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Shifting Cultivation in the Evergreen Forest of Southern Cameroon: Farming Systems and Soil Degradation

Final report

L. Nounamo and M. Yemefack

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Tropenbos-Cameroon
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The TCP is a research programme executed under the joint responsibility of the Ministry of Environment and Forests of the Republic of Cameroon and the Tropenbos Foundation

Tropenbos-Cameroon Reports 00-2

The Tropenbos-Cameroon Programme
Kribi, Cameroon
November 2000

PREFACE

This report is the result of the study on shifting cultivation practices in the evergreen forest of southern Cameroon, carried out within the framework of ITTO Project PD 26/92, which is part of the Tropenbos-Cameroon Programme (TCP). TCP comprises fourteen interrelated sub-projects in the fields of ecology, forestry, economy, social science, agronomy and soil science. The main implementing agencies of the PD 26/92 Project are the "Institut de la Recherche Agricole pour le Développement (IRAD)", "l'Office National de Développement des Forêts (ONADEF)", the Tropenbos Foundation and Wageningen University.

The authors wish to thank the General Managers of IRAD and ONADEF for selecting them to conduct this study.

The present study was financed by the International Tropical Timber Organisation (ITTO), the Common Fund for Commodities (CfC), the Tropenbos Foundation and the main implementing agencies. The authors thank these organisations for making this study possible.

We also wish to express our sincere gratitude to the TCP Team Leaders, Scientific Coordinators, colleague researchers and all the administrative and financial personnel for their support during the study.

We sincerely thank all the students who contributed to the study through the development of their thesis. We think particularly of Nlome Ekongo Emmanuel, Nama Alexandre and Nguegang Asaa Prosper from the University of Dschang, and Obam Félix-Marcel and Meyomesse Ongolo Calvin from the University of Yaoundé I.

Our special thanks go to Ndombou Jean, former Delegate of Agriculture for the Océan Subdivision, and his extension field staff for facilitating our introduction and contact in the villages of the TCP area.

Finally, but very important, we are very grateful to all the farmers and field assistants of the villages in the TCP area with whom we studied the farming systems practices and soil degradation in a friendly and participatory manner.

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1 INTRODUCTION

Between 1995 and 1997, a study on agricultural systems practised by the Bantu population was conducted in the research area of the Tropenbos Cameroon Programme (TCP). The TCP research area is about 180 000 ha in area, and located 70 km East of Kribi between Bipindi and Akom II (Figure 1.1). The study was to provide a comprehensive description on the shifting cultivation / natural fallow systems applied in the TCP research area, and insight in soil (fertility) degradation related to such agricultural practices. Criteria were to be developed for soil degradation evaluation. Data on actual agricultural practices, their trends and environmental impact were to be collected and analysed.

1.1 Background and justification

The objective of the Tropenbos-Cameroon Programme is to develop methods and strategies for natural forest management directed at sustainable production of timber and other products and services. These methods have to be ecologically sound, socially acceptable and economically viable, and to take other functions of the forest into consideration.
Shifting cultivation is the dominant farming system practised in the tropical forest zone of Cameroon. Although a good deal of publications exist on shifting cultivation practices in other areas of the world, and although shifting cultivation has been described for semi-humid areas in Cameroon, information on this type of land use in the moist evergreen forest of southern Cameroon is very sparse.
Although the Tropical Forest Action Plan (MINAGRI, 1989) does not foresee a significant agricultural pressure on forest land in southern Cameroon, the Rapid Rural Appraisal conducted by the Tropenbos Cameroon Programme revealed that present trends in this agricultural practices, under increasing influence of market economy as result of local infrastructure development (rural electrification and road construction), may well lead to expansion of agricultural land in the near future.
The TCP came to the conclusion that in order to achieve sustainability of forest production in the study area, sustainability of crop production must be studied conjointly, since shifting cultivation may represent a greater threat to forest than timber harvesting.

1.2 Objectives of the study

General Objective:

To limit the destructive effects of shifting cultivation on the forest by proposing to farmers complementary and/or alternative sedentary practices, and providing information to be utilised for the development of a forest management plan.

Specific Objectives:

1) To gain understanding of the farming systems practices in the evergreen forest of Cameroon, the problems, constraints and opportunities related to forest conservation and agricultural production.

2) To obtain insight in aspects of soil degradation under various agricultural land use systems applied in the evergreen forest of Cameroon.

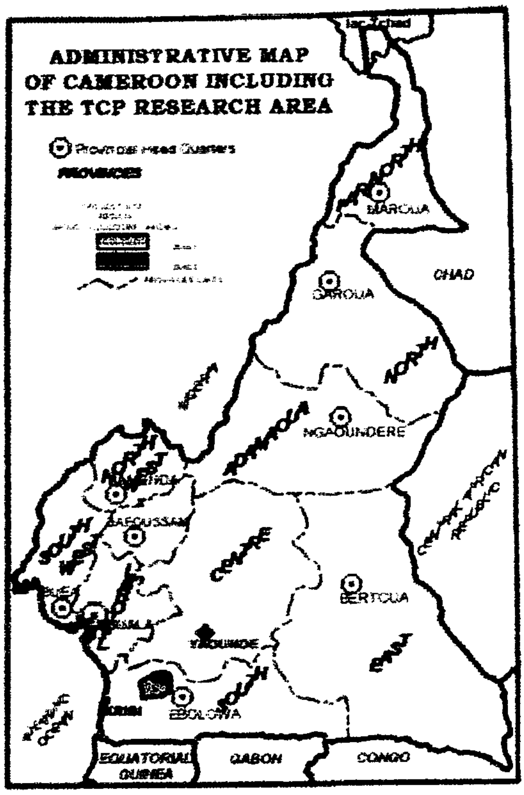
3) To find trends and relationships between field expansion, soil degradation, crop fallow, and socio-economic factors.

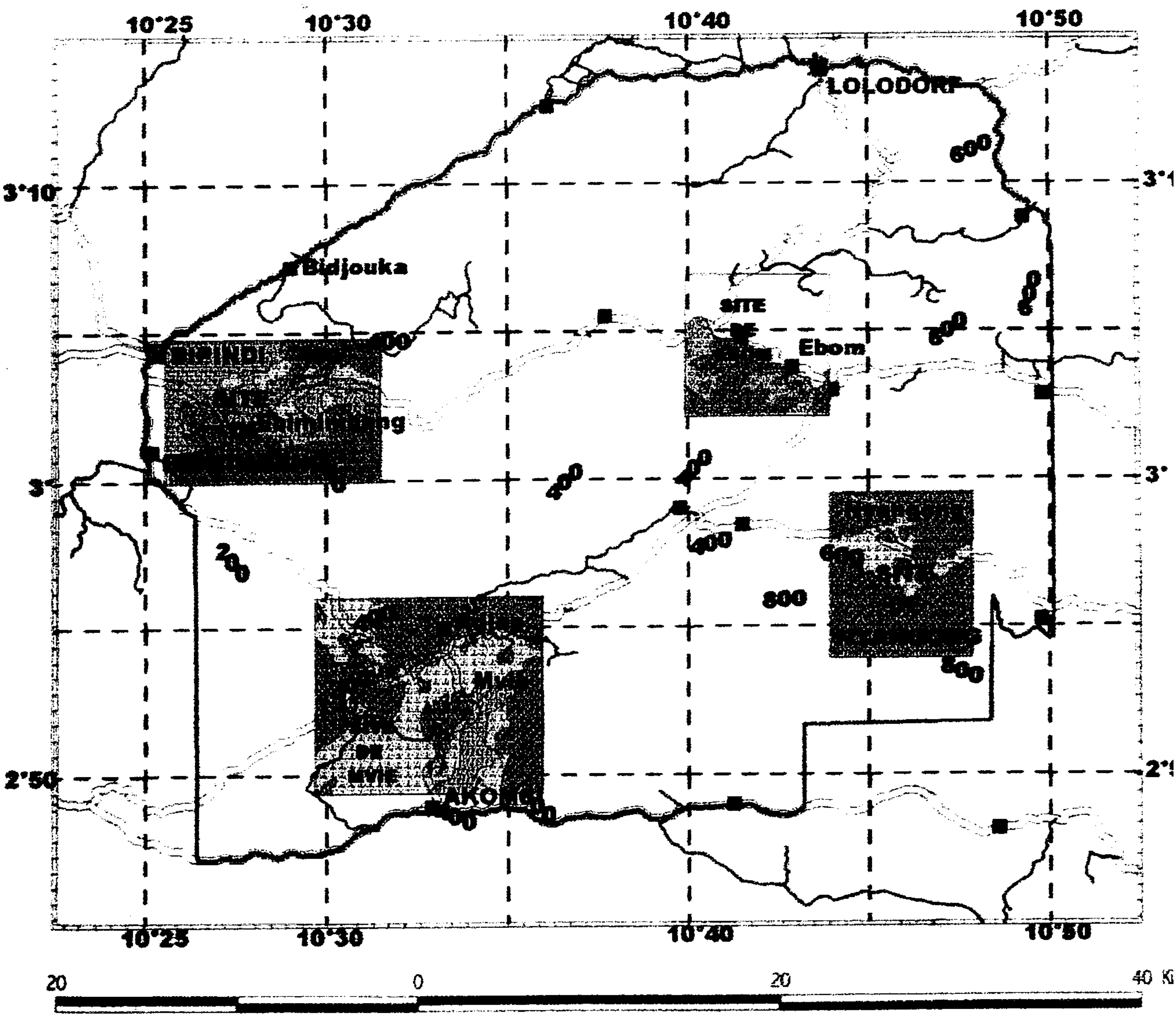
4) To propose solutions for farmers' problems and constraints related to forest consei and agricultural production, in order to reduce forest destruction by farmers, thereby ach the sustainable management of the forest zone of southern Cameroon.

1.3 The research area

The research area covers the TCP site, corresponding to the 180 000 ha of the concessi Wijma Douala SARL (GWZ). It is located 70 km east of Kribi (see Figure 1.1), betw 47' and 3° 14' North, 10° 24' and 10° 51' East; and between the low altitude evergreen and the mid-altitude evergreen Atlantic forest (Atlas Régional du Cameroun, characterised by the presence of *Lophira alata* (Azobé). It is part of the South Provi: Cameroon, lying across Ocean Division (covering Akom 2, Bipindi and Lo subdivisions) and Mvila Division (covering Ebolowa subdivision).
The area is sparsely populated, with most people living along the public roads which fo northern and southern boundaries of the site, and along passable logging roads which c the other two. Population density is about 9 inhabitants per km². The Bulu form the l ethnic groups, but other Bantu groups are present. In addition, there are several hundr pygmies (Bagyeli or Bakola). Population growth is moderate due to constant urban migr Agriculture, gathering, hunting and logging are the main forms of land use in the stud Farms are smallholdings; there are no large agricultural plantations in the immediate vi of the study area. Shifting cultivation is the main farming system for several food production, and cacao is the major industrial crop of economic importance.
Local population, especially the Bakola, exploits the forest for gathering and hu Selective logging has been practised for several decades in the area, and continues.

Figure 1.1. **LOCATION MAP OF THE TCP RESEARCH AREA INCLUDING THE SAMPLE AREAS (Land cover maps)**





2 METHODOLOGY

2.1. Site selection

Four sub-study sites were selected from the TCP research area for detailed farming systen and soil degradation studies. They were selected on the basis of the aerial photo interpreta map drawn by Touber (1993). According to van Gemerden and Hazeu (1999), this map subdivides the research area in four physiographic levels ranging from about 200 m a.s.l. (west) to more than 900 m a.s.l. (east and southeast). One sub-site was established in each physiographic unit. The four physiographic units are:
i) Ebimimbang near Bipindi, with elevations of 150-250 m a.s.l. Soils are mostly Ultisols sandy topsoil. They are called Ebimimbang soils.
ii) Ebom near Lolodorf, with elevation between 350-500 m a.s.l. Soils are Oxisols with c topsoil. They are called Ebom soils.
iii) Mvié near Akom II, elevation of 250-400 m a.s.l. Soils are Oxisols with clayey to They are called Mie soils.
iv) Nyangong is located towards the Ebolowa city, elevation greater than 500 m a.s.l. Soil Oxisols with very clayey topsoil. They are called Nyangong soils. Detail characteristics c four sub-sites are summarised in Table 2.1.

Table 2.1 *Characteristics of the four sample areas.*

	Sample areas			
Characteristics	Ebimimbang	Ebom	Mvié/Adjap	Nyar
Location	3° 03' N 10° 28' E	3° 04' N 10° 42' E	2° 54' N 10° 33' E	2° 10°
Elevation (m a.s.l.)	150-250	350-500	250-400	500
Landforms	-Dissected erosional plains -Dissected uplands -Isolated hills	-Dissected uplands -Isolated hills - Complex hills	-Moderate dissected uplands -Isolated hills - Complex hills	-Dissecte -Comp -Mou
Relief Intensity (m)	20-30	30-80	30-80	120
Main annual rainfall (mm)	1900	2000	2300	18
Main Monthly T (°C)	26	24.6	24	2
Geology (Precambrian Basement)	Ectinites (schists, micaschists, quarzites)	Migmatites (gneiss) Ca-Mg complex	Granites migmatites	Gra Ca-Mg
Dominant Soils	Moderately well drained, sandy Typic Hapludults	Well drained, clayey Typic Kandiudox	Well drained, clayey Typic Kandiudox/Kandiudults	Well dra clayey Kand
Ethnic group	Fang, Ngoumba	Bulu	Bulu	Bı
Population (Inhabitants)	515	592	978	4
(Household)	84	92	94	4
Main river	Lokoundje, Tchangue	Tchangue	Tchangue, Kienké	Tcha
Vegetation	Biafran Atlantic low and mid altitude forest vegetation rich in *Caesalpiniaceae* (Letouzey,			

2.2 Methodology for farming systems study

The methodology followed consisted of the collection of secondary data through consult of existing documents, interview of key informants, and the collection of primary data through participatory and exploratory survey, case studies, and measurements conducted in the research area.

2.2.1 Participatory approach

A team made available by the divisional delegate of agriculture conducted a survey, the agricultural chief of post for each area covered, a farming systems agronomist (agro-ecologist) and a soil scientist. Each member of the team played an important role, particularly the agricultural delegate who led the organisation of appointments and contacts with farmers, participated fully in the animation of the interviews, and took advantage of the exploratory tour to integrate extension messages into the survey themes.

2.2.2 Exploratory survey

The exploratory survey covered 20 villages out of the total of 49 identified. To achieve a representative sample, the choice of the survey villages took into consideration the villages characteristics such as ethnic group, accessibility, presence or absence of permanent or periodic market, soil and land characteristics.
The methodology consisted of a development of a "checklist" (annex 1) to use as interview guide, the interview of farmers grouped together in each village, and the visit of three or more farms for direct field observation.
During the interview, effort was made to explain the presence of the farming systems team, its role and activities in the villages now and in the future, in relation to the presence of TROPENBOS programme, Wijma Company, and ORSTOM researchers. Such clarification of roles at early stage of intervention of the research team was necessary and indispensable to avoid any misunderstanding that might jeopardise the future collaboration between the farmers and the team. During group interview, the "focus group" approach was used to obtain information on each item of the checklist. The group interview always ended with few minutes of conversation ("conversational interview") during which notebooks were closed, the atmosphere more relaxed, and farmers feeling free, confident, and more open to speak frankly. It was at this stage of the interview that information could be obtained on sensitive issues.
Field visits followed the group interview. Three or more fields were visited to observe, confirm and cross check some of the contradictory information obtained during the group interview.

2.2.3 Measurements of the size, expansion, crop density and yield of agricultural fields

*** Size**
In the four sub-sites described in Section 2.1, collaborative farmers from 35 households were randomly selected. The size of all the fields opened from 1995 to 1997 (290 fields in total) were measured, mapped and their geographic co-ordinates recorded using compass, GPS, measuring tape and GIS. The method consisted of subdividing the perimeter of the field to be sized into rectilinear segments and recording for each segment its length in meter using measuring tape and its direction in degree (or grade) using compass. The geographic co-ordinate of the field was recorded using the GPS. In the office, the reconstruction of these directions and lengths on a graphic paper re-built the shape of the field. The drawing obtained on paper was then digitised in GIS equipment and the computer provided the surface area of the polygon. The surface area of many fields measured could thus be computed at once.

**** Fields expansion***

Trends in agricultural field expansion are best studied by multi-temporal remote se images. In this study, only the 1984/85 aerial photo interpretation landscape ecologica was available showing undisturbed forest land and land under agricultural activities (T 1993). This 1984/85 landscape ecological map was digitised and computerised using ar software. To obtain the proportion estimate of the agricultural field expansion, the maps 290 agricultural sample fields opened between 1995 and 1997 were overlaid on the 19 aerial photo-interpretation landscape ecological map using arc-view software (see ann Fields that fell in the 1984/85 undisturbed forestland were grouped to compute the s proportion of the forest that has been transformed into agricultural land during the 13 period. The following formula was used to determine the total land area (A_{13} in ha) agriculture in 1997:

$$A_{13} = \frac{A_n \cdot A_0}{A_{n0}}$$

Where,

A_{13} = total land area under agriculture in 1997

A_0 = total land area under agriculture in 1984;

A_n = total measured agricultural sample fields population in 1995-1997;

A_{n0} = total measured agricultural sample fields population falling under the area agriculture in 1984.

The agricultural field expansion into the forest after 13 years is defined by $A_{13} - A_0$

**** Crop density and yield***

In each field, 4 to 5 squares of 4m x 4m were established for crop density and crop measurements. In each square, crop plants were counted for crop density determination density of each crop in the field was estimated as the average of all squares. D harvesting, all harvested crops from these squares were weighed. Sub-samples for estim of biomass and grain yield dry weight of maize and groundnut were taken, oven-drie weighed.

2.2.4 Farmers' priority setting

The study was to identify farmers' priority needs in time and space from and agricultura socio-economic point of view. Twenty (20) villages of the TCP area were covered structured questionnaire interview. Ten (10) farmers were interviewed per village, takin account age, sex, ethnic (or tribe) and accessibility. A total of 200 interviews were condu Relative frequency was used for priority setting. The rank of the priorities was determin the relative majority of choices expressed by the farmers from the sample size of 200.

2.2.5 Farmers' strategies for soil fertility management

The study was to assess farmers' way of coping with soil fertility problems in relati agricultural production. Fifteen (15) villages in the TCP area were covered by a struc questionnaire interview. Five (5) farmers were interviewed per village. A total c interviews were conducted. Farmers' fallowing strategies were assessed by measuring yields from farmers' fields and by sampling and laboratory analysing soils from correspo fallow plot nearby the crop field. Data were tallied manually. Data were analysed relative frequency and X^2 test. The rank was determined by the relative majority of choices expressed by the farmers from the sample size of 75.

2.3 Methods for soil degradation study

Soil degradation study aimed at assessing the impact of the various farming systems (shifting cultivation, perennial plantations, and home garden) on physico-chemical and biological soil properties, and evaluating the relationship between soil degradation and expansion of fields, crop/fallow rotation intensity, and crop yields. For that, the study involved many aspects related to soil studies, on-farm studies and analytical studies as well.

2.3.1 Soil description and sampling

Preliminary survey for farming systems description have allowed to identify and describe, in addition to primary forests (FV), three types of natural forest fallow most utilised by farmers. They are:
- Chromolaena (*Chromolaena odorata*) fallow (CF) of 3 to 5 years
- bush fallow (BF) of 7 to 9 years;
- forest fallow (FF) of more than 10 years.

These three types of fallow, the primary forest and new crop fields carrying groundnut-maize-cassava association (afoub wondo) were chosen for the study. The afoub wondo fields are opened in the fallow of 3 to 7 years. Farmers' fields under perennial crop such as cocoa and oil palm were also chosen. The selection was therefore based on the type of the field, the original fallow types and the availability of the farmer to collaborate with researchers. Each fallow type was replicated three (3) times in each of the four sub-sites. Mini-pits of 70cm depth were dug in each fallow plot, each afoub wondo and each perennial crop field. Soils were described according to the guideline of FAO (1990). Soils were sampled at planting and the end of cropping period to study the sudden and slower changes in soil physical, chemical and biological properties.

Sampling for routine laboratory analyses. Composite soil samples were collected with auger at five (5) spots on a diagonal basis in each fallow plot, each afoub wondo field, and each perennial crop field and the adjacent forest. Three depth slices were considered in the sampling scheme: 0-10, 10-20 and 20-50 cm.

Sampling for bulk density analysis. Two depths (0-10 and 10-20 cm) were used. Samples were taken with an inox iron cylinder of 100 cm^3. One sample was then composed of five (5) cylinders collected at five different spots.

Sampling for topsoil aggregate stability analysis. Only the 0-10 cm depth slice was used.

Sampling for microbial biomass carbon (MBC) analysis. Composite soil samples were taken from two different depths (0-10 and 10-20 cm) in each of the following land use types (LUTs) and the adjacent fallow per village:
- old cocoa plantation (more than 25 years old);
- young cocoa plantation (4 - 6 year old);
- forest fallow (more than 15 years old);
- bush fallow (7 - 9 years old);
- Chromolaena fallow (3 - 5 years old).

Three (3) villages (Ebimimbang, Ebom and Nyangong) were used as replicates.

2.3.2 Laboratory soil analyses

Soil samples were taken to the IRAD soil laboratory in Nkolbisson for routine analyses. The analyses were concerned with pH water and KCl (1:2.5 ratio), organic Carbon (Walk Black method), total Nitrogen (Kjeldahl digestion), available Phosphorus (Bray II me exchangeable bases (Extraction with 1M NH4OAc), Cation Exchange Capacity (extr with 1M NH4OAc at pH7), Exchangeable acidity (leaching with 1M KCl and titration l NaOH), particle size distribution (Robinson pipette method), bulk density (oven dry ; °C).

Aggregate stability was determined at Tropenbos laboratory in Kribi by Water-Drop I method (Imeson and Vis, 1984).

Soil samples for microbial biomass carbon were analysed at the microbiology laborat Yaoundé I university. Microbial biomass carbon was measured by fumigation-incul method (Jenkinson, 1976; Anderson and Ingram, 1993).

2.3.3 Soil micro-variability study

This study aimed at evaluating the micro-variability of soils within those mapping currently used for agriculture in Ebimimbang and Nyangong. Knowledge on this variatio useful for interpretation, comparison and extrapolation of soil degradation study re Transect method was used in this study. Four to five transects were established across all mapping units and auger observations were made systematically at 100 m along each tra Horizon thickness, colour and texture were the main soil properties recorded from auger Thereafter, pedological pits were dug on representative micro-units; and soils were described according to the FAO guidelines for soil description (1990). Soil samples col from each horizon were analysed for routine determination in IRAD soil laborato Nkolbisson.

2.3.4 The agricultural activities in relation to the forest management

The study was to assess the way of coping with problems of shifting cultivation in pla the sustainable management of tropical forests. Structured questionnaires, farmers' mapping, cropping systems descriptions, and population census were carried out in the (4) sample sub-sites (Ebimimbang, Mvié, Ebom and Nyangong) in order to draw out sh cultivation factors that should be taken into consideration in the management plan of the

2.3.5 Statistical data analyses

Cumulative frequency analysis using X^2 test was performed for priority setting. Analys variance (ANOVA) were performed for soil property changes under various land use Stepwise analyses of multiple linear regression were used to evaluate relationships bet soil properties variation and crop yields.

3 FARMING SYSTEMS DESCRIPTION

Farming systems study considers the farm as a whole and must deal with all the aspects of the farm. It aims at identifying and analysing all the subsystems of a farm and the interrelationships between them, in order to gain full understanding of the practices, problems, constraints and opportunities related to agricultural production and forest conservation.

3.1 Subsystems of the farms in the forest zone

Generally, the production system of a farm (Farming System) in the evergreen forest of Cameroon is composed of subsystems which are: household system, cropping system, animal system, soil system and non-agricultural activities such as hunting, fishing, off-farm activities, etc. These subsystems are interrelated and are under the influence of external biophysical and socio-economic parameters such as climate, road and market infrastructures, market price, land tenure law, credit availability, etc. (Figure 3.1).

According to 92% of the farmers interviewed, cropping system activities (Crop production) remain the first priority activity, followed by animal husbandry, then fishing, palm wine tapping, wild fruits collection, hunting, and oil palm exploitation (Table 3.1). In the cropping system, shifting cultivation involving food crop fields and fallow is the first priority land use type according to 80% of the farmers, followed by perennial plantations, then home gardens (Figure 3.1 and Table 3.2).

Table 3.1 *Farmers' priority activities*

Major Activities	**Rank**	**Frequency of ranking (%)**	**Reasons of Importance**
Cropping activities	1	92	Diverse consumption & revenues
Animal husbandry	2	29	Guests reception, dowry, ceremonies
Fishing	3	35	Local consumption, less revenue
Palm wine tapping	4	45	Consumption and non-sustained revenues
Wild fruits collection	5	22	Seasonal consumption and revenues
Hunting	6	32	Diverse consumption and revenues
Palm oil extraction	7	48	Simple local consumption

Sample size n = 200

Table 3.2 *Farmers' priority land use in a farm*

Land use type	**Rank**	**Frequency of ranking (%)**	**Reasons of Importance**
Shifting cultivation	1	80	High consumption and revenues
Perennial plantations	2	56	Decreasing revenues
Home garden	3	72	Various consumption with low revenues

Sample size n = 200

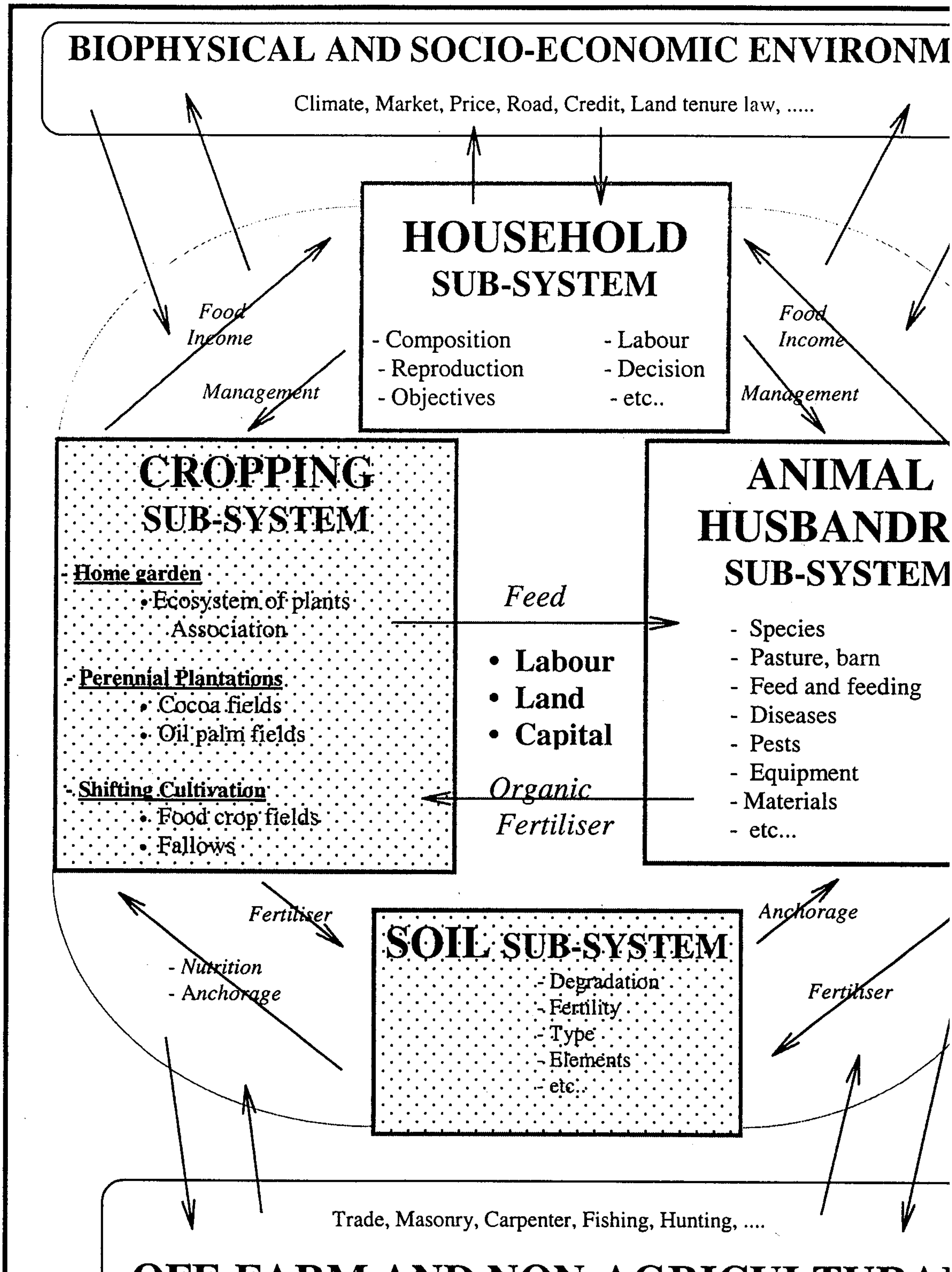


Figure 3.1. Subsystems of the farms in the forest zone

3.2 Characteristics of the physical environment

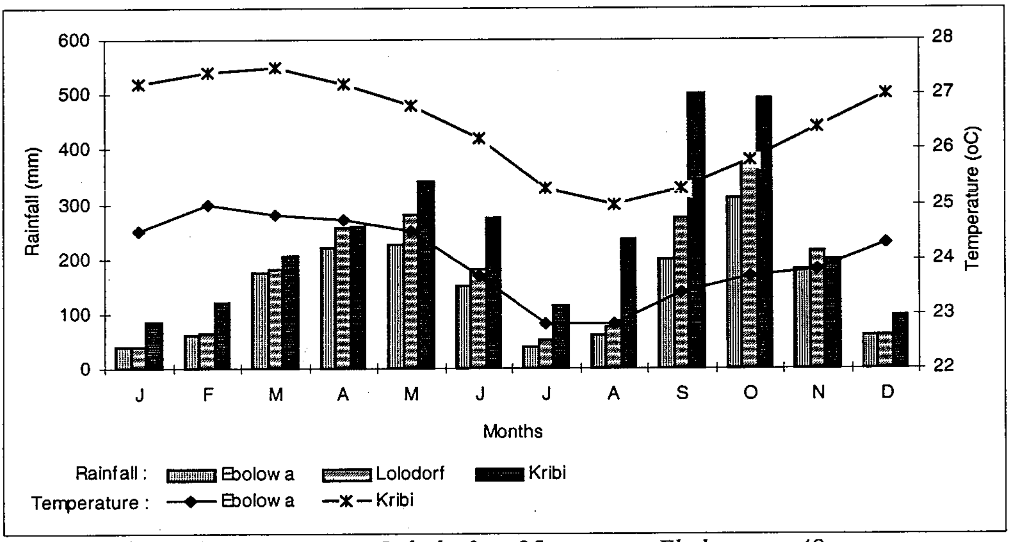
3.2.1 Climate

The climate of the research area is equatorial, classified as humid tropical (Köppen, 1936), characterised by two rainy seasons and a short and long dry season (Figure 3.2). The average rainfall per year is about 2000 mm. The monthly mean rainfall are 200 and 400 mm for April / may and September / October, respectively. October is the wettest month of the year. The two driest periods of the year are December/February and July/August, respectively, with less than 80 mm of rainfall per year. The bimodal rainfall pattern determines two growing seasons. The first starts in March and ends in July; the second starts in August and ends in November. Between the two seasons, from December to March, arable swamps and valley bottoms are cultivated that allow to produce off-season food crops. Such a climate has a mean temperature above 18°C during the coolest month, an annual temperature around 25°C with very little variation during the year, and finally a well delineated dry season. A summary of climatic data from some meteorological stations in the area is given in Table 3.3.

Table 3.3 *Summary of climatic data from some meteorological stations of the area (Olivry, 1986).*

	Weather station		
	Kribi	Lolodorf	Ebolowa
Altitude (m a.s.l.)	13	440	609
Mean annual temperature (°C)	26.4	24.6	24.0
Relative humidity (%)	84	n.a.	83
Mean annual vapour pressure (mbar)	29.3	n.a	24.6
Mean annual rainfall (mm)	2836	2096	1719
Wind speed below 4 m/s (% time)	98	n.a.	n.a.
Mean wind direction	SW	n.a	W

Kribi, n = 45 years ; Lolodorf, n = 25 years; Ebolowa, n=48 years; n.a. = data not available



Kribi, n=45 years ; Lolodorf, n=25 years; Ebolowa, n=48 years

Figure 3.2. Monthly rainfall and temperature averages for Kribi, Lolodorf and Ebolowa (after Olivry, 1986)

3.2.2 Vegetation

The vegetation of the study area is described in detail by van Gemerden and Hazeu (19
belongs to the Biafran Atlantic forest district of low and medium altitude (Letouzey,
Characteristics of the sub-mountain part of the Guineo-Congolian domain are found on
isolated hills. Along the main roads, and around villages and in agricultural zone
vegetation is strongly influenced by the human activities, and characterised by the prese
various pioneer species.

3.2.3 Landscape

Van Gemerden and Hazeu (1999) have defined six major landform units. These lan
units and their characteristics are given in Table 3.4.

Table 3.4 *Characteristics of the different landform units in the TCP area (adapted fro Gemerden and Hazeu, 1999).*

Landform units	Slope length (m)	Slope (%)	Relief intensity	N° of interfluves	Altitude range (m)	Surfac (Km²)
Dissected erosional plain (pd)	50 – 200	5 – 15	20 – 30	3 - 4	40 - 250	110
Uplands (U1)	100 – 200	10 – 20	10 – 40	3 - 4	120 - 700	480
Uplands (U2)	150 – 300	10 – 30	30 – 80	2 - 3	120 - 700	690
Isolated hills (H1)	250 – 500	30	120 – 300	-	200 - 900	116
Complex of hills (H1)	200 – 350	20 – 40	80 – 200	1	350 - 700	139
Mountain (M)						
- outside-slopes	>400	>30	>250	-	>500	100
- inside-slopes	250 – 400	30 – 60	120 – 250	-		
Valley bottoms (V)	-	0 –2	< 10	-	40 - 700	15

***The dissected erosional plain (pd)** is characterised by low altitude, relative flat topogr
and no prominent elevations or depressions. The erosional plain hosts the main
(Lokoundje, Tchangue and Moungue) draining the TCP area. The tributaries and cree
these rivers dissect the erosional plain giving the plain an undulating to rolling relief
plain is mainly restricted to the west part of the TCP area.

* **The moderately dissected uplands with rolling relief (U1)** are dissected plains wi
summits and interfluves at more or less the same level and presenting the characte
described in Table 3.4. This landform unit covers large surfaces in the centre (NNE - SS
the TCP area.

* **The strongly dissected uplands with hilly relief (U2)** has different valley morpholc
compared to those of U1 i.e. narrower valley bottoms, poor drainage, and more swamps.

* **The isolated hills (H1)** are steep-sided, isolated, residual and circumdenudated.

* **The complex of hills (H2)** is a complex of moderate to steep hills which are str
dissected. The slope length and relief intensity (Table 3.4) are relatively short anc
respectively compared to those of isolated hills and the mountains. Levels of summit
valley bottom vary greatly. The complex of hills unit is found in the transitional zone be
the uplands and the mountains and is absent in the TCP western part.

* **The Mountains (M)** are complex dissected plateaux or massifs which are isolated and rising above the surrounding landscape. The unit characteristics are given in Table 3.4. The unit is characterised by an abrupt rise in altitude to a higher plateau level. The mountain landform unit is mainly restricted to the eastern part of the TCP area, covering extensive areas.

3.2.4 Geology

Information on the geology of the area is provided by Champetier de Ribes *et al.* (1956; 1959). The area is part of the southern Cameroon plateau, a vast forest region slightly undulated and underlain by the Precambrian basement complex, characterised by acid metamorphic rocks traversed by intrusions of potassic alkaline syenite and basic rock dykes.
The metamorphic rocks consist of migmatites, gneiss, micaschists and quarzites with two micas. These rocks belong to the cristallophyllian series, ranging along the Lokoundje river basin and its main affluents (Moungue and Tchangue). These rocks are rich in biotite and amphibole.
The Ntem metamorphic complex occupies the western and the southwestern parts of the study area. It is a complex of calcium-magnesium rocks series composed of leuco-mesocrate gneiss with pyroxen, biotite and amphibole.
The intrusive rocks consist of potassic and/or calco-alkaline granite and syenite with amphibole. Some dykes of pyroxenic diorites and doloritic gabbros are also found.

3.2.5 Soils

Soils of the area are all derived from the above-mentioned geological basement complex. Except some poorly drained soils (Inceptisols/Entisols) encountered in narrow inland wet valley, the whole area is dominated by Oxisols and Ultisols (Soil Survey Staff, 1992). The main characteristics of these soil orders are the following:

Ultisols
They are mainly found along the Lokoundje river basin and its affluents Moungue and Tchangue, where the geology belongs to the cristallophyllian series. The soil taxa are Typic Hapludults, Typic Paleudult, Plinthudult (< biblio >) or Haplic Acrisols, Plinthic Ferralsols (FAO, 1988), or "Sols ferralitiques faiblement désaturés, sableux" (CPCS, 1967). These soils are dominated on dissected erosional plain of low altitude (150-350 m a.s.l.) region of Bipindi. Van Gemerden and Hazeu (1999) classify them as "Ebimimbang soils". They are moderately deep to very deep, moderately well to well drained, yellowish brown. They are characterised by sandy topsoil (70-90% sand) and gravelly sandy clay loam to sandy clay subsoils (30-60% sand). The pH is usually between 6 and 7 for the topsoil and 5-6.5 for the subsoil. The base saturation percentage is high (70-100%), but the CEC is low (less than 12 Cmol+/g of soil).

Oxisols
They are found where the geology is dominated by the Ntem Metamorphic Complex. The main soil taxa are Typic Kandiudox, Typic Hapludox (< biblio >) or Xanthic Ferralsols, Acri-xanthic Ferralsols (FAO, 1988), or "Sols ferralitiques moyennement à fortement désaturés, argileux" (CPCS, 1967). They are soils of high altitude areas (>350 m a.s.l.) around Lolodorf, Akom II and Ebolowa regions. They were classified as Ebom soils and Nyangong soils by van Gemerden and Hazeu (1999). They are deep to very deep soils, well drained, brownish yellow

to strong brown. They are characterised by a very low pH (3.8 to 5) and a high clay co
which can even reach 80% in the topsoil.

Inceptisols and Entisols
They are soils of the inland valley bottom. The main soil taxa are Aquic Dystr
Fluvaquent, Lithic Endoaquent (< biblio >) or Gleyic Cambisol, Dystric Fluvisol (
1988), or "Sols hydromorphes peu humifères" (CPCS, 1967). They are soils of all alt
and are sparsely found in the study area. They were classified as Valley Bottom soils b
Gemerden and Hazeu (1999). They are shallow to moderately deep soils, poorly to very p
drained soils developed in unconsolidated recent alluvium, dark brown to yellowish
brown. They are characterised by loamy sand to sandy clay loam particle size.

3.3 Socio-economic characteristics

3.3.1 Population

The TCP site is sparsely populated, with most people living along the motorable public
which form the northern and southern boundaries of the site, and along motorable lo
roads which connect the other two. Population density is around 9 inhabitants per km^2.
Four main ethnic groups are present: Bulu, Ngoumba, Fang and Bassa. Forty-nine villag
found in the site: one Bassa, one cosmopolitan, 5 Fang, 6 Ngoumba and 36 Bulu. The
forms the majority group. Some hundreds Pygmies live in the forest and depend on
products (hunting, harvesting and more and more agriculture) for their food. Popu
growth is moderate due to constant urban migration. However, there are cases were
jobless young people come back to the village; but their establishment in the village ma
be for longer period, due to difficulties coping with social and tension in the village.

3.3.2 Infrastructure

Roads
Three types of unpaved communication roads are present at the site: 1) motorable p
roads, 2) motorable logging roads and 3) footpaths. The two motorable public roads for
northern (road Kribi-Lolodorf via Bipindi) and southern (road Kribi - Ebolowa via Ako
boundaries of the site, and the motorable logging roads connect the two. Pathway
numerous and everywhere in the forest, joining the villages to agricultural fields, and se
the hunters. The condition of these earth roads depends on the season; speed during the
season may not exceed 25 km/h. Roads may temporarily be closed, due to slippery porti
to a damaged bridge. Out of 200 farmers interviewed in the site, 98% considered their
non practical, only 2 % thought that roads condition was acceptable.

Extension services
The support of agricultural extension is rare. The extension agents lack mea
transportation to reach the villages. Government effort is being made through the "Progr
National de Vulgarisation et Formation Agricole" (PNVRA) sponsored by the World Ba
reach as many farmers as possible with extension messages.

3.3.3 Labour

There are clear divisions of labour within the household and for farm work between me women. Women are expected to perform the household work and food crop production plus helping men harvest cocoa. Men do the heavy house repair in addition to taking care of cocoa, banana/plantain, and/or oil palm plantation. Shifting cultivation is mainly the work of the women. With the fall of the cocoa price on the market, men are more and more getting involved in the production of food crop for additional cash, performing the activities of tree felling, burning, land clearing and occasionally groundnut harvesting. Women perform tilling, sowing, weeding and transportation at harvest, processing, and marketing of food crops. The use of hired labour is rare, may concern tree felling and land clearing. However, working groups exist, formed between farmers to help each other curtail the labour shortage at peak period. Children help the parents during holidays, which fall at seeding and harvest period.

3.3.4 Land and land tenure

Traditionally, land was communal. Temporary usufruct rights were recognised by the community to kin groups and individuals for agricultural production. Often, there was considerable group migration within the shifting cultivation system, further limiting permanent claims to land.

Colonial activities after the turn of the century however had a profound effect on land tenure. For instance, cocoa was introduced in smallholder production; its long productive cycle led to the establishment of permanent villages and permanent land claims. Farmers in the TCP site may have acquired their rights to land about 100 years ago.

Today, land claim is by kin group according to first clearing of land (Nounamo and Foaguegue, 1999). Nearly all secondary forest is claimed by the kin groups that first cleared the land. Access to land is limited. Land is not rented out and user rights are only given to members of the family by the head of the kin group. Even short term user rights is not granted to migrants for fear of difficulties and disputes for future negotiations with the authorities of the expanding administrative settlements and industries. The non-granting of user rights to migrants, even for shorter term, should be foreseen as a potential constraint to the adoption of agroforestry techniques, by the latter, to stabilise shifting cultivation and reduce the destruction of the forest.

3.3.5 Farmers' organisation and credit source

Sustainable and well-structured organisations are non- - existing or difficult to find in the villages of the area. Organisations are limited to "tontine" groups, community groups, and work groups. "Tontine" groups are some kind of credit co-operative where farmers put together fund periodically, and one of them collects it. Work groups are labour groups formed to help each member with farm activities during peak period. About fifty per cent of the farmers belong to a work group, with women a little more than men. Community groups, an example is "Groupe d'Initiative Commune" (GIC), are organised to facilitate access to government credit such as FIMAC fund (Fonds d'Investissement pour Microprojet Agricole du Cameroun) for the financing of small agricultural production projects. Groups are formed by affinity. Dislocation of groups is very often caused by mismanagement of funds.

Two types of credit sources exist: formal and informal.

1) The formal source of credit is that granted by government institutions (ex. FIMAC, 'Crédit Agricole'...). Few smallholders are qualified for this type of credit and the interest rate is high.

2) The informal source is that called "tontine", explained above. Informal source of credit works better and farmers tend to prefer it to the formal.

3.3.6 Farm investment

Though most of farmers' financial revenues come from agriculture, very little of it is di re-invested in agricultural production. Table 3.5 gives priority expenditures of farmers site. One can observe that expenditures for agricultural production come in fourth pos occasionally to buy fungicides for cocoa spray.

Table 3.5 *Farmer's priority expenditures*

PRIORITY EXPENDITURES	RANK	Freq. (%)	PRIORITY EXPENDITURES	RANK	Freq. (%)
Kerosene, soap, drugs, consumable	1	68	Drink	7	47
Children school fees	2	57	Food	8	29
House building and repair	3	38	Seeds	9	32
Agricultural material	4	45	Kitchen utensil	10	30
Paid agricultural labour	5	33	Mourning / funeral	11	70
Clothing	6	37	Gifts and assistance	12	78

Sample size n=200

3.4 Cropping systems

3.4.1 Cropping calendar

Table 3.6 presents three cropping seasons. The first ("Essep"), running from March to Ju the most important. Most bush fallow and forestland opened in December/January are during that period for "ngon" cultivation. The long dry season, which is from mid-Nove till the end of February, allows the felling and drying of trees and branches from bush forest fallow clearings. The total area cultivated by a farmer is large (see fields size). second growing season ("Oyon"), from August to November, is less important than the season; mostly Chromolaena fallow is cleared; the preceding short dry season running July to mid-August is not long enough to allow tree felling and drying. The total cultivated by a farmer is reduced (see Section 3.4.3). Arable swamps and valley botton cultivated between December and March ("Assan") for off-season production of food c but not all the families own an "Assan" crop field, since not everybody possesses an a valley bottom or swamp.

Table 3.6 *Cropping calendar in the Bipindi - Akom II area.*

Growing seasons	Clearing	Felling	Burning	Planting	Harvest
"Assan" Valley bottom	Nov.	Dec.	Dec/Jan.	Dec/Jan.	Mar.
"Essep" 1st season	Dec/Jan.	Jan/Feb.	Jan/Feb.	Mar/Apr.	Jul.
"Oyon" 2nd season	Jun/Jul.	Jul/Aug.	Jul/Aug.	Aug/Sept.	Nov.

3.4.2 Land Use Types

Agricultural land use can be divided in three types: home gardens or 'guie pion' nea home, perennial plantations (cocoa, oil palm) at a some what greater distance, and shi cultivation (food crop fields and fallows) away from the farmer's dwelling. The cultivatic food crop field shifts every season from one place to the other by clearing and burning a portion of a fallow land or a primary forest. The fallow land can be a forest fallow (FF, "Afan"), a bush fallow (BF,"Nnom ekodok") or a Chromolaena fallow, dominated by *Chromolaena odorata* (CF, "Ekodok ngoumgoum"). Arable swamps and valley bottoms are also used during the long dry season for off-season production. It is common to find a stripe of forest vegetation between the home garden field and the perennial plantations. This forest stripe is the place of straying of animals, mainly pig. It is also the place used by farmers for immediate needs such as firewood, material for building repair and construction, and domestication of some forest tree species

3.4.3 Food Crop Fields

Crops, Cropping pattern, Cropping sequence

More than 40 crop species are grown in the site. In the food crop field, crops are grown in association. An association may be made up of more than 10 crops; those crops of the association represented in higher density are termed major crops; those crops represented in lower density are termed minor crops. Major food crops are cassava, cocoyam, banana-plantain, "ngon" (*Cucumeropsis m.*), groundnut, maize, and yam. Minor food crops are vegetables, fruit trees, sugar cane, and pineapple. New crops or crops being grown for 20 years only are soybean, "ndole" (*Vernonia*), Irish potato, citrus. Obsolete crops are rice, taro and sweet potato. Crops sold on the market or on the roadside are cassava, cocoyam, banana-plantain, maize, groundnut, yam, sugar cane, fruit, palm nut, coconut.

The 4 major crop associations, highly linked to the type of preceding fallow, are:

1- Cucumber / cocoyam / plantain / maize (from a cleared and burned forest follow);

2- Groundnut / maize/ cassava /cocoyam / plantain (from a cleared and burned bush fallow);

3- Groundnut / maize/ cassava /cocoyam (from a cleared and burned Chromolaena fallow);

4- Cucumber (var. "seng'le") cocoyam / plantain / maize (from a cleared and burned bush follow).

Minor crops are found in all associations mentioned above.

Shifting cultivation vs. rotational fallow

The traditional cropping sequence called shifting cultivation starts with clearing of primary forest. Cocoyam and plantain are planted first; the felling of trees and burning follow one month later. After burning, cucumber ("ngon") is seeded between felled trees together with the associated maize. The cucumber overgrows tree stumps and felled trunks and is harvested after six to eight months. Maize is harvested first; cocoyam and plantain are harvested continuously for a longer period (more than 5 years) if soil fertility is high and pest and disease problems are low. Chromolaena fallow takes over the land progressively. Gradually the Chromolaena fallow plot turns to forest and cropping returns to start with a cucumber field.

With the use of chain saw, the limited labour to open primary forest, and the limited access to new land, the traditional shifting cultivation described above is more and more giving way to what may be called "rotational fallow". That is, clearing is followed directly by felling of trees and burning before planting cocoyam and plantain. Also, a farmer tends to rotate in a total area of less than 10 hectares, where he clears each season, either Chromolaena fallow (aged 3 to 5 years) to plant groundnut and associated crops, or bush fallow (age 7 to 9 years) to plant groundnuts and plantain with other associated crops, or forest fallow (age more than 10 years) to plant cucumber with the associated crops.

Size of food-crop fields
An individual farmer may open 2 to 3 food crop fields a year: one or two during th growing season (March - June), and one during the second growing season (Au November). The size of a food crop field varies between 0.3 to 1.5 ha per seasc individual farmer may have one large food crop field (more than 1 ha) or 2 average foo fields (around 0.5 ha each) in the first cropping season and only one average food crop (around 0.5 ha per year) during the second season, for a total of 1 to 2 ha per year.

Distance to the food crop fields
Most farmers have food crop field at a distance of more than 3 km from their home; b long distance may not exceed 5 km, though exceptional cases may exist. Three main re may explain the location of the food crop field far away in the forest: the first reason search for fertile land; land near the compound is less fertile; the second reason is to animal divagation; the third reason is the unavailability of land closer to the village ai inheritance of land that is far away from the village. However, some farmers have lan distance of less than 1.5 km; the shorter distance may even be less than 1 km, in excep cases. The reasons for having food crop field near the village are that farmers dispose o near the village, or that they do not want to walk long distance, or that they want to transport the produce to the compound or to the market.

Crop density and yields
The density and yield were measured for maize, groundnut, cocoyam, cassava *Cucumeropsis mannii* grown in the different associations strongly linked to the prec fallow.
The biomass dry weight and grain yields of maize decreased as the age of preceding f increased. Crop density increased as the age of the preceding fallow increased (Table Maize biomass dry weight was 1.29, 1.61 and 1.1 ton/ha following Chromolaena, bush f and forest fallow, respectively. Maize grain yield was 0.33, 0.43 and 0.30 ton/ha follo Chromolaena, bush fallow and forest fallow, respectively. Maize density was 8985, 1151 12155 plants/ha following Chromolaena, bush fallow and forest fallow, respectively. I fallow is not a suitable preceding fallow for the growth of groundnut. Groundnut is g only after Chromolaena and bush fallow.
Groundnut density and biomass dry weight and grain yield decreased as the fallov increased (Table 3.8). Groundnut density was 133,950 and 115,810 plants/ha, biomas weight 0.98 and 0.63 ton/ha, and grain yield 0.58 and 0.40 ton/ha following Chromolaen bush fallow, respectively. Cocoyam (Table 3.9) density was higher following bush fallov the same following Chromolaena and forest fallow. The biomass fresh weight increasec the increase in fallow age. Tuber fresh weight was higher following bush fallow and fallow and lower following Chromolaena fallow. Tuber fresh weight was 5.16 and 4.3 t follow bush fallow and forest fallow respectively, and only 3.64 ton/ha follo Chromolaena fallow. Cassava density and root fresh weight yield were not signific different following Chromolaena and bush fallow (Table 3.10). The density was 230 2310 plants/ha, the root fresh weight yield 17.85 and 16.43 ton/ha following Chromolaen bush fallow respectively. The cultivation of cassava following forest fallow is not cor practice.
Cucumeropsis mannii is grown following bush and forest fallow. The yield was 188 an kg/ha following bush fallow and forest fallow respectively (Table 3.11).
Total land equivalent ratio (LER) for maize, groundnut, cassava, cocoyam in associatio higher than one for all the three fallow age; indicating that the practice of associati

advantageous compared to solid cropping of each of the crop. The LER decreased with the increase in fallow age.

Table 3.7 *Density and yield of maize grown following fallow of different ages.*

Fallow type (age)	Density (plants/ha)	Biomass dry weight (ton/ha)	Grain yield (ton/ha)	Land equivalent ratio (LER)
CF (3-5 yrs)	8985	1.29	0.30	0.I7
BF (6-9yrs)	11510	1.61	0.43	0.22
FF (>10 yrs)	12155	1.10	0.30	0.23

n =18

Table 3.8 *Density and yield of groundnut grown following natural fallow of different ages.*

Fallow type (age)	Density (plants/ha)	Biomass dry weight (ton/ha)	Grain yield (ton/ha)	Land equivalent ratio (LER)
CF (3-5 yrs)	133950	0.98	0.58	0.40
BF (6-9 yrs)	115810	0.63	0.40	0.35

n =18

Table 3.9 *Density and yield of cocoyam grown following natural fallow of different ages*

Fallow type (age)	Density (plants/ha)	Biomass fresh weight (ton/ha)	Tuber fresh weight (ton/ha)	Land equivalent ratio (LER)
CF (3-5 yrs)	4530	3.62	3.64	0.45
BF (6-9 yrs)	5415	5.55	5.16	0.54
FF (>10 yrs)	4780	5.90	4.30	0.48

n =18

Table 3.10 *Density and yield of cassava grown following natural fallow of different ages.*

Fallow type (age)	Density (plants/ha)	Root fresh weight yield (ton/ha)	Land equivalent ratio (LER)
CF (3-5 yrs)	2300	17.85	0.23
BF (6-9 yrs)	2310	16.43	0.23

n =18

Table 3.11 *Yield of Cucumeropsis mannii grown following natural fallow of different age.*

Fallow type (age)	Yield (kg/ha)
BF (6-9 yrs)	188
FF (>10 yrs)	156

n =4

Land preparation

Manual labour dominates land preparation. The use of chainsaw reduces labour input onl "ngon" field. All other operations remain manual. Two systems of land preparatio common in the area. They are :

- Forest or bush fallow is cleared with chainsaw or axe and cutlass for "ngon" establishment. Trees are left in the field and start to rot during the time "ngon" is grown. . "ngon" field, one year later, systematic clearing and burning take place for groundnut establishment and later cassava field, then a Chromolaena fallow takes place. Tilling ı hoe, is done simultaneously with the planting of groundnut and cassava. Forest and clearing is men's job. Women who cannot rely on men, hire labourers to prepare larger fi or do it themselves to end up with smaller size fields.
- Chromolaena fallow clearing 3 to 5 years after forest or bush fallow clearing, requires labour; only cutlass and hoe could be used; therefore, women alone may do it. On sandy the roots are torn out by hand. This tills the soil and further tillage with the hoe is only for seeding.

Clearing constitutes the basic operation for all cropping systems. It is performed bet December-November for "Essep", the first season planting and in May-June for "Oyon" second season planting and in October - November for "Assan" the dry season swan valley bottom planting.

Tillage is done for all the types of field, except for the "ngon" field and the solid sta maize. Some farmers seed maize before tilling the land. Low tillage is common pr because of the shallow nature of forest soil (less than 12 cm deep). Moreover, fa experience difficulties during tilling due to the presence of many roots in the soil. B tilling, the plant debris lying on field must be cleared and burned.

Seeding and planting

The period for seeding and planting may extend over three months in the same field a mostly done at the same time as tillage with hoe. Women and children nearly always d work. Land preparation as a combination of clearing, cleaning, burning and tilling deter field size and production potentials.

Seeds, planting materials and storage

The use of seed and cuttings from the farmer's own farm is the common practice. Spac inadequate post-harvest technology limit the storage of seeds and planting materials. Prol of insects, bird and rodent attacks are common. Grains are stored in the house ne fireplace, because smoke hinders insect attacks. The heat may, however, reduc germination rate. Therefore, women may pre-germinate maize (soaking seeds in water fc 3 days) before seeding into the field. Seeds used for planting are from the preceding ha the neighbours, or bought on the market.

Weed, pest and disease

Weeds in the zone comprise broadleaf weed and grasses. Chromolaena is the dominant weed. Like many other weeds, farmers control it manually, using hoe and hand pulling. Weeding is done only once, at flowering in the groundnut field, and during re-densification of cassava five to six months after planting. Weeds are hand pulled and stacked under a tree or on the ground in the middle of the field. The ngon field is not weeded; the ngon vines climb on trunks and branches of felled trees out of the reach of weeds. It is common to find large crop fields invaded by weeds because of labour shortage. Throughout the growing season, farmers' crops are exposed to grass cutters, grasshoppers, porcupines, birds, locusts (*Zonocerus variegates*) and domestic animal attacks. The harvest in storage is damaged by weevils. Maize in the field is subject to streak and stem borer attacks. Cassava and cocoyam tubers are susceptible to root rot; plantain suffers from nematodes attacks. There is difficulty growing cowpea (*Vigna inguiculata*) or soybean in the zone because of aphids, thrips and pod borers.

Harvesting and processing

All harvesting and processing operations are done manually. Women carry most of the produce to the villages, part of the harvest will be sold and part consumed. In remote villages, most of the harvest is for family consumption; a small part of the rest may be sold and another part kept as seeds for next season planting. Nearly all crops are harvested progressively, and time and labour are not constraints, but groundnut harvest must be done once, to prevent pods from getting rotten in the ground; therefore the operation is felt by farmers as time consuming and labour demanding. Processing operations concern palm wine and some crops. Cassava may be processed into flour to make "fufu" or transformed into "gari", "engouda", "beignet", "miondo", "bobolo" and "mintumba". Cassava and maize may be fermented for use as raw material to make "arki", an alcohol beverage. Palm wine distillation gives an alcohol beverage called "odontol". Sugar cane is transformed into "melanba", also an alcohol beverage, after four days of fermentation.

3.4.3 Home garden

A home garden is a limited space around the compound where the farmer maintains an ecosystem composed of useful domesticated forest trees, local and introduced fruit trees, annual/biannual and perennial food crops, and where he can have easy access day and night. In the Centre Province of Cameroon, Tchatat *et al* (1996) reported the presence of 124 plant species in the home garden, excluding weeds and ornamental plants. Domestic animals are also part of the home garden: goat, pig, chicken, sheep, duck. Domesticated forest trees produce fruits (*Irvingia gabonensis, Trichoscypha sp., Cola sp.* etc.), spices (*Ricinodendron heudelotii, Irvingia gabonensis, Monodora myristica,* etc.), medicine (*Alstonia boonei, Voacanga spp.*) and can also be of multiple uses: "caterpillar trees" such as *Triplochiton scleroxylon* and *Petersianthus macrocarpus* (Tchatat *et al.*, 1996), firewood, wood work and construction (*Baillonella toxisperma, Mansonia altissima, Pterocarpus soyauxii*). Local fruit trees are "safout" and "cola". Introduced fruit trees are: mango, avocado, citrus, orange, guava, papaya, grapefruit, "corosolier", etc.

The role of the home garden is to diversify the production of the farmer and to continuously supply him with produce, allowing him to go through the period of food shortage (April-May) with less difficulty. Also, the home garden is the place where some useful plant species threatened to disappear by forest exploitation are conserved, such as *Trichoscypha, Irvingia* and *Dacryodes macrophylla.* Home garden is the land use system continuously managed by the family (husband, wife, children); it may receive organic fertilisation and in some cases

watering.
Animal divagation constitutes the primary threat to home garden development. Durii rainy season, food crop fields and home garden require much labour input, which may l weed invasion in home gardens.

3.4.4 Trees and perennial plantations

Trees play a major role in the farming system. An important part of the production comes from trees. Despite the price fluctuation in the market of cocoa, it remains amou important cash earner and is grown even in remote villages. Fruit trees are planted in c land and are also harvested during the fallow periods. It is estimated that more than 3 species are planted or preserved for home use or market sale. The oil palm (*Elaeis guine* is of great importance, not only for palm oil production, but also as source of palm wine. wine is tapped from living trees but more often from felled trunks. Brooms, basket building materials may be derived from oil palm tree. The Raphia palm provides wine an materials for furniture and house construction. More and more semi-industrial plantatio oil palm are establishing in the TCP area and the phenomenon is likely to continue; mor will be needed and will be obtained through the clearing of more forestland.
The devaluation of the Franc CFA has not brought the price of cocoa to its original attr value; the price still remains low. With the low and fluctuating price, added t disorganised marketing system, new cocoa plantations are not being created, and old on not being well maintained. Cocoa as cash earner has lost its leading importance to a ser other cash earners such as cassava, cocoyam, fruits, palm oil, palm wine and groundnu bush butter tree (*Dacryodes edulis*) has gained an important economic role; it belongs most important crops sold on the market. Avocado pears (*Persea americana*) were intro during early colonial years and form an important part of the diet and cash earner. Dif citrus species (orange, tangerine, grapefruit, lemon) are part of many cocoa plantation home gardens where avocado, guava and mangoes may also be planted. Fruit trees to with oil palm are also made part of most fallow lands in the rotational fallow system desc in Section 3.4.3; this might indicate a potential for planted fallow and might indicate ne research on the suitability of selected trees in fallow systems.

3.4.5 Fallow type

Farmers are more and more adopting the "rotational fallow system" which consists of ro in a total area of less than 10 hectares, where they clear each season, either Chromc fallow (3 to 5 years) to plant groundnut and associated crops, either bush fallow (7 to 9 to plant groundnut and plantain with other associated crops, either forest fallow (more th years) or virgin forest to plant cucumber with the associated crops. The above classificati fallow based on vegetation age classes is the farmers' definition. It is difficult for farm recall the precise age of a fallow. The type of fallow cleared is highly linked to the crops to be grown. Virgin forest and forest fallow ("Afan") are cleared to grow "ngon" associated crops. Bush fallow ("Nnom ekotok") is cleared to grow "ngon" (var. Seng'le groundnut with associated crops, or to grow groundnut and plantain with associated Chromolaena fallow ("Ekotok Ngoumgoum") is cleared to grow groundnut and asso crops. The choice of the virgin forest or forest fallow to clear is based on the presence of tree species which indicate good soil fertility (Table 3.12). Other tree species are indicat infertile soil (Table 3.13).

Table 3.12 *Some tree species used by farmers as indicators of fertile soil*

Local or pilot name	**Scientific name**	**Family**
Eteng / Ilomba	*Pycnanthus angolensis*	Myristicaceae
Doum / Fromager	*Ceiba pentandra*	Bombacaceae
Akom / Fraké	*Terminalia superba*	Combretaceae
Essombo	*Rauvolfia macrophylla*	Apocynaceae
Asseng	*Musanga cecropioides*	Moraceae
Ekouk	*Alstonia boonei*	Apocynaceae

Table 3.13 *Some tree species used by farmers as indicators of infertile soil*

Local or pilot name	**Scientific name**	**Family**
Elon / Tali	*Erythrophleum ivorense*	Caesalpiniaceae
Alan	*Hylodendron gabunense*	Caesalpiniaceae
Adjom	*Aframomum citratum*	Zingiberaceae
Ebay	*Pentaclethra macrophylla*	Mimosaceae
Eyen	*Distemonanthus benthamianus*	Caesalpiniaceae

3.5 Trends in agricultural land expansion

From the Landscape Ecological Survey of the study area (van Gemerden and Hazeu, 1999) based on aerial photograph of 1984/85, over a total area of 167,350 ha and 51,180 ha were used for low and high intensity agriculture respectively. This agricultural area represented about 31% of the total TCP area (Table 3.14). A sample land area of 94.5 ha was mapped and used proportionally to the total TCP area for agricultural land expansion study.

The agricultural land expansion possibility in the TCP area may be influenced by many factors such as the population increase, available accessible landform, electrification though timidly, more roads opened though unpractical in the rainy season, more and more availability of market for food crop, the establishment of younger people in the villages and the active participation of elite in farming, opening new forest land for commercial production of banana-plantain, pineapple, cassava, oil palm and horticultural produce, and the expanding use of chainsaw for forest clearing.

Results show that from 1984 to 1997 the proportion of land under agricultural use expanded from 31 to 40.3%. This corresponds to an average annual expansion of 0.71% of the total land area (an absolute value of 1200 ha/year). Figure 3.3 gives the evolution of agricultural land area from 1984 to 1997, compared to the total land area and the potential agricultural land area of the TCP research area.

Table 3.14 *Extent of the areas influenced by shifting cultivation in 1984 and 1997 (ac from van Gemerden and Hazeu, 1999)*

Intensity of shifting cultivation	Extent /(ha)		% of total area	
	1984	1997	1984	1997
None to hardly any	116 170	99 472	69	59.7
Low to High intensity	51 180	67 652	31	40.3

	Total	Y95	Y96	Y97	Y84
(ha)	94,5	94,5	94,5	94,5	
Forest		7,7	8,4	8,8	116170
Agri		23,8	21,6	24,1	51180
(%)					167350
Forest		8,1	8,9	9,3	69
Agri		25,2	22,9	25,5	31
	1984	1995	1996	1997	
(ha)	0	13636	14876	15584	
	51180	64816	66056	66764	
	31	39	39,5	39,9	
Potential					
Actual Ag					

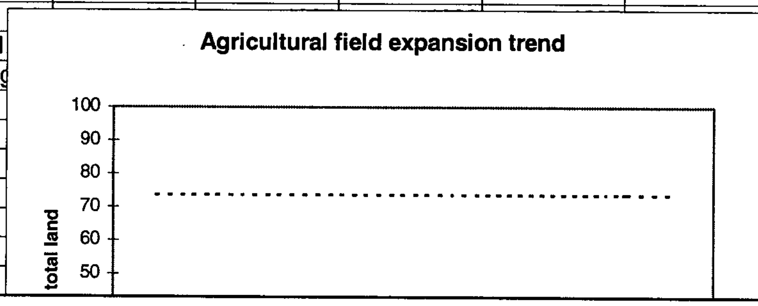


Figure 3.3. Trends in agricultural land expansion in the TCP area

In shifting cultivation system, because of yield decline during the cropping period, fielc abandoned and new fields are cleared in a natural fallow or in an undisturbed forest. degradation and weed infestation are reported to be the main reason for yield decline (Ny Greenland, 1960; Sanchez, 1976; 1977; Volkoff *et al.*, 1989; Gerold, 1995). In the study the topsoil structure and porosity changes may be the most important soil degrad characteristics and the main cause of field plot abandonment and shift.

Results show that today, the shifting characteristic of the cropping system is defined ir directions: 1)- the first direction is that of moving within natural fallow plots of different This constitutes a rotational system, which is common practice today. It concerns mainly crop fields. Seventy-six (76 %) per cent of food crop fields in the area rely on this rotat system.

2)- the second direction is that of agricultural fields expanding into new undistu forestlands. This is the traditional pure expansive system, which constitute more thre forest conservation and sustainable management system. This system which concerns tv four per cent (24%) of food crop fields is practised mainly for cucumber (*Cucumer mannii*) production and for establishment of semi-industrial farms by elite. For this syste average of 2200 m² of new forest land is opened by each household per year in the TCP This average surface corresponds to about 300 m² per inhabitant. Ebimimbang plains

Mvié uplands (annex 2) have the highest rate of forest encroachment per year and per household with values of 2450 m² and 2650 m² respectively. The higher rates in these two units can be explained by the fact that their landscape is more accessible for agricultural practices, and their area have been under commercial logging many times, leading to the increase in population (Table 3.15).

Table 3.15 *Population variation with landform units in the TCP area*

	Plains and Uplands of Ebimimbang and Mvié	Hills and Mountains of Ebom and Nyangong
Population	1593	992
Household	178	137

3.6 Animal system

3.6.1 Reared animals

Though important, animal husbandry is limited to the rearing of few goats, fowls, pigs and sheep. It is the second most important activity after crop production according to about 1/3 of the farmers interviewed. The ranking by the other 2/3 of the population is third and fourth. It is an activity practised by nearly every family, but it is neglected. The negligence that farmers give to the rearing of animals is reflected in the low cumulative frequency recorded in the ranking. Only 39% think that pig comes in second position, only 40% classify goat in third position, and only 43% place sheep in forth position. Constraints to the development of animal husbandry are diseases, absence of the technical know-how and limited use; the produce from the activity, by tradition, is not frequently consumed as part of the diet and is not income generating. Animals are used mainly for social events such as payment of dowry, guests' reception and ceremonies (wedding, funerals etc.)

3.6.2 Hunted animals

Van Dijk (1999) reported a number of 40 mammals as being hunted. The prioritisation of hunted animals in the present study concerned only the most solicited species and not all existing species. Farmers hunting activity is primarily in search of the following animal species: *Atherurus africanus* (African Bush-tailed Porcupine), *Cephalophus monticola* (Blue Duiker), *Cephalophus dorsalis* (Bay Duiker), *Cercopithecus nictitans* (Greater White-noosed Monkey), *Cercocebus cephus* (Moustached Monkey), *Cricetomys gambianus* (Giant Gambia Rat).
Prioritisation and farmers' reasons of importance for these most solicited species are given in Table 3.16. *Atherurus africanus* comes in first position, followed by *Cephalophus monticola*, then *Cephalophus dorsalis*, and in fourth and fifth position, *Cercopithecus nictitans* / *Cercocebus cephus* and *Cricetomys gambianus* respectively.

Table 3.16 *Most solicited hunted animal species.*

Scientific name	French name (Bulu name)	Rank	Fr. Cum. (%)	Reasons of importance
Atherurus africanus	Athérure/porc-épic (Ngom)	1	41	Increasing local consumptic diverse revenues
Cephalophus monticola	Céphalophe bleu /lièvre (Okpweng)	2	33	Increasing local consumptic diverse revenues
Cephalophus dorsalis	Céphalophe à bande dorsale noire/ Antilope (So)	3	43	Local consumption and reve
Cercopithecus nictitans/ Cercocebus cephus	Singes/ hocheur/moustac (Evembe/osok)	4	38	High revenues and consump large solicitations
Cricetomys gambianus	Rat de Gambie (kosi)	5	26	Locale consumption, easy tc capture

3.7 Farmers' agricultural production priorities

3.7.1 Priority activities and land use types

Crop production remains the first priority activity for all the farmers. It is the most imp because the produce of this activity has many destinations: consumption in many form diverse revenues. Animal husbandry is the second priority activity for the majority repres by one third of the farmers. This low majority shows that the activity is neglected though important. In third position comes fishing, but the produce is mostly for consumption anc little is for revenue. In fourth position comes palm wine tapping, which is a permanent s of consumption and revenue, but the quantity is limited due to the problem of conserv Wild fruit collection comes in fifth position followed by hunting in sixth and oil exploitation in seventh position (Table 3.17).

The crop production activity takes place in three land use systems. The most imp priority land use system is the food crop field according to more than 80% of the farmers food crop system is most important because it supplies produce which is consumed in forms and which is more and more a source for diverse revenues. The perennial plant systems dominated by cocoa farms used to be in first position because of the high rev drawn from cocoa production. Today, the revenue from cocoa production is low fluctuating. This situation has obliged farmers to put the system in second position; les less attention is being paid to the system; for instance, there is little investment for cocoa maintenance and no regeneration or new plantation is created. The home garden system c in third position because the system is less quantity producing and less income generating

Table 3.17 *Farmers' priority activities*

MAJOR ACTIVITIES	RANK	Frequency of ranking (%)	RAISONS OF IMPORTANCE
Crop production	1	92	Diverse consumption and revenues
Animal husbandry	2	29	Guests reception, dowry, ceremon
Fishing	3	35	Local consumption, little revenue
Palm wine tapping	4	45	Consumption and unstained reven
Wild fruits collection	5	22	Seasonal consumption and revenu
Hunting	6	32	Diverse consumption and revenues
Palm oil extraction	7	48	Simple local consumption

Sample size n = 200

3.7.3 Priority crops

Table 3.18 gives the priority crops in the area. Cassava is in first position according to 3/4 of the farmers because it is a crop for diverse consumption and multiple revenues, and can grow nearly everywhere. Groundnut is second according to the majority represented by 48% of farmers because it is frequently consumed, is part of nearly every meal and is increasingly important as source of income. The 35% majority of farmers have classified cocoa in third position because it is not a locally consumable product and is no longer a crop of high revenue as in the past; the low frequency percentage of 35 confirm that most farmers are disinterested of the production of cocoa because of low and highly fluctuating market price. Cocoyam is fourth in the area in general, but first in most villages of the Bipindi sub-division. The revenue from cocoyam is increasing and the consumption sustained. The rank and reasons of ranking for the other major crops are given in Table 3.18.

Table 3.18 *Farmers' priority crops*

MAJOR CROPS	RANK	Frequency of ranking (%)	REASONS FOR IMPORTANCE
Cassava	1	75	Multiple consumption and revenues
Groundnut	2	48	Frequently consumed, increasing revenue
Cocoa	3	35	Decreasing revenue
Cocoyam	4	64	Sustained consumption, increased revenues
Banana/plantain	5	45	Local consumption, sustained revenues
Cucumber ("ngon")	6	42	Luxury consumption, high revenues
Maize	7	37.5	Modest consumption and revenues
Yam	8	64	Consumption and revenues

Sampling size n=200

3.7.4 Priority crop associations

A wide variation exists in the number of crops associated in different fields and their arrangement. However, some important factors may be defined that influence the type of mixture and may allow prediction of crop associations and production methods in narrower ranges. Some of these factors may be the preceding fallow, the compatibility of some crop species, the main crop in the field and its destination, and the overall objective of the production. The main crop in the field defines the field type though farmers may not express it that way. Therefore, one could talk about groundnut field, cassava field, ngon field, banana/ plantain field etc., wherever these crops are dominant in the fields. The dominant crop is generally the priority crop of the association. The analysis of field types can help with the preparation of on-farm technology testing and extension, and the classification of priorities for interventions and alternative technology development. A priority association is here defined based on crop associations highly linked to the type of preceding fallow. The association plantain/cassava/cocoyam /groundnut / maize (from a cleared and burned bush fallow), where cassava was the main crops, was considered first priority by about 3/4 of the farmers; the association groundnut/ cucumber (Seng'le) / cassava/ cocoyam/ plantain (from a cleared and burned bush follow or Chromolaena fallow), where groundnut and seng'le were the main crops, was classified second by 65% of the farmers; the association of perennial crops (cocoa, fruit trees) was considered third by 48% of farmers; the association cucumber / cocoyam/ plantain / maize (from a cleared and burned forest fallow), where cucumber is the dominant crop, was put in fourth position by 58% of the farmers.

3.7.5 Priority fallow

Fallow types were defined based on vegetation age (X). Three classes of fallow were de shorter fallow (X < 3 years), Chromolaena fallow (3 < X > 5 years), bush fallow (6< X years), forest fallow (X > 10 years). The majority of farmers (64%) put Chromolaena fall first position because on one hand the soil is sufficiently fertile to allow growing many species and on the other hand little labour is required to clear the land. Bush fallow con second position (46% of farmers) because there is good fertility recovery, but ther difficulties clearing and tilling land with tree stubs. Shorter fallow comes in third po (60% of the farmers) because it is suitable for the growing of fewer crop species due t soil fertility, but interesting for farmers because of little bush clearance to do. Forest f comes in last position because it requires much labour for clearing and tilling land ca big tree trunks and stubs. The choice of short fallow over long fallow may lead t degradation. However, it is a positive sign of easy adoption by farmers of future introdu of sedentary agricultural technologies for reduction of the destructive effect of sh cultivation on the forest.

3.8 Agricultural priority production constraints

3.8.1 Socio-economic constraints

Socio-economic constraints for agricultural production are numerous. The first six cons reported and prioritised by farmers are given in Table 3.19, with the reasons of importance. According to 66% of farmers, the first most important constraint is condition of road that enclaves the villages rendering travelling and transport of g difficult, and discouraging increase in production. Out of 200 farmers interviewed, 98% roads were not practicable, only 2% said that the condition of roads was acceptable. second constraint raised by 58% of farmers was the absence of good markets where one get a good price for his produce. If one cannot get a good price, he will not be motivat produce in large quantity. The third constraint (52% of the farmers) is ignorance o production techniques and of how to acquire production input. This ignorance o technique and availability of input keeps farmers' agricultural practices rudimentary. fourth constraint (35% of the farmers) is price fluctuation of cash crops (cocoa) devaluation of the Franc CFA; farmers are frustrated, pessimistic for the future and motivated to produce more. The fifth constraint (29% of the farmers) is land tenure; the uneven distribution of capital land, the access to land for younger people is limited and l agricultural production. The sixth constraint (33% of farmers) is absence of capita investment in agriculture. Systems of formal credit (e.g. FIMAC) are timidly being p place by the government, and have yet to reach the majority of the farmers. All s economic constraints mentioned above were raised and prioritised by farmers themselves believed that agricultural production may improve if these constraints are alleviated.

Table 3.19 *Priority socio-economic constraints for food crop production in the TCP area*

Socio-economic constraints	Rank	Cum. freq.(%)	Reasons of the importance
Poor road condition	1	66	Travelling and transport of goods difficult discouraging the increase in crop production
Absence of good market	2	58	Limit crop production
Ignorance of production techniques and how to acquire input	3	52	Rudimentary agricultural practice
Fluctuation of the price of cash crop	4	35	Limit crop production, pessimism for the future
Uneven distribution of land	5	29	Limit youth involvement in agriculture
Absence of capital for investment	6	33	Limited production; absence of mechanisation

3.8.2 Agronomic constraints

Nounamo (1997) reported a number of agronomic constraints for food crop production in the forest zone of Cameroon in general; their severity level and the intervention of research (Table 3.20).

Table 3.20 *Food crop production constraints in the forest zone*

Constraints	Severity level	Research intervention
Low soil fertility	High	Solutions being tested
Soil erosion	High	Advice given
Low yielding varieties	High	Solutions being tested
Poor quality seeds	High	Advice given
Shade	Low	Advice given
Weeds	Low	Solutions being tested
Maize stem borers	High	Advice given
Maize streak leaf rust	Low	Solution being tested
Groundnut rosette	Low	No advice given
Groundnut Cercospora leaf spot	Low	No advice given
Cassava root rot	High	Solution being tested
Cassava mosaic virus	Low	No advice given
Rodents	High	Advice given
Birds	Low	No advice given
Grasshoppers and grasscutters	High	No advice given

In the TCP site the crop production constraints are similar to those of the overall forest zone. The major ones are: low soil fertility, cassava and cocoyam root rot, maize stem borer, poor quality seeds and planting materials, insects and rodents, animal damages, and weed invasion after short fallow. Farmers identified roughly six major constraints to their agricultural production. For crop production, 57% of the farmers ranked the attack of rodents, birds, grasshoppers and grasscutters first. 53% of the farmers ranked the disease problems (cassava and cocoyam root rot, and groundnut rosette and Cercospora) as second. Forty-eight (48%) of the farmers placed the attacks of aphids (Capsides) and cocoa brown rot in the third position. Low soil fertility was mentioned by 37% of the farmers as coming in fourth position. 42% of the farmers ranked the problem of unavailability of fertilisers and pesticides in the fifth position. 37% of the farmers ranked weed infestation in the sixth position. According to farmers, all the above constraints are important because they contribute to the reduction of crop production.

For animal husbandry, farmers identified and ranked three major constraints to a production. 47% of the farmers ranked animal diseases and pests in the first position. 3 the farmers rank animal predation in second position, and 22% of farmers ranked probl feed and feeding in third position. According to farmers, animal diseases and pests predation reduce the production of animals, and the problem of feed and feeding le animal divagation and development of conflicts among farmers.

4 SOIL DEGRADATION UNDER SHIFTING CULTIVATION

4.1 Literature review

Soil under forest cover is generally protected from the direct impact of raindrops and associated splash erosion by a continuous litter layer. In the process of clearing the forest for traditional agricultural purpose, the slashed biomass and the litter are burned such that the topsoil becomes fully exposed. The impact of burning and subsequent cropping system may lead to physical and chemical degradation of soil as well as accelerated soil erosion.
Many studies in the tropical forest zone have shown that taken into shifting cultivation (without input), forest land productivity decreases rapidly and the land becomes unproductive after two or three years of cropping. Various factors are recognised to be responsible of this situation: (1) depletion of available nutrients from the soil and deterioration of soil physical properties; (2) weed encroachment; (3) increase in diseases, insects, and parasitic nematodes. However, abundant diagnostic research in the humid tropics of Latin America, Africa and Asia have described the situation as being mostly soil-related (Nye and Greenland, 1960; Sanchez, 1976; 1977; Volkoff *et al.*, 1989; Gerold, 1995). These soils undergo not only rapid elimination by leaching and erosion of nutrients, but also undesired changes of physical properties such as structural stability, bulk density, etc. (Volkoff *et al.*, 1989).
In shifting cultivation agriculture, burning of slashed vegetative material and fallow system are meant to improve soil fertility during and after cropping phase respectively. In the virgin forest, there is an equilibrium between soils and the vegetation they support. During the cropping period the equilibrium is lost because of the fertilising effect of the ash, followed by rapid soil degradation, while during the fallow period soils along with their new vegetation start a new process towards the equilibrium. This implies a dynamic process in which soil productivity and soil constituents are involved. For the cropping period, quantitative experiments have revealed the amounts of nutrients that are added to the soil on clearing, and how fast they are lost by leaching, by erosion of topsoil or by removal in crops. According to Nye and Greenland (1960), in addition to analysing the effects of shifting cultivation on the soil, one has also to consider how far the nature and response of soil accounts for the pattern of farming systems.
Studies regarding this aspect are few. Kotto-Same *et al.* (1997) studied the carbon dynamics in different land uses of slash-and-burn agriculture in the east part of the study area. The results showed no significant variation of soil carbon with land use types. Other studies were conducted in west and central Africa on soil organic matter dynamics and soil fertility under different fallow and cropping systems. The two years study of the influence of *Cajanus cajan* on soil fertility at Minkomeyos, Yaoundé-Cameroon revealed differences in maize yield and slight increase in soil organic matter (Mulongoy and Tonye, 1992). Also, results from a study on effects of cropping and fallowing on some soil fertility parameters in southern Nigeria (Mulongoy *et al.*, 1992) showed that fallow length tended to increase both organic carbon and humic acid contents of soils. Slaats (1995), making an agronomic assessment of *Chromolaena odorata* fallow in food cropping systems in south-west Ivory Coast, showed that the transformation of shifting cultivation into the *Chromolaena odorata* fallow system increased the productivity of land use and should be an important cropping system in areas of the humid tropics where short fallow is required in shifting cultivation. Its shortcomings nevertheless, are the reduction of the species diversity. Van Reuler (1996) tested also the nutrient management over extended cropping periods in the shifting cultivation system of southwest Ivory Coast. He concluded that in extended cropping periods, alternating rice and maize, applications of N,

P and K were not sufficient to maintain the yield level obtained in the first season after clearing. Data on the efficiency of utilisation of absorbed P indicated that the deteriorati soil physical properties should be another factor causing the yield decline in shifting cultivation systems.
For better understanding of the functioning of forest soils under the cropping phase a fallow period, this research was carried out in relation to farming systems in both "Regı series" (rate of soil degradation under agricultural use) and "Progressive series" (rate regeneration during the fallow period) in the study area. Cropping phase included mixe crop fields, perennial plantation, and solid stand of pineapple plantation. Results of studies are given here below followed by some comments.

4.2 Food crop fields and soil properties changes

The analysis of soil behaviour in traditional food crop field takes into account two phase first phase is concerned by the sudden changes in soil following clearing and burning vegetation biomass. The second phase deals with the slower changes in soil ph chemical and biological properties, leading to field abandonment.

4.2.1 Clearing and burning

In the forest area, burning is essential. It is the only way to properly clear the ground great mass of slashed undergrowth and felled trees, and make it accessible for tillage planting food crops. Other beneficial effects of the burning as reported in the literatu killing of weed seeds in the topsoil and of stump sprouts which would shade out crop sp and partial sterilisation of the soil (Nye and Greenland, 1960; Sanchez, 1976). Bu practice has remarkable positive as well as negative effects on soil surface properties. 4.1 presents results of soil properties changes from fallow to food crop fields. Soils sampled at planting.

Soil chemical changes
Ashes from burned vegetation biomass at the beginning of the cropping period act as fertiliser and significantly ($P<0.05$) influence soil properties such as pH, exchangeable (specially calcium), exchangeable acidity, available phosphorous and C/N ratio. O carbon, CEC and base saturation do not show clear variation with burning. (see Table The pH increase by ash consequently alleviates Al toxicity and other acidity problems magnitude of changes is negatively related to the age of the vegetation cleared. Young fa (Chromolaena fallow) produce more burning materials than old forests which biom mostly made of large size woods that can not burn easily. Burning materials are then rela the age of the cleared vegetation and decrease in the order: CF>BF>FF>=FV. After a air-drying period of slashed vegetation, 45% of total biomass could be burnt on a 4 fallow against 15% for a 20 years fallow in Côte d'Ivoire (van Reuler, 1996). Consequ chemical changes in soil are in the same sequence. Fields from CF have a higher pH be of the substantial increase in available phosphorous, this type of fallow is commonly us farmers to grow groundnut (*Arachis hypogea*). While FF and FV, because of their re richness in decomposable soil organic matter, are preferentially used to grow cucı (*Cucumeropsis mannii*) and other vegetables. In intermediate fallows, crops are indisı growth.
The chemical and nutrient effects of burning are generally considered to be short-lived soil pH values returning to pre-burn levels within 3 years in low to moderately burned

(Chandler *et al.*, 1983). Factors influencing the persistence of these changes likely include leaching by rainwater, burn intensity, erosional removal of ash, and crop harvest.

Table 4.1 *Soil property changes from fallow field to food crop field after burning*

	0-10 cm slice on **sandy topsoil (Ultisols)**						0-10 cm slice on **clayey topsoil (Oxisols**				
	Crop field types						Crop field types				
	CF		BF		FF		CF		BF		Fl
	fa	fcf	fa	fcf	fa	fcf	Fa	fcf	Fa	fcf	fa
pH	6.9	7.2	5.4	6.8	5.7	6.8	4.5	4.9	3.9	4.6	3.6
OC (%) *	2.6	1.8	2.3	2.5	2.1	2.1	3.1	2.6	3.3	2.9	3.6
C/N ratio	8.8	12.5	9.9	13.0	12.1	12.6	10	14	10.5	13.5	13.7
P av. (ppm)	14	33	4	23	6	17	8	17	7	15	7
Ca (cmol/kg)	9.3	12.6	4.6	11.3	5.8	6.5	2.3	3.4	1.0	3.1	0.5
Σbases	11.8	14.4	6.6	13.7	7.9	9.3	3.9	5.2	2.0	4.8	1.6
Al^{3+} (cmol/kg)	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.5	2.4	1.0	3.5
CECs (cmol/kg)*	6.7	6.8	4.5	9.6	9.6	8.9	9.9	9.3	9.1	11.9	14.8
BSP (%)*	99	99	97	98	82	96	54	81	28	72	16
B.d. (g/cm^3)	1.21	1.35	1.16	1.23	1.03	1.17	1.11	1.10	0.99	1.05	0.89
SS (water-drops)	68	13	78	51	136	35	144	133	182	166	142
Clay (%) *	13	15	17	17	15	10	33	28	33	31	39
M.B. (µC/g soil)	-	-	-	-	-	-	976	901	1263	755	1023

Keys: CF = Chromolaena Fallow
BF = Bush Fallow
FF = Forest Fallow
fa = fallow soil
fcf = food crop field
OC = Organic Carbon
P av. = available phosphorous
BSP = Base Saturation Percentage
M.B. = Microbial biomass
CECs = Cation Exchange Capacity (soil)
Σbases = sum of bases
Ca = Calcium
B.d. = Bulk density
SS = Structural Stability

* Effect of burning not significant at $p<0.05$

Soil physical changes

The immediate soil surface heating by burning and tillage have some direct effect on soil physical properties such as reducing aggregates stability (Table 4.1). Burning destroys the humic porous topsoil A_1 horizon of old fallow as shown on Figure 4.1.

Soil microbial biomass

Burning contributes to partial sterilisation of the soil although microbial populations rapidly increase after the heating effect (Jordan, 1985). On clayey Oxisols of the study area, soil microbial biomass was 10 to 45% lower under cropped land than the adjacent fallow land (see Table4.1).

Conclusion

The presence of ash from high intensity burns has several important effects on soil. The plant available nutrient status of the soil is increased as a result of the fire induced release of organically bound nutrients such as K, Ca, Mg, and P (Sanchez, 1976). The dissolution and leaching of white ash results in soil pH values increase by 5 to 15%, which promote changes in soil mineralogy, and presumably, other materials with pH-dependent charge. For example, the step-by-step reaction of hydroxylation of Aluminium may proceed, leading to insolubilization of Al toxic cation occurring in important rate in low pH soil. This process can lead to the formation of gibbsite (Al precipitate) and the decrease in soil Al toxicity.

4.2.2 Cropping phase

After slashing and burning, the existing equilibrium between the natural fallow vegetatio
soil is broken and a new cycle is established between disturbed soil and crops/\
vegetation. Processes acting in this new system result also on changes in soil status.

Soil physical status

During the cropping period, important deterioration of soil physical conditions o(Erosion, crusting and sealing phenomena contribute to changes in topsoil compa porosity and bulk density (Figure 4.1). These soils become more compact and c Compared to soil under undisturbed forest (FV), the bulk density increases by 10 to during the cropping period and thus, inversely does the soil porosity. Clay content decreases within the same range.

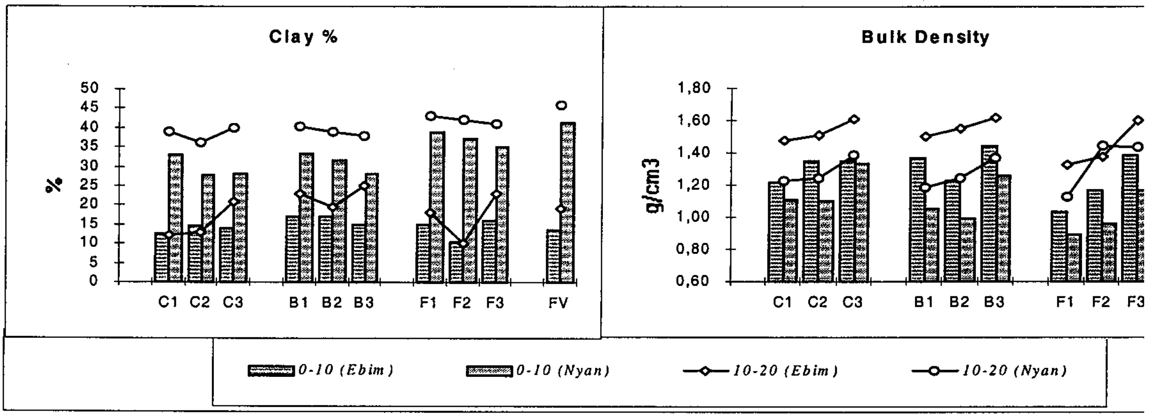


Figure 4.1. Some soil physical property evolutions during cropping period

Keys: C1 = Soil under Chromolaena fallow (1996); C2 = Soil at the beginning of the cropping period (1996) c cleared from Chromolaena fallow ; C3 = Soil at the end of the cropping period (1998) of field clearei Chromolaena fallow. B1 = Soil under Bush fallow (1996); B2 = Soil at the beginning of the cropping period of field cleared from Bush fallow ; B3 = Soil at the end of the cropping period (1998) of field cleared fron fallow. F1 = Soil under Forest fallow (1996); F2 = Soil at the beginning of the cropping period (1996) c cleared from Forest fallow; F3 = Soil at the end of the cropping period (1998) of field cleared from Forest fallo

Soil chemical status

During the cropping period, the liming effect of ashes is reduced by crop harvesting, erosion on bare soil and leaching of cations. Data collected at the end of the cropping p did not show clear variation of soil pH, sum of bases, available P, CEC and organic carb the top 10 cm of the soil profile, but a tendency in the increase of pH, C/N ratio, CEC and of bases is observed in 10-20 cm slice of soil (Figure 4.2). This tendency of increase in l is likely the result of percolation and leaching. Ulery *et al.*, (1993) and Durgin and Vogel (1984, cited in Ulery *et al.*, 1993) reported that potassium is by far the most abundant w extractable cation in fresh ash. Consequently K is the most readily leached catio rainwater. The lime effect of wood ashes in the two soil types of the area is mainly contr by calcium, which highly correlates with soil pH and sum of bases. This might be one c reasons that pH and sum of bases still remain high at the end of cropping period in 0-1 soil slice. However, the rate of ash removal by leaching and sheet erosion on soil surface vary from one field to another, depending on many other factors of the environment. A by Ulery *et al.* (1993) showed that wood ash was completely removed by leaching on slopes (30% gradient), three years after burning. But, on gentler slopes (5% gradient), darker ash was still retained on soil surface.

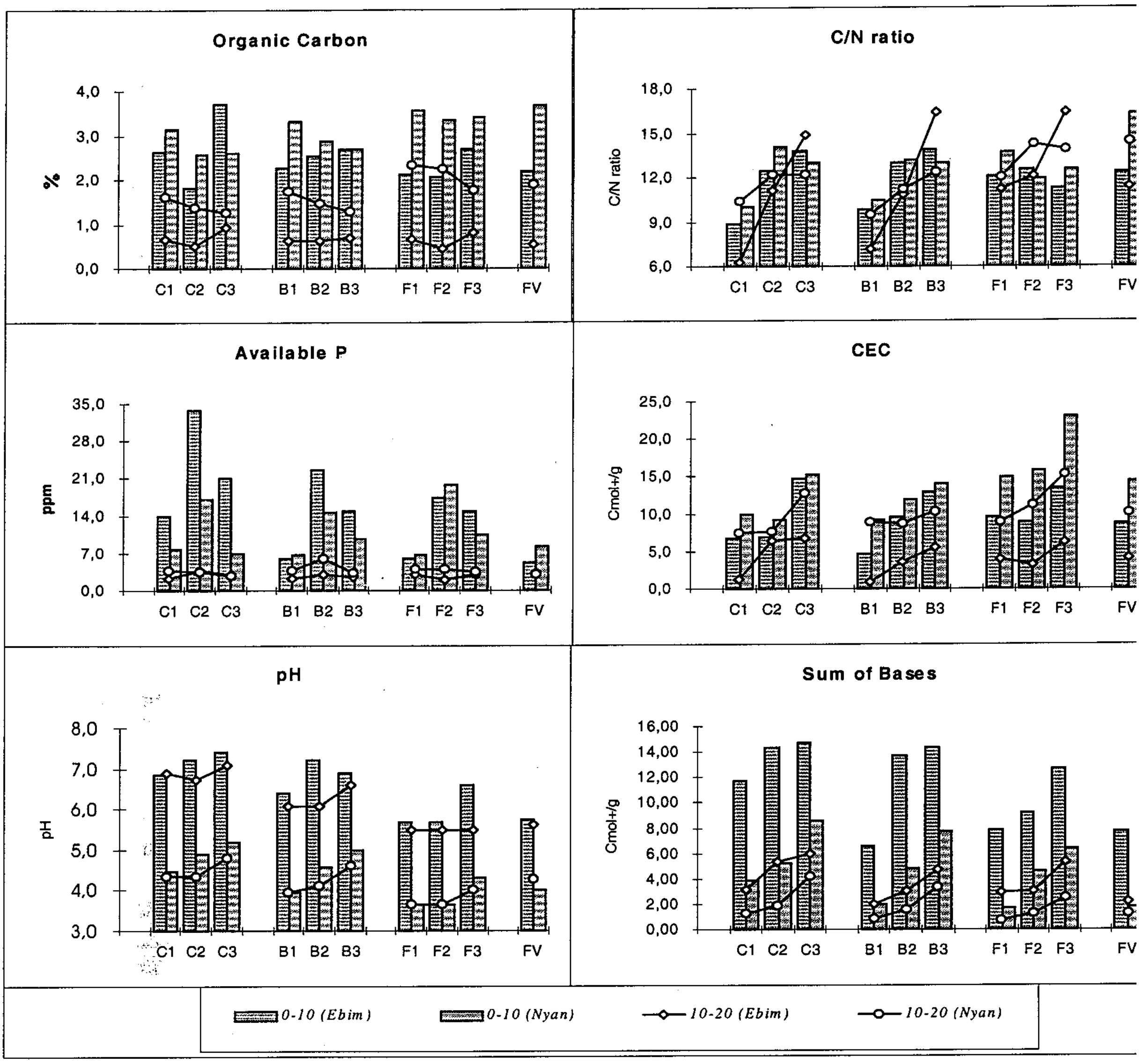


Figure 4.2. Chemical soil property evolutions from fallow to the end of the cropping period

Keys: C1 = Soil under Chromolaena fallow (1996); C2 = Soil at the beginning of the cropping period (1996) of field cleared from Chromolaena fallow ; C3 = Soil at the end of the cropping period (1998) of field cleared from Chromolaena fallow. B1 = Soil under Bush fallow (1996); B2 = Soil at the beginning of the cropping period (1996) of field cleared from Bush fallow ; B3 = Soil at the end of the cropping period (1998) of field cleared from Bush fallow. F1 = Soil under Forest fallow (1996); F2 = Soil at the beginning of the cropping period (1996) of field cleared from Forest fallow ; F3 = Soil at the end of the cropping period (1998) of field cleared from Forest fallow.

Soil erosion

At the course of this study direct erosion measurement in farmers' fields was not carried out. Nevertheless, erosion hazard in shifting cultivation systems could be inferred from other environmental characteristics. The evidence in the field is that under heavy and strong rainfall on bare soil at the beginning of the cropping period, soil erosion is accelerated. The consequence is the removal of an important part of topsoil and ashes from the burned vegetation. According to many authors (Tulaphitak *et al.*, 1980; Prat, 1990), the most important loss of ash nutrients during the cropping period in shifting cultivation takes place in the short period between burning and the soil surface covering by crops. In fact, mixed cropping systems as it is practised in shifting cultivation in the tropical area are reported to

favour fast soil cover, which minimises runoff, soil loss and nutrient leaching. A stu conducted on an Ultisol located in the east of the study area by Ambassa-Kiki and Nill (199 showed that traditional mixed cropping preceded by manual land preparation produces l runoff and soil loss after four years of cropping, and conserves for longer period a lower bu density. This comparison was made with treatments that involve sole cropping preceded the use of heavy machinery for land preparation.
However, during the two years cropping period in our study area, soil porosity was reduced 10 to 20 % (Figure 4.3) due to increase in bulk density. This is indeed, followed by increasi surface runoff and erosion hazard.

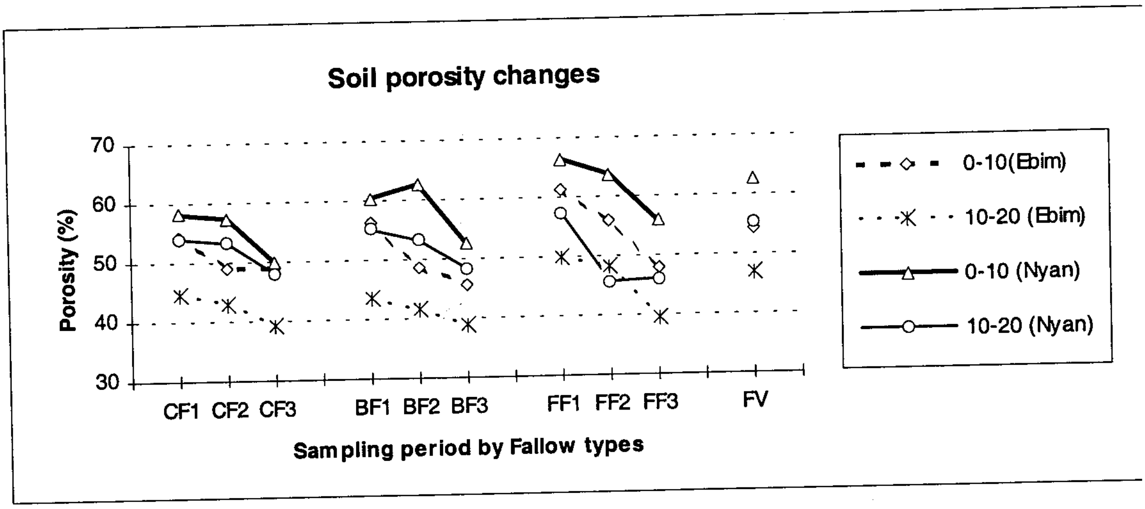


Figure 4.3. Soil porosity variation during the cropping period
Keys: CF1 = Soil under Chromolaena fallow (1996); CF2 = Soil at the beginning of the cropping period (1 of field cleared from Chromolaena fallow; CF3 = Soil at the end of the cropping period (1998) of cleared from Chromolaena fallow. BF1 = Soil under Bush fallow (1996); B2 = Soil at the beginning o cropping period (1996) of field cleared from Bush fallow; BF3 = Soil at the end of the cropping p (1998) of field cleared from Bush fallow. FF1 = Soil under Forest fallow (1996); FF2 = Soil a beginning of the cropping period (1996) of field cleared from Forest fallow; FF3 = Soil at the end o cropping period (1998) of field cleared from Forest fallow.

Conclusion

In general, changes in soil chemical and physical properties observed after two years u cultivation were modest. However, soil physical properties were significantly affe negatively by cropping likely leading to the increase in soil erosion hazard.

4.2.3 Effects of soil property changes on crop yield

Effects of physical and chemical soil properties changes on various crops yields evaluated for the topsoil layer using a stepwise multiple linear regression analyses. Becau the absence of any significant difference between 0-10 cm and 10-20 cm slices, resul these analyses are presented for the top 0-20 cm soil layer. The analysis took into accour two main soil types of the study area. Multiple linear regression coefficients from analyses are shown in Table 4.2.

Table 4.2 *Multiple Linear Regression Equations of various crop yields as functio physico-chemical soil properties in 0-20 cm soil slice (at $p<0.05$)*

Sandy topsoil types (Ultisols)

Crop Yield Regression Equation (Ton/ha)	r^2	n
Mbio = 0.73Bd + 0.32Clay	0.94	18
Mgr = 0.04Pav + 0.09Clay	0.90	18
Clayey topsoil types (Oxisols)		
Crop Yield Regression Equation (Ton/ha)	**r^2**	**n**
Mbio = 0.69C/N + 0.67CEC - 4.1OC	0.88	28
Mgr = 0.15C/N + 0.11CEC + 0.04Clay - 1.2OC	0.92	28
Gnbio = 2.19Bd - 2.9Ca	0.91	22
Gngr = 1.08Bd	0.88	22
Coyam = 0.87C/N	0.82	28

Keys: Mbio = Maize biomass yields; Mgr = Maize grain yields;
Gnbio = Groundnut biomass yields; Gngr = Groundnut grain yields;
Coyam = Cocoyam tuber yields.

These results show that in the area, the biomass yield of maize and groundnut is controlled by chemical soil properties; while grain yield is controlled mainly by physical soil properties. Cocoyam yield correlates positively with soil CEC and the level of the organic matter, but, negatively with the ash effect measured by the soil calcium content (Table 4.2).

4.3 Fallow age and soil regeneration

Fallow is essential in shifting cultivation systems. When crop yield drop under the acceptable level, farmers abandon the field to the dynamic of natural fallow. Our study also tackled this aspect and important information arose from analyses on the natural fallow regrowth and the rate of soil recovery underneath.

4.3.1 The natural fallow regrowth

After slashing and burning a primary forest portion, a new vegetation dynamic sets in during the fallow period. From an imaginary land cover transect going from a 2-years fallow to a more than 20-years fallow, the following evolution of the vegetation types can be observed: at 2 years, the vegetation is dominated mainly by the *Chromolaena odorata* shrub whereas the seeds of pioneer species germinate under its cover. These pioneer species grow rapidly and after 5 to 8 years, they replace completely the Chromolaena which do not support the shadow. Seeds of other forest species start their germination and grow under the pioneer species. Forest species will replace pioneer species after about 15 years. The vegetation evolves then towards a secondary forest and may reach the stage of a primary forest after centuries. This trend of vegetation dynamic is also confirmed by Nsangou and Bongjoh (pers. comm.).

4.3.2 Soil recovery under the natural fallow

During the fallow period the dynamic of the vegetation regrowth affects the behaviour of soils and their properties change from the morphological to the physico-chemical point of view.

Soil morphology

The most important change in soil morphology during the natural fallow regrowth occurs on the topsoil thin (3-5 cm) A_1 organic horizon. This horizon is dominant under the virgin forest and is used as one of the main characteristics of tropical forest soils. In shifting cultivation systems, this horizon is destroyed by tillage. During the natural fallow regrowth, this horizon is recovered at the age 7 to 9 bush fallow (Figure 4.4).

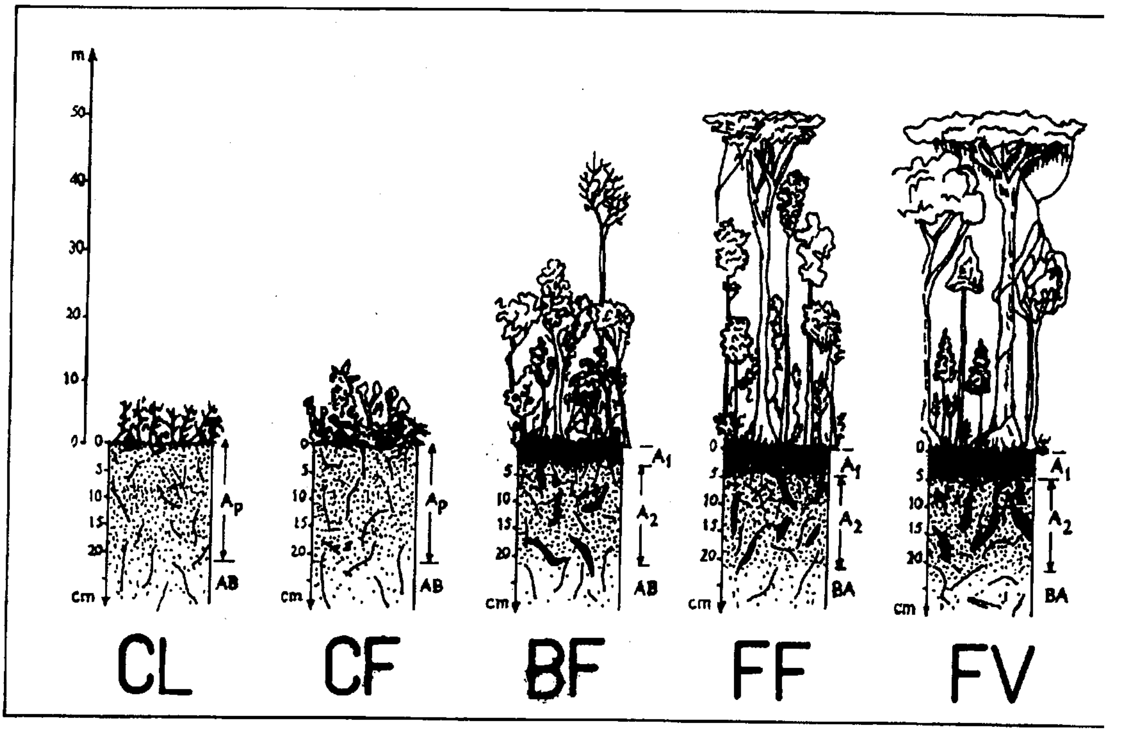


Figure 4.4. Development of the topsoil layer with the age of the natural fallow.
Keys: CL= Crop Land ("*afoub wondo*" based on groundnut-maize-cassava association); CF = *Chromolaena o.* Fallo 5 year old); BF = Bush Fallow (7 to 9 year old); FF = Forest Fallow (more than 15 year old); FV = Virgin (control).

Under the bush fallow and forest fallow, the A1 horizon is observed in the field for all of soils encountered in the area. This soil horizon is humic, very rich in fine roots, friable, very porous, with a granular subangular structure induced by the fine rooting sy It is within this A_1 horizon that farmers plant with zero-tillage, cucumber (*Cucumer mannii*) and maize (*Zea mays*) seeds when they clear an old forest.

Chemical soil properties

Figure 4.5 shows variation curves of soil chemical properties under natural fallow of va ages. The two main soils of the area are taken into consideration in two soil depths (0-1 10-20 cm). The third depth (30-50 cm) has not shown considerable changes with the f age.

Organic matter: Organic carbon increase slightly with the age of natural fallow in the tw types. This relative constancy of the soil carbon under various vegetation cover type earlier been reported in the eastern part of the study area by Kotto-Same *et al.* (1997). ratio shows two parts in its evolution. In recently cropped fields (CL) where there are many vegetal organic particles in the soil, the C/N ratio is not different from the control from the virgin forest. During the cropping period and the beginning of the fallow phase, vegetal particles decay rapidly and the C/N ratio diminishes significantly ($p<0.05$) com to the control FV. During the fallow years, the humic organic matter is reconstituted und forest fallow (FF) and the ratio increases towards values obtained under the virgin forest.

Available Phosphorous: The available phosphorous is generally very low in the soils o whole study area. It is around 5 ppm in the first 20 cm of the soil profile. But, the conve of these soils into the traditional agricultural use increases significantly ($p<0.01$ availability in 0-10 cm of the surface layer. The values obtained from the virgin forest are multiplied at least by three in the cropped land (CL) after burning of the vegetal material. The ageing of the fallow reduces this availability of phosphorous. This is no doubt due to P absorption by plants and storage in vegetation biomass. After about eight (8) years of natural fallow, the situation becomes similar to that of the virgin forest.

Cation Exchange Capacity (CEC), Bases Saturation Percentage: The CEC is low in all the soils of the area (less than 14 Cmol+/g of soil). It is relatively high in 0-20 cm layer of Nyangong soils. The fallow age has little influence on the CEC, but the general pattern is an increase of CEC in old fallow and undisturbed forests. The Bases Saturation Percentage (BSP) decreases under older fallow. This decrease in BSP is more sensible in Oxisols of Ebimimbang with significant difference ($p<0.05$) between cropped land (CL) and virgin forest (FV).

pH and Exchangeable bases: At the two soil depths, pH is very significantly high ($p<0.01$) when land is taken into agricultural use. After the cropping period, it decreases progressively with the fallow age. In bush fallow (BF) and forest fallow (FF), their values are similar to those obtained in the virgin forest. ECEC is very significantly high only in the 0-10 cm depth of Ultisol, when land is taken into cropping; it decreases as land goes back to forest fallow. This increase in pH and Exchangeable Bases by cropping is ascribed to the effect of ashes from burned vegetation biomass at the beginning of the cropping period which act as lime fertiliser. From cropping to fallow, this liming effect of ashes is reduced by crop harvest, sheet erosion on bare soil and leaching of cations. The contribution of Calcium in these variations of pH and Exchangeable Bases is about 85%.

The difference ΔpH between pH water and pH KCl shows a different evolution in the soil at 0-20 cm depth. It decreases significantly ($p<0.05$) under cropped land (CL) and increases with the fallow age. The linear regression between pH and ΔpH was highly significant ($p<0.01$) with negative regression coefficient ($r = -0.61$ for $n = 62$). This leads to presume that these soils have the capability to modify according to the pH, their adsorption complex towards improving nutrient exchange capacity with the soil solution. This may explain why no difference in crop yield was observed from the two soil types of the study area.

Total Acidity and Exchangeable Aluminium: Total acidity and exchangeable aluminium are almost zero in Ultisols where pH values are above 5.5. This is true for all land use/land cover type. But, in soils with pH values below 5 (Oxisols) they occur and increase with the fallow age. The difference between the control FV and cropped land (CL) or younger fallow CF) is significant ($p<0.05$). The contribution of exchangeable aluminium to these variations of the total acidity is 75%.

Physical soil properties

Some physical soil properties were also assessed under the natural fallow dynamics. Figure 4.6 shows variation curves of these properties. These properties vary with the fallow age. The variation is less than that of chemical soil properties and is not significant at 5% probability. In terms of morphological development of the A horizon under the natural fallow, the soil structure and porosity are the most variable physical soil properties in the study area.

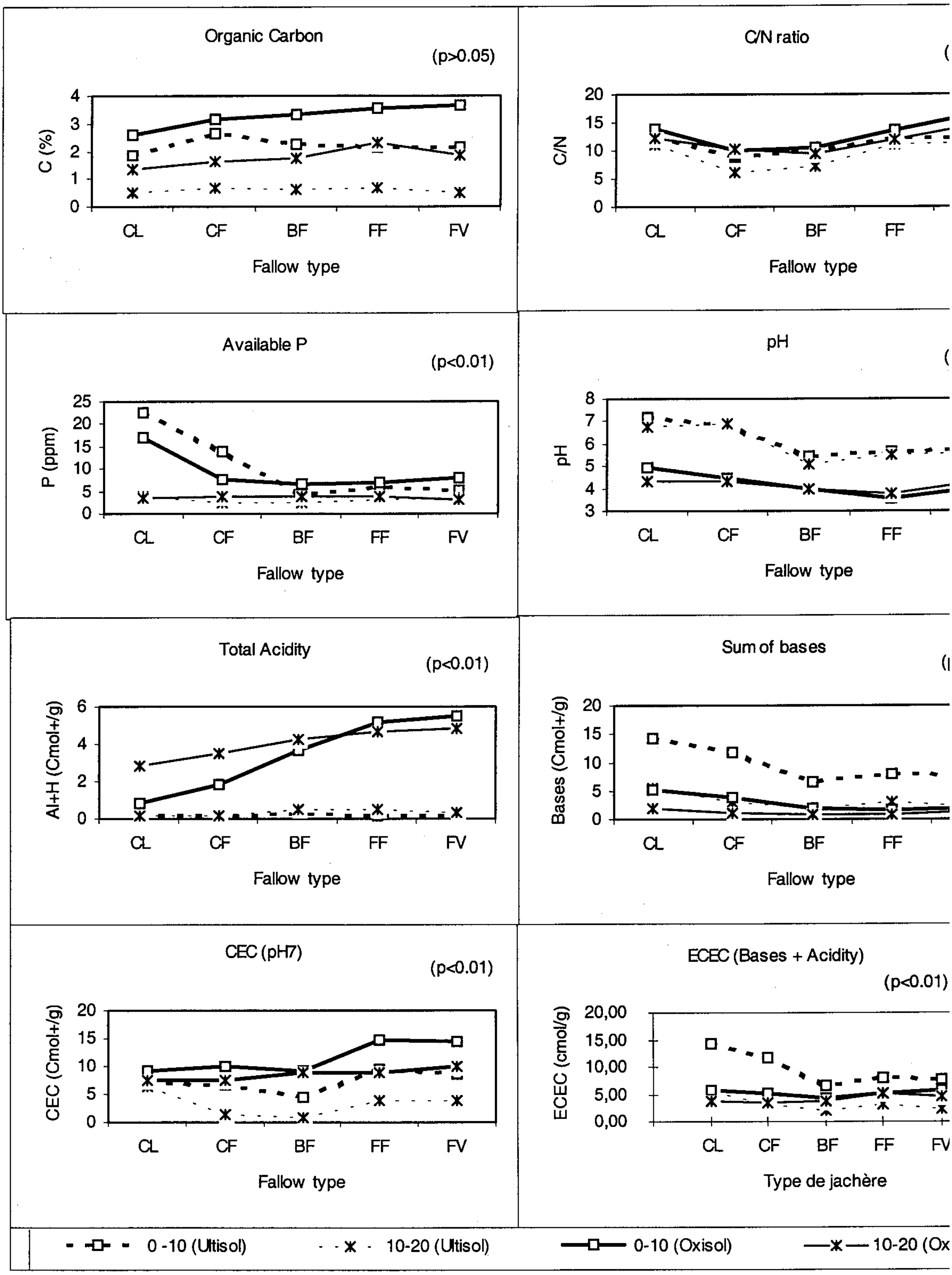


Figure 4.5. Chemical soil properties variation within the shifting cultivation system

Keys: CL= Crop Land (*"afoub wondo"* based on groundnut-maize-cassava association); CF = *Chromolaena o.* Fallc 5 year old); BF = Bush Fallow (7 to 9 year old); FF = Forest Fallow (more than 15 year old); FV = Virgin (control).

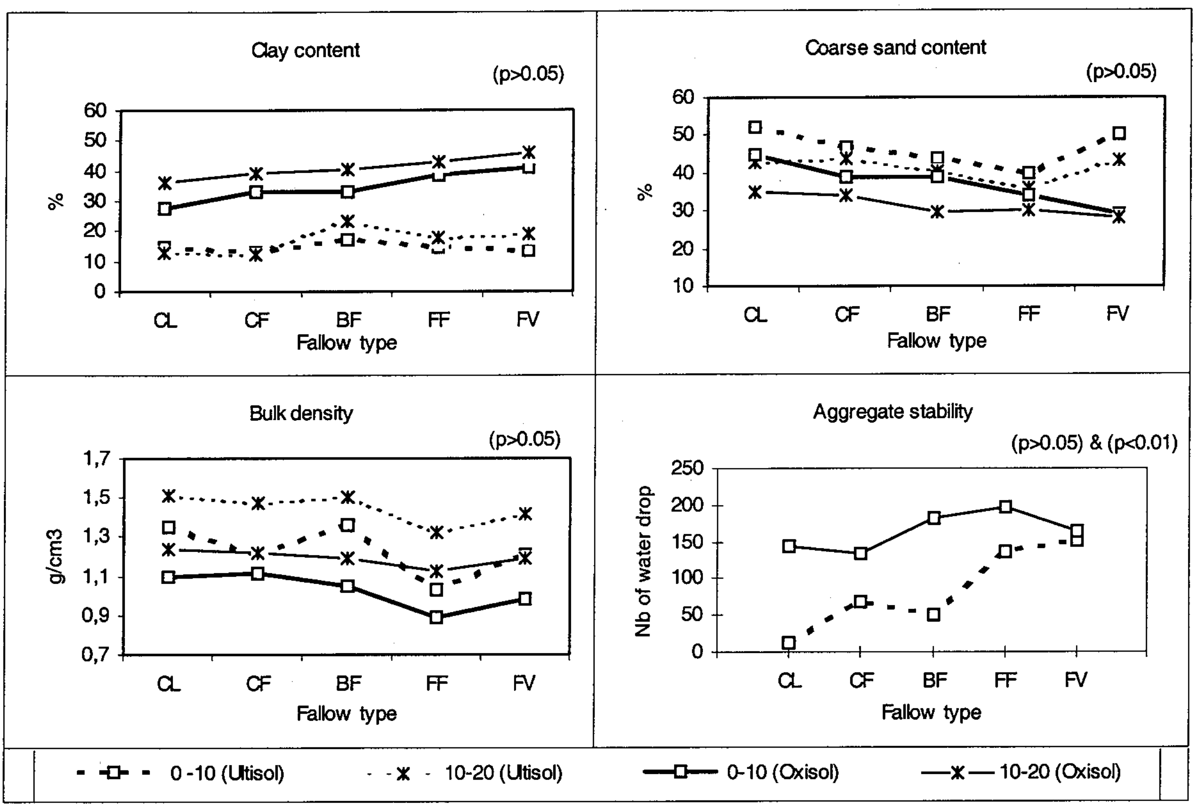


Figure 4.6. Physical soil properties variation within the shifting cultivation system

Keys: CL= Crop Land (*"afub wondo"* based on groundnut-maize-cassava association); CF = *Chromolaena o.* Fallow (3 to 5 year old); BF = Bush Fallow (7 to 9 year old); FF = Forest Fallow (more than 15 year old); FV = Virgin Forest (control).

Biological soil properties

The soil microbial biomass carbon measured by fumigation-Incubation in two soil depths (0-10 and 10-20 cm) varies little with the fallow age (Figure 4.7). Under cropped lands and Chromolaena fallows, there is no significant difference between the two soil types of the area. But, under older fallows, the soil microbial biomass carbon is over 1000 µC/g of dry soil under Oxisols and less than 1000 µC/g of dry soil under Ultisols...

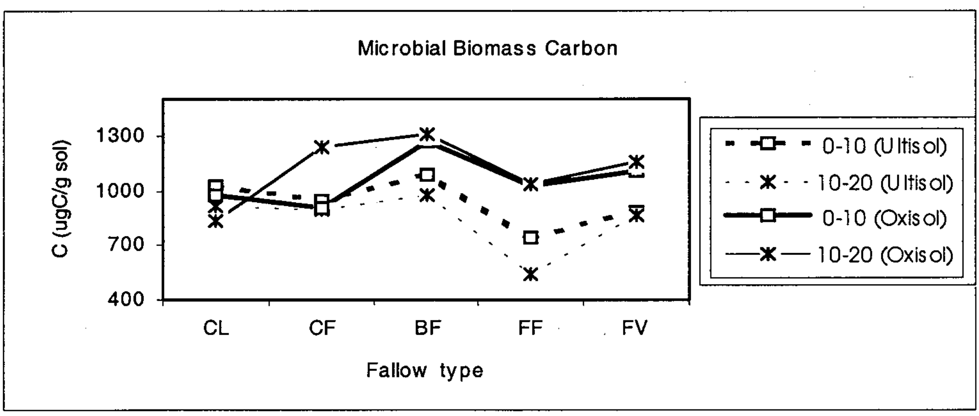


Figure 4.7. Variation of soil microbial biomass carbon within the shifting cultivation system

Keys: CL= Crop Land (*"afub wondo"* based on groundnut-maize-cassava association); CF = *Chromolaena o.* Fallow (3 to 5 year old); BF = Bush Fallow (7 to 9 year old); FF = Forest Fallow (more than 15 year old); FV = Virgin Forest (control).

Discussion and conclusion: optimum natural fallow length

The natural fallow within the shifting cultivation system is the main and unique source of productivity reconstitution for poor farmers of southern Cameroon. From clearing a piec forestland for cropping to the formation of a secondary forest during the fallow period, constituents undergo important changes. But the width of these changes varies from one property to another. The results of this study group roughly the studied soil properties in categories according to their behaviour vis-à-vis the vegetal cover type. There is a categor more variable soil properties and the category of less variable ones. In the more vari category, the morphological development of A_1 subhorizon, the pH, the exchangeable ba the exchangeable acidity and the available phosphorous are more variable soil prope under the effect of the natural fallow age. In the category of less variable, the organic ma soil microbial biomass carbon, CEC, soil texture, bulk density and aggregate stability are soil properties relatively less variable.

Ashes from burned vegetation biomass at the beginning of the cropping period act as fertiliser and significantly influence chemical soil properties. This liming effect of ashe reduced by crop harvesting, leaching of cations, sheet erosion due to heavy and st rainfalls on bare soil at the beginning of the cropping season. According to various aut (Tulaphitak *et al.*, 1980; Prat, 1990), the most important loss of ash nutrients during cropping period in shifting cultivation takes place in the short period between burning an soil surface covering by crops. This process of soil exhaustion continues during the w cropping period, and after 2 to 3 years cropping, the piece of land is abandoned.

The beginning of the natural fallow phase constitutes an era of new vegetation dynamics. natural vegetation grows rapidly, partly from new seedlings and partly from root sys inherited from the previous fallow. The vegetation cover considerably reduces the erosion leaching processes. Besides, the biotic processes are intensified between the new veget and the soil surface. Nutrient elements released from litter decomposition are either immediately by the vegetation in place or added directly to the topsoil. At the same time the nutrients are increasing in the topsoil so also is its humus content. The vegetal popul develops a dense fine root criss-crossing system in this topsoil horizon to better ensure nutrition. This results in A_1 horizon formation. This A_1 horizon, although very humic, is thin (3-5 cm) and its contribution to the organic carbon content in the 0-20 cm layer i enough to provide significant difference in organic matter between the different fallow c In this process of natural reforestation, a number of physical soil properties seem n benefit from these changes. Besides, the soil structure and the porosity of the topsoil laye certainly highly influenced by erosion and the development of the A_1 horizon. The rooting system in this A_1 horizon changes the subangular blocky structure of the e topsoil into a porous granular structure. The similarity between the increase of aggr stability and organic carbon content denote the effect of organic matter acting as stabi agent of soil structural stability.

Finally, these results showed that all the processes taking place under natural fallow directed towards the climax equilibrium existing under primary forests. Important differ generally existed between the primary forest and cropped land or younger fallow. Fro bush fallow, these differences were significantly reduced. While, under the forest fallow, were almost no differences with the primary forests. This is thus, an important output c study because we can conclude that the optimum fallow that can restore natural soil ferti the humid tropics of southern Cameroon is situated between bush fallow and forest f The fallow period should be at least 10 years. This leads to admit that in the area, so recover its optimum equilibrium under natural fallow only if this fallow is left undisturb at least 10 years. The shifting cultivation system can then be replaced by a "Rotational Fallow System" in which a farmer should come back on a piece of fallow land only after 10 years. But, in such a "rotational fallow system", over 12 years, only 2 consecutive years will be used effectively for crop production. This is not sufficient. With the increasing pressure of the population growth, farmers will more and more shorten the fallow period, hence reducing the fertility of the soil and the vigour of the forest regrowth when land is abandoned. Grasses may invade the land and be burnt during the dry season; thus the forest may give way to savannah, maintained by annual burning. For a sustainable management of the forest zone of southern Cameroon, this study implies that research has to be carried out on possibilities to intensify crop production within this rotational system. This intensification can be achieved by prolonging the cropping period without complete degradation of soil fertility or by shortening the fallow phase by applying improved fallow technologies. To extend the cropping phase, a solution can be found in the Integrated Nutrient Management methods defined by Janssen (1993), based on combined application of mineral and organic fertilisers.

4.4 Perennial crop and soil degradation

A young mature (4 to 7 year old) cocoa plantations (YCA), an old (more than 15 year old) cocoa plantations (OCA), and a mature oil palm plantation (YOP) were selected as perennial agricultural system, while a pineapple field (YANA) was studied as semi-industrial cultivation system. Results of these studies are given in Figure 4.8.

4.4.1 Cocoa plantations: mature (4 -7 years) and old (> 15 years)

In the event of land clearing for agricultural development, cocoa cultivation seems to behave like a fallow system, which allows rapid crown coverage and generates biomass and nutrient levels approaching those of humid tropical forests after 15 years.
Cocoa plantations are created at the end of cropping period of food crop fields. For that, the land preparation follows the process of slash and burn agricultural systems and affects soil chemical and physical status as described in Section 4.2. The establishment of the cocoa plantation is the beginning of a controlled fallow. This type of fallow is composed of cocoa tree shrubs as the main tree layer under which develops an important understorey vegetation. To maintain the plantation, the understorey vegetation is cleared at least once a year. Nutrient elements released from the slashed biomass by decomposition are either used immediately by the vegetation in place, or added to the topsoil, increasing the topsoil humus content. This process results also in the development of an A_1 horizon and the improvement of soil physical properties (Figure 4.8). Finally, the effects of cocoa plantation growth are similar to those of the fallow system in which all the processes taking place are directed towards the climax equilibrium existing under the primary forests.

4.4.2 Oil palm plantations

Only one young oil palm plantation (YOP) situated in the Mvié area was studied, which was not enough to draw important conclusions. But, as showed in Figure 4.8, the effects of slash and burn processes on soil chemical properties were remarkable compared to undisturbed forest of the same area. Bulk density was also particularly high under the oil palm plantation. This may be the effect of soil exposure to rain drops, sunshine and sheet erosion due to the poor crown coverage of young oil palm plantation.

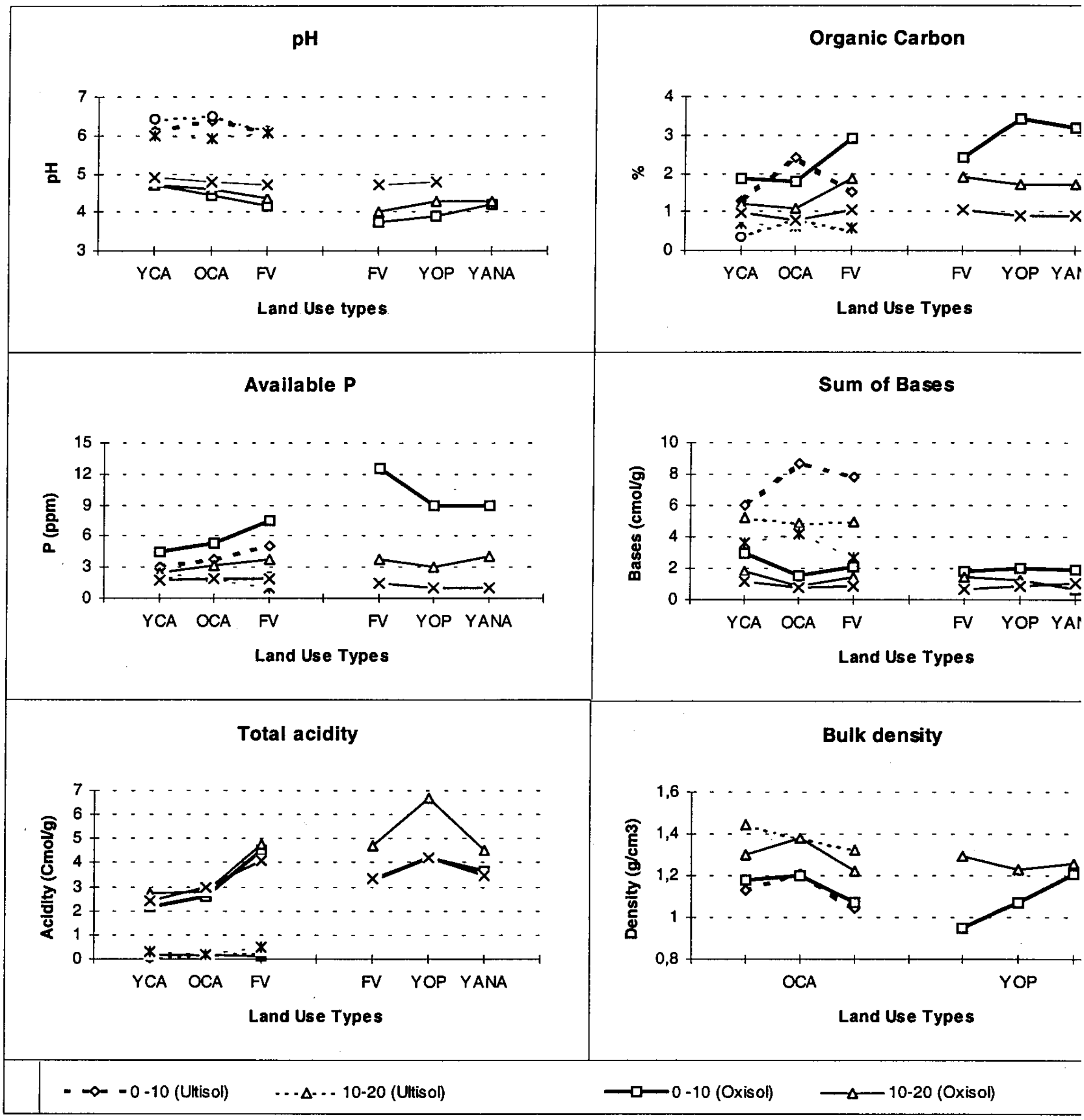


Figure 4.8. Some chemical and physical soil property variations under perennial crop an annual crop compared to virgin forest.

Keys: YCA= Young cocoa plantations (4 to 7 year old); OCA = Old Cocoa plantations (more than 15 ye YOP= Young mature oil palm plantation; YANA= Pineapple field (sole annual crop); FV = Virgin (control).

4.5 Pineapple plantations and soil degradation

A semi-industrial mono-cropping of pineapple was also studied in the Mvié area. This was solid stand grown on the same plot for three years. The liming effect of burning a pH was still remarkable (Figure 4.8). No significant difference was found in soil che status between the continuous cropping plot and the surrounding undisturbed forest. B continuous cultivation on the same plot increased the bulk density of the top 20 cm c from 0.9 to 1.21 g/cm^3. This corresponds to an increase of almost 30%.

This result is important to be taken into account when the intensification of annual crop be established in the area. In the study area the topsoil structure and porosity changes mi the most important cause of field plot abandonment

4.6 Main causes of soil degradation and crop field abandonment

In shifting cultivation systems many processes take place during either the natural fallow period or the cropping period. Processes at work during the cropping phase result in land degradation and crop yield decrease, and farmers are forced to abandon crop field to natural fallow. The causes of these processes of land degradation are numerous and vary from soil and vegetation conditions to weeds, diseases, pests and insects encroachment.

4.6.1 Soil factors

Chemical changes in soils
Burning the slashed vegetation causes volatization of a large part of nitrogen stored in the organic matter, whereas other macronutrients (Ca, Mg, P, K) and micronutrients (Mn, B, Zn, Cu, etc.) remain in the ash (see Section 4.2.1). Nutrients stored in the ash layer are mobilised during periods of rainfall and are transferred to the soil by percolating water or washed away by sheet erosion. In the soil, part remains available for crop nutrition and crop removal while another part is leached. Decomposition of soil organic matter, combined with a lack of fresh input of organic matter, result in decreasing C and N content during the cropping period (see Section 4.2.2).
Physical changes in soils
During the cropping phase of the shifting cultivation as practised in the area, the direct impact of raindrops and sunshine on exposed soil results in increased rain splash and subsequent sheet erosion. This, combined with a decrease in organic matter content of the soil, result in loss of soil aggregates stability (see Section 4.3.2) and soil structure, which in turn results in soil compaction, increased bulk density and decreased infiltration rate and water holding capacity of the soil. This leads to an increase in overland flow and further increase in erosion and degradation of topsoil. The practice of tillage also removes the topsoil thin (3-5 cm) A_1 organic horizon, which is predominant under the virgin forest (see Section 4.3.1). This A_1 horizon is humic, very rich in fine roots, very friable, and very porous, with granular subangular structure induced by a fine root criss-crossing system. It is within this A_1 horizon that farmers plant with zero-tillage, cucumber (*Cucumeropsis mannii*) and maize (*Zea mays*) seeds when they clear an old forest.

Soil degradation by accelerated erosion
The accelerated erosion is considered as man-induced erosion. The change of the soil chemical and physical properties under land cropping leads to an increased soil loss hazard due to detachment and transportation. In general, agricultural land in the study area are mostly located only dissected plains and rolling uplands landform units (van Gemerden and Hazeu, 1999) where the existing gentle slopes limit the effects of soil erosion processes. However, the soil type and the cropping systems/farming systems are the most important factors affecting erosion hazard variation in the area. From our field observation in the study area, sheet erosion occurs under the impact of the early rains at the beginning of the cropping period in annual crop fields. The consequence of this erosion is the rapid deterioration of the physical condition of the soil surface and leaching of nutrients from ashes. This process is lessened when the first crops cover the ground. When the first crop has been harvested, the soil surface is again exposed to some extent, but intercrops, weeds and the residues from the harvest provide some protection.

Soil fauna

Soil micro-organisms together with soil macrofauna act as agents of nutrient cycli regulating of the retention and flux of nutrients in the soil system through proces decomposition, mineralisation and immobilisation. Soil micro-organisms also enhan amount and efficiency of nutrient acquisition by plants through the role of plant sym such as mycorrhiza and nitrogen fixing bacteria. These functional relationships might be evident in the natural ecosystems but also play a key role in determining the productivi sustainability of agricultural systems. The activity of soil microbiota can be measured by is called "microbial biomass". This aspect should not be left out when one is to thoroughly the effect of shifting cultivation on soil degradation.

4.6.2 Other factors

Weeds, diseases, pest and insects

Weed growth is often of profound hindrance to crop production in tropical agriculture. competition with crop is considered as a factor limiting the effectiveness of soil ava nutrients in increasing crop yield. Nematode and insect fauna and pathogenic microbe also diverse in the tropics. High population of these parasite species often cause signi damage to crops. The parasite population, which might have built up during the cro phase, is likely to be greatly reduced in numbers after several years of fallow.

Vegetation biomass reduction

In selecting a site for clearing, shifting cultivators, in general, judge the suitability prospective cropping site on the basis of existing vegetation rather than on soil characte (see Section 3.4.6). In the study area, soils are classified in general lower chemical fe levels (van Gemerden and Hazeu, 1999). A large part of nutrients is stored in the biom vegetation. The mature forest has adapted to the low nutrient level of soil by maintaini almost closed nutrient cycle. Through recycling, these nutrient stocks remain almost con When clearing the forest destroys this nutrient equilibrium, the nutrient cycle is sev interrupted and through crop harvest, leaching and erosion, part of the nutrients disappea of the system; and the land becomes unproductive.

Effects of burning

The direct effect of burning vegetative materials are: (1) concentration of mineral nutrien contained in the vegetative material into ash spread over the soil surface; (2) loss of ca nitrogen and volatile sulphur from the burned material to the atmosphere; (3) temperatures of soil surface layer affect the physical and chemical properties of soil col biological populations, nutrient availability and destroy some weed seeds.

Sanchez (1983) and Andriesse and Schelhaas (1987) reported in tropical Latin Americ tropical Southeast Asia striking changes in soil properties due to burning. Accordi Andriesse and Schelhaas (1987), successive burns result in 20-25% decrease in or carbon, 5-10% decrease in CEC and less than 10% decrease in total phosphorous. M affected are the minerals in the top 25 cm of the soil. Fertility improvement from ash result of burning was observed at the same depth with increases in available Sulphur (2-6 available phosphorous (50-300%), Calcium (50-200%), Magnesium (15-45%), and Potas (6-80%). The increase in bases led to higher pH. Burning, on one hand, improved the fertility, but on the other hand, left the soil bare leading to intense leaching and erosi bases during cultivation resulting in subsequent pH decrease.

5 THE SUSTAINABILITY OF THE PRESENT SHIFTING CULTIVATION SYSTEM

Shifting cultivation is an agricultural practice where a short period of mixed cropping alternates with a long period of natural fallow. The role of the natural fallow in the system is to recycle nutrient elements for soil fertility restoration and to suppress weeds, pests and diseases (Nye and Greenland, 1960). As long as there is enough land and population pressure is low, this is an efficient system of soil management, but only for subsistence farming since it is difficult to find prosperous shifting cultivators in the evergreen forest of Cameroon.

Soil can recover its optimum equilibrium under natural fallow only if this fallow is left undisturbed for at least 10 years after cropping (Nounamo and Yemefack, 1997). The shifting cultivation system to be applied is a "rotational fallow system" in which a farmer comes back to a piece of fallow land only after 10 years.

But, with the actual practice in the area, farmers are more and more shortening the fallow length because of unsuitable land tenure rights, market driving production and soil chemical gains from burned vegetation biomass. Most farmers (64%) are clearing Chromolaena fallow (3-5 years), or bush fallow (7-9 years) for food crop production. In these conditions, the cycle of weed, pests and diseases control, and nutrient replenishment is broken. Physical and organic soil fertility are drastically reduced, the vigour of the forest re-growth also. This renders the shifting cultivation practices unsustainable.

The sustainability of the shifting cultivation practice is a dilemma. On one hand, farmers must produce more for consumption and revenue gain in order to move from poverty subsistence farming to food security guarantee and poverty alleviation. This means shortening the fallow by cropping the same piece of land frequently with the risk of soil degrading. On the other hand, shifting cultivation involving the clearing of long fallow land must be practised to efficiently restore soil fertility after cropping.

For a sustainable management of the forest zone of southern Cameroon, solutions must then be found to two main problems: (1) for the shortening of fallow length leading to soil degradation, soil conservation may be the solution; (2) for the sustainable but non-prosperous subsistence farming practice destroying the forest ecosystem, income generating farming is the solution.

Soil productivity conservation: researches have to be carried out on possibilities to intensify crop production within this rotational system. This intensification can be achieved by prolonging the cropping period without complete degradation of soil fertility or by shortening the fallow period applying improved fallow technologies. To extend the cropping phase, a solution can be found in the Integrated Nutrient Management methods defined by Janssen (1993), based on combined application of mineral and organic fertilisers. Improved fallow and agroforestry technology packages are available at ICRAF.

Prosperous farming: shifting cultivation should move from subsistence farming to income generating farming to guarantee food security and alleviate poverty of the local population. This can be possible if the following parameters are improved or adopted: land tenure rights and laws, market system, integrated low input and short fallow agricultural system, improved fallow, integrated cropping system and improved animal husbandry, and diversification of farmers' crop production. A survey carried out in the area (Table 5.1) shows the willingness of farmers to adopt changes in the actual farming system.

Table 5.1 *Farmers' predisposition to innovations in the area.*

	Activities				
	New crops	**Integration of improved animal husbandry**	**Agricultural intensification**	**Bee keeping**	**Othe innovat**
Frequencies of responses (%)	97	78	75	60	97

n = 200

6 CONCLUSIONS

The study have produced number of information amongst which the following are to be highlighted in order to provide reliable tools for the sustainable management of the forest zone of southern Cameroon:

1. The cropping system is far the most important activity system for the farmers of the area. Animal husbandry comes second in their ranking.
2. Dissected plains of Ebimimbang area and undulating uplands of Mvié are the most important mapping units used for this cropping system.
3. Some tree species are also used as indicators of suitable or unsuitable lands.
4. The food crop production is mainly for the subsistence of the household and is practised mainly by women.
5. Due to land and labour shortage, land tenure rights, population pressure, etc., farmers are replacing the expanding shifting cultivation by the rotational short fallow.
6. Seventy six per cent (76%) of food crop fields rely actually on this rotational system, which consist of rotating in a total area of less than 10 hectares.
7. Nevertheless, agricultural land is expanding into forest because of the needs for *Cucumeropsis mannii* production and the opening of new fields in the primary forest by elite for semi-industrial plantations establishment. The *Cucumis sativum* variety adapted to short fallow fields may be a good substitute for *Cucumeropsis mannii.* Some farmers are already introducing it.
8. Current rate of agricultural land expansion into virgin forest is greater at Ebimimbang and Mvié areas, and the average for the whole area is 2200 m² per household per year.
9. An optimum fallow length is at least 10 years old.
10. Needs are raised to intensify this agricultural system, either by improving the natural fallow system or to extend the cropping period using external input such as organic manure or other fertiliser, with the aim to guarantee food security and alleviate poverty of the local people.
11. Non Timber Forest Products (NTFP) should also be taken into account in the agricultural system. Research must find way to domesticate them.

7 RECOMMENDATIONS

For a sustainable land use of the forest zone,

1. Cropping practices must be considered as the prime activity that involves more users o forest resources.
2. This agricultural system must move from subsistence farming to income generi farming. For that, the following parameters must be improved: market and road sys animal husbandry, land tenure law, readily available extension services etc.
3. Crop diversification should be considered.
4. Only improvement of the system is required, not alternatives.
5. Research ahead must develop and test sedentary technologies to improve farn unsustainable, subsistence shifting cultivation and to link these technologies with sc economic policies providing disincentives for further deforestation.
6. Government must be sensitised on the necessity to review land tenure rights and laws.

REFERENCES

Ambassa-Kiki, L.R and Nill, D. (1994). *Some soil characteristics as affected by conservation practices in Central Cameroon.* Paper presented at the International Workshop on Conservation Farming for Slopping Lands in Southeast Asia: Challenges, Opportunities, and Prospects. 20-26 November 1994. Manila, Philippines.

Anderson, J.M. and Ingram, J.S.I. (1993). *Tropical Soil Biology and Fertility: Handbook of Methods.* Second edition. CAB International, Wallingford, United Kingdom.

Andriesse, J.P. and Schelhaas, R.M. (1987). A monitoring study of nutrient cycles in soils used for shifting cultivation under various climatic conditions in tropical Asia: III - The effect of land clearing through burning on fertility level. *Agriculture, Ecosystems and Environment* 19: 285-310.

Atlas Régional du Cameroun (1993). *Sud - Ouest 1, République du Cameroun.* ORSTOM, Yaoundé, Cameroon.

Champetier de Ribes G. and Reyre, D. (1959). *Carte géologique de reconnaissance (1/500 000) : Notice explicative sur la feuille Yaoundé-ouest.* Direction des Mines et de la Géologie, Yaoundé, Cameroon.

Champetier de Ribes, G. and Aubague, M. (1956). *Carte géologique de reconnaissance (1/500 000) : Notice explicative sur la feuille Yaoundé-est.* Direction des Mines et de la Géologie, Yaoundé, Cameroon.

Chandler, C., Cheney, P., Thomas, P., Trabaud, L. and Williams, D. (1983). *Fire in forestry. Forest fire behaviour and effects.* John Wiley & Sons, New York, USA.

CPCS (1967). *Classification des sols.* Travaux Commission de Pédologie et de la Cartographie des Sols.

Dijk, J.F.W. van (1999). *Non-timber forest products in the Bipindi-Akom II region, Cameroon: a socio-economic and ecological assessment.* Tropenbos-Cameroon Series 1. The Tropenbos-Cameroon Programme, Kribi, Cameroon.

FAO (1988). *FAO/UNESCO Soil Map of the World, Revised* Legend. World Resources Report 60, FAO, Rome. Reprinted as Technical Paper 20, ISRIC, Wageningen, 1989.

FAO (1990). *Guidelines for Soil Description.* 3rd edition (revised). FAO, Rome, Italy. 70pp.

Gemerden, B.S. van, and Hazeu, G.W. (1999). *Landscape ecological survey (1:100 000) of the Bipindi -Akom II - Lolodorf region, Southwest Cameroon.* Tropenbos-Cameroon Documents 1. The Tropenbos-Cameroon Programme, Kribi, Cameroon. 164pp.

Gerold, G. (1995) Soil differentiation and degradation by Agricultural and logging impacts in tropical forests of West Africa. In: *Proceedings of International Congress on soils of tropical forest ecosystems. Third conference on forest soils (ISSS-AISS-IBG) Volume 2: Soils degradation and conservation.* Mulawarman University Press, Samarinda, Indonesia.

Imeson, A.C. and Vis, M. (1984). Assessing soil aggregate stability by water-Drop Impact and Ultrasonic Dispersion. *Geoderma* 34:185-200.

Janssen, B.H. (1993). Integrated nutrient management: the use of organic and mineral fertilizers. In: van Reuler and Prins (eds.*). The role of plant nutrients for sustainable food crop production in Sub-Saharan Africa.* Pp. 89-105.

Jenkinson, D.S. (1976). The effects of biocidal treatments on metabolism in soil. IV. The decomposition of fumigated organisms in soil. *Soil Biol. Biochem.* 8:203-208.

Jordan, C.F. (1985). *Nutrient cycling in tropical forest ecosystems.* John Wiley & Sons, New York, USA. 190p.

Köppen, W. (1936). *Das geographische System der Klimate. In: Köppen, W. and Geiger R. (eds.). Handbuch der Klimatologie.* Verlag von Gebrüder Bornträger, Berlin, Germany. 44pp.

Kotto-Same, J., Woomer, P.L., Moukam, A. and Zapfack, L. (1997). Carbon dynamics in slash-and-burn agriculture and land use alternative of the humid forest zone in Cameroon. *Agriculture, Ecosystems and Environment* 65: 245-256.

Letouzey, R. (1985). *Notice phytogéographique du Cameroun au 1:500 000.* Institut de la Carte Internationale de la Végétation, Toulouse, France. 142pp.

MINAGRI (1989). *Plan d'Action Forestier Tropical*. Table Ronde Internationale, Yaoundé :
avril 1989. Rapport de Présentations. MINAGRI, Yaoundé, Cameroun.

Mulongoy, K., Kunda, K.N. and Chiang, C.N.K. (1992). Effect of alley cropping and fallowir some soil fertility parameters in southern Nigeria. In: Mulongoy and Merck (eds.). *Soil or; matter dynamics and sustainability of tropical agriculture*. Proceedings of an internat symposium organised by K.U. Leuven and IITA, 4-6 November 1991, Leuven, Belgium.

Mulongoy, K. and Tonye, J. (1992). Influence of *Cajanus cajan* on soil productivity at Minkom Yaoundé, Cameroon (1990-1991). In: *Dynamics of soil organic matter and soil fertility ı different fallow and cropping systems*. IITA/KUL collaborative project, final report.] Yaoundé, Cameroon.

Nounamo, L. and Yemefack, M. (1997). Shifting cultivation in the evergreen forest of Sou Cameroon: Farming systems results. Lu2 interim report. The Tropenbos-Cameroon Prograı Kribi, Cameroon. 27pp.

Nounamo, L. (1997). Farming systems research in the bimodal humid forest zone of Cameroon exploratory survey results of IRA/IITA/IDRC project. In: R. Ambassa-Kiki and Tiki-M (eds.). *Biophysical and socio-economic characterization of the forest zone of Camei* Proceedings of the National Symposium of the Cameroon "Alternatives to Slash and Agriculture" project held at Kribi, Cameroon, 6-8 December 1993.

Nounamo, L. and Foaguegue, A. (1999). Understanding conflicts between farmers and researc The Cameroon experience. *Forest, Trees and People Newsletter* No 39: 10-14.

Nye, P.H. and Greenland, D.J. (1960). *Soil under shifting cultivation*. Technical communicatio 51. Commonwealth Bureau of Soils, Harpenden, United Kingdom.

Prat, C. (1990). *Relation entre érosion et systèmes de production dans le bassin-versant sud dı Managua (Nicaragua)*. Cah. Orstom, sér. Pédol., vol. XXV, no 1-2, 171-182.

Reuler, H. van (1996). *Nutrient management over extended cropping periods in the shi cultivation system in south-west Côte d'Ivoire*. PhD thesis. Landbouwuniversiteit, Wagenir the Netherlands.

Sanchez, P.A. (1976). *Properties and management of soils in the tropics*. John Wiley & Sons, York, USA.

Sanchez, P.A. (1977). Soil management under shifting cultivation. In: Sanchez P.A. (eds.). *Revie soils research in tropical Latin America*. Tech. Bull. no. 219. North Carolina State Univeı Raleigh, USA.

Sanchez, P.A. (1983). Nutrient dynamics following rainforest clearing and cultivation. *Proceedin international workshop on soils*. Townville, Queensland, Australia. 12-13 September 1983.

Slaats, J.J.P. (1995). Chromolaena odorata fallow in food cropping systems: an agronomic assess in south-west Ivory Coast. PhD thesis. Landbouwuniversiteit, Wageningen, the Netherlands

Soil Survey Staff (1992). *Keys to Soil Taxonomy*. SMSS Technical Monograph no. 19, 5th USDA, Blacksburg, Virginia, USA. 541pp.

Tchatat, M., Puig, H. and Fabre, A. (1996). Genèse et organisation des jardins de case des z forestières humides du Cameroun. *Rev. Ecol. (Terre Vie)* 51: 197-221.

Touber, L. (1993). *Air photo interpretation for overall land inventory of the research area (' Lu1)*. Explanatory note. Internal document. SC-DLO, Wageningen, the Netherlands.

Tulaphitak, T., Pairintra, C. and Kyuma, K. (1985). Changes in soil fertility and tilth under shi cultivation: Changes in soil nutrient status. *Soil Sci. Plant Nutr.* 31 (2): 239-249.

Ulery, A.L., Graham, R.C. and Amrhein, C. (1993). Wood-ash composition and soil pH follo intensive burning. *Soil Science* 156, No. 5.

Volkoff, B., Cerri, C.C. and Andreux, F. (1989). *Matière organique et conservation des sols en z tropicales forestières : voies actuelles de recherches*. 9eme réunion du Comité ouest et c africain de corrélation des sols. 14-23 novembre 1988. Cotonou, Bénin.

ANNEXES

Annex 1: Checklist for the exploratory survey in the TCP area

1. *Cropping patterns and land use*
    - crops, cropping patterns, crop associations
    - occurrence and utilisation of land types
    - number, size and location of fields per household
    - differences in cropping patterns among fields; reasons
    - criteria for choosing/abandoning field
    - duration and utilisation of fallow
    - products collected from the bush
    - obsolete, new crops ; reasons
    - farmer's perception of rainfall and consequences for crops
2. *Cropping techniques*
    - time and method of land preparation and planting
    - crop varieties and their characteristics
    - sources of seeds and planting materials
    - soil fertility maintenance ; use of organic and inorganic fertilisers, use of household refuse
    - harvesting methods
    - use of farm implements
    - estimates of yields
    - changes in farming practices over the last ( ) years
3. *Crop disorders*
    - weeds, time and methods of control
    - pests and diseases, estimates of crop losses, control measures
    - nutrients deficiencies
4. *Post harvest*
    - storage facilities (household, community)
    - storage losses (pests, moulds, rots) and protection methods
    - utilisation of crops, proportions marked and consumed
    - processing of crops and food by the farm household
    - utilisation of crop residues and by-products
5. *Livestock*
    - livestock systems, species, husbandry, seasonal feeding regime, interaction with the cropping system
6. *Non-farming and off-farm activities*
    - fishing, hunting,, off-farm activities
7. *Socio-economic environment*
    - access to land and tenure rights arrangements
    - ownership of crops
    - sources and cost of labour, family and hired
    - distribution of labour, peaks, slack periods and bottlenecks
    - division of labour between sex
    - sources and primary uses of cash
    - consumption patterns and food preferences ; sorts of purchased food
    - water and fuel requirements and sources
8. *Farmers' organisations and services*
    - availability of extension and input delivery systems
    - farmer's access to these
    - farmer's organisations
9. *Others*

Annex 2: Agricultural land expansion in the TCP area: Landscape ecological ma overlain by agricultural sample fields opened between 1995 and 1997.

Landcover map of Ebimimbang area

(Zones of agricultural activity in 1985 and positions of monitored farmers' fields of 1995-1997)

5 0 5 Kilometers

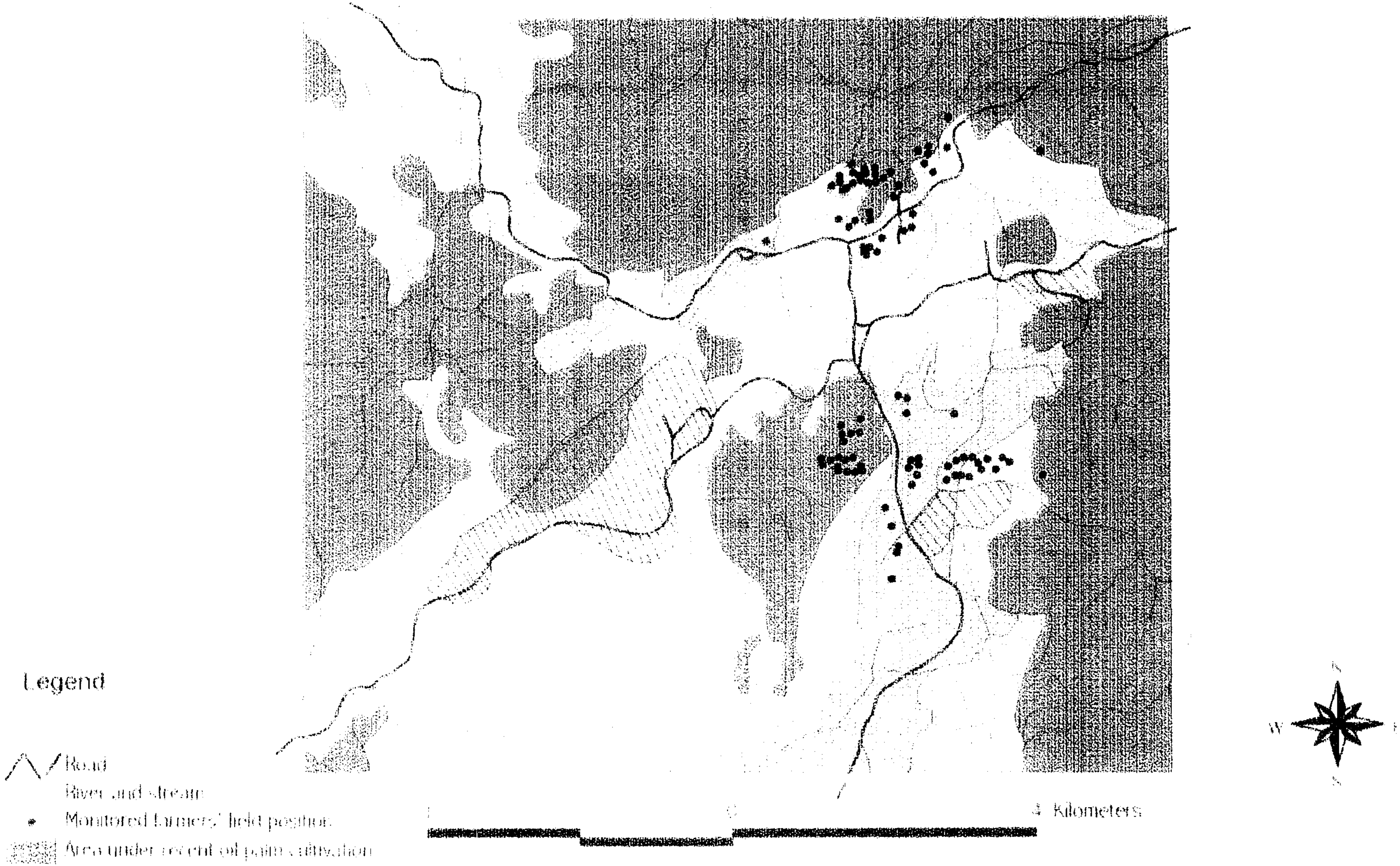
Legend

Road
River and stream
• Monitored farmers' field position

High intensity shifting cultivation area (>40% actual and recently abandoned agricultural fields; <20% young secondary forest)
Low intensity shifting cultivation area (5-20% actual and recently abondoned agricultural fields)

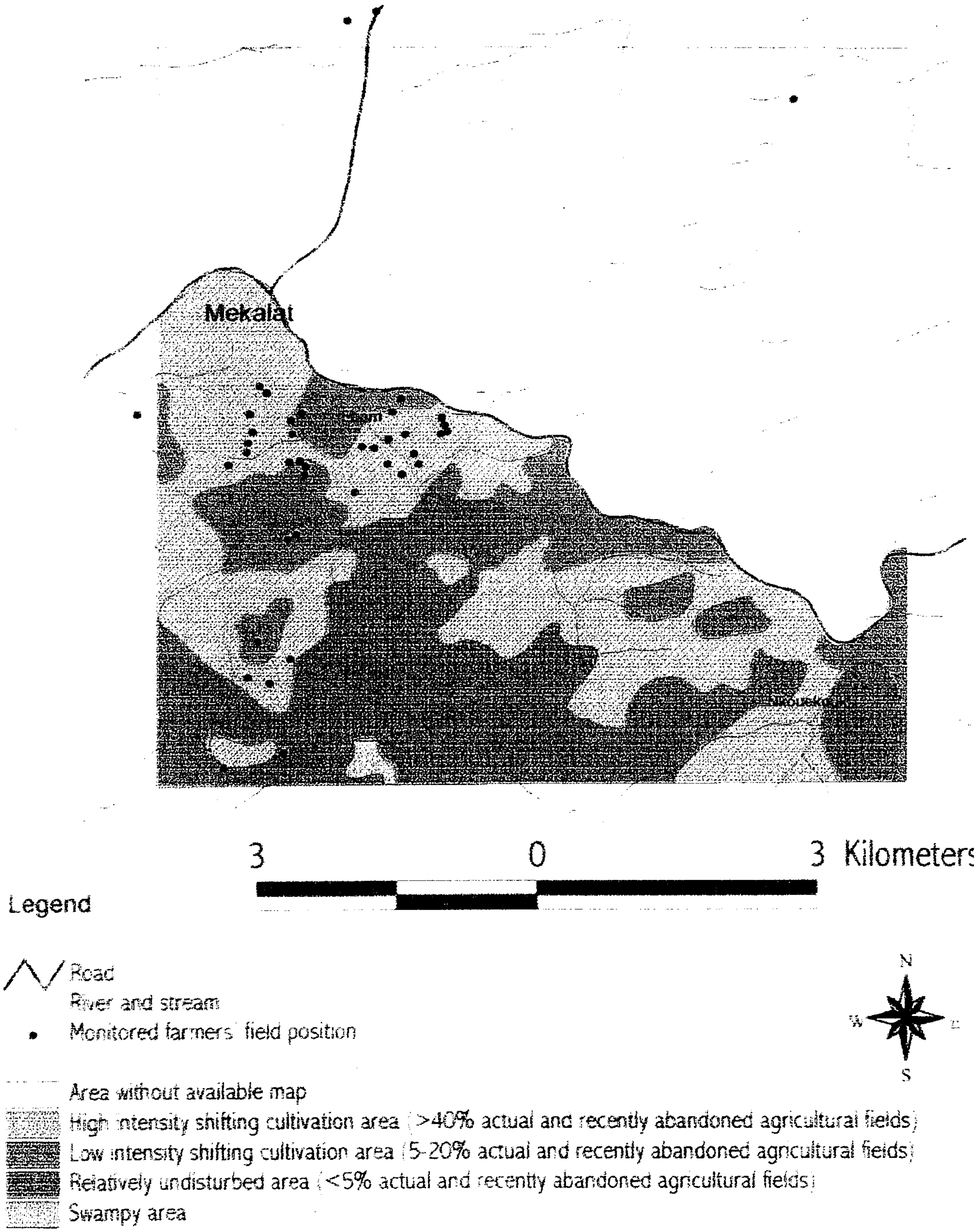
Landcover map of Mvié area

Zones of agricultural activity in 1985; positions of monitored farmers' fields of 1995-1997
and recently created oil palm industrial plantations



Landcover map of Ebom area

(Zones of agricultural activity in 1985 and positions of monitored farmers' fields of 1995-1997)



Landcover map of Nyangong area

(Zones of agricultural activity in 1985 and positions of monitored farmers' fields of 1995-1997)