversification of components is emphasised to secure a stable income and keep the system’s biodiversity as close to the natural forest as possible.

Fruit and shade trees (*Irvingia gabonensis and Albizia*) are randomly inter-planted with the cocoa, to provide permanent shade and soil nutrient addition/recycling. As when considering the litter bank system, the design is strictly hypothetical, with the number of components and the proportions used not being correct.

Figure12 illustrate a possible design of the multi-strata/homegarden system (1ha)

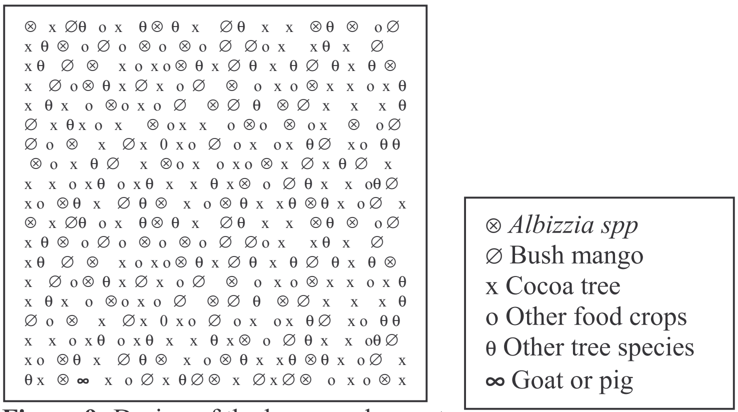


Figure 9: Design of the homegarden system.

The farm size is considered to be one hectare. Food crops as cassava, plantains, cocoa yams, etc. are also cultivated in the system. Also integrated are other tree species, such as fruit trees (oranges, papaya, avocado). All components are randomly mixed. The main components of the system (cocoa, *Albizia* and bush mango) are only considered in the further analysis.

Structure

The multi-strata home garden system consists of three different layers. The upper layer consists of bush mango and *Albizia* trees. The middle layer consists of cocoa plants, along with other fruit trees. The above ground layer is divided in two: the lowermost layer (below one meter in height) is dominated by different vegetables and medicinal plants and the second layer (between one and three metres) is dominated by food crops (cassava, yams, cocoa yams). Cocoa, being the main cash crop in the system, occupies ½ of the hectare while *Albizia* and bush mango each occupy one sixth of the cultivated area. Other food crops and tree species occupy the rest of the cultivated area.

Cocoa usually produces higher yields when close spacing is used, although this characteristic will decrease with the age of the trees. Space between cocoa trees should be kept at a distance of 2.5 x 2.5 m, as this will favour a better yield and incorporation of other components in the system. Furthermore, close spacing also minimises weed growth and soil erosion. By introducing other tree components in the system, the free space between the cocoa trees will be reduced, resulting in a possible increased competition. On the other hand, the shade provided by the other trees is required for increased cocoa yield when fertiliser are not used. Shade providing trees are especially important to the young cocoa plants during the establishment in the nursery and field (Willson, 1999).

9.2.5 Nitrogen balance

Only a simplified nitrogen balance including *Albizia chinensis* and cocoa is estimated to illustrate the potential of the system for nitrogen improvement. Including all components of the multi-strata system would give the best picture of the nitrogen balance, but since *Albizia* is the main component actually adding nitrogen to the system, this is most interesting. The balance corresponds to a cocoa yield of approximately 1 t/ha (Rehm and Espig, 1991) and is made with the assumption that cocoa residues are returned to the soil (see appendix 5).

Plant litter produced by *Albizia* (3rd year) (kg/ha):	10,986 (Iosefa and Rogers, 1997)
Nitrogen content (kg/ha):	505 (Iosefa and Rogers, 1997)
Proportion of nitrogen derived from fixation (%):	50 (Estimated)
Nitrogen derived from fixation (Kg/ha):	252.5
Nitrogen available (%):	30 (Nielsen, 2000)
Nitrogen available (kg/ha):	75.8
Nitrogen produced in 1/6 ha. (kg):	12.6
+	
Atmospheric nitrogen deposition (kg/ha):	10 (Nielsen, 2000)
-	
Nitrogen removed in cocoa beans (kg/ha):	20 (Rehm and Espig, 1991)
Nitrogen removed in ½ ha. (kg):	10
Nitrogen balance: (12.6 kg/ha + 10 kg/ha - 10 kg/ha):	12.6

As the balance indicates, *Albizia* together with atmospheric deposition can produce enough nitrogen to meet the nitrogen lost from cocoa harvest. The nitrogen mineralised naturally every year in the soil, will also contribute to the total balance, making the result even better. But additional losses of nitrogen, through the harvest of other products (bush mango, food crops), will reduce the total balance to some extend.

In the balance the nitrogen availability is estimated to by only 30% of the total nitrogen input. This amount could be higher, since the multi-strata system is very closed and losses due to leaching and erosion are reduced.

9.2.6 Advantages of Using the Multi-strata System

The highest valued advantage in this multi-strata home garden system is the increased and diversified income opportunities for the small-scale farmer. The opportunity for earning higher income per hectare using the multi-strata home gardens have been documented by many authors (Gupta, 1979 and 1983 and Stoler, 1978 c.f. MacDicken and Vergara, 1990). Intensification and diversification of species in the cocoa agroforests such as the random integration of bush mango on cocoa farms will give the farmer increased income opportunities. As mentioned earlier in this project, bush mango has the potential for earning extra cash for the small-scale farmer in the humid forest zone of southern Cameroon. Diversification of plant species and crops helps reduce the economic impact of price fluctuation of any single crop (Ayuk et al., 1999).

Irvingia is an indigenous tree species in southern Cameroon and because of this, the local farmer already has knowledge about its products. This could make the introduction of this tree species on the cocoa-farm easier. However, some farmers lack the knowledge about the potentials when including the tree in a complex multi-strata system (see disadvantages) (Ayuk et al., 1999).

The diversification of species in the cocoa agroforest gives room for the production of a variety of products from the same piece of land throughout the year, where food, fruits, fuelwood and green manure are important (Lodoen, 1998; Nair,1993). Further, *Irvingia* is mentioned as significant contributor to the food security in southern Cameroon (Ayuk et al., 1999) as the seeds are rich in fats (Nair, 1993). Finally, *Irvingia*, *Albizia* and other integrated tree species are regarded important as shade for the cocoa trees (Anim-Kwapong and Teklehaimanot, 1997; Ayuk et al., 1999).

The cocoa agroforest is very important for the rural population in maintaining the plant biodiversity. *The complex multi-strata systems serve as biological reserves for many of the indigenous forest species used and traded by the local population* (Lodoen, 1998).

Because of the many components included in the multi-strata system, the labour requirements can be high (see disadvantages), but since the work is evenly distributed over different periods of the year, the requirements do not feel high. The effect of these year-round activities leads to the elimination of the labour peaks and the continuity, rather than seasonality, benefits the household families. Further, because of the low light penetration at ground level, the growth of weeds are reduced resulting in lower labour requirements for weeding (MacDicken and Vergara, 1990).

Perennials rather than annuals dominate the multi-strata system. This combination may result in relative more nutrient stored in the vegetation compared to in the soil, and thereby a more effective nutrient cycle (see nutrient cycle in appendix 6) and minimum losses by leaching and erosion. Further, the deep rooted perennials extract nutrients from deeper soil layers and translocate them to the above ground parts resulting in the maintenance of the nutrient status (Nair, 1993). Finally, the *Albizia* has the potential to provide inputs of nitrogen to the system due to the ability to fix atmospheric nitrogen.

9.2.7 Disadvantages of Using the Multi-strata System

Competition for nutrients, growing space, light and moisture are the main disadvantages in the multi-strata system (Ong, 1996). Moisture and nutrient competition is however lower in the cocoa agroforest, due to the combination of deep-rooted bush mango and *albizia* and shallow-rooted cocoa trees. Furthermore, light competition is not considered a major problem in cocoa agroforest since cocoa is a shade tolerant tree (Willson, 1999; Ayuk et al., 1999).

Albizia germination is poor and a hot water soak is needed for a faster and successful germination (Halos and Fabian 1987 c.f Roshetko, 1997; Willson, 1999). This can give some problems for the small-scale farmer since he may not have the technical knowledge and the method is time consuming.

Cocoa trees needs pruning to achieve the required shape for maximum production and facilitate harvesting and maintenance. This can be labour demanding and the small-scale farmer lacks the knowledge about it (Willson, 1999).

A survey from the humid lowlands of Cameroon about the local farmers views on bush mango's effect on other crops has been carried out. The results (Table 4) show that some farmers feel that the effect of the bush mango on tree and food crops is negative and due to shading.

Table 4: The effect of bush mango on different crops as indicated by the farmers in the lowlands of Cameroon (% of respondents)

		Division		
		Lekié	**Haut Nyong**	**Mvila**
Tree crop	**Increase**	13	9	11
	Reduce	7	64	26
	Mixed	0	0	5
Food crop	**Increase**	0	0	5
	Reduce	0	36	26
	Mixed	7	9	16

The percentage does not add up to 100 because some farmers did not provide answers to all the questions (Ayuk et al., 1999).

The effect on food and tree crops is generally perceived to be negative, especially in Haut Nyong and Mvila divisions, shading being the main negative effect. The positive effect on tree crops indicated by farmers in Lekié may be due to a better intensification strategy resulting from land scarcity (Ayuk et al., 1999).

Albizia is an indigenous tree species in the humid lowlands of Cameroon, but the local farmer does not know the species' potentials, and a domestication is needed if the tree is to be included in new or modified multi-strata systems (Ayuk et al., 1999).

When including many different species in a multi-strata system, there is an increased possibility for pest and disease problems. Some shade and crops trees can for example be potential hosts for cocoa pathogens (Willson, 1999).

During management practices and harvest operations, there can be an increased risk for mechanical damage of some of the components in cocoa agroforest due to intensive mixture of trees and crops.

9.3 Conclusion

The litter bank system and the multi-strata system are examined as regarding their possibilities as alternatives to shifting cultivation in southern Cameroon. The choice of components and practices in the two systems is made using the following main criteria: Use of multipurpose trees, use of leguminous trees, use of indigenous practices and finally, use of already known food and cash crops.

The litter bank system is functioning as a food crop production system where cassava, maize and groundnut are cultivated surrounded by litter banks of the nitrogen fixing *Calliandra calothyrsus*. The function of the litter banks is to supply the field with mulch that will enhance the fertility of the soil. Furthermore, the litter banks will supply the farmer with firewood. The specific design of the system is developed in connection to the nitrogen requirements of the crops and the firewood requirements of the small-scale farmer. The two nutrients balances estimated are showing that there are possibilities to obtain positive balances in this system, depending on the crops cultivated.

Thus, the most important advantage of this system is the improved soil fertility when mulch from the litter banks is applied, resulting in the possibility of continuing annual crop production. Further, the production of firewood, the ability of the *C. calothyrsus* to grow on poorer soils not suitable for crop production, and the even distribution of labour requirements throughout the year are listed as the main advantages of this particular system.

The multi-strata system is defined as a cocoa-agroforest in which the production of cocoa is the main objective. The system includes a wide variety of other components where *Irvingia spp*. (bush mango) and *Albizia spp*. are the most important. The main function of this system is to supply the small-scale farmer with a diversified source of income from the cocoa, bush mango and other products. Furthermore, the *Albizia* is improving the nitrogen input to the system due to the ability of fixing atmospheric nitrogen. Finally, bush mango and *Albizia* function as shade trees for cocoa. The positive nutrient balance estimated is showing, like in the litter bank system, that there is a possibility to obtain a positive balance in this system. Finally, the prices on bush mango presents another source of income besides cocoa.

Thus, the most important advantage of the system is the ability to provide a diversified source of income for the small-scale farmer. Further, increased biodiversity, production of a variety of products and even distribution of labour requirements throughout the year are listed as important advantages.

Generally, the two systems have the same main disadvantage: Lack of knowledge about management of the systems, including establishment of the trees, pruning techniques and how to avoid competition.

10 DISCUSSION

In this chapter, a general discussion of the results achieved and the methods used will be conducted.

The humid lowlands of Cameroon still have extensive forest resources. As the main forest areas not yet are threatened by extinction or total depletion, the need to address the deforestation issue in Cameroon may be questioned. However, as mentioned in the problem analysis, the main reason for addressing deforestation now is the possibility to prevent situations where the extinction of species or degradation of the environment is an imminent threat.

Three direct causes are mentioned as threatening the forest environment: logging, fuelwood extraction and transformation of the forest to other uses. Logging has been argued to have a smaller effect on the deforestation than often perceived. However, Cameroon being the sixth largest exporter of tropical timber in the world (Egbe, 1998), the impact of logging on the environment is probably of a considerable size. Studies seems thus to be needed on the impact of logging activities on the rain forest. Further, firewood collection is argued to be a reason for deforestation mainly on the city margins. In rural areas, firewood collection is degrading the forest, however (using the FAO definition) not being a reason for deforestation. The agroforestry systems suggested are based on the assumption that the needed firewood should be produced preferably by the agricultural systems, extensive extraction from the forest being negative. However, no study has been found examining the influence of firewood extraction on the Cameroon rain forest. Thus, further investigations seem to be needed also on the impact of firewood extraction on the forest.

The transformation of forestland to other uses, mainly using shifting cultivation practices, has been argued to be the main reason for deforestation and forest degradation in Cameroon. This created by an increasing demand for land, mainly due to population growth, poverty, and government policies. Traditional shifting cultivators are not considered to degrade the forest significantly, due to indigenous knowledge of sustainable practices. Non-traditional shifting cultivators, on the other hand, are assumed to be the main degrading factor. The extent of non-traditional practices is reported to be increasing, thus creating an increasing pressure on the forest resources. In this project, it is assumed that non-traditional shifting cultivation is induced mainly by poverty (the impoverishment approach) or possibilities for non-subsistence income generation (the neoclassical approach). However, even if many sources state this to be a fact, no study has been found examining neither the extent nor the underlying causes for non-traditional shifting cultivation in Cameroon. Thus, research seems to be needed on the extent of non-traditional shifting cultivation, and its impact on the forest environment. Further, research should be done on the underlying causes of deforestation, to examine if poverty or income generation (the impoverishment approach or the neoclassical approach) or factors as economic activities of large-scale corporations (the political economy approach) may be of major impact.

The loss of soil fertility is another reason for addressing shifting cultivation as a problem. The decrease is considered a consequence of the shortening of fallow period and bad shifting cultivation practices. This is a general perception that has been described by several authors. Based on literature and the interviews saying that short fallow is usual in Cameroon, the assumption was made as to decreasing soil fertility being a problem also in the Cameroon forest zone.

Political aspects and land tenure are issues that have not been considered in this report. Many of the underlying causes for deforestation may probably have less effect if government policies and legislations were changed or moderated. Aspects as poverty, economic development, accessibility, and population growth are all factors that could be improved with the right policy making. Ownership laws on land could secure that larger companies or plantation owners did not crowd out small-scale farmers. An improved labour market could provide possibilities for other income generating activities than subsistence farming, then decreasing shifting cultivation.

Further, economic policies securing income for cocoa and coffee plantations could reduce the transformation of cash crop plantations to commercial shifting cultivation. As the cocoa prices on the international market were reduced, and the Cameroonian government cut the subsidies for fertiliser and fungicides, the market did not give sufficient returns on the cultivation. A continuation of the subsidies given could have decreased the incentives to start commercial shifting cultivation. Regarding the multi-strata system suggested, the cocoa prices are an important limitation. If the prices are kept at a low level, the incentive to establish a cocoa agroforest will remain low. However, the multiple sources of income generated by the multi-strata system give possibilities to overcome recessions or periods when prices are low. Even with cocoa prices currently being low, the cocoa agroforest should thus be economically viable, not only due to the multiplicity of species, but also due to the plant being well adapted to the multi-strata system.

Around 40 questionnaires were sent to Cameroonian people living in Europe. The information was used as a comparison and a guideline when considering the information obtained from literature. In the review, the size of the farms (1-2 ha) and the crops grown (cassava, maize, groundnut, beans, plantains) confirmed the observation that the agriculture in southern Cameroon is mainly subsistence agriculture, using however some cash crops such as coffee and cocoa. This support the choices of addressing the problem only at a small-scale level. More over, it shows that the crops chosen in the alternative systems are already cultivated in the area. Further, the answers indicate that clearing and burning has been practiced a long time (many generations). The answers support the choices of agroforestry systems as alternatives to shifting cultivation, as trees and shrubs are selectively left standing (usually fruits trees, or trees used as shelter against wind or as shade trees). Thus, the use of trees seems already included in the traditional land use systems. Indigenous knowledge seems to exist on agroforestry practices. Finally, the information support our assumption of shifting cultivation as being a problem. Most of the answers state that the fallow period is becoming shorter (1-3 years), and that yields are declining fast (after 3-4 years) after the initial cultivation phase. Questions on the forest show that the trees are mainly used for fuelwood and fruits. This underlines the reason for choosing fuelwood as one of the major constraints, and the choice of fruit tree species in the agricultural systems

As the report is based on a literature study, a deep-going understanding of the situation in southern Cameroon has been difficult to obtain. However, the analysis conducted has been based mainly on experiments and scientific publications recently done in the region. Thus, the results obtained may have a certain value even when no fieldwork was carried out.

Agroforestry practices are assessed as alternatives to shifting cultivation. The systems have been shown to have advantages and disadvantages, the benefits though clearly outweighing the constraints. However, also other options, not being a part of the agroforestry concept, may be valid alternatives. Inputs as fertiliser and fungicides have been addressed in the problem analysis, concluding that high prices and lack of infrastructure are major constraints. If these issues were improved (e.g. by road construction and subsidies), the use of fertiliser may be beneficial, giving high increases in crop yields. Fertiliser may thus favour intensively cultivated systems, with no trees needed.

Two systems were identified as possible alternatives to shifting cultivation in Cameroon.
The cocoa multi-strata systems provide a diversified source of income as well as subsistence crops for the small-scale farmer. The idea of the diversification being that the farmer should have a stable income even when the cocoa prices are low. The incentive to change to commercial shifting cultivation should thus be lowered, with a decreased pressure on the rain forest as a result. However, if increased income generation could be achieved by transforming the forest to agricultural lands, the farmers may continue the pressure on the forest having a functional system or not. On the other hand, as the interviews showed, the small-scale farmer does not have sufficient tools or labour to cultivate larger areas, making expansion difficult

The most important advantage of the litter bank system is the improved soil fertility when mulch from the litter banks is applied, and the ability to produce firewood. Thus, annual sedentary cropping should be possible to conduct, making shifting cultivation unnecessary. However, the population increase lead to less and less land available even for sedentary cropping in the highly populated areas. To find alternative land uses may thus be only a temporary solution, the problem of population increase being in need of political and cultural changes.

Both agroforestry systems suggested improved the nitrogen balance. For two of the three balances calculated, the result was even positive. This suggests that these alternatives do not need additional fertiliser input if the yield level should be maintained. However, these balances are very simplified, and the results should only be regarded as illustrative. In the balances conducted, only the main components have been included. As both systems, especially the multi-strata system, are thought to have a multiplicity of species, both the output and input (see figure 1, page 29) would be considerably changed. Further, several factors are not considered in the balances. An example could be the physical and chemical properties of the soil. These may differ significantly, no specific information on soils having been considered when the balances were made. The purpose of the balances was to illustrate the extent of the input compared to the output. The important factors to consider are the amount of nitrogen the legume trees or crops may add to the soil through nitrogen fixation, and the amount of nitrogen removed through harvest. Thus, the balances conducted suggest the systems to be interesting alternatives to shifting cultivation.

11 CONCLUSION

In relation to the specific objectives, the following conclusions have been reached:

1. The general causes of deforestation may be divided in direct and underlying causes. Three direct causes to deforestation have been identified: Logging, fuelwood collection, and alternative land uses. Further, several underlying causes have been identified: Agricultural and population growth, economic development, poverty, accessibility, government policies and ownership rights.

   The humid lowlands of Cameroon possess large forest resources. The forest is a major resource for the country, now threatened by deforestation and forest degradation, mainly through shifting cultivation practices. This is created mainly by an increasing demand for land. The resource is still of a considerable size, but is considered an important area to address due to a fast and increasing pressure on the forest.

2. Shifting cultivation is an agricultural system with a cultivation phase (two to three years), followed by a longer fallow period (ten to twenty years) on land cleared by slashing and burning. Shifting cultivation may be divided in two main categories: Traditional and non-traditional shifting cultivation. Traditional shifting cultivators possess sufficient knowledge of the forest to practice the discipline in a sustainable way. The traditional shifting cultivators shift frequently to other areas, abandoning the field to regenerate after only two or three years of cultivation. Non-traditional shifting cultivators, on the other hand, are farmers with less knowledge of the forest and the practice, often migrants moving into the forest zone from other areas. These are often more settled than the traditional shifting cultivators, and enlarge the clearing around the house rather than moving on to other areas. The fallow period is thus often shortened, the forest and the soil not having time to regenerate. These unsustainable practices performed by non-traditional shifting cultivators are identified as the main cause of deforestation. Two main reasons for non-traditional shifting cultivation in Cameroon have been identified: Shifting cultivation performed by small-scale farmers for subsistence reasons, and shifting cultivation for commercial production of food-crops.

3. Agroforestry systems suitable for the humid tropics have been assessed as alternatives to shifting cultivation, the emphasis put on the two above-mentioned reasons for non-traditional shifting cultivation. Two agroforestry disciplines e identified as interesting for the humid lowlands of southern Cameroon: The litter bank system, and the cocoa multi-strata home garden system. They have both several important advantages: They improve the soil organic matter content, they keep the nutrient content in the soil on an improved and thus more sustainable level, and they produce firewood. The litter bank system has low economic requirements, making it interesting for the subsistence farmer. For a sustainable cultivation of cocoa or other cash crops, the multi-strata home garden system seems to be a good option, without the need for extensive additional nutrient inputs or a significant danger of crop failure or economic losses.

Thus, if the small-scale farmers apply and use the litter bank system or the cocoa multi-strata home garden system, the deforestation in Cameroon may be decreased. A partial fulfilment of the overall objective may thus be achieved.

12 PERSPECTIVES

In this project, only the technical and biological aspects were considered. However, its global realisation would require a holistic approach, considering several other constraints: Environmental inputs, spatial arrangement of the system, gender and age balance, land tenure, forest policy, energy policies, livestock, etc (Steppler, 1990; Erskine, 1991). Thus, this report cannot be considered as a whole project on itself, as many aspects are missing (Institutional, socio-economic, cultural, ecology, etc). May one of these aspects become a problem, the whole project should be abandoned. Further, a very important point is to keep in mind the basic "down-to-earth" problems while writing the report. This project has been written, when possible, with the perspective of a possible practical implementation.

Even if the systems are based on indigenous knowledge, the components and their arrangement have been modified. Thus, training is needed in order to make the systems applicable by the local farmers. Villagers need training, but so do politicians or technicians. Politicians should be made aware of the biological and physical constraints of agroforestry and should have a better understanding of the social and economic aspects. Villagers require applied training. In the past agroforesters tended to teach them just specific systems, until they realise villagers were capable of learning principles, which enable them to develop their own systems. Technicians require more in depth and thorough training, with both principles and practices applying to everyday problems. Technicians should be broadly trained in social and biophysical aspects in order to prevent them ending up just trying to apply a few system in every situations (Fisher, 1990).

There is a growing number of degree, non degree, post graduate courses, seminars, workshop, conferences taking place all around the world each years about agroforestry. However, it is the lower and intermediate level of agricultural education with a production of qualified farmers who are the real agents of change. Institutions at this level have normally more flexible structures and programmes and have easier contacts with rural communities. Boehnert (1988), suggest that the involvement of secondary and primary school would offer *a great potential and new possibilities in agriculture, environment, implementation and maintaining of agroforestry systems, with a strong* *emphasis on ecological practices*. Thus, it seems that it is trough the children and students that an interest and knowledge about trees is being introduce more widely into the family.

Implementing agroforestry in the tropical rural areas can face many other problems like reaching farmers with information, advice and services; how to convince people to adopt a new land use practice and its constraints of management. Lack of funds, roads and extension services are some aspects that makes communication rather difficult (Boehnert, 1988). However, one of the biggest constraint is the time between planting a tree and getting a measurable profit out of it. Foley and Barnard (1984, cf Boehnert, 1988) state that *It is here by demonstrating new faster-growing species, and suggesting management techniques that allow useful products to be harvested after a short period, that tree growing programmes may have an important role in tipping the balance, and persuading farmers that tree growing is worthwhile*. Usually, young farmers may be more inclined to plant crops, but tree planting may be favoured by the older generation (Arnold and Dewees, 1995, c.f. Huxley, 1999).

Today, development organisations prefer to use participatory approaches (PRA and RRA), as it is commonly thought that the chances of success of the project are increasing if the stakeholders are actively involved. Farmers and others who participate actively in a project are able to accept more easily new policies and technologies promoted. More over, participation of beneficiaries allows the organisations to exploit the potentials of indigenous technical knowledge (Hansen and Sthapit, 1998).

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Appendix 1

Social, cultural, economic and political aspects of shifting cultivation and the use of fire.

Burning objectives and attitude towards fire may vary a lot depending on the different groups. For its traditional practicers, shifting cultivation is a way of life, not just for selected individuals, but for the group as a whole. It is no surprise, then, that burning among traditional cultivators is often a communal activity, if not in labour, then at least in timing. A short dry season dictates a short burning season that demands intense labour (Spencer, 1966, cf Peters and Neuenschwander, 1988). Many swidden groups observe a sexual division of labour. In many societies, the fire phase is dominated by the men whereas the cropping is usually executed by women. Magic and religious consideration may also play a role in communal burning (Peters and Neuenschwander, 1988).

From an economic point of view, the aim of the shifting cultivator is economic optimisation, that is, to get maximum return for minimum effort. Indeed, one of the main economic consideration that sustains this way of life is the high yield for a low. Fire cleaning is used as a tool, simply easier and more efficient than any other method. One estimate shows the total labour required for the burning phase to be as low as 0,4 % of the total required for all components of the swidden cycle. A shifting cultivator's pressing concern is survival today. Within the economic constraints of most swidden cultures, slash and burn has met the challenge of survival for millennia (Peters and Neuenschwander, 1988).

Recent political efforts have emphasised the need to control or contain shifting cultivation and the use of fire. Shifting cultivation has become an issue of concern among many governments of developing and developed nations alike. It is often viewed as an inefficient and destructive method of agricultural and land use that causes severe environmental degradation (Vergara, 1976, cf Peters and Neuenschwander, 1988). Although, attempts to eliminate shifting cultivation and force its practitioners to become sedentary agriculturists may lead to disastrous ecological and social consequences (Peters and Neuenschwander, 1988).

Appendix 2

Top 10 species in Cameroon from the small farmers point of view (Mollet et al., 1995). These are the species that the local communities depend on for food, condiments, medicine and raw materials for various others use (Diguma et al., 1990c. f. Ayuk et al., 1999).

Species name	Total Ranking points	Interviews in which the species was mentioned (%)	Main use of the tree
Irvingia gabonensis	187	86.6	Fruits, medecines
Baillonella toxisperma	179	76.6	Timber, medecines
Dacryodes edulis	137	66.6	Fruits medecines
Eaeis guineensis	132	53.3	Oil, fruits
Ricinodenron heudelotii	122	66.6	Fruits, medecine
Alstonia boonei	108	63.3	Medecines, timber
Guibourtia demensei	103	53.3	Medecines, timber
Entandrophragm cylindricum	77	60	Timber
Garcinia lucidia	57	33	Medecines
Chlorophora excelsa	53	36.6	timber

(Adapted and modified from Mollet et al., 1995)

Appendix 3

Questionnaire about small-scale farmers in the humid lowlands of Southern Cameroon

Personal background

Sex:

☐Female ☐Male

Age:

Answer:

Education:

Answer:

Profession and working experience:

Answer:

From which area in Cameroon do you come from?

Answer:

Is your family cultivating the land?

☐Yes ☐No

General questions

1. How big is a normal farm?

☐0,5 ha ☐1 ha ☐1,5 ha ☐2 ha ☐3-5 ha ☐6 or more ha

2. What crops are grown?

Answer:

3. What month(s) of the year is planting/sowing carried out?

Answer:

4. Are different crops grown together (intercropping) or is there only one crop on the field at the time?

☐Crops grown together ☐Crops grown separate ☐Both methods are used

5. Are trees/hedges grown together with crops in the field?

☐Yes ☐No ☐Sometimes

6. Who are cultivating the crops?

☐Women ☐Men ☐Children ☐Combination

7. Is hired labour used in labour demanding periods?

☐Yes ☐No

8. What tools are commonly used for land preparation?

☐Tractors ☐Chainsaws ☐Local tools (machetes, hoes, diggers etc.)

9. Is the field slashed (cleared) and burned before planting/sowing?

☐Yes ☐No

Specific questions about clearing and burning methods

10. What month(s) of the year is the field cleared and burned?

Answer:

11. Who does the clearing and burning?

☐Men ☐Women ☐Children ☐Combination

12. Are trees left standing after clearing and burning?

☐Yes, all ☐No ☐Some

Which and why?

13. How long is the cultivation period after clearing and burning before fallow (abandonment)?

☐1-3 years ☐4-7 years ☐8-12 years ☐13 or more years

14. How long is the fallow period - after how many years do the farmer return to the old cultivated land?

☐After 1 year ☐After 2 years ☐After 3 years ☐After 4-5 years ☐6-9 years

☐After 10 or more years

15. After how many years does the yield decline substantially?

☐1-2 years ☐3-4 years ☐5-6 years ☐7 or more years

16. For how long have clearing and burning in general been used in your area?

☐Only the last 1-5 years ☐All the time the present farmer has been there ☐Since one generation before ☐Since many generations before

17. Why do you think, farmers use clearing and burning for growing crops?

Answer:

18. What do you think, are the beneficial effects of clearing and burning?

Answer:

19. What do you think, are the disadvantages connected to clearing and burning?

Answer:

20. What do you think could be the alternatives?

Answer:

Specific questions about the trees/forest

21. What are the tree materials used for?

☐Feeding animals ☐firewood ☐Building material ☐Incorporated in the soil/left above the soil for decomposition (green manure/mulch) ☐Other:

22. What tree species are grown and/or allowed standing on the farmland?

Answer:

23. What forest products are used for household consumption and/or selling?

Answer:

24. What do you think, will be the long time consequence of clearing and burning the forest?

Answer:

Socio-economic questions

25. For the crops mentioned in question 2, list their uses (home consumption, sale etc.)?

Answer:

26. How far does the farmer travel to find a suitable forest plot for cultivation?

☐0-1 km ☐2-3 km ☐4-5 km ☐6-7 km ☐8-9 km ☐10 km or more

27. Who owns the forestlands?

Answer:

28. How is land for cultivation obtained?

Answer:

29. Is it necessary to consult the government before cultivation in forest areas owned by the state?

☐Yes ☐No

30. Do the farmer get in conflict with any organisation or authorities (NGO, state or group of people) when they clear and burn forest for cultivation?

☐Yes ☐No ☐Sometimes

Appendix 4

Answers to the questionnaires.

Personal background									
Sex									
Male	13	**female**	4						
Age									
20-25	5	**26-30**	12						
Education									
High school	2	**Bsc**	7	**Msc**	3	**Post graduate**	5		
Profession and experience									
None	10	**farmer**	1	**Agriculture/related**	3	**teacher**	2	**Other**	1
Area									
Southern Cameroon	12	**Northerm Cameroon**	3	**Western Cameroon**	2				
Comes from farming family	15/17								

General questions								
Farm size								
1-2 ha	10	**3-4 ha**	3	**6 or more**	2	**no answer**	2	
Main crops	Beans, cocoyams, plantains, vegetables, maize, cassava, potatoes, yams, groundnuts							
Other crops	Cocoa, coffee, pepper, palms, banana							
Sowing month	March, April, May, June							
Intercropping								
Crops together	12	**crops separate**	1	**both**	4			
Trees/hedges	Yes (or sometimes)		15/17					
All family cultivate the crops	15/17							
Hired labour	10/17							
Local tools used	15/17							
Slash and burn	15/17							

		Clearing and burning methods							
		Time of the year							
January, February, March									
		Workers							
Combination	10	**Men**	6	**No answers**	1				
		Trees left standing							
All	6	**Some**	10	**No**	1				
		Length of the cultivation period							
1-3 years	8	**4-7 years**	4	**8 or more**	3	**No answers**	1		
		Length of the fallow							
1 year	8	**2 years**	4	**3 years or more**	3				
		Yield decline after							
1-2 years	2	**3-4 years**	8	**5-6 years**	4	**More than 7**	3		
		Since when is SC used							
Since the farmer has been there	5	**Many generation before**	11	**No answers**	1				
		Why slash and burn							
Increase yield and productivity	12	**Clean grasses, weeds**	3	**Cheap and easy cleaning**	3	**Easier planting**	2	**Cultural**	1
		Beneficial aspects							
Higher SOM, nutrients, humus	9	**Easy clearing**	6	**No answers**	2				
		Negative aspects							
Kills bacteria and organism that produce humus	9	**Pollution**	3	**Yields decrease fast**	3	**Erosion**	3	**Deforestation**	1
		Alternatives							
Manure and fertiliser	6	**Clearing without burning**	2	**MPTs**	1	**Education**	1		

SC = Shifting Cultivation

				Trees and forest					
				Trees left standing used for					
Firewood	14	**Building mat**	9	Medicines, feed animals, fruits, herbaceous climber					
				Tree species					
Fruit trees (mango, pear, orange, plums)	9	**pines, conifer**	2	**Eucalyptus**	1	**Cocoa, coffee**	1		
				Forest products					
Stem and trunks for firewood	7	**Timber**	3	**Spices/herbs**	3	**Leaves/bark, medicine**	4	**Fruits**	5
				Consequences of burning					
Erosion and degradation of soil	9	**Loss of fertility**	4	**Pollution**	4	**Deforestation**	4	**Loss of biodiversity**	2

	Socio-economics				
Crops used for home consumption and sales					
	Distance to travel to field				
0-3 km	5	**4-9 km**	4	**10 km or more**	7
Individuals or government owns the land					
	How land is obtained				
Buying/renting to private owner	11	**Asking permission to gvt**	9	**Inheritage**	4
Necessary to ask permission to gvt	13/17				
	Conflicts with gvt and NGOs				
Sometimes	12	**Yes**	3	**No**	2

Appendix 5

Flow chart of material (inputs and outputs) and farmer's management through the homegarden system (adapted from Dhyani, 1998).