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Ecology and socio-economic importance of short fallows in the humid forest zone of Southern Cameroon.

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ECOLOGY AND SOCIO-ECONOMIC IMPORTANCE OF SHORT FALLOWS IN THE HUMID FOREST ZONE OF SOUTHERN CAMEROON

By

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ABSTRACT

The study aimed to provide quantitative information on the ecology of short fallow systems in southern Cameroon, and their socio-economic value to farming communities of that area. Results from this study will lead to recommendations for the design of appropriate conservation and management decisions and plans that will improve the productivity and guarantee the sustainability of shortened fallows in the area. The specific objectives of the present research were to assess species diversity as impacted by fallow age and fallow type, both during the fallow phase as well as during the subsequent cropping period, and to evaluate the productivity of some key fallow trees identified by local farmers that could be components of productive agroforests. To address these objectives, field activities included ethnobotanical surveys throughout 15 villages of the study area, vegetation surveys of fallows and food crop fields at Mengomo (over two years), and monitoring of about 100 fruit trees at Kaya (during 19 months). Analyses of the results showed that local farmers of the study area do have an extensive knowledge of their environment. Using a common criterion – the fallow duration – they were able to distinguish short, medium and long fallow systems (of respectively, <6, 7-10, and >10 years old) as well as the characteristics and constraints associated with their agricultural management. The effect of the resource use intensity was particularly evident on the availability and distribution of short and long fallows across the three study resource domains. About 174 useful plant species were identified, from which nearly 58 % were collected in fallows of less than 10 years old. Most frequently mentioned useful species that farmers collect from all fallow classes included 'wild' fruit trees and forest species. The present study revealed that species and functional diversity were significantly associated with vegetation structure and plant community composition in 5-7 years old fallows under different land use intensity regimes. The ordination analyses showed a clear pattern of distribution of species along a gradient of resource use intensity: recurrent *Chromolaena odorata*-dominated fallows (reflecting high land use intensity) were clearly separated from fallow sites that had been forests in the previous cropping cycle (corresponding to relatively lower land use intensity). The pattern of the responses of maize, groundnut and cassava to the three fallow types did not differ over the two years of the study, all crops producing higher yield in fields established after clearing *C. odorata*-dominated fallows than in fields following bush fallows. *Coula edulis*, *Dacryodes edulis*, *Irvingia gabonensis* and *Ricinodendron heudelotii* were recorded at very low density values in fallow lands of the study area (< 10 individuals of more than 10 cm dbh ha^{-1}), suggesting the need to develop preferential management of regeneration for these species. Apart from leaf flushing, flowering and fruiting phenology of these species was seasonal, with irregular flowering/fruiting observed for some *D. edulis* and *I. gabonensis* individuals over the two years of monitoring. Fruiting was concentrated between July and October (and up to January for *R. heudelotii*), coinciding with the rainy season. An individual of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* produced, on average, 236±48 fruits (9.6±2.1 kg fresh weight in 2001, 335±94 fruits and 10.9 ±2.9 kg in 2002), 235±94 fruits (12.5±5.1 kg in 2001 and 801±246 fruits, 51.4±16.0 kg in 2002), 547±212 fruits (71.8±24.9 kg in 2001 and more than 2002 fruits, 133.3±30.0 kg in 2002), 2018±467 fruits (72.2±16.4 kg in 2001), respectively. Regression analyses showed that tree size parameters were correlated with fruit production for some species, but generally, do not explain an important pat of the production data of the study species ($r^2 < 60\%$).

DEDICATION

I respectfully dedicate this piece of work to the memory of my father, Albert Nkongo, who died on January 30, 1996 and to all whose valued support and belief made this onward journey possible.

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"What is twisted cannot be straightened;
what is lacking cannot be counted ...

For with much wisdom comes more sorrow;
the more knowledge, the more grief."

Ecclesiates 1: 15, 18.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of variance
C:N	Carbon/Nitrogen ratio
CI	Confidence interval
DBH	Diameter at breast height
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information Systems
GLM	General Linear Model
ICRAF	International Centre for Research in Agroforestry
IRAD	Institut de Recherche Agricole pour le Développement
IITA-HFC	International Institute for Tropical Agriculture-Humid Forest Ecoregional Centre
LSD	Least significant difference
SAFS	School of Agriculture and Forest Sciences
SE	Standard error

CHAPTER I

INTRODUCTION

1.1. SHORTENED FALLOW DURATION IN TROPICAL AGRICULTURE

Although there is disagreement as to the exact rates at which tropical deforestation is occurring, partly because of the difficulty of defining what constitutes 'deforestation', it is estimated that each year millions of hectares of tropical forest are being cleared for various uses. FAO (1998) estimates a deforestation rate of 0.6% (1 201 000 ha year^{-1}) for the Congo basin. In Cameroon, deforestation has been lately recorded as proceeding at a rate of 129 000 ha per annum (FAO, 1999). In the particular case of the Congo basin, most of the deforestation is attributed to smallholder agriculture using extensive slash-and-burn techniques (Gockowski *et al.*, 1998a). Poverty, inequitable land distribution and low productivity of this agricultural system combined with increasing demographic pressure have precipitated the downward spiral of continual extension of the forest margins in the area.

As the natural forest declines, fallow lands become increasingly more important in local agricultural systems because of their functions. As reported in many studies on this practice, during a fallow period, there is an increase in the amount of nutrients both in the vegetation and in the topsoil (Nye & Greenland, 1960; Ruthenberg, 1980; Floret, 1998; Manlay *et al.*, 2002b). The rate of this increase is known to depend on the maximum of fertility level that can be attained under the fallow (i.e. the fallow history), and on the properties (or characteristics) of the fallow itself. Furthermore, parallel with these chemical changes, an improvement of the physical constitution of the soil occurs, which becomes less compact and more permeable, thus more protected from erosion. Moreover, fallows are increasingly major providers of non timber forest products (NTFPs) with social, economic and environmental benefits. Therefore, it is clear that fallow characteristics and fallow species composition are very important parameters determining the productivity of the whole agricultural ecosystem.

In the past, tropical countries had both substantial natural forests and ecological conditions suited for long fallow lands. However, over the past decades rates of fallow duration have often fallen far short of what is required to meet local needs and to sustain the agricultural system (Brady, 1996). Fallow length has not kept pace with demography or resource use pressure.

One harmful consequence of the continued shortening of the fallow period is that small-scale farmers are facing more and more weed problems in their food crop fields (Brady, 1996). Moreover, the resulting decrease in food production forces them to move progressively up into new forest stands. These forests, when available, are usually located far from the village, are expensive to clear and extremely sensitive to environmental damage. In many cases, the lack of properly monitored land-use strategies and poor weed management practices has led to the degradation of much of the once forested lands.

In contrast to the declining forest resource, it is predicted that the demand for NTFPs in the world, and in Africa in particular, will rise in the future (Sanchez & Leakey, 1997; van Dijk, 1999). A further pressure has fallen on natural forests during the last thirty years, with the development of new trends in wood market forces. Population growth, increased urbanisation and industrialisation in developing countries have led to the emergence of a strong home market for both commercial and domestic wood products, with urban centres tapping increasingly large forest (and fallow) lands for firewood, charcoal, sawn timber and premium species, much of which previously only supplied the export market (Ayuk *et al.*, 1999).

Therefore, in the context of diminishing native forests, land degradation, shortening of fallow period and rapidly increasing demand for NTFPs, there are strong arguments in favour of intensifying the productivity of fallows in the tropics (Brady, 1996; Sanchez & Leakey, 1997; Mertz, 2002). These arguments can be summarised as the need to assure future sustainable fallow management strategies whilst productively using and environmentally protecting previously logged-over forestlands.

In tropical small-scale agriculture, farmers try to provide weed-free land conditions for crops. A common land-use system to achieve this goal has been the practice of 'shifting cultivation', described as the periodic 'abandonment' of cropped land to natural re-growth or fallow (Mertz, 2002). The traditional form of this system with a long fallow period (of 10-20 years) has allowed the regeneration of natural vegetation; and, within communities, utilisations of fallow lands were many-fold (Nye & Greenland, 1960; Moody, 1975; Ruthenberg, 1980).

In summary, fallows constitute an important component of the agricultural production system within forest regions in developing countries. Within that system, they interact with rural economy, weed ecology, crop production and the environment. Therefore, it is expected that a fallow management practice might influence each component of the agricultural production system. Norris (1992) has studied and confirmed this hypothesis (Figure 1.1).

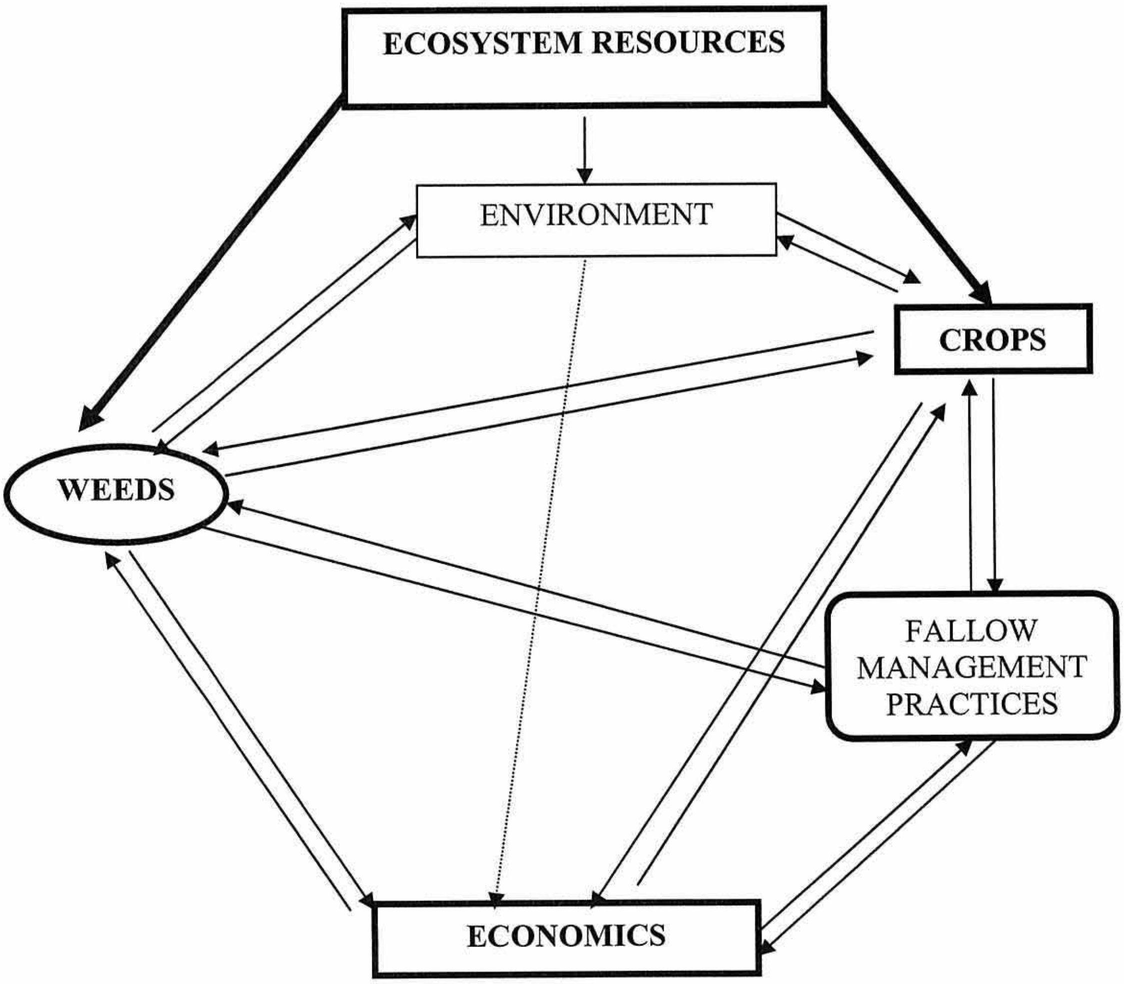


Figure 1.1. Interaction between weeds and other components of the agricultural production system. (Adapted from Norris, 1992).

1.2. PROBLEM STATEMENT

Traditionally, farming systems based on fallowing and slash-and-burn practices have allowed small-scale farmers to carry out agriculture at a subsistence level of food production. Yet, nowadays, increasing land demand due to higher demographic pressure along with the 1980s economic crisis has broken this equilibrium state. In the humid forest zone of Cameroon in particular, sectoral and macroeconomic policy reforms that occurred in the late 1980s have led to a land-use intensification process (Gockowski *et al.*, 1998a). These reforms took place in the context of an over-valued local currency and depressed world cocoa (and coffee) markets. As a result, cash crop plantations were neglected in favour of small-scale food crop fields and a significant additional pressure was put on forestlands. Furthermore, in many rural areas, a reliance on 'short' fallows increased since households became short of young men to clear new forest stands for cropping due to rural exodus (Weise & Tchamou, 1999). Additionally, an increase was noticed in the number of households headed by widowed (or single) women unable to clear forests (Russell, 1993).

In both cases, long fallows (i.e. fallow lands of more than five-years-old) became less and less feasible in the area. The traditional farming system is now 'short-circuited'. Herbaceous fallow lands dominated by one species are replacing bush fallows (Figure 1.2). In particular, bushes of *Chromolaena odorata* (L.) R. M. King & H. Robinson (Asteraceae) are gradually replacing secondary forest pioneer species.

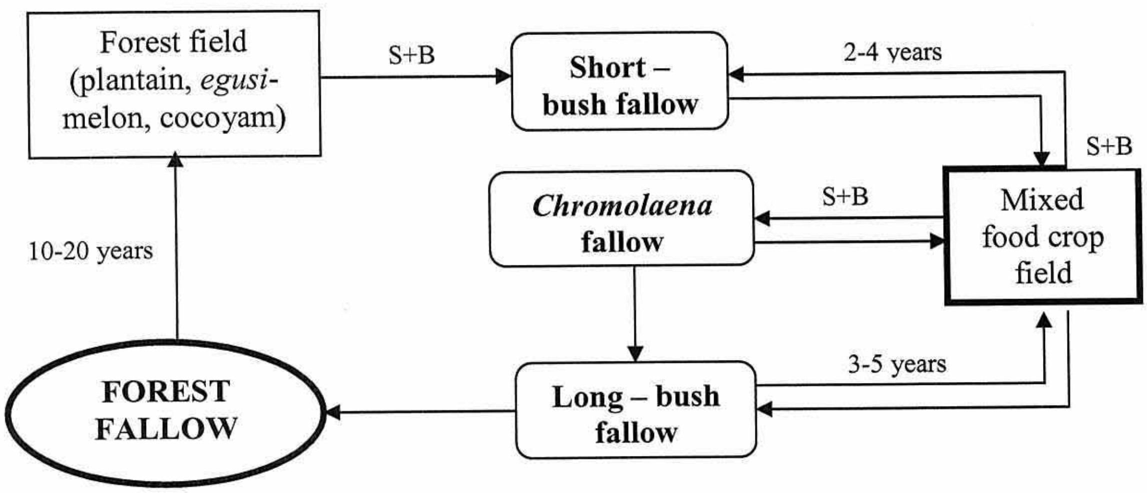


Figure 1.2. Agricultural production systems in the humid forest zone of southern Cameroon (adapted from Weise & Tchamou, 1999). S+B = slash and burn.

In southern Cameroon, the International Institute of Tropical Agriculture (IITA) and the "Institut de Recherche Agricole pour le Développement" (IRAD - Cameroon Institute for Agricultural Research) developed a "benchmark" area for research on sustainable farming systems and resource management. Covering 15 400 square kilometres of humid forest, the benchmark area is a typical research site covering a population gradient from urban regions (where there is intensive land use) to thinly populated zones (with less land use pressure). This differing intensity of resource use presents a gradient around which it is possible for researchers to develop and evaluate farming systems and resource management practices. The gradient ranges from dense forest and low population in the southern part of the benchmark to degraded forest and high population density in the north (Gockowski *et al.*, 1998a).

Previous studies carried out within the area (Russell, 1993; Diaw, 1997; Gockowski *et al.*, 1998a; Weise, 1995; Weise & Tchamou, 1999 among others) give insight into some of the implications of this situation. However, these studies have focused mainly on only one component of the production system, the socio-economic changes. There is a lack of quantitative information about fallow – weeds – yield interactions (Mertz, 2002). That knowledge is essential for the development and/or implementation of sustainable land management strategies that aim to accommodate the needs of farmers. In this sense, research needs to answer some basic questions:

1. How do rural populations classify, characterise and use fallows within the study area?

2. What are the effects of shortened fallow systems on the functional diversity and species diversity during the fallow phase?

3. What is the impact of previous cycles of short fallow/cultivation on the weed species community and on yield of subsequent crop fields?

4. How are those effects related to soil physical and chemical properties?

5. How can alternative agricultural technologies (such as improved short fallow systems) be integrated into the actual cropping system in order to increase smallholder farmers' welfare and the biological diversity of natural fallows?

1.3. OBJECTIVES

The aim of this study was to assess the impact of fallow age and type on species diversity both during fallow and during crop growth, and to evaluate the effect on crop yields. The major specific objectives of the study were:

- To assess local farmers' typology of natural fallows and their main uses of key fallow species.

- To determine the effects of the previous fallow type on the plant community composition and functional diversity of three identified short fallow types.

- To evaluate crop yields and weed dynamics as affected by the fallow type of the previous cropping cycle.

- To study the vegetative and reproductive phenology of some selected high-value fruit trees found in fallow lands, and estimate their productivity.

1.4. THESIS STRUCTURE

A total of nine chapters are presented in this thesis as outlined below.

Chapter one is a general introduction that underscores the ecological consequences of shortening fallow duration in tropical areas, with particular attention to the situation in the humid forest zone of southern Cameroon, and states the research questions addressed in this study. Also included in this chapter are the research objectives and a summary of the structure of the thesis.

Chapter two presents a review of the literature on the characteristics, functions and uses of fallow in tropical agriculture, emphasizing the role of fallow as a weed-break.

A review of the relationship between weeds and crop yields after fallow on one hand, and between weed and fallow type and age on the other hand is also provided in this chapter. It presents a synopsis of alternative management strategies associated with weed control and improvement of the productivity of short fallow systems.

Chapter three provides a description of the climate, soil and socio-economic profiles of the humid forest zone of southern Cameroon in general, as well as broad outline of the methodology used for this study.

Chapter four presents local farmers' typology and characterization of natural fallow lands throughout the study area. It also describes the main agricultural uses associated with each defined fallow class, and the major constraints to their management.

Chapter five presents the key fallow species used by local communities in the study area, and the pattern of their distribution and abundance across different fallow classes.

Chapter six presents the species and functional diversity during the fallow phase as affected by the fallow type and by the fallow type of the preceding cropping cycle.

Chapter seven considers the impact of three types of short fallow on the species diversity and community dynamics of the weed flora during the subsequent cropping phase. The relation between weed density and crop yields is also examined, in relation to variation in some soil physical and chemical properties.

Chapter eight gives details on the distribution and abundance of four key productive fallow trees across various habitat types. The chapter also includes a description of the leaf flushing, flowering and fruiting phenology of these species, as well as estimates of their productivity.

A general discussion of all results, remarks and conclusions to the study are presented in chapter nine. Some recommendations for future investigation are also provided in this chapter.

Chapter four to eight are each sectioned into an introduction, a description of the methods used, results and discussion of the results.

CHAPTER II

BACKGROUND RESEARCH

2.1. INTRODUCTION

Data are now available to rural resource managers from a rapidly increasing number of studies conducted on fallow duration/vegetation interactions, productivity and improvement. However, many of the reports produced concern the savannah regions, and mainly address the socio-economic aspect of the relationship between fallow length and vegetation, with few studies integrating socio-economic, botanical and agronomic aspects (Brady, 1996). It is therefore intended in this review to concentrate on those aspects of the fallow system, which critically affect the plant community composition, yield and weed flora of subsequent crops.

In tropical areas and in West Africa particularly, numerous studies (and more than 30 theses) have been carried out on fallow. Published reports on tropical fallows have mostly described vegetation dynamics, uses of fallow species, socio-economic benefits and changes in soil under fallowing. Since 1994, a complex Network, known as PHARMEL, involving five countries (Burkina Faso, Côte d'Ivoire, Mali, Niger and Senegal) as well as fifty African and European research organisations has been established (Floret, 1998). Beyond the compilation of medicinal uses as such, the main value of the database lies in it proposing a standardised mode of coding the collected data. The key to these codes has been published by Adjanohoun *et al.* (1989; 1992).

2.2. NATURAL FALLOWS

2.2.1. Classification and characteristics of fallows

Although there is no generally accepted terminology to cover the range of fallows, there seems to be a great consensus within rural resource managers to consider the broad physiognomic type of the vegetation as the main criterion of distinction among fallow types (Nye & Greenland, 1960; Sebillote, 1985). Details of the fallow vegetation depend very much on the fallow age, the cropping history over years (which reflects the utilization or cultivation intensity) and the type of soil. Nye & Greenland (1960) distinguished 'woody' and 'grass' fallow types; whereas Ruthenberg (1980) grouped fallows into forest, 'bush', savannah and grass lands. These fallow types are defined and characterised by their floristic composition.

2.2.2. Plant community composition of fallows

Many studies have been reported on vegetation characteristics and dynamics of tropical fallows (Aubréville, 1947; Nye & Greenland, 1960; Letouzey, 1968; de Rouw, 1995; Donfack *et al.*, 1995, among others). Compared with the forest area, tropical African savanna fallows have received far more scientific attention. Floret (1998) and Floret & Pontanier (2000) have published a detailed survey of these studies in sub-Saharan Africa (Mali, Senegal and North Cameroon).

Detailed information on the dynamics of fallow vegetation in forest areas is only available for some African countries: Hall & Okali (1979) and Akobundu *et al.* (1999) in Nigeria, de Rouw (1991; 1995) and Kent *et al.* (2001) in Côte d'Ivoire, Mitja & Hladik (1989) in Gabon and Mauray *et al.* (2002a) in Senegal. These studies along with recent reports of Kotto-Samè *et al.* (1999), Gillison (2000), Zapfack *et al.* (2000) and Carrière *et al.* (2002) give an idea of the wide range of floristic composition to be encountered in fallows of the humid forest area of southern Cameroon.

After a cultivated land is abandoned, the first phase of the succession is less diversified and dominated by ephemeral (i.e. short-lived) weeds, including grasses (de Rouw, 1995). In the humid forest zone of southern Cameroon, the vegetation at this stage is commonly dominated by the Asteraceae species *Chromolaena odorata* (de Rouw, 1995; Weise & Tchamou, 1999; Gillison, 2000; Zapfack *et al.*, 2000). The second phase of the succession, usually occurring after a relative period of 4-5 years, is more 'woody' and is dominated by a "chaotic wilderness" of herbs, climbers, shrubs and trees (Nye & Greenland, 1960; de Rouw, 1995). The details of the floristic composition at this stage depend very much on the cultivation intensity of the site (i.e. the land history) and the type of soil. According to Hall & Okali (1979) and Gillison (2000), most species in this fallow class are members of four families. These are Euphorbiaceae (containing notably *Alchornea* spp., *Manihot esculenta* Crantz. and *Manniophyton fulvum* M. A.), Fabaceae (containing notably *Albizia* spp.), Poaceae (grasses) and Rubiaceae (dominated by *Rothmania* spp. and *Diodia scandens* Benth.). The species *Haumania danckelmaniana* (Marantaceae) is also frequently mentioned.

At the third stage of the succession, fallows (8-10 years old) are characterised by the dominance of rapid-growing, light-loving trees, among which are *Macaranga* spp., *Musanga cecropioides* R. Br., *Myrianthus arboreus* P. Beauv. and *Milletia* spp. (de Rouw, 1995; Gillison, 2000; Zapfack *et al.*, 2000). The vegetation profile of fallows of this class shows two canopy layers: a patchy upper canopy at 15-25 m and a continuous one at 4-7 m (Letouzey, 1968).

The final stage of the succession is a young secondary forest, dominated by a variety of slower-growing woody species (members of the Sterculiaceae and Ulmaceae families) with long stems, and is characterised by the presence of more lianas (Floret, 1998). Depending of the cropping history of the fallow land, an old secondary forest scarcely distinguishable from the 'original' is eventually developed (Nye & Greenland, 1960).

2.2.3. Functions and various uses of fallows

Many studies have outlined the relation between the characteristics of fallows and their functions or uses in tropical rural communities. In the tropical forest zone, the functions of the fallow are various, but can be grouped into four categories, which are soil fertility restoration, weed control, rural economy and biodiversity conservation (Nye & Greenland, 1960; Brady, 1996; van Dijk, 1999; Mertz, 2002).

2.2.3.1. Soil fertility restoration

In tropical cropping systems, several authors have studied the effects of fallow on soil properties (Ruthenberg, 1980; Ola-Adams & Hall, 1987; Levang, 1993; Some, 1994; de Rouw, 1995; Alegre & Cassel, 1996; Juo & Manu, 1996; Roder *et al.*, 1997; Mauray *et al.*, 2002a and b; Murty *et al.*, 2002 among others). Above all, the detailed survey of Nye & Greenland (1960) provides a fine background for a review of this function of fallow.

During the course of the fallow, beneficial changes occur in the soil, particularly in the topsoil. These changes are closely related to increases in soil humus, which determines the amount of nutrients in both the topsoil and the fallow vegetation. Year by year, fallow plants increase their amount of nutrients, which increases the amount of litter supplied to the soil organisms (mostly termites, ants and bacteria), thus increasing the build-up of humus in the topsoil (Murty *et al*, 2002). Consequently, in small-scale agriculture, the level of organic matter in soil is closely related to the amount of above and below ground organic matter inputs from plants growing in the soil.

However, the rate of increase of humus depends on the initial organic-matter level of the soil, in relation to the maximum that can be attained beneath the fallow. Thus, a soil much below its 'equilibrium' level may show a high rate of increase of its humus. Additionally, the increase in the soil organic matter content may also depend on the properties of the fallow itself such as its vegetation type and the number of fallow-cultivation cycles following clearing of the primary forest land (Floret, 1998). However, Nye & Greenland (1960) emphasised that levels of humus in the topsoil of a 5 year-old-forest fallow are not subject to significant changes with successive periods of fallow and cropping. The same authors reported that soils under forest fallow contain more total nutrients (especially phosphorus and calcium) in the surface and sub-surface horizons than in lower layers.

Parallel with this function of the fallow on soil chemical properties, Nye & Greenland (1960), followed by Floret (1998), have outlined the improvement of the physical constitution of the soil, which occurs during the fallow phase. Due to the presence of fallow trees which fine roots mould the surface soil into soft porous granules or crumbs, the soil becomes less compact thus, more permeable and protected from erosion.

Nevertheless, despite the reported great amount of nutrients stored in fallow soils, Nye & Greenland (1960), followed by Brady (1996), suggested that the availability of these nutrients to plants during a subsequent cropping phase might be affected by burning. In tropical agricultural systems, burning is known to be the most practicable way for smallholder farmers to clear the great mass of felled vegetation and make the land accessible for cultivation. Many damaging changes associated to this practice have been reported (Brady, 1996). Firstly, large quantities of nutrients (particularly nitrogen, sulphur and carbon) are lost in the burn. Secondly, the resulted alkaline ash may raise the pH and availability of cations in the topsoil. Finally, the direct effect of heat on the microbiological population, though restricted to local patches within the stand, might modify the physical and chemical properties of the soil colloids.

2.2.3.2. Weed control

Several authors have reported that weed infestation is one of the main reasons (with soil fertility decline) for smallholder farmers to abandon a cropped land (Jouve, 1993; de Rouw, 1995; Anderson, 1996; Roder *et al.*, 1997; Akobundu *et al.*, 1999; Mertz, 2002 among others). As early outlined by Nye & Greenland (1960) and confirmed in southern Cameroon by Weise & Tchamou (1999), a farmer tends to abandon a stand when he finds easier to obtain subsistence production by clearing and cropping a new stand than weeding the existing one.

Two indigenous knowledge-based practices were reported, which might have helped small-scale farmers in the tropics to traditionally control weeds during the cropping phase (Nye & Greenland, 1960; Zimdahl, 1999). First is the traditional practice of mixed food crop fields where short-term (like cereals or groundnuts) and long-term crops (such as cassava, cocoyam or plantain) overlap, and their shade is sufficient to make the labour of weeding relatively light. Second is the knowledge, by farmers, of fallow species indicative of a land ready for clearing. Although already investigated in other forest regions of Africa, like in Nigeria (Akobundu *et al.*, 1999; Ekeleme *et al.*, 2000; Chikoye & Ekeleme, 2001) and in Côte d'Ivoire (de Rouw, 1995; Johnson & Kent, 2002), little information is available to verify these two assertions in the humid forest area of southern Cameroon (Weise, 1995; Weise & Tchamou, 1999).

Moreover, it has been reported that the cropping history of the stand, along with its location in relation to surrounding vegetation types (areas of forest, bush or herbaceous fallows), may determine the incidence of weeds and may affect the regeneration process of secondary formation (Nye & Greenland, 1960; Floret et Serpantié, 1996; Floret, 1998; Zimdahl, 1999).

2.2.3.3. Fallow in the rural economy

Within the forest zone of West tropical Africa, several studies have identified many fallow products that farmers exploit and trade to improve their income (Okafor, 1990; 1991; 1998; Cunningham, 1993; Ndoye, 1995; Sanchez & Leakey, 1997; Ayuk *et al.*, 1999; van Dijk, 1999; Dounias *et al.*, 2000). Due to increasing population pressure and the attendant deforestation, fallows actually appear to be the main niches of Non Timber Forest Products in the area. The term "forest" being used here, embraces 'all the natural ecosystems where trees and shrubs form a significant component' (FAO, 1995).

Aside from timber, fallows in the forest tropical zone provide valuable resources (food or drink, fuelwood, medicinal products, building material, etc.) and are also reported to be vital for the social well-being of the smallholder communities (Diaw, 1997; Dounias *et al.*, 2000). Through their collection, marketing and processing, NTFPs provide employment and income (Dounias *et al.*, 2000).

This contribution of fallow lands as NTFPs' provider has been less investigated in southern Cameroon. However, surveys conducted by Ndoye *et al.* (1997), Ndoye *et al.* (1998), Ayuk *et al.* (1999), Eyebe *et al.* (1999), van Dijk (1999) and Atangana *et al.* (2002) have listed many useful fallow species in southern Cameroon and their main uses.

Stems or branches of fallow plants, used as fuelwood, represent the main use category (Floret, 1998; Okafor, 1998; Eyebe *et al.*, 1999). In a context of low population pressure, when fallow products used as combustible are dry wood or result from land preparation activities before cropping, their collection is not damageable to the environment (Letouzey, 1968).

Another important use category for fallow plants commonly reported in the Cameroonian forest area concerns building materials. In southern Cameroon, reported studies of Letouzey (1968) and van Dijk (1999) have shown that building poles of local houses are essentially made of durable wood of Olacaceae trees, which include *Coula edulis*, *Strombosia* spp., *Strombosiopsis* spp. or *Massularia* spp. Also widely used for construction of walls, are stems of various rattan species (*Calamus*, *Ancistrophyllum*, *Eremospatha* spp., etc.), whereas, leaves of *Elaeis guineensis* are frequently used as roof materials. Moreover, pygmies' populations leaving in the forest utilize leaves of various Marantaceae fallow species (such as *Ataenidia*, *Sarcophrynium* or *Megaphrynium*) to construct their huts.

The third group of commonly used materials collected from fallow lands in southern Cameroon are food or drink products. The most listed edible products include starchy crops (wild *Dioscorea* spp. or *Parkia biglobosa*), leafy vegetables (such as edible mushrooms, *Corchorus olitorius*, *Gnetum* spp., *Talinum triangulare*), fat or oil products (of *Baillonella toxisperma*, *Desbordesia glaucescens*, *Irvingia* spp., *Lophira lanceolata*, *Pentaclethra macrophylla*, etc.), spices (*Afrostyrax lepidophyllus*, *Tetrapleura tetraptera*, etc.), indigenous fruits or seeds (of *Annona senegalensis*, *Anonidium mannii*, *Cola* spp., *Coula edulis*, *Dacryodes edulis*, *Irvingia gabonensis*, *Myrianthus arboreus*, etc.), and drink (from *Elaeis guineensis* or *Raphia* spp.).

Also mostly collected and used by local communities are fallow species used to make traditional medicinal preparations. According to a report published by Bulletin Arbres, Forêts et Communautés Rurales (1997), about 80 per cent of the population in West Africa rely on traditional medicine. Such categories of medicinal products include, for example, leaves of *Morinda lucida* (Rubiaceae) and *Carica papaya* (Caricaceae) used as anti-malaria herbal tea; seeds of *Garcinia kola* (Guttiferae) and *Xylopia* spp. (Annonaceae) used as health drinks, etc. (Okafor, 1998).

Moreover, as basic ingredients of 'modern' medicine substances, some fallow products are reported to be intensively exploited and traded. Some illustrations of this 'over-exploitation' concern the species *Prunus Africana* (Rosaceae), *Voacanga Africana* (Apocynaceae), *Pausinystalia johimbe* (Rubiaceae) and *Strophantus gratus* (Ndoye *et al.*, 1998). Other uses of fallow products that have been reported in southern Cameroon include forage, fodder, cottage, small-scale industries, clothing, traditional tools and wrapping materials.

Studies conducted by Ntamag (1997), Tchatat *et al.* (1998) and Eyebe *et al.* (1999) have assessed the main niches of NTFPs in the humid forest zone of southern Cameroon (Table 2.1). Although the range of fallow ages used in the studies is not specified, it appears that, except for *Irvingia* spp. and *Garcinia lucida*, most high-value NTFPs are extracted from fallow lands in southern Cameroon.

Table 2.1. Main niches of some Non Wood Forest Products in southern Cameroon (values expressed as percentages).

NTF species	*C. odorata*-fallow	Long fallow	Secondary forest	Primary forest	Others*
Irvingia spp.	1.82	15.38	68.06	75.00	3.43
Garcinia kola	-	1.10	-	-	0.19
Garcinia lucida	-	-	-	25.00	-
Ricinodendron heudelotii	10.91	27.47	27.78	-	5.90
Cola acuminata	-	2.20	-	-	26.47
Gnetum spp.	12.73	12.09	1.39	-	-
Elaeis guineensis	70.91	37.36	2.77	-	19.58
Dacryodes edulis	3.63	4.40	-	-	44.43
TOTAL	100	100	100	100	100

*Includes: cocoa plantations, home gardens and coffee farms.

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

2.2.3.4. Ecological functions

In West tropical Africa, many studies have emphasised the fact that local populations, over many generations, have accumulated a profound knowledge of the local flora, local land management systems and site conditions (Floret, 1998; Okafor, 1998).

Recent advances in rural resource management have revealed that new initiatives are seeking to integrate into tropical cropping systems (i.e. natural fallows), indigenous trees whose products are widely used by local farmers (Leakey & Jaenicke, 1995; Brady, 1996; Franzel, 1996; Sanchez & Leakey, 1997; Leakey & Simons, 1998). This incorporation of trees on farms, known as 'farm forestry' or (sequential) agroforestry, is reported to be a promise way to overcome the dire shortages of useful fallow products, and to reduce the environmental degradation on the densely inhabited areas. Furthermore, Leakey & Simons (1998) have suggested that agroforestry practices should be seen as stages in the development of a complex agroecosystem composed of many niches, which increase the ecological stability and diversity of the system. Additionally, by deliberate genetic conservation, agroforestry practices using domesticated fallow species are expected to maximize the genetic base of new cultivars.

More than 2,500 local tree species have been listed as potential components of such agro-ecosystems in the tropics (Franzel, 1996). Leakey & Simons (1998) have analysed the current policies of ICRAF (International Centre for Research in Agroforestry) to define the basic components of an efficient poverty-alleviating agroforestry. According to these authors, it is essential to first identify priority fallow species, which should be studied for domestication. Previous studies conducted in the forest area of Cameroon by ICRAF, Ndoye (1995), Eyebe *et al.* (1999), among others, have determined about 5 to 8 priority tree species for domestication based either on farmers' preference or on market surveys data (Table 2.1).

Further steps in the domestication process of useful wild fallow trees, currently carried out by ICRAF and its partners in southern Cameroon, mostly include germplasm collections, phenotypic variation in tree form, phenology and fruit characteristics (such as colour, shape and sweetness) of *Irvingia* spp. (Ladipo *et al.*, 1996; Atangana *et al.*, 2002). Additionally, aspects of genetic structure, amount of variation, ecogeographic partitioning, hybridisation and molecular characterisation of *Prunus africana* along with characterisation of *Dacryodes edulis* fruits are being examined (Tchio & Kengue, unpublished; Leakey & Simons, 1998).

2.3. WEED ECOLOGY AND BIOLOGY

Small-scale farmers in the tropics continue to suffer undue labour (more than 40% of their labour) or yield losses due to high weed pressure (FAO, 1995; de Rouw, 1995; Roder *et al.*, 1997; Akobundu *et al.*, 1999; Weise & Tchamou, 1999; Zimdahl, 1999). Not all weed scientists and weed managers agree about the definition of the term 'weed'. However, weed scientists commonly refer to weeds as "plants growing out of place or growing where they are not wanted" (Zimdahl, 1999). This definition differs from the ecological sense, which regards weeds as "plants characteristic of lands where man has replaced the native vegetation with a controlled system of cropping and management" (Anderson, 1996). According to Labrada and Parker (1994) the term 'weed' is finally not an absolute category, but instead an anthropocentric concept.

2.3.1. Characteristics of weeds

Regardless of the difficulty to agree on the definition of weed, most authors recognize that weeds share some fundamental characteristics (Cousens & Mortimer, 1995; Zimdahl, 1999). Characteristics that contribute to weeds' competitiveness are mainly related to growth physiology, reproduction and cultural practices (Anderson, 1996; Zimdahl, 1999). In an intermixed community with crop plants, the aggressiveness traits of weeds usually include a rapid seedling growth and a higher growth rate, as compared to the crop with which they infer.

Additionally, weeds are characterised by a short vegetative period to flowering, a rapid reproduction cycle, a high photosynthetic rate, a low carbon dioxide compensation point and high light saturation intensity, which allow them to be shade-tolerant. A rapid (exploitive) root system growth and a high tolerance for environmental variations or constraints due to their genotype also contribute to the competitiveness of weeds. Other advantageous features attributed to these plants are: an allelopathic activity for some extremely competitive weeds, a long period (sometimes continuous) of seed production under a wide range of environmental conditions, special adaptations for their seeds' dispersal in space and a crosspollination achieved by non-specialized agents or by wind. Their seed dormancy which allow them to resist soil degradation and disperse in time, along with their morphological (size and shape) and physiological (maturation period) similarity to crop seeds give weeds another advantage over crops in a mixed food crop system.

Finally, because of their dual modes of reproduction (vegetative and sexual) for perennials, the brittleness at lower rhizome nodes (or on root stocks) and their ability to regenerate from small root segments, perennial weed species are more competitive than annuals. However, in an ecological sense, some studies have revealed that most weed plants do not tolerate extreme shade and lack the ability to invade (or survive) in established vegetation, which may render them less competitive than anticipated from their aggressiveness (Anderson, 1996).

2.3.2. Effects of weeds

2.3.2.1. Harmful effects

Weeds are the most underestimated pests in tropical agriculture although their unpleasant effects are largely acknowledged (de Rouw, 1995; Cousens and Mortimer, 1995; Floret & Serpantié, 1996; Roder *et al.*, 1997; Floret, 1998; Akubundu *et al.*, 1999 among others). Zimdahl (1999) listed as many as nine negative effects attributed to weed species.

Because they serve as hosts for other plant pests, weeds are known to increase crop protection costs (Anderson, 1996). For example, *Pistia stratiotes* (water-lettuce) is known to be the preferred host for *Mansonia mosquitoes* as well as an insect vector for the human encephalitis and rural filariasis. Weed seeds in grain crops reduce the quality of both farm products and seed crops. This results in extra-production costs, due to the necessity to clear seed crops before sale (Zimdahl, 1999).

Some weeds are poisonous for animals that ingest them (Anderson, 1996; Zimdahl, 1999). Among the most listed poisonous weeds are *Pteridium aquilinum*, *Solanum* spp. and *Asclepias verticillata*. In addition to this poisoning effect, other weeds are reported to cause mechanical damage to ruminants (through sharp spines for example).

Many authors have reported allelopathic interactions caused by weeds in croplands (Anderson, 1996). Allelopathy is the production, storage and secretion of chemicals (in leaves, stems or roots) which are harmful to other plants. In this category of extremely harmful weeds, many species have been listed among which *Chromolaena odorata* is the mostly cited in forest areas of West Africa.

For smallholder farmers in the tropics, weed plants increase production costs because they imply control operations (mainly from hand pulling and hoeing), which over-charge their agricultural calendar. Because they can cause allergies (such as hay fever), skin irritations or rashes, weeds may also be a potential hazard to humans. Moreover, a few weed species might even be poisonous when consumed, especially by children (Zimdahl, 1999).

2.3.2.2. Positive effects

Few authors have outlined the positive contribution of weeds to humans (Nye & Greenland, 1960; Moody, 1975; Mishra & Ramakrishnan, 1981; Toky & Ramakrishnan, 1981; Anderson, 1996; Roder *et al.*, 1997; Zapfack *et al.*, 2000). Zimdahl (1999) reported more than seven beneficial effects of weeds. Many authors have identified weeds that may be used for human food. Among these are *Amaranthus* spp. and *Digitaria* spp. Moreover, some weed species, such as *Lemna* spp., have a high nutritional value. Some weed plants make good pasture and forage, such as *Amaranthus* sp and *Setaria faberi*.

One of the most popular utilization of weed plants acknowledged in literature concerns their medical uses (Okafor, 1998; Zimdahl, 1999; Dounias *et al.*, 2000). Many weeds are listed among the most useful African plants (Adjanohoun *et al.*, 1992; Lejoly, 1997). Examples in this category include *Helianthus annuus* and *Pistia stratiotes*. In southern Cameroon, Zapfack *et al.* (2000) have identified the most common weeds used in traditional medicine, among which are *Ageratum conyzoides*, *Alchornea cordifolia*, *Bidens pilosa*, *Costus afer* and *Solanum torvum*.

There are several illustrations of plants introduced because of their (potential) agricultural use(s), and which finally became serious weed problems (McFayden & Skarratt, 1996; Zimdahl, 1999; Costello *et al.*, 2000). A typical example of this in southern Cameroon concerns *Chromolaena odorata*. Introduced to West Africa in the early 1960s, the species was used as a green manure crop in cocoa plantations (McFayden & Skarratt, 1996). Successful for that use, the species rapidly became an important weed problem in Central and West Africa countries since 1970 (Weise, 1995).

An important role attributed to weeds is related to agriculture in shifting cultivation systems. Weeds are reported to be useful by recycling nutrients, maintaining soil chemical properties or productivity, and reducing erosion (Moody, 1975; Swamy & Ramakrishnan, 1988). Although weeds are known to shelter insects and disease organisms, some weeds might have beneficial effects in pest management when used intentionally as traps. For instance, *Eleusine indica* is grown with beans to attract leafhoppers (*Empoasca kraemeri*) in India (Zimdahl, 1999). Finally, some weed species provide fuel (or energy) or are used to insulate clothing (using fibre from *Asclepias* spp., for example).

2.3.3. Classification of weeds

Whilst weed species may be defined as those plants "out of place", it appears that it is not easy to classify them on a narrow set of morphological, phenological or taxonomic criteria. Consequently, commonly reported groupings of weed species employ habitat-land use-life cycle-based classification (Anderson, 1996; Zimdahl, 1999).

Based on ancestry and botanical similarity, weeds are also grouped into families, genera, species and variety. Among the 200 world's worst weed species, 68% belong to 12 plant families, with Poaceae, Cyperaceae and Asteraceae accounting for about 43% of that total (Zimdahl, 1999. Table 2.2).

Table 2.2. Families of the most important world weeds.

Family	Number of species	Percentage		
Poaceae	44			
Cyperaceae	12	27%	43%	
Asteraceae	32			
Polygonaceae	8			
Amaranthaceae	7			
Brassicaceae	7			
Leguminosae	6			68%
Convolvulaceae	5			
Euphorbiaceae	5			
Chenopodiaceae	4			
Malvaceae	4			
Solanaceae	3			
Other (47)	≤3			

Source: Zimdahl, 1993.

Weed species are commonly grouped into categories such as ferns, sedges (Cyperaceae), grasses or broadleaves (Dicotyledons). Classifying weeds based on their habitat type is also a common practice. On this basis, weed species are grouped into categories such as terrestrial (either on croplands, rangelands or forests) and aquatic (Anderson, 1996). According to Zimdahl (1993), parasitic weeds should be added as a third category in this latter classification.

Though less systematic, another common classification of weeds is based on their life cycle (or life history). On this basis, weed species are grouped as annuals, biennials and perennials (Akobundu *et al.*, 1999). Annuals are plants that complete their life cycle (from seed to seed) in one growing season or within less than 12 months. In tropical regions, such weeds include *Echinochloa* spp., *Eleusine indica*, *Portulaca oleracea* L., *Amaranthus* spp. and *Rottboellia cochinchinensis*. Annual weeds are reported to be relatively easy to control. Less common than annuals, biennial weeds require more than one (but not more than two) years to complete their life cycle. Examples in this group are quite rare in tropical agriculture (Zimdahl, 1999). Perennial plants are usually divided into 'simple' perennials and 'creeping' perennials. Simple perennials propagate primarily by seeds, such as *Asclepias* spp., whereas creeping perennials reproduce both by seeds and asexual means. Examples include *Cyperus* spp., *Chromolaena odorata*, *Solanum* spp., *Convolvulus* spp., *Imperata cylindrica* and *Paspalum* spp.

2.3.4. Chromolaena odorata (L.) R. M. King & H. Robinson

2.3.4.1. Characteristisation

Chromolaena odorata (ex. *Eupatorium odoratum* L.), also known as bitterbush (or 'siam weed'), is a perennial-scrambling shrub that can rich up to 5m tall. Although found in many soil types, *C. odorata* prefers well-drained soils (McFayden & Skarratt, 1996). This dicotyledononous Asteraceae species does not tolerate shade, prefers open areas and is alleged to have a high allelopathic activity that might modify soil chemical properties. In tropical regions, while fire kills most vegetation during the preparation phase of the field, the stumps of *C. odorata* remain alive, sprout immediately after the first rain and the species becomes the main vegetation in the stand (Slaats *et al.*, 1998).

C. odorata is a creeping perennial that spreads primarily by seed. From January to March, it usually produces an abundant number of seeds (50,000 to 2,000,000 seeds per plant) that are dispersed mainly by wind (McFayden & Skarratt, 1996). Muniappan & Ferrar (1991) reported that, as many weed species, *C. odorata* seeds germinate only near the soil surface (1-3 cm). *C. odorata* grows very rapidly (a few weeks) and luxuriantly. Its oil content is reported to have insecticidal and bactericidal properties, which limit its susceptibility to insect or disease attacks; thus ensuring a high rate of survival (McFayden & Skarratt, 1996). Another competitive characteristic of *C. odorata* is the high survival rate of its seeds. Addressing this issue, Gautier (1996) obtained a germination rate of 79% with *C. odorata* seeds of 60 months (i.e. 5 years) old.

2.3.4.2. Origin, distribution and importance of C. odorata

Native to tropical America, *C. odorata* was introduced to Africa in the 1930s (McFayden & Skarratt, 1996). Starting its expansion slowly in the 1970s, the plant has since spread rapidly throughout the whole of Central and West Africa. *C. odorata* was introduced into Cameroon from Nigeria in the early 1960s for use in cocoa plantation as a cover crop (Gautier, 1996). Nowadays, the plant is a serious weed problem in pasture lands, disturbed forests, roadsides, waste lands, fence rows, river banks, reserve forests, cash crop plantations and food crop fields in the area (Akobundu *et al.*, 1999). *C. odorata* is reported to host several plant pests such as *Aphis spiraecola*, *Brachycaudus helichrysi* and *Aphis fabae*. Moreover, it has been suggested that, being a non-nutritional source to *Zonocerus* sp in West Africa, *C. odorata* might encourage an eventual population build-up of this pest (Müller *et al.*, 2002).

Although the harmful effects of the plant have been mainly studied and acknowledged, some authors (Weise, 1995; Slaats *et al.*, 1998; Gillison, 2000) suggested that *C. odorata* might positively contribute to ecosystem soil fertility. *C. odorata* long deep roots may be capable of extracting nutrient elements that have been leached into the deeper soil layers, and the rapid decomposition of the roots later releases high nutrient content within eight months. Muniappan & Ferrar (1991) reported that by incorporating the plant in the soil, quantity and quality of organic matter are substantially improved.

2.3.4.3. Management strategies for C. odorata

In the traditional shifting cultivation system, methods used to control weeds in general, and particularly *C. odorata*, are mechanical and include slashing, hand pulling and hoeing (de Rouw, 1995). Although effective for the control of weed seedlings and established annuals and biennials, hand pulling is reported to be of minor value in the control of established perennial weeds such as *C. odorata* (Anderson, 1996). This is because underground vegetative reproductive parts are not usually disturbed. Additionally, hand pulling of *C. odorata*-dominated crop fields is extremely time-consuming (Weise & Tchamou, 1999).

Hoeing can also be used more effectively to control *C. odorata*, if practised at intervals of 1-2 weeks during the cropping phase (Anderson, 1996). Use of cover crops such as *Centrosoma pubescens*, *Pueraria phaseolides* or *Tephrosia purpurea* ,as well as use of the pasture grass *Brachiaria decumbens*, have been reported to prevent or reduce the incidence of *C. odorata* in plantation crops and pasture lands respectively (Munniapan & Ferrar, 1991).

In more industrialised countries, methods to control *C. odorata* (and weeds, in general) include the use of chemicals and biological agents. The use of phytotoxic chemicals, particularly triclopyr (a herbicide with a LD_{50} of 713) to control *C. odorata* has given encouraging results (Munniapan & Ferrar, 1991). However, there are many limitations to the use of herbicides in small-scale agriculture, such as:

- the high cost of the products and their application;
- their potential effects on the environment;
- their hazard to humans and animals;
- and their non-compatibility in many cropping situations.

Biological control methods to tackle *C. odorata* are currently used in Ghana and South Africa and are being widely encouraged. Introduced and established in the southern part of China, the plant's natural enemy, *Pareuchaestes pseudoinsulata* rego Barros (Lepidoptera: Arctiidae), is reported to suppress this weed (Munniapan & Ferrar, 1991). Other natural enemies to *C. odorata* listed and currently studied include *Pareuchaestes aurata*, *P. insulata*, *Mescinia parvula* (Lepidoptera: Pyralidae) and *Cionothrix praelonga* (Basidiomycotina: Uredinales) (Goodall & Erasmus, 1996).

2.4. WEEDS AND CROPS

In sub-Saharan African countries, food crops are traditionally cultivated in mixed systems in rotation with natural fallow. The cultivation frequency is considerably variable and is influenced by the soil type, the population density and the related land pressure (Juo & Manu, 1996). On newly cleared land in the forest zone, more than three crop species are generally planted in a random mixture. Major crops in that system include cassava, yams, maize, upland rice or groundnut. However, for this mixed-cropping system to be advantageous, one important aspect should be that competition between crops, and competition between crops and weeds, are reduced to a minimum.

2.4.1. Cassava

2.4.1.1. Taxonomy, origin and distribution

The genus *Manihot*, of the family Euphorbiaceae, comprises about 75 species. Within the *Manihot* genus, *M. esculenta* Crantz, commonly known as cassava, is the only edible species. It comprises many cultivars that are usually distinguished by either the hydrocyanic acid (HCN) content (in leaf and fresh root) or the maturity time. Based on HCN content, cassava varieties are broadly divided into sweet (with low HCN content) and bitter (with high HCN content) cassava. On the basis of maturity time, cassava cultivars also fall into two groups. Short season types, often sweet cassava, mature in 6-11 months, while long-season types, mostly bitter cassavas, take at least 12 months to mature.

Introduced during the late 16^{th} century, from Latin America, the crop is widely cultivated throughout the wetter regions of sub-Saharan Africa (Radosevich *et al.*, 1997). In these regions, cassava is mostly grown for human consumption (leaves and tubers) and livestock feeding. It has been reported that productivity per hectare is lowest in areas with high human pressure on land, or when cassava is grown as an intercrop in mixed food crop systems.

2.4.1.2. Crop development pattern

Cassava is a perennial woody shrub growing up to 2-5 m high. It is vegetatively propagated using stem cuttings of about 30 cm long. Roots and leaves usually form within 5-10 days of planting, and starch deposition can be first observed 2 weeks later. Cassava is a long duration-crop (10-24 months) and is relatively slow growing, particularly during the first 3 to 4 months. However, about 12 months after planting, depending on the cultivar, maximum tuber dry weight and starch concentration are usually reached.

2.4.1.3. Crop-site relations

Cassava is relatively adapted to a wide range of climatic conditions, including a minimum of 500 mm average annual rainfall, an altitude limit of 1800 m and a lower limit temperature of 18°C. According to Doll & Piedrahita (1973), the wide climatic adaptability of cassava might be related to its perennial nature and its low water requirements or drought avoidance.

Although it grows best in well-aggregated clay soils with a light to medium bulk density, cassava is renowned to survive and produce in tropical acid soils of the humid forest region where other species will fail (Olunuga &Akobundu, 1980). This edaphic tolerance might be attributed to the well-developed root system of the crop and its high reliance on mycorrhizal association for nutrient uptake of phosphorus, potassium, sulphur, zinc and magnesium. However, the effectiveness of the association depends on the species of mycorrhizal fungi and on soil pH. Cassava is also reported to be very susceptible to soil alkalinity and salinity, with yield declines reported above pH 8.0, above 2.5% soil sodium saturation and above 0.5-0.7 dS m^{-1} electrical conductivity (Olunuga &Akobundu, 1980).

2.4.1.4. Place in mixed crop systems

In West Africa, cassava is typically grown in mixed systems where the main feature is an association of crops with different growth duration (Hladik *et al.*, 1993). This leads to a gain of total yield, through better utilization of time and space. Because of a slow growth rate and low leaf area during the first six weeks after planting, cassava crop systems often result in an inadequate coverage in terms of soil-surface protection and weed control (Olunuga &Akobundu, 1980). Therefore, by intercropping cassava with fast-growing annual crops (such as maize, melon or beans), better ground coverage can be achieved, thus reducing the erosive impacts of early-season rain and weed infestation.

In mixed food crop systems involving a fallow phase, because of its ability to yield well in low fertility soil, cassava is usually the last crop to be harvested and may even remain in the ground for 3-4 years after planting (Olunuga &Akobundu, 1980).

2.4.1.5. Pests, diseases and weed competition

Cassava is vulnerable to many diseases, which may contribute to considerable tuber yield variation (Olunuga &Akobundu, 1980). In West Africa, the incidence of maize borer and cassava root-knot nematodes seems to be reduced in cassava-maize-groundnut intercropping (Hladik *et al.*, 1993). Common diseases and pests associated with cassava mixed systems include cassava mosaic virus and its vector (the white fly, *Bemisia tabaci*), cassava bacterial blight (*Xanthomonas campestris pv. manihotis*) and the variegated grasshoppers (*Zonocerus* spp.).

During the slow-growing period of 3-4 months after planting, cassava is very sensitive to weed competition. Once a crop canopy has been formed, further weeding of cassava is reported to be not necessary (Hladik *et al.*, 1993). Weed competition for light, water and nutrients considerably affects the canopy development of cassava as well as its root yield, and severe infestation can cause 40 to 70% yield reduction. In regions with bi-modal rainfall pattern, planting of cassava early in the wet season might lead to minimize weed growth. Furthermore, the use of improved cultivars, more resistant to disease and pests, associated with high plant density (about 15,000 plants per hectare) are reported to reduce weed growth.

Common weed species interfering with cassava in mixed-cropped fields include *Imperata cylindrica, Smilax kraussiana, Commelina* spp., *Mucuna pruriens* and *Mimosa invisa.* To control these weeds, many chemicals have been tested with efficiency in tropical agriculture and include Diuron, Atrazine and Fluometuron (Zimdahl, 1999). Nevertheless, recent studies revealed that cassava yield stability could not be maintained in the humid tropical environment by systems using mixed crop species alone, without an economically viable means for maintenance of soil fertility (Hladik *et al.*, 1993).

2.4.2. Maize

2.4.2.1. Taxonomy, origin and distribution

The genus *Zea* (family Poaceae and subfamily Panicoideae), is divided into four species, of which one, *Z. mays* L. subsp. *mays* is the cultivated maize (Hladik *et al.*, 1993). Many attempts to classify genotypes within the species have been made, primary based on endosperm and now in relation with altitudinal effects on development pattern. Possibly originated from the south American continent and introduced in West Africa by the late eighteenth century (and in the Congo basin after 1930), maize is now widely cultivated in the region mainly for human food consumption and livestock feeding.

2.4.2.2. Crop development pattern

The development (in particular, the appearance of leafs) of maize and the duration to maturity are reported to be highly dependent on soil temperature throughout growth, a lower temperature resulting in better yield (Hladik *et al.*, 1993). Although it seems not possible to generalize about development patterns, many tropical land cultivars commonly reach anthesis (or syngamy) at about 50-60 days and come to maturity in 80-120 days after planting. However, the same authors noticed that the duration to maturity increases with altitude, at a mean rate of 7.6 days per 100 m.

2.4.2.3. Crop-site relations

In the tropics, maize grain yield is relatively low (Hladik *et al.*, 1993). Possible explanations include supra-optimal temperature (more than 30°C), tillage and radiation received after floral initiation, which might affects time to flowering and rate of grain filling. Additionally, water deficits at flowering appeared to reduce grain survival, leaf area, leaf photosynthetic rate and particularly, grain number (Hladik *et al.*, 1993). Furthermore, inefficient distribution of dry matter to grain may also contribute to limit maize yield.

In wet tropical areas, maize is commonly grown on well-structured soil of intermediate texture (ranging from sandy loams to clay loams), which provides adequate soil water, aeration and infiltration rate (Hladik *et al.*, 1993). It was reported that crust formation induced by mound-building termites or extensive agricultural practices (such as the use of machinery to clear vegetation) might increase soil bulk density, which affects root growth.

2.4.2.4. Place in mixed crop systems

In West tropical Africa, maize is commonly grown as a component of two- to six-crop mixtures (Hladik *et al.*, 1993). The mixture commonly includes cassava, yam, cocoyam, banana, beans or groundnut. In most of these mixed crop patterns, maize is one of the earliest crops to be planted, because it makes relatively high demands on soil nutrients; and is among the first to be harvested.

2.4.2.5. Pests, diseases and weed competition

Maize is very sensitive to weed infestation, especially during the first two to 4-6 weeks after planting (Hladik *et al.*, 1993). The slow growth rate at this stage and wide-spaced rows create an environment ideal for the growth of both annual and perennial weeds. In fields with high weed density, two hand-weeding, at 2-3 weeks and at 6 weeks after planting, are usually necessary during the cropping phase. However, effects of weeds on maize mainly depend upon the cultivar used and the planting density. Improved high yielding varieties, resistant to weeds, stem borers and diseases, are reported to lead to early canopy closure; thus are competitive against weeds. Furthermore, early maturing cultivars, high plant density (from 40,000 to 60,000 plants per hectare), early planting and high soil fertility, by allowing early shading, might reduce weed growth.

In forest regions, the principal weeds that interfere with maize are *Rottboellia cochinchinensis*, *Brachiaria* spp., *Chromolaena odorata*, *Euphorbia* spp., *Ipomoea* spp., *Paspalum* spp., *Panicum* spp., *Digitaria* spp. and *Eleusine* spp. (Olunuga &Akobundu, 1980).

2.4.3. Groundnut

2.4.3.1. Taxonomy, origin and distribution

The genus *Arachis* comprises more than 37 species, is a member of the family Papilionaceae (Fabaceae). Groundnut, *A. hypogaea* L., is an annual herb classified into two main subspecies (*hypogaea* and *fastigiata*) (Olunuga &Akobundu, 1980). Originated from South America, cultivated groundnut might have been introduced to Africa between the sixteenth and eighteenth centuries. In tropical West Africa, *A. hypogaea* constitutes one of the most important crops mainly cultivated for its oil.

2.4.3.2. Crop development pattern

Although early development events are not the same for all varieties, groundnut subspecies usually come to maturity in 90-160 days, depending on cultivar and season of planting (Olunuga &Akobundu, 1980). However, under tropical conditions, indeterminacy and subterranean fruit production have led to an extended period of seed formation and to low reproductive efficiency. For instance, Hladik *et al.* (1993) reported a percentage of pegs bearing pods ranging from 20 to 70%.

2.4.3.3. Crop-site relations

Previous experiments indicate that speed emergence of groundnut seeds generally increases with increasing temperature, up to nearly 33°C (Olunuga &Akobundu, 1980). However, a temperature range of about 27-28°C is reported to lead to highest growth rates. In general, maximum growth rate is coincident with maximum leaf area index (LAI), which mainly explains the rate of rhizobial nitrogen fixation. Also affected by high temperature and high radiation are flowering, duration of pegging, number of pods, pollen viability and final pod size.

Various studies have demonstrated that pod formation, pod growth rate and final crop yield are particularly sensitive to variation in photosynthate supply and are characteristic of each cultivar (Hladik *et al.*, 1993). *A. hypogaea* is known to be sensitive to water deficits, particularly at its early reproductive stages (49-60 days after sowing). In fact, it has been demonstrated that groundnut yield responses often reflect the pattern of soil water availability. Moreover, drought during pod filling might cause abortion and up to 45% of yield loss (Hladik *et al.*, 1993).

Most groundnut cultivars reportedly grow best in well-drained sandy soils of a loose to friable consistence, whereas heavy clay and light-textured soils are less suitable. Though being tolerant of high aluminium and manganese concentrations, groundnut seems to be very sensitive to calcium deficiencies, resulting in infertile (but greater) flower production and reduced kernel yield (Olunuga &Akobundu, 1980). Groundnut is also considered tolerant of acid soil.

2.4.3.4. Place in mixed crop systems

Within the tropics, groundnuts are cultivated both as a sole crop and as a component of intercrop mixtures. In the South Cameroon, associated crops in mixed cropping patterns that include groundnut are mainly maize and tubers (or plantains) (Weise & Tchamou, 1999). However, despite its importance in traditional slash-and-burn agricultural systems, Hladik *et al.* (1993) questioned the role of groundnut in restoring the topsoil nitrogen.

2.4.3.5. Pests, diseases and weed control

In adequate cropping conditions and if the planting density is convenient, groundnut may reduce weed infestation in the field (Juo and Manu, 1996). Like maize and cassava, groundnut is very sensitive to weed competition at the early stage of its cropping phase (Anderson, 1996). In small-scale tropical agriculture, one single weeding, carried out about 30 days after planting, is reported to maintain weed infestation at low intensities. However, severe infestation can cause up to 40% yield reduction if no weed control has been applied beyond the first four weeks of cropping. The most important weed species that interfere with groundnut include *Chromolaena odorata*, *Cyperus rotundus*, *Ageratum conyzoides*, *Celosia trigyna*, *Mariscus alternifolius* and *Oxalis corniculata* (Zimdahl, 1999).

2.5. SHORTENING FALLOW DURATION AND AGRICULTURAL SYSTEMS

2.5.1. Shortened fallow and vegetation characteristics during the fallow phase

Natural regeneration of tropical lands after slash-and-burn agriculture has been documented by several studies (Nye & Greenland, 1960; Letouzey, 1968; Hall & Okali, 1979; Uhl *et al.*, 1982; Ola-Adams & Hall, 1987; Gillison, 2000; Zapfack *et al.*, 2000; Chinea, 2002). In terms of vegetation structure, it was reported a decline in stem density, tree basal area, tree height with shortening fallow duration. However, Carrière *et al.* (2002) demonstrated the impact of remnant trees on these vegetation structural parameters. It was observed that, shortened fallow sites located under the crown of standing trees generally present some characteristics of older secondary regrowth, with relatively tall trees and sparse, shaded undergrowth. This means that relatively mature forest stages can be reached sooner in shortened fallows with remnant trees than in shortened fallows without remnant trees.

In terms of species diversity, it was demonstrated that, although site age is the best predictor of species richness and diversity, distance to older fallow at the time of abandonment added significantly to the explained variability (Chinea, 2002). This argument underscores the importance of seed dispersal for the colonization of abandoned agricultural fields, as stressed by Aide *et al.* (1996). It is argued that the occurrence of isolated trees in the surroundings of shortened fallow lands provides for seed sources and perches for animal dispersal.

Previous studies of natural re-vegetation in tropical fallows have stressed the importance of environmental and land-use history factors on patterns of species composition (Chinea, 2002). Site age, elevation, distance to forest, time since abandonment and slope were among the factors that may influence species abundance. Shortened fallows are reportedly characterized by an abundance of shade-intolerant species and a dominance of arable weedy plants (de Rouw, 1995). Meanwhile, few forest plants appear, mainly because felling and burning had permitted a germination of the seed stock but not its replacement.

2.5.2. Shortened fallow and weed growth

The reduction in fallow period has substantially increased the labor requirement for weeding, and farmers in wet tropical areas generally attribute more importance to effects of fallow on weed than upon soil fertility (Roder *et al.*, 1997; Mertz, 2002). Various studies conducted in tropical Africa reported a two-fold effect of shortening fallow duration on weed pressure of subsequent crops (de Rouw, 1995; Mertz, 2002). The shortening of fallow duration influences the quantity of viable weed seeds in the soil as well as their dynamics, while the weed community composition in the field is modified.

2.5.2.1. Length of fallow and weed seed bank

As defined by Anderson (1996) and Radosevich *et al.* (1997), the weed seed-bank in crop fields consists of viable seeds on and in the soil (i.e. up to 20 cm depth). In cultivated land soil, seed bank composition and weed flora are mostly influenced by cropping sequence (Anderson, 1996). Where natural vegetation is disturbed, more weeds arise from seeds lying dormant in the soil. In general, the number of weed seeds in arable soil is very large, from 30,000 to 350,000 seeds per square meter (Zimdahl, 1999). It is generally assumed that 2 to 10% of weed seeds in the soil seed bank emerge each year.

Generally, weed species produce seeds at the end of the cropping phase (i.e. before the crop is harvested) whereas pioneer ligneous species produce seeds only after 1-2 years (Jouve, 1993; Floret, 1998). It has been stated that weed seed densities are greatly influenced by the history of the land; that is, by past cropping practices and length of fallow (Radosevich *et al.*, 1997). At the time of crop harvest, weed seeds are disseminated to the ground surface and during (or at the end of) a fallow, are incorporated into the soil where they augment a buried seed-bank accumulated from previous generation (Cousens & Mortimer, 1995).

However, various studies have shown a decreasing density of seeds with increasing fallow length (de Rouw, 1995; Akobundu *et al.*, 1999). In long-fallow systems (where the fallow period is 19-21 years and the cropping phase lasts 6-month), de Rouw

(1995) noticed that the number of seeds in the soil bank was low and belonged mostly to pioneer species. On the contrary, as the fallow period decreased, an increase in the number of seeds in the soil bank occurred.

2.5.2.2. Length of fallow and weed species diversity

In cropping systems with shortened fallowing of less than 6 years, the plant community is rapidly dominated by herbaceous weed species of various groups (de Rouw, 1995; Roder *et al.*, 1997; Akobundu *et al.*, 1999). Meanwhile, in 'short-cycle' fallow systems (that is, systems with many cycles of 1-5 years of fallow-cultivation) the weed community appeared to be constituted mostly of grasses. De Rouw (1995) reported the dominance of heliophytic weed species, such as grasses, sedges and annual dicotyledons, in fallows of less than 6 years old. The dominance of *C. odorata* was reported to constitute a serious threat to the installation of fallow vegetation comprising both pioneer trees and Marantaceae species. It was hypothesized that intensive use of shortened fallow systems can be possible if shade trees are preserved or planted during fallow growth, are allowed to grow out during the subsequent cropping phase and afterwards.

2.5.3. Shortened fallow and crop yield

Another problem that occurs in shortened fallow systems of the humid tropics (with no chemical or organic fertilizers used) is the decline in soil fertility, leading to decreased crop yield (Nye & Greenland, 1960; Sanchez, 1976; Ruthenberg, 1980). Burning of the vegetation leading to volatilization of nitrogen and sulphur, crop export, erosion, leaching, weed infestation and poorer soil physical properties are reported to result in a decline in nutrient availability, thus a decline in soil productivity.

However, Mertz (2002) has questioned the theory of a correlation between shortened fallow length and yield decline in slash-and-burn agriculture systems. Some studies showed no correlation between fallow length and yield (Roder *et al.*, 1995; Roder *et al.*, 1997), while others have provided indications of a positive relationship between fallow and yield (e.g. Mishra & Ramakrishnan, 1981; Toky & Ramakrishnan, 1981) and few reported a negative relationship (Mishra & Ramakrishnan, 1981). These conflicting results point out the questionability of whether the fallow length is the main factor explaining yield decline in shortened fallow systems. Mertz (2002) stressed the need to take into account other bio-physical parameters of the ecosystem, such as management practices, heterogeneity of the soil and vegetation, history of previous cultivation cycles.

2.6. SHORTENED FALLOW AS PRODUCTIVE ECOSYSTEM

The fact that a relatively high number of studies have reported a decline in yields in intensively managed tropical farming systems has stressed how seldom the short fallow-crops rotation is, in fact, unsustainable (Mauray *et al.*, 2002a). It has been therefore recommended, in areas when this system is unavoidable, to develop and promote the development of substitutes to long fallow that will increase the productivity of the existent agro-ecosystem by providing more production and resource services.

Recently, several researchers have hypothesized that ecological and economical benefits associated with long-duration fallows could be obtained from agroforestry-based systems (Sanchez & Leakey, 1997; Akobundu *et al.*, 1999). Agroforestry is defined by Alegre & Cassel (1996) as “a land use that involves the deliberate introduction or mixture of trees in crop/animal production fields to benefit from the resultant ecological and economic interaction”. As an alternative to shortened fallow systems, techniques to convert some of the indigenous high-value species into domesticated crops in agroforestry systems are being increasingly acknowledged (Sanchez & Leakey, 1997). Examples of such high-value species that can be used in improved short-duration fallow systems include many wild fruit trees.

Guidelines for the implementation of such improved agro-ecosystems have been developed and reported by Franzel *et al.* (1996) and Jaenicke *et al.* (1996). Important research areas that scientists need to address are the domestication and the commercialization of key productive NTFPs. The domestication process involves the identification, production, management and adoption of agroforestry tree genetic resources (Leakey & Simons, 1998). From various studies conducted on the subject, it is recognized that a farmer-oriented approach to domestication and commercialization that would raise local farmers' incomes, benefit the environment and enhance biodiversity is a critical step towards the adoption or non-adoption of agroforestry (Fischer & Vasseur, 2002).

CHAPTER III

THE STUDY AREA: THE FOREST MARGINS BENCHMARK AREA (FMBA) OF SOUTHERN CAMEROON

3.1. GENERAL CHARACTERISTICS

The International Institute of Tropical Agriculture (IITA), in close collaboration with the National Agricultural Research and Extension Services (NARES) of West and Central Africa, and other International Agricultural Research Centres (IARCs) and agricultural research organizations established the FMBA in 1993. Serving as a focal point for strategic and diagnostic research in the sub-region, the benchmark approach was developed and implemented through the Ecoregional Program for the Humid and Sub-humid Tropics of Sub-Saharan Africa (EPHTA).

Covering 1.54 million hectares, the FMBA is located in southern Cameroon. The area stretches from latitudes 2°20'N to 4°30'N and longitudes 11°00'E to 11°50'E (Figure 3.1). Within the benchmark area, 45 villages (with 6 pilot research and characterization villages) were chosen as representative of the range of resource use intensities found in the Congo Basin ecoregion. The six pilot villages, situated across the gradient of resource use intensities in the benchmark, were among the 16 villages in which this study was conducted. The study villages were situated in three resource domains: Yaoundé, Mbalmayo and Ebolowa (Appendix 3.1).

The northernmost Yaoundé domain has excellent access to the close Yaoundé market. Administratively, it belongs to the Centre Province, which has the highest rural population density (14-88 inhabitants km^{-2}) of the FMBA, and a total population of about 1 516 332. The close proximity of the Yaoundé market provides the opportunity to study the impact of urban market access on traditional slash-and-burn agriculture. Many of the population in this domain are employed in Yaoundé, and consequently labour is a constraint because of its high opportunity cost. The average fallow duration reported in this domain is approximately 3.9 years.

Centrally located in the FMBA, the Mbalmayo domain is located around three urban centers: Mfou, Mbalmayo and Sangmelima. It is characterized by relatively poor market access, moderate rural population density (10-41 inhabitants km^{-2}) and a total population of approximately 187,587. The presence of some paved roads across the area allows for a modest market access and relatively abundant land resources. The average fallow length reported in the area is nearly 5.4 years (Gockowski *et al.*, 1998a).

In the southern part of the FMBA, is the Ebolowa domain, with more abundant land resources and the lowest rural population density (2-15 inhabitants/km^2). The area lies around the urban center of Ebolowa (accessible by dirt road) and the main trade route to Gabon and Equatorial Guinea, which allows for relatively good access to the frontier market (at Abang Minko'o and Kyo'si). However, villages of that domain are characterized by the highest transport cost to market. The domain has the lowest resource use intensity, with an average fallow length of about 7.5 years.

The characteristics of the defined resource domains within the FMBA of southern Cameroon indicate a spatial gradient and variability in many socio-economic and bio-physical factors, from the Yaoundé domain which is close to the major centre of the country towards the Ebolowa domain in the South (Table 3.1). With respect to the intensity of resource use, and from high to low, the three resource domains of the FMBA can be ranked as follows: the Yaoundé domain, the Mbalmayo domain and the Ebolowa domain. It has been reported that the gradient within the benchmark is driven by proximity to one major centre, as well as by village characteristics such as the size of the village, road infrastructure and social infrastructure (Gockowski *et al.*, 1998a).

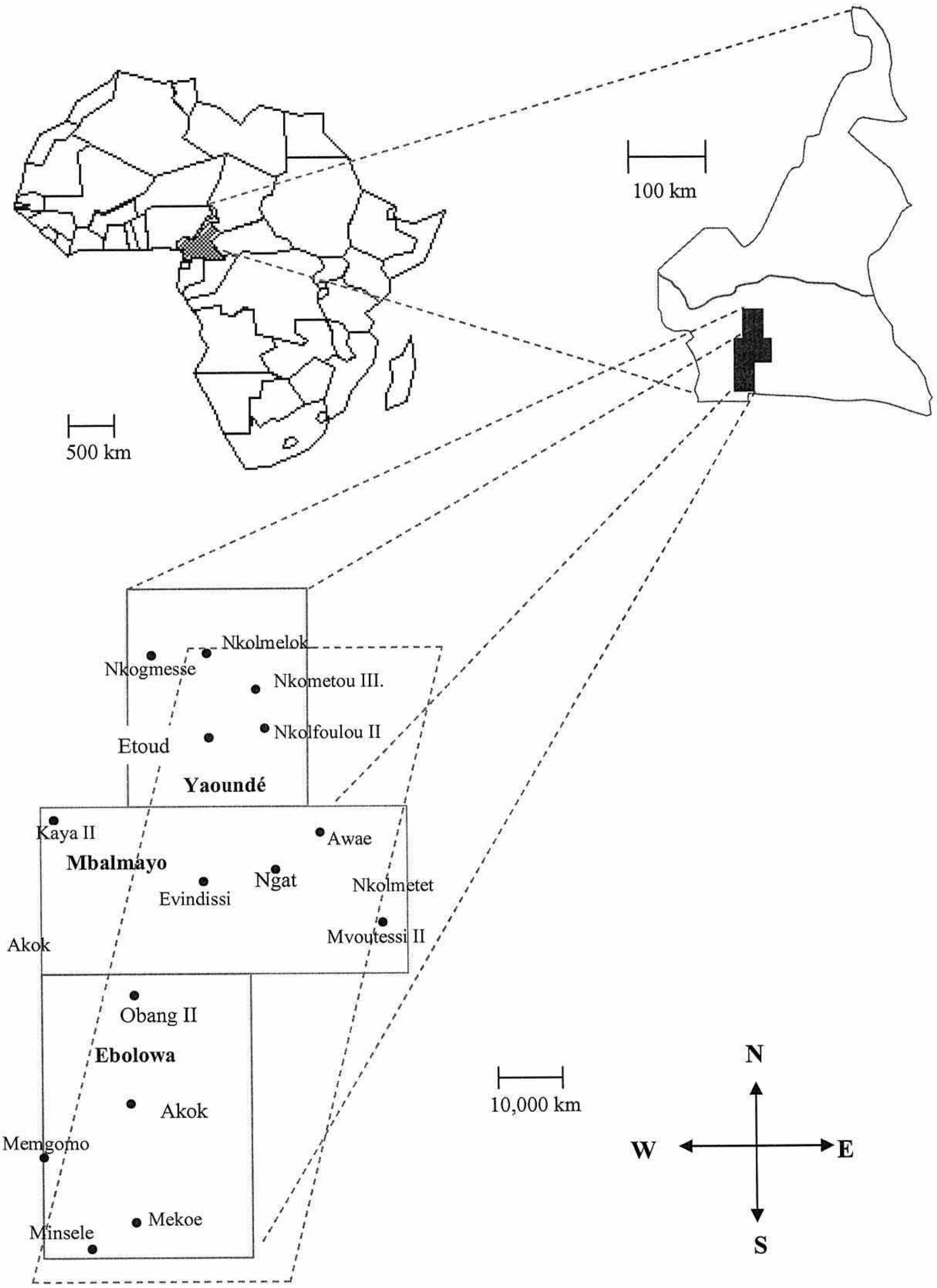


Figure 3.1. The Forest Margins Benchmark Area (FMBA) of southern Cameroon, encompassing three resource domains (Yaoundé, Mbalmayo and Ebolowa).

Table 3.1. Major characteristics of the three resource domains of the FMBA of southern Cameroon.

	Yaoundé area	**Mbalmayo area**	**Ebolowa area**
Mean annual rainfall*	1510	1643	1820
Mean annual temperature (°C)	22°9	25	24°4
Rural population density (inhabitants per km^2)	14-88	10-41	2-15
Mean distance to market (km)	17	20	21
Average fallow duration (years)	3.9	5.4	7.5
Estimated mean annual land cover per household (ha)	1.4	0.9	1.1
Ethnic group	Eton	Ewondo	Bulu

*Ten years average.

Source: Gockowski *et al.* (1998a).

3.2. LANSCAPE, SOILS AND CLIMATE

The research area consists of humid tropical forested landscapes of southern Cameroon, between 420 m (Mbalmayo domain) and 725 m (Yaoundé domain) above sea level. The region is drained by numerous streams and small rivers that flow in small "V"-shaped valleys towards the river Nyong in the Yaoundé and Mbalmayo domains, and towards the river Ntem in the Ebolowa domain (Santoir & Bopda, 1995). Valleys cut into a basement complex formed of micaschiste and gneiss near Yaoundé. In the Mbalmayo and Ebolowa domains, the basement is formed mainly of granite and schist characterized by quartz enclosures.

The red and red-yellow soils in the benchmark area fall mainly into the broad FAO soil class of Orthic Ferrasols that are characteristic of areas with an equatorial climate (Table 3.2). From Yaoundé to Ebolowa, four soil profile classes, with distinctive physico-chemical properties, form a North-South fertility gradient (Gockowski *et al.*, 1998a). In the southern part of the benchmark area, yellow ferralitic soils are more frequent. These fragile soils are acidic with pH mostly less than 4.5, clay content between 10 and 50 per cent, lime content of less than 8 per cent, organic matter around 2 per cent, humus content ranging between 1 and 4 per cent, and a nitrogen level of 0.007 to 1 per cent. These features all indicate poor soil fertility potentials. More frequent in the Yaoundé domain, red soils are close in structure to yellow soils but are less acidic (pH between 5 and 6), less compact and more stable with higher mineral reserves (calcium, magnesium, potassium).

Table 3.2. Soil types of the benchmark research area and their general characteristics

Soil type	**Characteristics**
Orthic Ferrasols (Oxisols-Ustox or Orthox)	Low content of fertilizing elements. Dark red or red-yellow soils.
Rhodic Ferrasols (Oxisols-Eutrustox)	Highest agricultural value of Ferrasols. Dusky-red.
Xanthic Ferrasols (Oxisols-Ustox)	Low base saturation. No mineral reserve. Yellow.
Dystric Nitosols (Ultisols)	Soils of medium value, subject to erosion.
Eutric Nitosols (Alfisols)	High fertility. Among best soils of the tropics.
Ferralitic Arenosols (Psamments)	Lie underneath the savannas of southern Congo-Kinshasa.
Dystric Gleysols (various)	Poorly drained, swamp forest on sandy substratum.
Humic Gleysols (various)	Require considerable agricultural engineering to make suitable for cultivation.

Source: FAO-UNESCO *Soil map of the world: Volume VI. Africa* in Gockowski *et al.* (1998a).

Analytical data presented in this chapter are based on a number of investigations conducted by IRAD and IITA researchers throughout the FMBA, which Tchienkoua & Ambassa-Kiki (1997) have synthesized (Table 3.3). Furthermore, as these studies reported that any impact of land use in the area is mostly limited to the topsoil, only data for this soil depth are presented here. In general, benchmark soils display insufficient levels of organic carbon and total nitrogen, whereas C:N ratio seems adequate for belowground biological activity. With a low effective cation exchange capacity (less than 5 $cmol^{+}\ kg^{-1}$), these soils are reported to present limited ability to retain nutrient cations. Moreover, though having good internal drainage and aeration, benchmark soils do have a very weak macrostructure, which predisposes them to nutrient losses by leaching.

Table 3.3. Analytical results of the 10 cm soil top layer from 6 benchmark villages. (Averages represent 10 samples from each village).

	Yaoundé	area	Mbalmayo	area	Ebolowa	area
	Nkolfoulou II	Nkometou III	Awae	Mvoutessi	Akok	Mengomo
pH (H_2O)	5.4	5.6	5.1	6.4	4.9	5.1
Al saturation (%)	0.04	0.03	0.10	0.01	0.17	0.14
Total N (%)	0.223	0.122	0.169	0.147	0.167	0.191
Total C (%)	3.22	1.46	2.02	1.61	1.91	1.96
C:N ratio	14	12	12	11	12	10
Total P (ppm)	18.7	6.3	10.0	21.4	10.7	9.0
Ca ($cmol^+/kg$)	3.76	2.96	2.73	5.01	2.03	3.62
Mg ($cmol^+/kg$)	2.09	1.44	1.37	1.43	0.99	1.08
K ($cmol^+/kg$)	0.44	0.25	0.34	0.27	0.32	0.30
Al ($cmol^+/kg$)	0.19	0.11	0.47	0.09	0.55	0.53

Source: Tchienkoua & Ambassa-Kiki (1997).

The climate of the benchmark is characterized by two rainy seasons and two dry seasons (with heavy rains). The first long rainy season occurs in March-July, followed by a short dry season, in July-August (Figure 3.2). Occurring in August-November, the short rainy season is followed by a longer dry season from mid-November to mid-March. Although an increasing precipitation gradient has been reported from the northwest to the southeast of the benchmark area, in both resource domains, annual precipitation follows the same bimodal pattern and ranges from 1350 mm to 1900 mm. The bimodal rainfall pattern determines two cropping seasons in the area. Climatic data indicate vegetative growth duration of nearly 295 days per year (Santoir & Bopda, 1995).

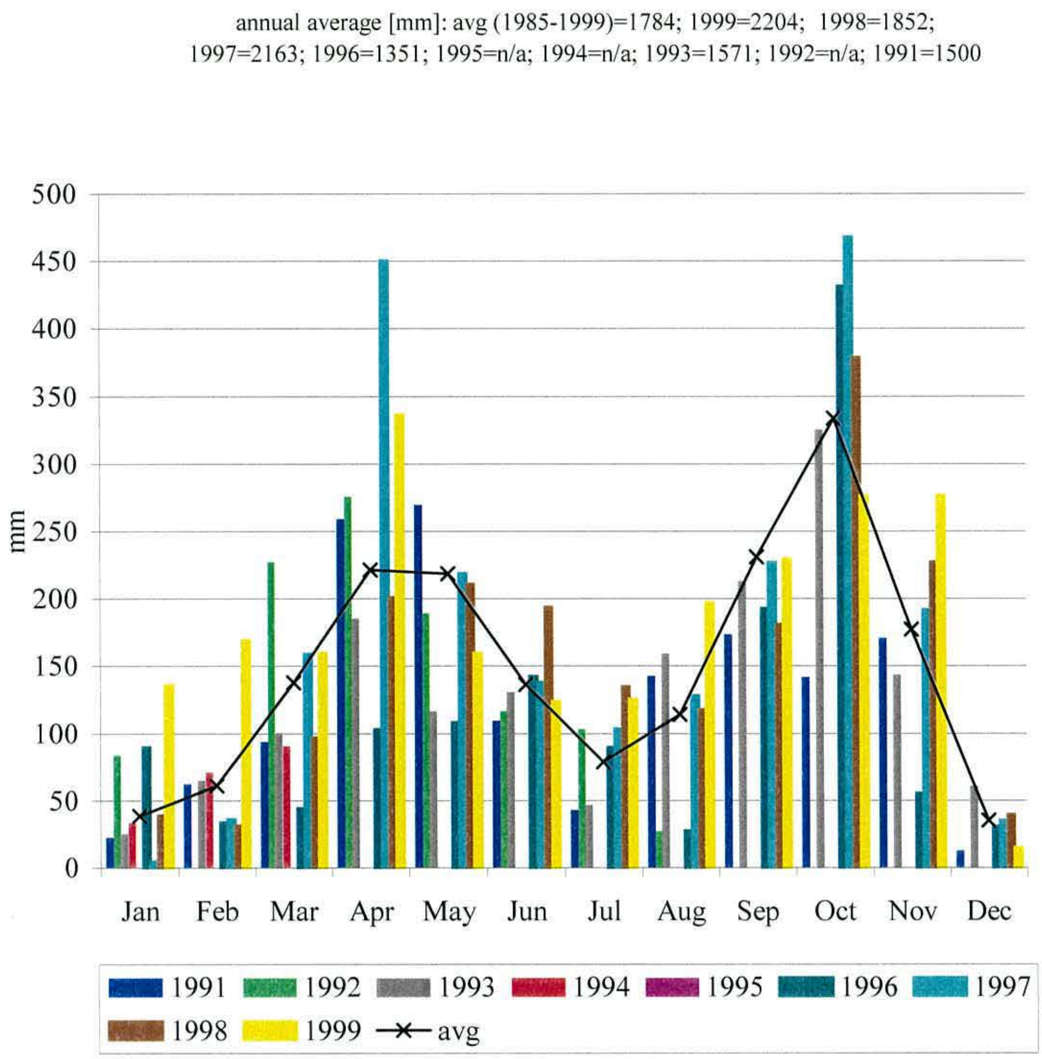


Figure 3.2. Rainfall in Ebolowa - monthly totals (from IITA Monograph, 2000. Data compiled by C. Nolte). n/a=data not available.

In spite of the similarity of the climate features throughout the benchmark area, there are typical specific differences between resource domains. Comparisons of the three domains (Table 3.1) indicate that the Yaoundé domain, with its subtropical climate type, has overall lower annual precipitation. The southern part of the benchmark is characterized by a typical equatorial climate, resulting in overall better rainfall distribution.

3.3. SOCIO-ECONOMIC ENVIRONMENT

The agricultural production of the benchmark area of southern Cameroon is based on manual labour inputs, mainly from family members (Gockowski *et al.*, 1998a). Remote sensing estimates revealed the existence of infrastructural and institutional cross-domain differences within the area. The Yaoundé resource domain, where population densities are higher, has much better developed institutions (e.g. a competitive marketing system) and infrastructures (e.g. higher rural road densities) as compared to Mbalmayo and Ebolowa domains. Rural exodus is also reported to affect labour resources and influence agricultural production methods (Kotto-Samè *et al.*, 2000). Consequently, there has been a tremendous growth in urban populations, which means an increasing number of urban consumers. Among indicators for labour constraints are shorter fallow periods, also reported in areas where land is not limited, as clearing long-duration fallows require more time (Zapfack *et al.*, 2000).

Throughout the benchmark area, the population consists mainly of the Bantu language group whose origin has been traced to what is now the Benué Valley in Nigeria (Russell, 1993). In anthropological studies (Dounias, 1993; Russell, 1993; Diaw, 1997), it is argued that the Bantu were not originally forest dwelling peoples. And, as such, are not really adapted to forest life and brought with them savanna cultivation techniques as they migrated. Thus, the people of the benchmark area possess many common practices that can be linked both to collective ethnic origin and adaptation to forest agriculture. The Bantu population in the study area consists of different ethnic groups belonging to the same linguistic group of Bëti-Fang (Dounias, 1993; Diaw, 1997; van Dijk, 1999). The type of ethnic group differs across domains: the majority of the Yaoundé block is formed by the Eton. The other main ethnic groups are the Ewondo and Bulu, respectively in the Mbalmayo and Ebolowa domains.

Data from the last agricultural census of 1987 estimate the total population of the humid forest zone of Cameroon to be over 5 millions inhabitants, from which 47 per cent live in rural areas (Santoir & Bopda, 1995). However, the Cameroon benchmark area encompasses a reported gradient of population densities (Gockowski *et al.*, 1998a). Yaoundé, Mbalmayo and Ebolowa domains form a North-South population density gradient with 85, 25.5 and 2.7 persons per km^2, respectively. The average size of a household within the area ranges between 5 and 6 persons. In the benchmark area, rural exodus leads to a reduction in the number of producers and to an ageing of local populations, which result in a decline in the available labour force. Both the volume of traders and the volume of products in the most important single market of the benchmark (i.e. Yaoundé) are reported to grow at a rate of about 10 per cent per year (Kotto-Samè *et al.*, 2000).

One of the main problems encountered by small-scale farmers in the benchmark area is that of market opportunities for agricultural products, especially during the rainy season. Most frequently grown crops include plantain (*Musa paradisiaca*), vegetables, cocoyam (*Xanthosoma sagittifolium*), 'wild' fruits, cassava (*Manihot esculenta*) and maize (*Zea mays*). There is significant spatial variation in market access within the benchmark area (Table 3.1). Moreover, transport problems usually induce changes in the number of traders and in the amount of products available for sale. Near the city of Yaoundé, there are indications that food production tends to become an important cash earning enterprise for smallholder agricultural producers (Gockowski *et al.*, 1998b). One indication of this situation is that long-term fallow lands, formerly reserved for the cocoa production, are nowadays used for food crop fields.

3.4. VEGETATION

Most of the benchmark area is covered by dense humid forests, which have been classified by several authors (e.g. Letouzey, 1968). In general, the FMBA has a climax vegetation of two main types. The "dense humid semi-deciduous forest", covering nearly 40,000 km^2, is characteristic of the Yaoundé area and extends southwards into the Mbalmayo domain. The "dense humid Congolese forest", covering 81,000 km^2, reaches the Mbalmayo domain and extends to the Ebolowa domain in the South. In addition to these two types, small patches of the "moist evergreen Atlantic forest" are found along the western border of the Mbalmayo and Ebolowa areas.

The benchmark primary and secondary forests are dominated by numerous tree species, common to all West African regions, such as *Terminalia altissima*, *T.*

superba, *Ceiba pentandra*, *Piptadeniastrum africanum*, *Musanga cecropioides*, *Albizia zygia*, *Alstonia boonei* and *Chlorophora excelsa* (Letouzey, 1968).

In all cropping systems throughout the benchmark, maintenance of soil fertility is achieved mainly through the fallow system (Russell, 1993). In the traditional fallow system, a small plot of forest land was cleared, cropped, harvested and gradually allowed to go into a fallow phase for up to 15-20 years. The development of a secondary forest allowed fertility restoration. However, in some areas of the benchmark, this traditional bush fallowing system is being transformed to a rotational fallow system, especially when population pressures are high (Kotto-Samè *et al.*, 2000). A large plot of forest is cleared with chainsaws and is used in a permanent rotational fallow system in which some perennial useful crops form part of the farming system. Each cropping season, a subplot of the field is prepared for groundnut-cassava-based food fields.

In the benchmark agricultural system, the effectiveness in fertility restoration is determined by several parameters such as the fallow period, the number of previous cropping cycles and the natural soil fertility status (Floret & Pontanier, 2000). Although forest lands controlled by individual farmers are still common in the benchmark, significant differences exist across resource domains in terms of frequency of fallow fields (Table 3.4). Fallow fields of more than five years old are much more common in the Mbalmayo and Ebolowa domains.

Table 3.4. Frequency of fallow land by resource domain in southern Cameroon.

Study area	**Percentage of households**		
	Short-term fallows (< 6 years old) (1)	**Medium-term fallows (6-10 years old)**	**Long-term fallows (> 10 years old)**
Ebolowa	30	70	67
Mbalmayo	25	73	67
Yaoundé	54	45	21
Overall	37	62	51

Source: Gockowski *et al.* (1998a). n = 221 except for (1) where n = 190.

3.5. FARMING SYSTEMS

Throughout the benchmark area, village houses are generally situated near the roads (Kotto-Samè *et al.*, 2000). Imposed by the colonial administration, this organization had made people abandon their scattered hamlets in the forest. Home gardens and cocoa plantations surround village houses. In order to be protected from village livestock (goats, sheep, pigs), food crop fields are established between 2 and 8 km away. However, bush animals are reported to be frequent, resulting in additional labour input for the fencing of fields and the setting of traps.

Though significant differences exist across resource domains, about 25 percent of the total land area is estimated to be in some agricultural use, including fallows (Gockowski *et al.*, 1998a). The predominant cropping system is the groundnut-cassava-based mixed food crop field, which largely guarantees household food security and generates income in regions with good market access (Table 3.5). The next most important cropping system is the cocoa plantation, which represents the largest source of agricultural revenues in the benchmark area. The third most common field system consists of the plantain/banana-based and the melon-based (*esep*) fields, generally targeted to longer duration fallows and secondary forest lands.

Table 3.5. Frequency of different cropping systems by resource domain in southern Cameroon.

Crop field types	Yaoundé area	Mbalmayo area	Ebolowa area	Overall
	------------------	% of households	----------------	
Groundnut-cassava based fields	91	85	91	89
Cocoa plantations	63	74	96	78
Plantain/banana based fields	68	55	85	70
Monocrop systems	74	32	38	48
Melon based fields	27	21	55	33
Home gardens	42	24	33	33

Source: Gockowski *et al.* (1998a).

Input intensive monocrop systems are mostly encountered in the Yaoundé domain, which has the best access to urban markets and the highest labour:land ratio across the benchmark area. Associated with the diversity of cropping systems reported throughout the benchmark are field differentiation and farm size (Table 3.6). The higher field differentiation (more than 5 field types) reported in the Yaoundé domain is in line with the IITA working hypothesis of increased resource use intensification in the benchmark area.

Table 3.6. Field differentiation and estimated mean farm size across the benchmark domains of southern Cameroon.

		Yaoundé area	Mbalmayo area	Ebolowa area
No. of distinct field types:	0-2	4.7	25.5	3.6
	3-4	32.8	47.1	52.7
	5-8	62.5	27.5	43.6
Annual new fallow land converted to farmland (ha)		1.4	0.9	1.1

Source: Gockowski *et al.* (1998a).

Mainly because of the tse-tse fly, cattle raising is not well practiced in the benchmark, whereas free range small stock and poultry production are generally practiced in an extensive fashion (Gockowski *et al.*, 1998a). Significant livestock production (pork and poultry farms) mostly occurs in the urban peripheries of Yaoundé, Mbalmayo and Ebolowa.

3.5.1. Characteristics of land use

The benchmark area can be characterized as a mosaic of different land use systems comprising annual food crop fields, forest fields, fallows and cash crop plantations. As a consequence of the land use intensification process, Weise & Tchamou (1999) reported an increasing abundance of *Chromolaena odorata*-dominated short fallows from the South to the northern part of the benchmark. Remote sensing images also revealed the invasion of *Imperata cylindrica*-dominated grasslands in parts of the Yaoundé resource domain (Kotto-Samè *et al.*, 2000).

Besides considerations of distance and security from bush animals, soil fertility assessment determines where to start a new farm (Kotto-Samè *et al.*, 2000). In general, this "traditional" knowledge of the fertility or sterility species indicators (trees, shrubs and herbs) also influences the proportion of crop mixtures. Reported examples of indicators for good food production conditions include *Alstonia boonei*, *Baillonella toxisperma*, *Ceiba pentandra*, *Ricinodendron heudelotii*, *Terminalia superba*, *Trema orientalis*, *Pennisetum purpureum*, *Aframomum* spp. and *Triumfetta cordifolia*. Whereas species such as *Albizia* spp., *Chlorophora excelsa*, *Cylicodiscus gabonensis*, *Distemonanthus benthamianus*, *Erythrophleum suaveolens*, *Lophira alata*, *Piptadeniastrum africanum* and *Setaria megaphylla* are cited as indicators of bad conditions for food production, though many of them may serve as traditional medicine or timber, and may therefore be preserved in the farm.

3.5.2. Crops and their production

Exploratory surveys carried out within the benchmark area by IRAD and IITA scientists have identified technical and socio-economic constraints that need to be tackled in order to improve agricultural production (Weise & Tiki-Manga, 1995; Gockowski *et al.*, 1998a; Weise & Tchamou, 1999). Major technical constraints for food production include lack of seeds and planting materials, animal damage (at crop establishment and at harvest) and weeds. Whereas socio-economic constraints are mainly lack of transport to markets, labour shortages, especially for weeding, ageing of farm operators, limited extension system and lack of alternative forest food production methods. The largest source of agricultural revenues comes from cocoa agroforests. Additionally, fruit trees planted in cleared lands and harvested (for home use or market sales) during the fallow phase also form a major component of the farming system.

Elaeis guineensis is very popular in the benchmark area, providing wine, oil palm, brooms, baskets or building materials (van Dijk, 1999). Also cited as important parts of the rural farmer's diet and cash earner are avocado pears (*Persea americana*), the bush butter tree (*Dacryodes edulis*) and some "wild" trees used as spice providers (*Tetrapleura tetraptera*, *Monodora myristica*, *Scorodophleus zenkeri*). Although mainly found in cocoa or oil palm plantations, useful trees (wild or planted) are reported to be part of most fallow lands in the traditional agricultural system (Zapfack *et al.*, 2000).

The most important food crop is cassava, the chief starch source, which provides about 29% of the total calories produced (Kotto-Samè *et al.*, 2000). In villages, small cassava-dominated crop fields are common. About one dozen varieties of cassava, mostly sweet, are planted in a mixed food crop system. In addition to boiled edible tubers, cassava leaves are also an important vegetable food. The second major crops are groundnuts, the dominant source of plant protein (about one quarter of the total amount) and ingredients of nearly all local dishes in the area (Gockowski *et al.*, 1998a). Other major crops in the benchmark are plantain, maize, cocoyams, and leafy vegetables, which are consumed at almost every meal. Plantains provide about 13% of the total calories and are followed by palm-oil (11%), sweet banana (*Musa sapientum*: 5.2%), groundnuts (3.1%) and cocoyams (1.7%).

In general, rural farmers of the benchmark area practice a system of slash-and-burn agriculture (Weise & Tchamou, 1999). The traditional cropping sequence starts with the clearing of young and adult secondary forests. One to two months after this activity, the dried material is burnt, leaving larger trunks (stumps) and branches in the field. This forest field, locally called *esep* (or *ngon*), is then planted to a sole crop of plantain or intercropped with *egusi* melon (*Cucumeropsis mannii*) and cocoyam, which are harvested after about one year. The melon covers the felled trees which, during the growing period, start to decay and the roots decompose.

In the second year, re-growth is slashed, burnt and a groundnut-cassava-based field (called *afub owondo*) is planted in association with maize, plantain, cocoyam and a variety of leafy vegetables. A light hand-weeding is often necessary at about seven weeks later. Three to four months after planting, groundnut and maize are harvested. This pass over the field with a hoe also serves as a second weeding. Cassava, cocoyam and plantain remain in the field and are continuously harvested for a longer period if soil fertility is high, and if pest and disease problems are low. The field is then gradually allowed to fallow, and in the traditional agricultural system, a new forest plot would be prepared for another *esep* field. In the FMBA of Cameroon, the majority of rural households are reported to clear and plant two groundnut-based fields each year (Gockowski *et al.*, 1998a). The first is established in mid-March, and the second in September.

Cocoa plantation is the second most common cropping system, grown by nearly 78 percent of rural households in the benchmark area (Gockowski *et al.*, 1998a). The incidence of this cropping system is reported to be highest in the Ebolowa resource domain (96% of farm households), followed by the Mbalmayo (74%) and Yaoundé (63%) domains. Using slash-and-burn techniques, young cocoa plants are commonly grown in association with plantain (*Musa paradisiaca*), which serves as shade crop (Kotto-Samè *et al.*, 2000). Also found in the cocoa plantation are some food crops (mainly groundnuts and maize) and high value forest trees used for food, medicine, construction or timber (Ndoye, 1995). However, since the downturn of the late 1980s in Cameroon, there has been little new planting of cocoa, and most cocoa plantations are getting old (25 years-old or more).

3.6. LAND PREPARATION AND PLANTING

Planned in relation to the dry season (January-March for the first cropping season, July-August for the second), land preparation is a combination of many operations, which include cutting, burning and clearing; activities determining the production potentials of the field (de Rouw, 1995). Only for the *esep* field where the use of chain-saws reduces labour input, land preparation operations throughout the benchmark area are manual.

Considered male work in the benchmark area, cutting of the under storey trees, herbs, saplings, vines and small trees is done using a cutlass with a single edged blade of about 50 cm long and 5 cm wide. Trees are cut close to the ground to reduce coppice growth and to make human movement in the stand easier. However, depending on the type of fallow cleared (forest, long fallow, bush fallow or *C. odorata*-dominated fallow), this activity takes between 7 to 12 person-days per hectare (de Rouw, 1995). In addition, the resulting wood is usually cut to small pieces to allow better drying. Women who cannot rely on male family labour (often widowed or divorced), may recruit a man, especially to slash the large trees (Russell, 1993). The labour input for clearing *Chromolaena odorata*-dominated fallows is reported to be less demanding and may therefore be done by women (Weise, 1995).

However, some trees are left standing in the field because their cutting is not found worth the considerable labour required (Carrière *et al.*, 2002). These trees are usually left standing because they have extremely hard wood (*Erythrophleum ivorense*, *Lophira alata*), large buttresses (*Ceiba pentandra*, *Piptadeniastrum africanum*), or because their poorly developed crown (or high crown) makes them harmless to the crop (such as *Diospyros* spp.). Some trees may be retained for their usefulness (wild fruit trees or "religious" trees). On the contrary, some "noxious" trees have to be cut and well burnt for they are reported to seriously damage the crop if surviving in the field, because of their vigorous coppice growth or because they may attract animals feeding on planted crops. These include *Alchornea cordifolia* and Sterculiaceae in general, except for *Cola* spp. trees preserved for their edible seeds.

Generally done by men at the end of the dry season (February-March, or July-August), burning has always been an important and defining factor of the agricultural system in the tropics (Nye & Greenland, 1960; Ruthenberg, 1980; Akobundu *et al.*, 1999). Numerous studies conducted in forest areas have demonstrated that burning is necessary for its many beneficial effects on agricultural production. It cleans the field and eliminates many weed seeds, thus reducing weed pressure. It softens the topsoil making it more friable, and the ashes fertilize the soil (de Rouw, 1995). However, the success of the burn is largely dependent on the correct timing of cutting activities, proper judgment of the weather conditions and adequate fire techniques. In the benchmark area, re-burning is not considered worth the trouble, mainly because of the approach of the rainy season.

Essentially manual, cleaning is done by both men and women. Un-burnt debris (logs and stumps) are torn out by hand and removed to the edge of the field. This operation tills the soil and further tillage with a hoe is only done for planting. Mostly done at the same time as tillage with a hoe, planting is nearly always accomplished by women and it is considered throughout tropical Africa as the most tedious work in cultivation (de Rouw, 1995).

In the traditional groundnut-based field, groundnut is the sole crop and is planted, in every square metre of suitable ground area. Other crops are then added to the field, cultivated simultaneously (maize) or in a relayed fashion (cassava). Seeds and cassava cuttings from farmer's own farm are commonly used (Russell, 1993). However, in some regions of the benchmark, a number of varieties are also bought from other farmers or in markets.

CHAPTER IV

TYPOLOGY AND AGRICULTURAL USES OF FALLOW SYSTEMS IN SOUTHERN CAMEROON

4.1. INTRODUCTION

In the humid forest zone of southern Cameroon, an increasing population associated with improved market access has led, over the past two decades, to noticeable shifts in the slash-and-burn cropping system (Weise & Tchamou, 1999). Characterised by land shortages, the new system is mainly based upon fallows of shortening length. In order to achieve a subsistence crop production without increasing the labour input, local small-scale farmers clear an increasing number of new forest lands, thus putting additional pressure on the forest margins (Gockowski *et al.*, 1998a). Approximately 3.3% of the total area is annually cleared and brought into food crop production.

Previous land-use studies have provided an extensive database on the characteristics of the traditional farming systems among the shifting cultivators of southern Cameroon (Gockowski *et al.*, 1998a; Kotto-Samè *et al.*, 2000). However, information documenting specifically local farmers' nomenclature of the fallow systems is scarce or not available. Reported land use studies all used a "researcher-led" typology of fallows based on various criteria. For instance, Russell (1993), Diaw (1997), Gockowski *et al.* (1998b) and Carrière *et al.* (2002), based on the fallow length, distinguished short fallows (of less than 4 years old), medium fallows (aged from 5 to 10 years) and long fallows (of more than 10 years old). Zapfack *et al.* (2000) adopted a typology based both on the length and the main vegetation type of the fallow, whereas Gillison (2000) used instead an index (the "V" index) computed from a multidimensional scaling analysis of vegetation elements affected by the distribution of some environmental variables.

By using a "bottom-up" participatory approach, this part of the study aimed to provide the current farmers' perspectives of fallow systems throughout southern Cameroon. The specific objectives were:

- to describe the local indigenous classification(s) of fallow systems across the study sites;
- to assess the geographical distribution and abundance of fallow classes within the study zone;
- and to determine the current traditional agricultural uses and constraints associated with each fallow class.

4.2. METHODOLOGY: VILLAGE SURVEYS

A total of 15 villages were surveyed from January to April 1999. The research methods used on all sites followed a common strategy, the "Participatory Rural Appraisal" (PRA), as defined by Biggs (1989). Increasingly used in agricultural research and land use studies, PRA, by paying more attention to farmers' opinions, aims to make use of their indigenous experience (Chambers *et al.*, 1989). To achieve greater uptake of viable resource management technologies, land-use studies using a participatory approach have been recommended since the 1980s. This approach, also termed "bottom-up participatory approach" (Goma *et al.*, 2001), has been found to benefit all stakeholders and the environment.

The term "fallow", as used in this study, was defined as "a field making full part of the agricultural system of a farm and that is not cultivated for a determined period, as part of a rotational soil fertility management system" (de Wolf *et al.*, 2000). Therefore, this definition excluded (1) fields not cropped for more than 15 years and for which the farmer has no intention of cropping in the foreseeable future, (2) previously cropped fields that have been abandoned for more than 15 years (these were considered as secondary forests), and (3) lawns around the houses. On the contrary, this definition included fields planted on waterlogged soils. Additionally, as already suggested by Gillison (2000) and Zapfack *et al.* (2000), attention was paid to differences that may occur among fallow fields in terms of their dominant vegetation type.

In each study site, a PRA was carried out among a group of 15-20 participants. The group comprised members of the local community aged 21 and over, with at least four females (in an inclusive process). The chief of the community arranged the constitution of the group some days before the meeting. Group discussions were all held in the afternoon and, in general, approximately two hours were sufficient. All interviews were conducted in the local language.

The PRA took the form of a relaxed semi-structured interview as described by Biggs (1989). In this type of interviews, a fixed-length questionnaire is used, where questions are not open-ended but have a limited range of possible responses (Appendix 4.1). Classical PRA tools (diagrams, ranking and scoring) were used. When clarification was necessary, two or three individual farmers were visited for more in-depth discussions.

The first part of the appraisal investigated the local typology of natural fallows and the determinant(s) of the classification. In the second part, each resulted fallow class was characterised, outlining its dominant vegetation type, its geographic distribution and abundance across the site, its main agricultural uses and the three most important constraints to its management as perceived by farmers.

4.3. RESULTS

4.3.1. Indigenous typology of fallows in southern Cameroon

Four distinct fallow typologies (or classifications) were recorded across the study sites. While the simplest classifications including only two or three fallow types were recorded in about 73 percent of the study area, two typologies with respectively four and five fallow classes were reported in four villages (Table 4.1).

The typology with three fallow classes was the most common (reported in 60 percent of the study villages). The main criterion used for classification was the fallow duration or length. Based on the age since abandonment, farmers distinguished short-term fallows (of less than 6 years old), medium-term fallows (of 6 to 10 years old) and long-term fallows (of 10-15 years old).

Table 4.1. Frequency distribution of fallow typologies within the humid forest zone of southern Cameroon

Number of fallow classes	Number of sites reporting the typology	Frequency of presence (in % of total number of study sites)
2	2	13.3
3	9	60.0
4	3	20.0
5	1	6.7

Although the fallow age was used as the main criterion of classification across all sites, in the village Nkongmesse (Yaoundé area), a second criterion was mentioned. Respondents, particularly elders, also categorised fallow systems based on the soil colour, distinguishing yellow soil fallows from red soil fallows.

Farmers' indicator of the fallow duration across the study sites was the main vegetation type of the fallow. Hence, the Asteraceae species *Chromolaena odorata* (locally named *nkodengui* or *dongmo*) was considered to characterise short-term fallows (of less than 6 years old), whereas secondary forest pioneer trees were reported to dominate fallow lands of 7 to 15 years old.

The indigenous typology of fallow systems appeared to be commonly used and recognized by the entire community. In relation to their geographic location, local farmers designated fallow classes by various names that often referred to a particular plant species or group of species dominant in fallow lands of the considered class. For example, *ekorók m'esseng* was used in the Mbalmayo area to designate medium-term fallows (of 6 to 10 years old) dominated by the species *Musanga cecropioides* (Cecropiaceae).

4.3.2. Distribution and abundance of fallow classes across the FMBA

The importance of the three main fallow classes did vary over the three study resource domains (Table 4.2). Long-term fallows were less important than medium or short-term fallows in all areas, covering 2 to 23% of the overall area under fallow, against 34-55% and 29-45%, respectively.

Table 4.2. Frequency of presence of the three fallow classes across the FMBA (southern Cameroon)

Resource domain	Proportion (%) of sample area under fallow (over all fallow farms)		
	Short-term fallows (< 6 years old)	**Medium-term fallows (6-10 years old)**	**Long-term fallows (10-15 years old)**
Ebolowa	34	45	21
Mbalmayo	48	29	23
Yaoundé	55	43	2
Overall	45.7	39.0	15.3

Between-areas comparisons of the distribution show that in the Ebolowa area, fallows of 6 to 10 years old were more important (45%) than short or medium-term fallows, whereas the Mbalmayo and Yaoundé domains were dominated by the short-term fallow system (48 and 55%, respectively).

4.3.3. Indigenous agricultural uses of fallows

Both food crop farming (FCF) and perennial crop plantations (PCP) were found to be common agricultural uses of fallows across the study sites. However, farmers' preferences for FCF or PCP in the management of each fallow class did vary over the three areas (Table 4.3). Across the whole study zone, more than 80% of short-term fallows were preferably cleared for the establishment of FCF while only 9 to 17% were cleared and adapted to PCP.

Similarly, farmers expressed their preference to establish FCF on medium-term fallow lands (more than 60% of farm area under this fallow class), especially in the Ebolowa and Mbalmayo areas. Over these two areas, farmers reported equal use of long-term fallow lands for the establishment of FCF and PCP, whereas in the Yaoundé area, this fallow system was mostly related to perennial crop production.

Table 4.3. Proportion of fallow lands cleared for the establishment of FCF (food crop farming) or PCP (perennial crop plantations) across the FMBA (southern Cameroon)

		Proportion (%) of fallow area used (over all fallow lands)		
Resource domain		**Short-term fallows (< 6 years old)**	**Medium-term fallows (6 to 10 years old)**	**Long-term fallows (> 10 years old)**
Ebolowa	FCF	90.5	80	45
	PCP	9.5	20	55
Mbalmayo	FCF	88	75	53
	PCP	12	25	47
Yaoundé	FCF	83	65	63
	PCP	17	35	24*

*An additional 13% is used for horticulture.

4.3.4. Known constraints to the agricultural uses of fallows by local communities

It was revealed that farmers' problems associated with the agricultural management of fallow systems vary with respect to the fallow class considered (Table 4.4). Over the whole study zone, farmers considered weed incidence as their major constraint to the agricultural use of short-term fallow lands though in the Yaoundé area, low soil fertility was also considered as equally important.

More specifically, farmers consistently mentioned the invasion of *Chromolaena odorata* in crop fields established on short fallows and the resulting labour increase as important threats to sustainable food crop production.

Table 4.4. Ranking of major constraints to the agricultural uses of fallows across the study areas (southern Cameroon)*

Problem Categories	Short-term fallows (< 6 years old)			Medium-term fallows (6-10 years old)			Long-term fallows (>10 years old)		
	Ebol.	**Mbal.**	**Yaou.**	**Ebol.**	**Mbal.**	**Yaou.**	**Ebol.**	**Mbal.**	**Yaou.**
Weeds	1	1	1		2	1			2
Land preparation	2			1	1	2	1	1	1
Rodents	3	2	3	2	3		2	3	
Ants			2			3	3	2	3
Poor soil fertility		3							
Pests				3					

Other important constraints associated with the use of short-term fallows were wild animals (mostly rodents and ants) attacks and low soil fertility. In most villages, respondents listed the giant Gambian rat, *Cricetomys gambianus* (*kossi*), the brush-tailed Porcupine, *Atherurur africanus* (*ngom*) and the cane rat, *Protoxerus stangeri* (*mvok*) as the most noxious rodents in crop fields established on short fallows. The most damageable ants invading food crop fields in the short fallow system were designated *kamisi*, the red ants.

Throughout the study zone, farmers invariably ranked difficult land preparation before cropping and animals' attacks as the predominant constraints to the agricultural use of medium-term fallows. However, though the incidence of *C. odorata* was less important, weed problems were still mentioned among the major constraints to the management of medium-term fallows. Long-term fallows were invariably said to be difficult to clear (before cropping) and more preferrably attacked by rodents and ants.

4.4. DISCUSSION

4.4.1. Indigenous typology of fallows

The people of the humid forest zone of southern Cameroon were able to classify natural fallow systems present in their environment. The number of typologies or classifications obtained could be explained by the existing contrast between the study sites in terms of resource use intensity (see Chapter 3, Table 3.1).

The sites (Etoud and Nkolmelok) which reported a typology of 2 fallow classes belong to the Yaoundé resource domain, characterised by a high resource use intensity associated with high population densities and land shortages (Gockowski *et al.*, 1998a). On the contrary, the typologies with 4 and 5 fallow classes were recorded in villages (Mekoe, Mengomo and Obang II) of the Ebolowa area, where low population densities and poor market access lead to lower pressure on land, and could explain farmers' ability to build a more complex fallow nomenclature.

Farmers of the study zone generally distinguished three main fallow classes based on the fallow length. Thus, short-term fallow lands of less than 6 years old were clearly distinguished from medium-term fallows (of 6 to 10 years old) and long-term fallows (of more than 10 years old). This indigenous classification of fallows concurs with the "scientific" fallow typology found in various reports of research works conducted in the region (Russell, 1993; Diaw, 1997; Gockowski *et al.*, 1998a; Weise & Tchamou, 1999; van Dijk, 1999; Nkamleu *et al.*, 2000; Carrière *et al.*, 2002).

Another interesting revelation of this study was the use of soil colour as a second criterion of classification of fallow systems by local people. Although only reported by farmers in one site (Nkongmesse), de Wolf *et al.* (2000) have already mentioned the use of this criterion by farmers in western Kenya where soil colour was associated to the fallow land fertility potentials (red soils being assumed to be more fertile than yellow soils).

4.4.2. Distribution and abundance of fallow classes across the study areas

The distribution and abundance of the three defined fallow classes across the three resource domains (Ebolowa, Mbalmayo and Yaoundé) tends to follow the South-North increasing gradient of population, market access and resource use intensity reported in the region. This effect of resource use intensity was particularly evident on the availability and distribution of short and long-term fallows.

Short fallows were found to be most abundant in more intensified sites (of the Yaoundé area) where long-term fallows were almost absent. In fact, it is argued that the intensification process, by affecting the farm size, has an impact on the availability of fallow lands in an area (de Wolf *et al.*, 2000). The mean farm size is reported to be higher in the Yaoundé area than in the Ebolowa or Mbalmayo areas (Gockowski *et al.*, 1998a).

However, though the intensification process may explain the abundance of short fallows and the scarcity of long fallows in the Yaoundé area, it does not explain why medium-term fallows are still important (43% of the overall fallow lands) and more abundant in that area as compared to the Mbalmayo domain (29%) where the resource use intensity is lower. The heterogeneity of fallow class distribution and abundance across villages might be one explanation to this situation. For instance, the villages Etoud and Nkolfoulou II stood out of the general trend reported in the Yaoundé area where long fallows were presumed to be scarce. In these sites, medium-term fallows were reported to occupy nearly 50% of overall fallow lands of the area, contrasting with the average 33% recorded in the other three sites of the domain. These figures could be related either to an uncommonly low population density (case of Nkolfoulou II, which population density is about 38 inhabitants per km^2) or to a poor market access (case of Etoud, which is however only 18 km from the nearest market) due to a hilly terrain (Gockowski *et al.*, 1998a).

In contrast with the pattern reported by Baker and Dvorak (1993) *in* Gockowski *et al.* (1998a) who found a significant difference between the Ebolowa and Mbalmayo areas with respect to the distribution pattern of long-term fallows, this study showed that about 22% of overall fallow lands in both areas belong to this fallow class. Similarly, this study shows a fallow distribution pattern contrasting the one reported by Gockowski *et al.* (1998b) and presented in Chapter 3 (Table 3.4). However, these apparent contrasting figures could simply be attributed to the sampling unit used for each study. Whereas figures of this study are expressed as percentages of total farm area under fallow (for farms under fallow only), these studies reported instead percentages of households managing fallows in each fallow class.

Another possible factor determining the abundance and distribution of fallow classes across the study areas is ethnicity. The Eton people inhabit the Yaoundé area where long fallows are scarce, whereas Bulu and Ewondo ethnic groups, less dynamic, inhabit respectively the Ebolowa and Mbalmayo domains (Diaw, 1997). De Wolf *et al.* (2000) also found possible links between the presence of fallows and ethnicity in western Kenya.

4.4.3. Indigenous agricultural use of fallows

This study shows that farmers of the humid forest zone of southern Cameroon generally adapt specific cropping systems to fallow lands of specific age. Overall, it appeared that food crop fields (mainly groundnut-based) were targeted to short-term fallow systems of 2 to 6 years old. This finding concurs with the reported work of Gockowski *et al.* (1998a) conducted in the region who indicated that the farmers' decision to have food crop fields mainly on short fallows was due to the rapidly increasing labour requirement for clearing as fallow period lengthens.

In the Ebolowa and Mbalmayo domains where medium-term fallows (of 6 to 10 years old) are still important, these land use systems are also adapted to food crop fields, though to a lesser extent compared to short fallows. It also appeared that farmers in the Yaoundé area adapted a higher proportion of medium fallows to perennial crop production as compared to farmers in the less intensified Ebolowa and Mbalmayo areas.

This situation is likely to be due to the scarcity of long fallow lands in the Yaoundé area because normally, farmers do prefer to establish perennial tree crop plantations in long fallows in order to capture the fertility rent (Kotto-Samè *et al.*, 2000). This hypothesis was clearly supported by the figures recorded in the Yaoundé area where the proportion of long fallows under perennial crop farms was higher than the proportion of fallows of that class targeted to food crop fields.

Surprisingly, in the Ebolowa and Mbalmayo areas, although long-term fallow lands were more available, they were almost equally used for both food crop fields and perennial cropping, thus contrasting the above hypothesis. This suggests that in these areas, although farmers preferably establish perennial tree crop farms on long fallows, they also commonly adapt this cropping system to short fallow. A reason for this practice could be the reported decline in cocoa profitability and the reduced foreign exchange earnings that occurred in the last decade, and which has induced farmers in Ebolowa and Mbalmayo areas (the biggest cocoa producers of the country) to shift from cocoa systems to long fallow-intercrop rotations targeting the production of *Cucumeropsis mannii* (Kotto-Samè *et al.*, 2000).

In the Yaoundé area, nearly 13% of long fallows were used for monoculture, particularly of tomatoes. With gross revenues believed to surpass $ 2 000 ha^{-1} in one season (Kotto-Samè *et al.*, 2000), farmers in the Yaoundé area preferably practice high value horticulture on long fallows, though scarce, in order to capture the fertility rent. This cropping system, which primarily targets commercial goals, has already been mentioned in the area by Gockowski *et al.* (1998a). These authors mainly associated this cropping system with short-fallow intercrop systems, with inorganic fertilizer often applied.

The importance of horticultural cropping, basically in the Yaoundé area, has been related to the fact that its profitability requires good market access for the input supply (Kotto-Samè *et al.*, 2000). Therefore, poor market access limits the extent of these monoculture systems in remote villages of the Ebolowa and Mbalmayo resource domains. An analogous diversification of agriculture in the humid forest region has occurred in Côte d'Ivoire and Ghana, particularly in areas with regular and reliable market access.

4.4.4. Constraints to the agricultural uses of fallows by local communities

In all study sites, weed problems were considered the major constraint to sustainable agricultural management of fallow lands of various ages. However, as already noted by Weise & Tchamou (1999), the importance of their incidence declines as fallow length increases. Rodent and ant attacks were also reported as serious constraints in short fallow systems, followed by problems related to soil fertility or the resulting yield decline. Most important in the Yaoundé area, soil fertility problems were also reported by Gockowski *et al.* (1998a) who linked it to the high resource use intensity noticed in the area.

The incidence of weeds was still high in medium-term fallow systems. However, as previously reported by Weise & Tchamou (1999) and by Zapfack *et al.* (2000), farmers indicated a clear difference between short and medium fallow systems with respect to the weed community composition. Whereas short fallow systems were found dominated by *C. odorata*, forest re-growth plants, such as *Trema orientalis*, dominated medium fallow systems.

Although weeds still represent the major problem in medium-term fallow systems for farmers of the Yaoundé area, respondents in the Ebolowa and Mbalmayo areas showed a greater concern about land preparation. This behavioural difference may confirm the uneven distribution of labour availability noticed by Gockowski *et al.* (1998a) across the three resource domains, the Yaoundé area displaying the highest labour-land ratio.

Of the main problem categories associated with the agricultural management of long fallow systems, land preparation was the most frequently cited by farmers of the study region. This finding is in line with the hypothesis that longer fallows require greater labour when clearing before cropping.

4.5. CONCLUSION

Overall, it can be concluded that this study gave some insights into the way farmers of the humid forest zone of southern Cameroon perceive their fallow systems, confirming the extensive knowledge they have of their environment, which was already acknowledged by numerous authors (Dounias, 1993; Russell, 1993; Diaw, 1997).

The village communities of the study zone, using a common criterion (the fallow duration), were able to distinguish short, medium and long fallow systems as well as the characteristics and constraints associated with their agricultural management.

Despite the small sample size of the study, the local nomenclature of fallows reported here is assumed to offer a realistic picture of these land use systems.

Farmers' local typology of fallows should be recognized and integrated in all approaches designed to study these important elements of the farming environment. Not only does it enhance the trust-building process involving researchers and local communities, but the indigenous fallow typology also gives valuable insights into the way farmers perceive their changing environment (Landais, 1998).

However, indigenous typologies present some limitations. For instance, Landais (1998) argued that the quality of a typology produced depends on the quality of the way in which the PRA is applied. Therefore, before use, the gathered information should be sufficiently backed by references derived from on-farm studies. Furthermore, because of the perpetual changing farming characteristics, fallow typologies need to be regularly up-dated.

CHAPTER V

USEFUL PLANTS OF FALLOW SYSTEMS IN SOUTHERN CAMEROON

5.1. INTRODUCTION

Numerous functions of fallows for small-scale farmers in the tropics, particularly from an ecological and agronomic point of view, have been outlined in several studies (e.g. Nye & Greenland, 1960; Ruthenberg, 1980; Dounias, 1993; Floret & Pontanier, 2000; Kotto-Samè *et al.*, 2000; Carrière *et al.*, 2002). Ecologically, traditional fallows protect the soil from erosion, restore soil fertility (thus preventing yield decline), reduce weed pressure on-fields and provide habitat for beneficial fauna. Fallows also play an essential part in the social management of land. In the traditional agricultural system, fallow duration represents the multi-purpose production history and memory of the community.

Due to the loss and degradation of tropical forests, and because of the greater proportion of agricultural area under fallow, the importance of fallow systems as sources of non-timber forest products (NTFPs) is also increasingly acknowledged (Brocklesby & Ambrose-Oji, 1997; Floret & Pontanier, 2000). For peasant farmers, fallows provide a wide variety of useful products including timber, firewood, construction materials, fruit, traditional medicines and other non-timber products. Recognition of such benefits has renewed interest in classical works on shifting cultivation (Ruthenberg, 1980) and prompted research that pays particular attention to the fallow phase of shifting cultivation or slash-and-burn systems (Irvine, 1961; Dvořàk, 1993). Fallows are therefore increasingly being described as productive lands which, if necessary, may develop into types of agroforest (Mauray *et al.*, 2002a). These fallow agroforestry systems are considered as potential models for enhancing sustainable rural development among small landholders in the humid tropics. Moreover, increasing the productivity and performance of shortened fallow systems is imperative in areas where the traditional long-fallowing farming system is no longer feasible (Mauray *et al.*, 2002a).

However, few quantitative studies have been dedicated to the understanding of the functioning of natural fallows, especially of short duration, as suppliers of non-timber products for rural households in the humid forest zone of southern Cameroon. In fact, fallow lands, as NTFPs suppliers, have so far received low priority in national land use and conservation policies. Moreover, the extent to which the resource use intensification process reported in the region (Kotto-Samè *et al.*, 2000) has also affected the social (or ethnobotanical) function of these agroecosystems has not been determined. NTFP inventories in the forest zone have mainly focused on useful products collected from forests (secondary and primary forests). Among the few studies dedicated to the utilization of plants collected in anthropogenic land use systems, are published reports on cocoa and coffee agroforests, on cultivated sites near houses, gardens and courtyards (Ndoye, 1995; Tchatat, 1996; Carrière, 1999; van Dijk, 1999; Dounias *et al.*, 2000; Leakey & Tchoundjeu, 2001). Except for the works of van Dijk (1999) and Zapfack *et al.* (2000), little quantitative information is available on the potential of natural fallow lands as NTFP suppliers in the humid forest zone of southern Cameroon. Farmers' utilization of fallow plants associated with the traditional fallow typology in the study zone is still scarce.

The study aimed to ascertain whether differences in resource use intensification in the humid forest zone of southern Cameroon were reflected in the type, distribution and abundance of plant species that local farmers value (economically, socially or in some other ways) across different fallow classes. Of specific interest was local farmers' identification of key useful fallow species and their various uses.

It was hypothesized that different fallow classes would provide different useful plant products, long fallows being expected to provide more NTFPs than other fallow classes. It was also hypothesized that farmers' preferences for particular useful plants would vary across the study zone.

Specific research questions included:

- Which plant species commonly used are collected in fallow lands of the study area?
- To what extent does the shortening of fallow duration affect the availability of these resources?

This work presented a rare opportunity to get some insight into farmers' indigenous knowledge, and the expected results may be relevant not only to scientists working on tropical fallow agricultural systems but more broadly to those seeking to evaluate these anthropogenic land use systems as non-timber products suppliers. Farmers' knowledge of useful fallow products in the humid forest region of southern Cameroon would be important in selecting key productive fallow species. It will also allow the identification of plant attributes that might be sensitive to management intended to benefit local communities, or merit management in their own ecological right (i.e. endangered species). Additionally, farmers' knowledge will be important in detecting long-term ecological changes which might need attention.

Moreover, the integration of trees into the short fallow system, if managed properly, may improve fallow productivity and farmers' welfare as well as relieve pressure on forests and woodlands for fuelwood, thereby helping to reduce the rate of deforestation and to ameliorate related environmental problems such as soil erosion (de Rouw, 1991). In the long term, this study, by contributing to the socio-economic (and ethnobotanical) assessment of useful fallow plants, aims to propose concrete recommendations for the integration of shortened fallow systems in sustainable resources management technologies and practices.

5.2. METHODOLOGY

5.2.1. Study sites

This phase of the project was conducted in the fifteen villages selected in three resource use domains of the humid forest zone of southern Cameroon: the Yaoundé, Mbalmayo and Ebolowa areas (Chapter 3).

5.2.2. Group interviews

To gather information on key fallow useful species, we adopted the common local farmers' typology of three fallow classes (Chapter 4): fallow lands of less than 6 years old, of 6 to 10 years old and of more than 10 years old, which thereafter, will be referred to as short fallows, medium-term fallows and long fallows respectively. Semi-structured interviews were undertaken with 15-20 people in each sample village.

In the interviews, farmers were asked the local name of useful fallow species, its actual (or potential) use(s) to local farmers, and its availability in each fallow class of the site. A checklist of these issues is attached in Appendix 4.1. For each fallow class, the question, 'which species (and for which use category) do you collect from fallow lands?' was asked to the respondents. A number of plant species were first listed, which were then recorded by the interviewers (using local names).

Afterwards, the ten most useful species from the list given were ranked by decreasing order of importance. The participants critically assessed the listing and the ranking and when they were satisfied with the results, the uses of the listed species were determined. The participants were also asked to choose within a fixed list of use categories, which included food or drink products, fuelwood, construction materials (or household equipment), wrapping materials and traditional medicines. Additionally, for each species, the plant parts used were chosen from a list including leaves, fruits, grains, bark, exudates and roots, and recorded. The PRA method included a scoring procedure to assess the relative importance of listed plants within the community (in terms of frequency of use and frequency of presence). The scoring was done by respondents using a 3-level scale for each parameter (frequency of presence in the fallow class and frequency of use of the plant). The species local names given by the informants were clarified and later translated to scientific names.

5.2.3. Data analyses

Scientific names corresponding to local names were identified as far as possible (using available literature - e.g. Zapfack *et al.*, 2000; van Dijk, 1999 – and on-field collection of specimen for species identification by botanical experts at the Yaoundé National Herbarium). However, the identification of some plants was either not fully reliable or not possible. Sometimes, the available literature on useful plants studied in south Cameroon that we consulted (Aubréville, 1947) gave, in several cases, scientific names that differed from the names recorded during this study for the same local name. In such cases, a further trip to the targeted village was organized to collect some specimen for identification by botanical experts.

For the overall tabulation of useful fallow species recorded across the study sites, all species listed during group interviews were considered, including species whose scientific names could not be determined consistently. Resource use domains (Ebolowa, Mbalmayo and Yaoundé) and fallow age-classes (short, medium-term and long fallows) were analysed separately, in terms of the total number of useful fallow species listed per category. Fallow classes within each study area were compared in terms of mean number of useful species listed by farmers during the interview (using LSD tests, Proc GLM SAS, SAS Institute Inc, 1990).

5.3. RESULTS

Overall, up to 174 different species were reported by local communities as useful plants that they collect from fallow lands of various age-classes (Table 5.1). The average number of useful species, considering all sample villages, did not vary much with the fallow age-class: 17 (±1.82 s.e.), 18 (± 2.12 s.e.) and 15 (± 2.29 s.e.) for the short-term, medium-term and long-term fallows, respectively. Despite a high variability within study areas, farmers of the Yaoundé villages consistently listed more useful fallow species than respondents from other areas.

Of all plant species listed as used by local farmers, 37 were available in fallow lands of all age-classes and 100 were exclusively found in one specific fallow class. Most of the useful species collected in all fallow classes were plants that provide food or drink products, such as *Xanthosoma sagittifolium*, *Manihot esculenta*, *Dioscorea* spp., *Saccharum officinarum*, *Capsicum frutescens*, *Musa paradisiaca* and *M. sapientum*, residuals of the previous cropping period. Other useful plants consistently found in all fallow age-classes included trees used for fuelwood or for building materials (e.g. *Macaranga* spp., *Musanga cecropioides*, *Morinda lucida*, *Terminalia superba*, *Milicia excelsa*). *Irvingia gabonensis*, *Dacryodes edulis*, *Coula edulis*, *Ricinodendron heudelotii*, *Trichoscypha acuminata* and *Baillonella toxisperma*, which farmers valued mainly for their wild edible fruits, were also widely distributed.

In fallow lands of less than 6 years old, although farmers of the study zone collected preferably food or drink plants (cassava, cocoyam, sugar cane, pepper and bananas), the tree *Alstonia boonei* was among the ten most popular useful species found in fallows of that age-class because of its medicinal use (Figure 5.1).

Table 5.1. Number of useful plant species recorded in 15 villages of the humid forest area of southern Cameroon, recorded by fallow age-class.

Area	Village No.	Short Fallows	Medium Fallows	Long Fallows	Overall
Ebolowa	1	18	7	10	28
	2	8	14	14	29
	3	16	17	13	38
	4	17	17	6	38
	5	14	14	21	44
Mbalmayo	11	18	15	13	42
	12	20	19	20	35
	13	14	20	12	37
	14	15	19	21	34
	15	19	19	10	43
Yaoundé	6	18	14	16	27
	7	19	22	22	28
	8	21	24	n/a	39
	9	20	21	21	33
	10	19	24	n/a	39
	Overall	**101**	**100**	**84**	**174**

n/a, fallow class reported not available in the locality.

In medium-term fallows, the most popular useful species listed by farmers consisted of plants used for fuel (mainly *Musanga cecropioides* and *Macaranga* spp.) or for construction (particularly, *Petersianthus macrocarpus*), some food plants (essentially, the *Musa* spp.) and *Dacryodes edulis* (Figure 5.2). Finally, long fallows plants were reported valuable by and large because they provide materials for construction (such as *Erythrophloeum ivorense*, *Petersianthus macrocarpus*), important traditional medicine (*Alstonia boonei*) or ritual products (*Guibourtia tessmannii*), and also 'wild' marketable fruits (*I. gabonensis*, *D. edulis*, *Coula edulis*, *R. heudelotii*, Figure 5.3).

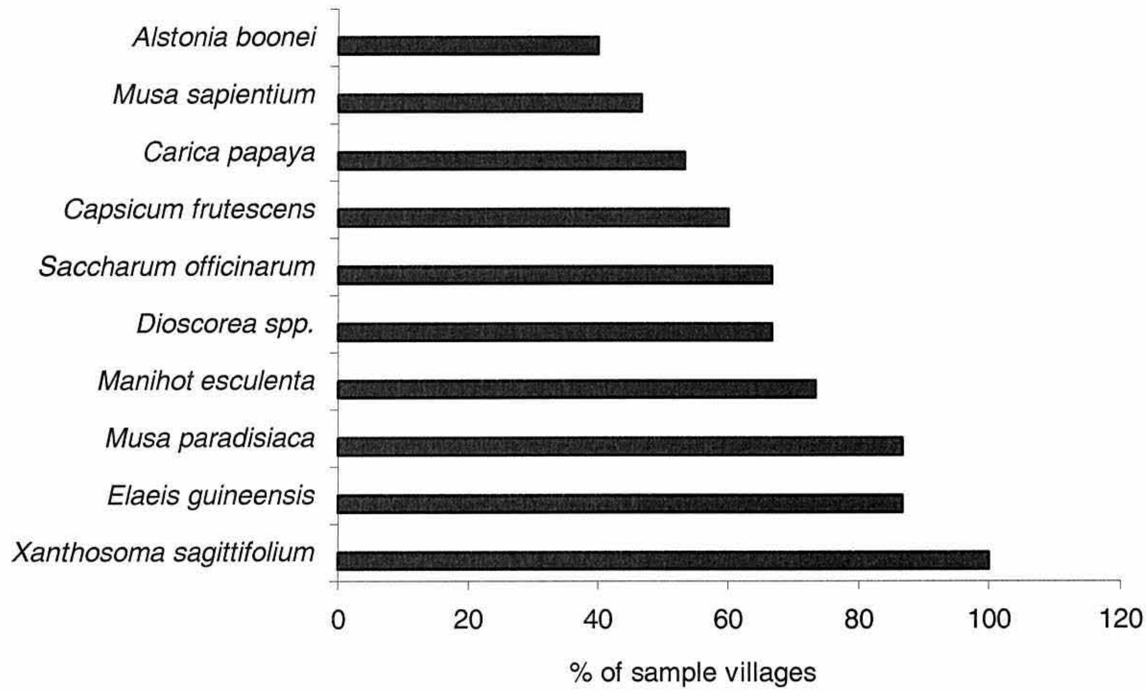


Figure 5.1. The ten most popular useful species collected in short fallows in the humid forest zone of southern Cameroon.

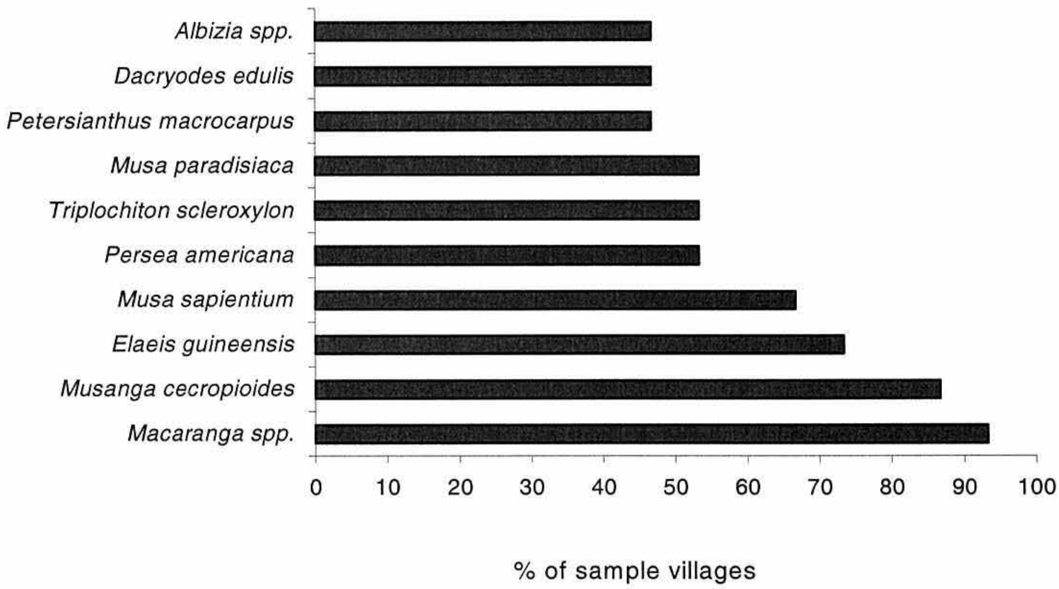


Figure 5.2. The ten most popular useful species collected in medium-term fallows in the humid forest zone of southern Cameroon.

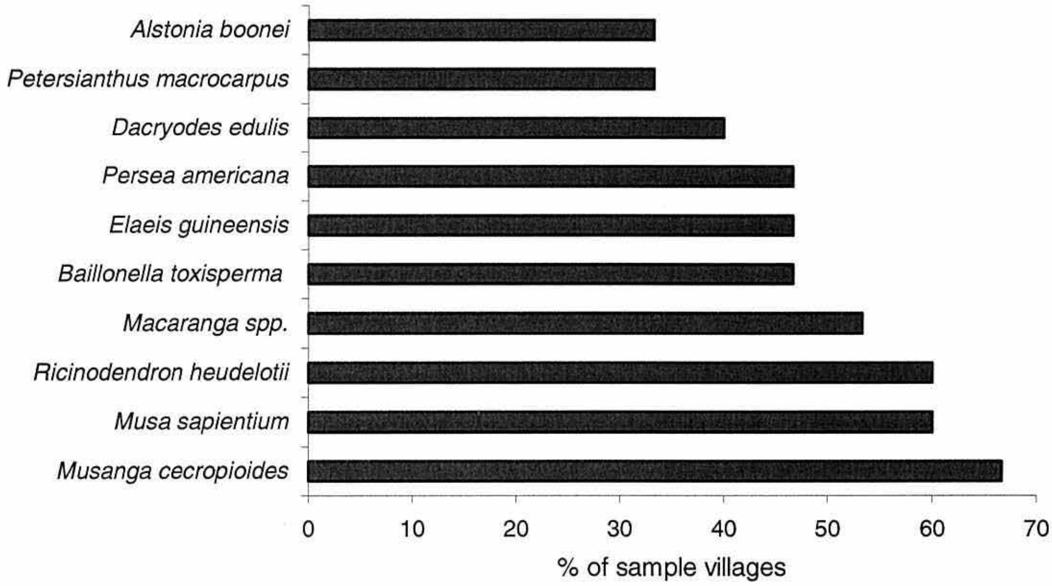


Figure 5.3. The ten most popular useful species collected in long fallows in the humid forest zone of southern Cameroon

To detect trends, the study looked at the differences among resource use domains, with respect to the number of useful species reported by farmers in each area for each fallow age-class. The assumption is that the trends in number of listed useful fallow species between different areas reflect trends on local land use intensity level. LSD tests (at $\alpha = 0.05$, Proc GLM SAS) were used to compare mean values of number of useful plants reported by interviewees.

Significant differences in the mean number of useful fallow plants were observed among the study resource domains. The mean number of fallow species recorded in the Yaoundé area (20) was higher compared to the Mbalmayo and Ebolowa areas (17 and 14, respectively) (P=0.0002, LSD = 2.75).

Overall, four villages reported a listing of useful fallow species that differed from other sites in the same area. These villages are Akok and Obang II (in the Ebolowa area), where the number of useful species in the long fallows were respectively 6 and 21, while in the same area, the village Minsélé listed 7 plants found in medium-term fallows. The village Nkolfoulou II (of the Yaoundé area) also showed an unusual number of useful species in medium-term fallows (14 species).

There was no marked difference among the three fallow age-classes in terms of average number of useful plants identified by local farmers in each study area ($P>0.05$).

5.4. Fallow species used for food or drink

Farmers of the humid forest zone of southern Cameroon listed 66 species collected from fallow lands of different ages as the most useful plants providing food or drink products. However, as shown in Table 5.2, the presence of food (or drink) plants appears to vary across fallow classes and between resource use domains.

Table 5.2. Proportion (%) of total number* of fallow species providing food or drink products across the three resource domains of southern Cameroon.

Fallow Class	Ebolowa area	Mbalmayo area	Yaoundé area	**Overall study zone**
Short fallows	38	20	24	**53**
Medium-term fallows	23	21	14	**42**
Long fallows	24	21	2	**35**
Total fallows	**58**	**56**	**36**	**100**

*Some species were recorded in one or more fallow class.

The distribution of fallow species collected for food or drink products was not uniform among the three resource domains (chi-square test, d.f. = 6, $P=0.023$) or between the three fallow classes (chi-square test, d.f. = 6, $P=0.030$). Except in the Mbalmayo area, short fallows of the humid forest zone of southern Cameroon were reported to be richer in plants used for food or drink than fallow lands of more than 6 years old (35 species listed against an average of 25, respectively). Farmers appeared to collect fewer food and drink products from long fallows (of more than 10 years old), particularly in the Yaoundé area.

5.4.1 Food or drink species in short fallows

On average, in the Ebolowa and Yaoundé areas, about 66% of food or drink plant products were collected from fallows of less than 6 years old against 35% in the

Mbalmayo area. Edible plant parts included rhizomes, roots, bark, leaves, grains, fruits and cotyledons.

Overall, fruits and exudate of the oil palm tree, *Elaeis guineensis* were cited most frequently as the short fallow products collected for consumption. Other major edible plants mostly collected from short fallows included *Manihot esculenta*, *Xanthosoma sagittifolium* (for their tubers and leaves) and *Musa paradisiaca* for its fruits (Figure 5.4). Various short fallow edible plants were collected for their use as vegetables, such as *Vernonia amygdalina* and *Gnetum africanum*.

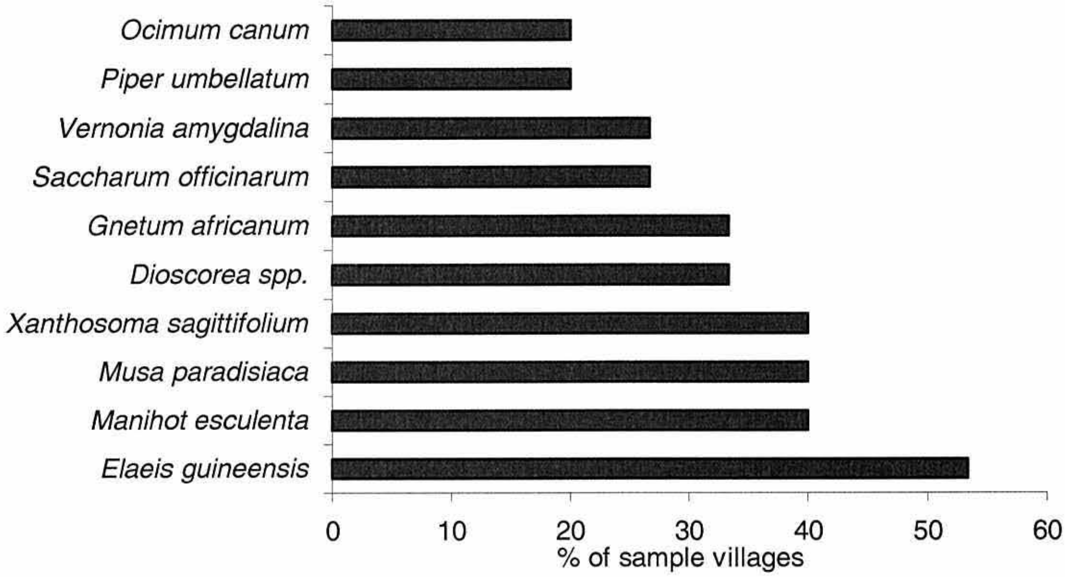


Figure 5.4. Popularity of the ten most important short fallow species used as food or drink in southern Cameroon

Various yam species of the genus *Dioscorea* were also listed among the most preferred useful food plants collected from short fallows. Another popular group of food species consisted of fallow plants used as condiments or spices such as the climber *Piper umbellatum* and the 'wild Basil' species, *Ocimum canum* collected for their peppery fruits. Sugar cane, *Saccharum officinarum*, was also frequently reported as a useful species collected from fallow lands of less than 6 years old. Most popular in the Ebolowa area, this species is mainly used for its edible stem but also, for its exudate used as a basic ingredient for the preparation of local palm wine.

5.4.2. Food or drink species in medium-term fallows

As many as 28 species have been listed within the study zone, with the Ebolowa and Mbalmayo areas reporting more plants of this category than the Yaoundé resource domain (15 and 14 species against 9, respectively). Among the most preferred food or drink species collected from fallow lands of this class, trees producing edible fruits or nuts were the most popular (Figure 5.5). Listed species included the umbrella tree *Musanga cecropioides*, the oil palm tree *E. guineensis* and the African prune tree *Dacryodes edulis*, appreciated for their fruits which are eaten as vegetables after cooking. Also frequently mentioned was the bush mango tree *Irvingia gabonensis*, preferred for its oil-rich and highly marketable fruits. From medium-term fallows, farmers in the study region preferred wild trees of *Ricinodendron heudelotii*, *Coula edulis*, *Baillonella toxisperma* and *Triplochiton scleroxylon* for their oil- and protein-rich seeds. Fruits and leaves of *Aframomum citratum*, fruits of *Haumania danckelmaniana* as well as fruits of the cultivated species *Persea americana* and *Musa sapientum* were listed in some sites (less than 40% of the total number of villages) as most popular food products collected in medium-term fallows.

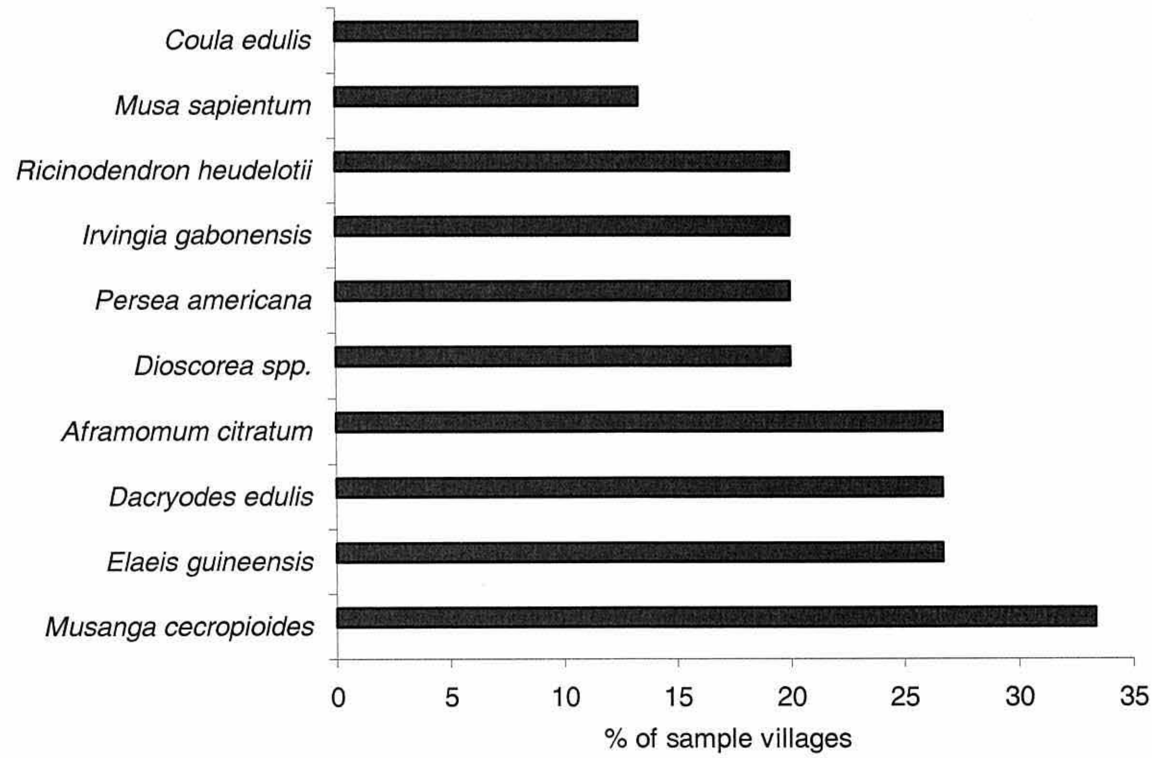


Figure 5.5. Popularity of the ten most important medium-fallow species used as food or drink in southern Cameroon

5.4.3. Food or drink species in long-term fallows

When assessing farmers' preference among the ten most important food (or drink) plants they collect from long fallows, a list of 23 different species was obtained (35% of the total number of species used as food or drink. Table 5.2), revealing differences in farmers' preferences between the study areas. *R. heudelotii*, *B. toxisperma*, *I. gabonensis* and *Trichoscypha acuminata* were by far the most popular (Figure 5.6). *Dacryodes macrophylla*, the cola tree *Garcinia kola* and the bitter cola tree *Cola acuminata* were mostly appreciated in only one site of the Ebolowa area.

Overall, the number of plants used for consumption and collected from fallow lands of this age-class (more than 10 years old) appeared to be lower compared to other fallow classes, particularly in the Yaoundé area, where only one species was listed.

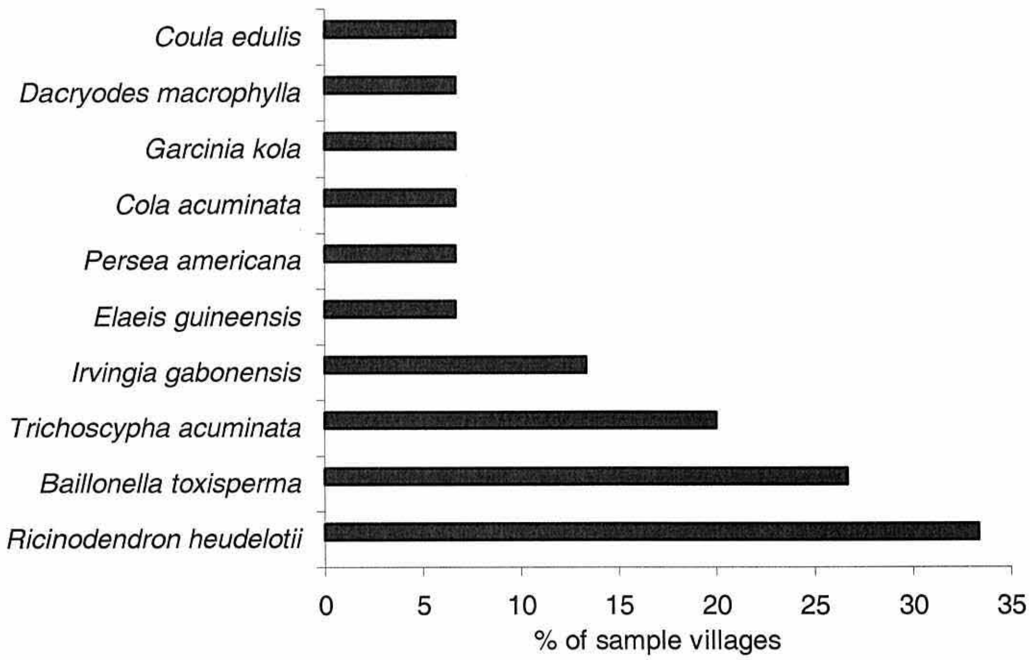


Figure 5.6. Popularity of the ten most important species collected from long fallows and used as food or drink in southern Cameroon

5.5. Fallow species used for fuel

Another category of useful fallow species recorded in the study sites comprised plants providing fuel. Throughout the study zone, about 46 species were mentioned, which are collected from fallows lands of various ages (Table 5.3).

Table 5.3. Proportion (%) of total number* of fallow species providing fuelwood across the three resource domains of southern Cameroon.

Fallow Class	Ebolowa area	Mbalmayo area	Yaoundé area	Overall study zone
Short fallows	15	20	17	**48**
Medium-term fallows	43	46	35	**83**
Long fallows	13	37	9	**54**
Total fallows	**50**	**57**	**43**	**100**

*Some species were recorded in one or more fallow class.

There was a significant non-uniform distribution of species providing fuel between the three resource domains (chi-square test, d.f. = 6, P=0.033) and between the three fallow classes (chi-square test, d.f. = 6, P=0.025). As shown in Table 5.3, fallows of 6 years old and more appeared to be richer in fuel species than short-term fallows of less than 6 years old, in all study areas. Also, the number of fuel species collected from fallow lands in the Mbalmayo domain was higher compared to the Ebolowa and Yaoundé domains.

5.5.1. Fuelwood species in short fallows

Fuelwood species collected in short fallows appeared to vary from one resource domain to another, with an average number of eight species mentioned per domain. Among those listed, *Alstonia boonei* was the most frequently mentioned (Figure 5.7). Other fuelwood products included fallen branches of *Dacryodes edulis* and stems of various young secondary forest pioneer trees such as *Nauclea diderrichii*, *Terminalia superba*, *Albizia* spp., *Margaritaria discoidea* and *Spathodea campanulata*.

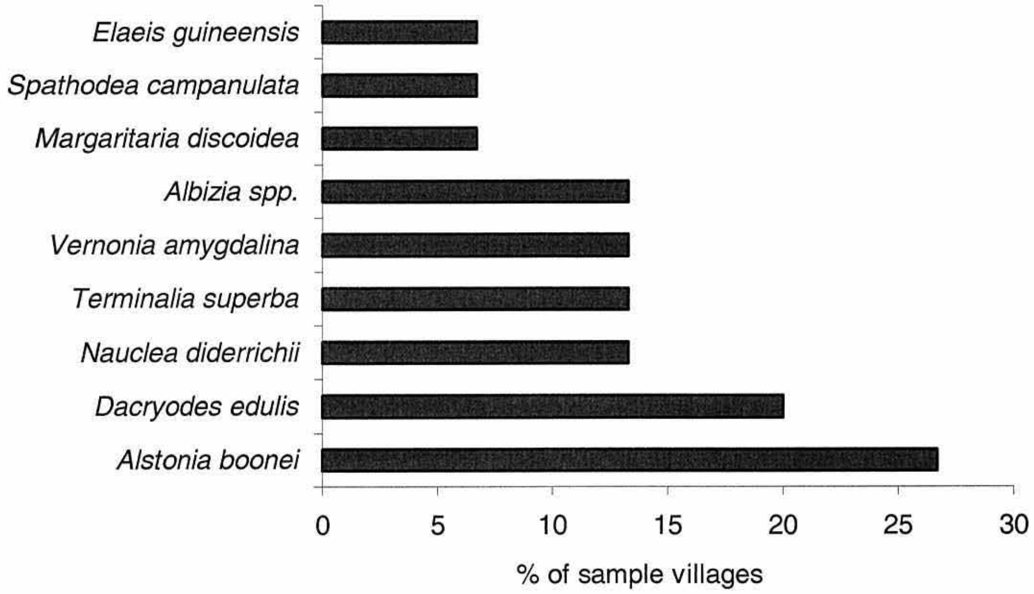


Figure 5.7. Popularity of the most important short fallow species used for fuel in southern Cameroon

5.5.2. Fuelwood species in medium-term fallows

Approximately 83% of fuelwood species were reported to be collected from this fallow age-class (Table 5.3), almost twice the supply of short fallows. Throughout the study zone, the most frequently cited (in more than 60% of the total number of study sites) fuelwood species was the secondary forest tree *Musanga cecropioides* (Figure 5.8). Although mainly mentioned in villages of the Mbalmayo area, *Triplochiton scleroxylon* and *Petersianthus macrocarpus* were also reported as most preferred fuelwood medium-term fallow plants. Other frequently cited fallow species that provide fuel products included the shrub *Vernonia conferta* along with the trees *Margaritaria discoidea*, *Terminalia superba*, *Milicia excelsa* and *Albizia* spp.

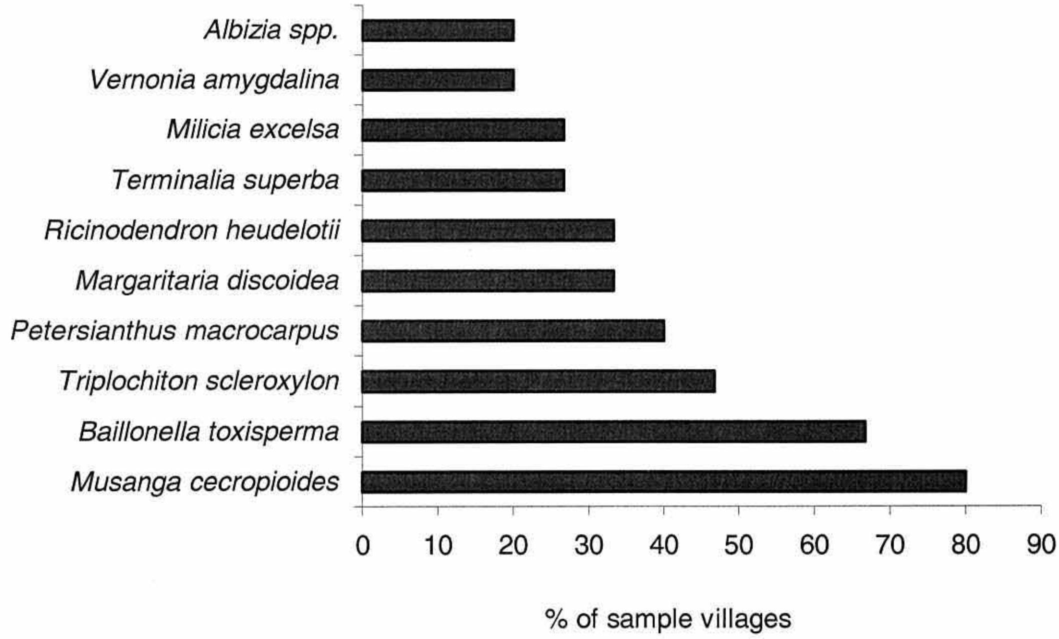


Figure 5.8. Popularity of the ten most important medium-term fallow species used for fuelwood in southern Cameroon

5.5.3. Fuelwood species in long-term fallows

About 25 different species providing firewood were listed as being collected from fallows of more than 10 years old. Specially mentioned as principal sources of fuelwood were *Erythrophloeum ivorense*, *B. toxisperma* and *R. heudelotii* (Figure 5.9). Though of lesser importance, *Ganophyllum giganteum*, *Entandrophragma cylindricum*, *Guibourtia tessmannii* and *Lovoa trichilioides* were also among the ten most preferred fuelwood species found in this fallow class.

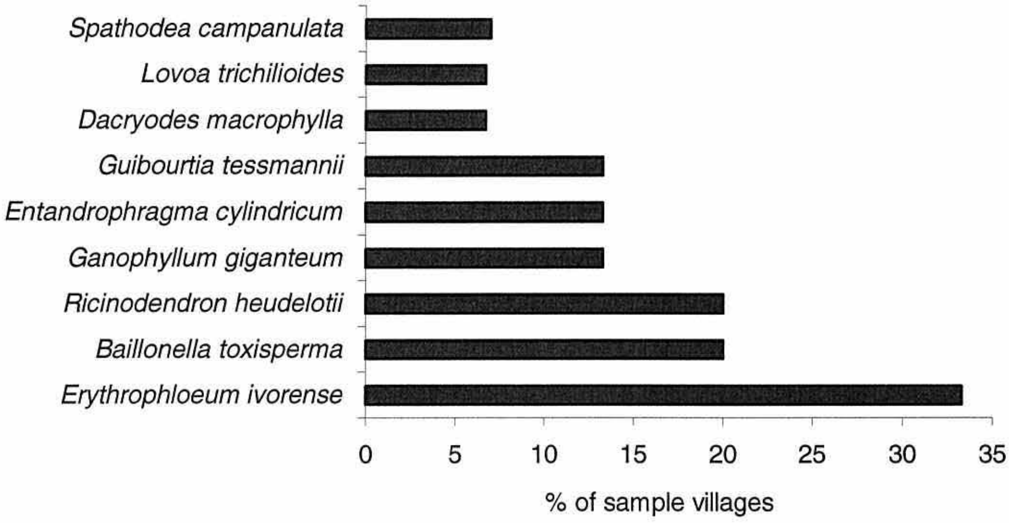


Figure 5.9. Popularity of the ten most important long fallow species used for fuelwood in southern Cameroon

5.6. Fallow species used for building or household equipment

A total of 38 different fallow species that can provide construction materials were recorded across the three study areas. The distribution of species used for building or household equipment was not uniform across the three resource domains (chi-square test, d.f. = 6, $P<0.0001$), with the Yaoundé resource domain being less rich than either Ebolowa or Mbalmayo (Table 5.4).

Species for this use category were mostly collected from fallow lands of 6 to 10 years old (about 71% of the total number of plants listed for this use category).

Table 5.4. Proportion (%) of total number* of fallow species providing construction materials across the three resource domains of southern Cameroon.

Fallow Class	Ebolowa area	Mbalmayo area	Yaoundé area	**Overall study zone**
Short fallows	21	8	5	**29**
Medium-term fallows	42	34	37	**71**
Long fallows	16	32	0	**45**
Total fallows	**66**	**61**	**37**	**100**

*Some species were recorded in one or more fallow class.

When considering study areas separately, it appears that plants providing construction materials were not evenly distributed across the fallow age-classes (chi-square test, d.f. = 6, $P<0.0001$). Short fallows (of less than 6 years old) were particularly poor, with less than 30% of the total number of plants recorded over all listed species for this use category (Table 5.4). Additionally, except when considering medium-term fallows, farmers' listing of fallow species used for construction did vary across the three resource domains.

5.6.1. Species providing construction materials in short fallows

The number of plants providing building materials that farmers collect from fallow lands of less than 6 years old was low (Table 5.4), mostly mentioned in the Ebolowa area, and almost negligible in the Yaoundé and Mbalmayo areas. Among the species collected in short fallows, *Milicia excelsa* was the most frequently mentioned (in 40% of the overall study villages), followed by *B. toxisperma* and *Terminalia superba* (Figure 5.10). Other short fallow species in this category included the oil palm tree *E. guineensis*, *I. gabonensis*, *Alstonia boonei*, *Coula edulis* and *Harungana madagascariensis*.

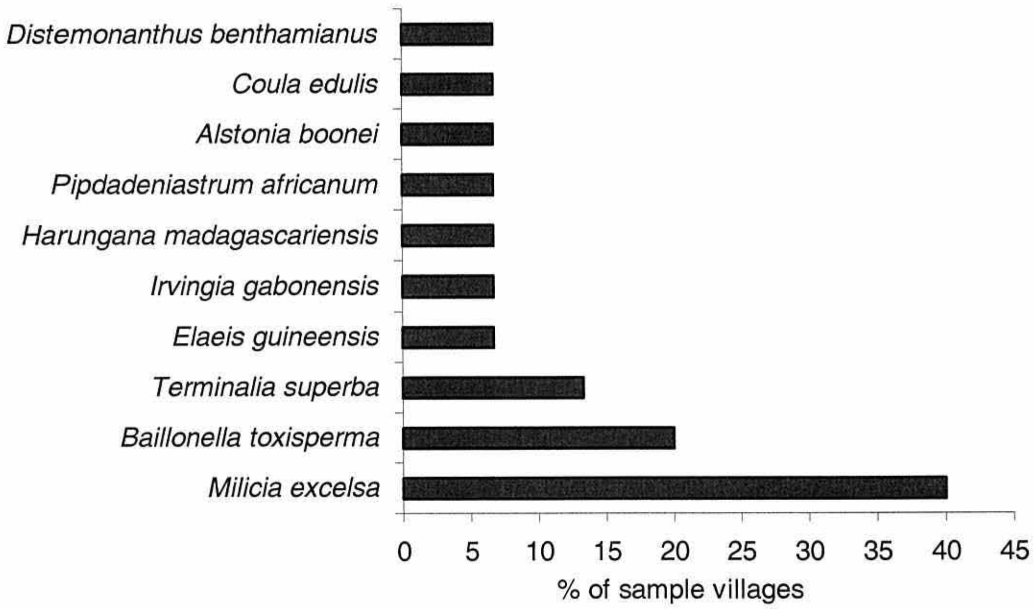


Figure 5.10. Popularity of the ten most important short fallow species providing construction materials in southern Cameroon.

5.6.2. Species providing construction materials in medium-term fallows

Within the study region, farmers reported medium fallows (of 6 to 10 years old) as the principal source of materials used for construction or furniture making (Table 5.4). Although almost the same number of species for this use was recorded across the three study areas (14 species), listed species differed, especially between the Ebolowa and Yaoundé areas.

Among the ten most frequently listed plants used for building purposes and collected in medium fallows, were *Milicia excelsa*, *Petersianthus macrocarpus* and *Alchornea cordifolia* (Figure 5.11). Although of lesser importance, *Morinda lucida*, *B. toxisperma*, *E. guineensis* and *I. gabonensis* were also commonly preferred.

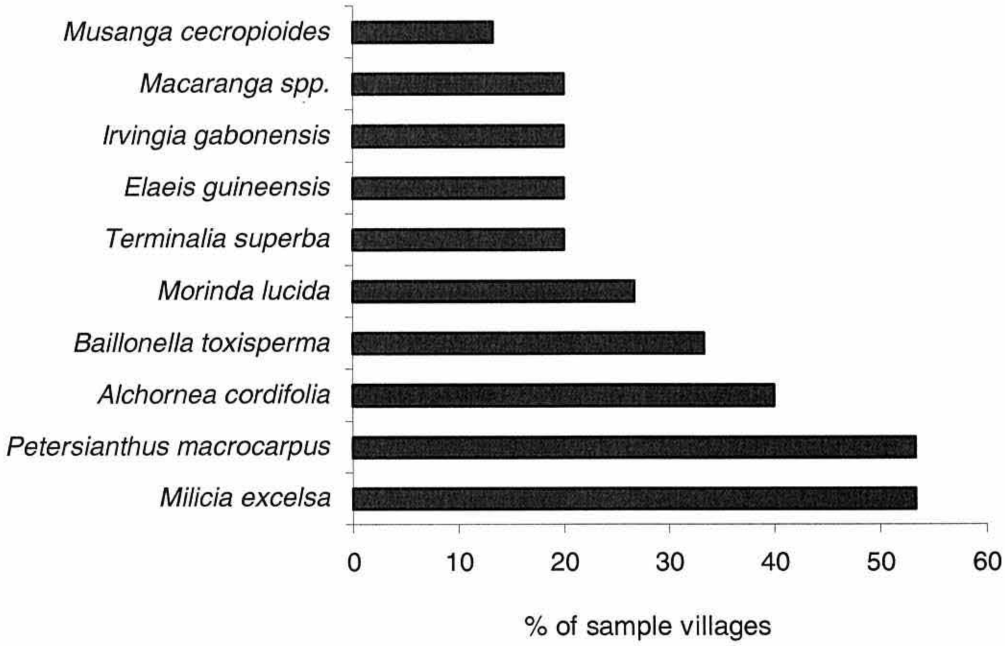


Figure 5.11. Popularity of the ten most important medium fallow species providing construction materials in southern Cameroon

5.6.3. Species providing construction materials in long fallows

Long-term fallows (of more than 10 years old) were also an important source of construction materials. There was an uneven distribution of these species across the study zone (Table 5.4). Farmers in the different resource domains mentioned different species for this use. Overall, while farmers of the Ebolowa area reported only 6 long fallow plants used for building, respondents in the Mbalmayo area listed 12 species. The number of long fallow species providing materials for construction was zero in the Yaoundé area.

Among the most commonly used materials for house building collected in long fallows throughout the humid forest zone of southern Cameroon, were wood products from *Canarium schweinfurthii*, *Petersianthus macrocarpus*, *Ganophyllum giganteum*, *Uapaca guineensis*, *Entandrophragma cylindricum*, *T. superba*, *Lovoa trichilioides* and *Erythrophloeum suaveolens* (Figure 5.12).

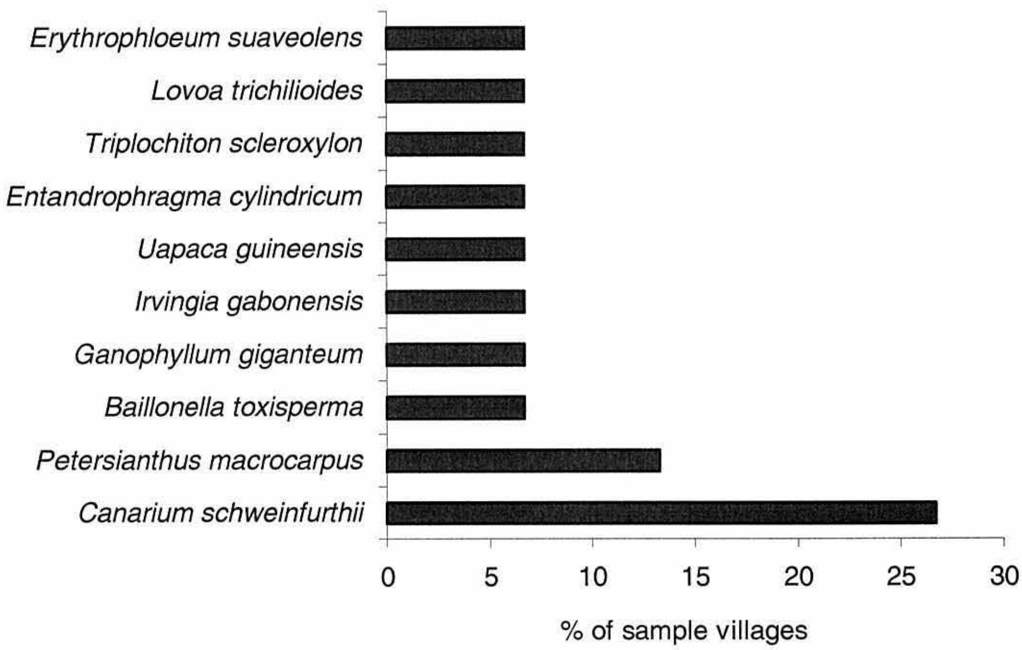


Figure 5.12. Popularity of the ten most important long fallow species providing construction materials in southern Cameroon

5.7. Fallow plants providing wrapping materials

Another use of fallow species is the provision of materials for wrapping. Plant parts used for this purpose were mainly leaves and stems. A total of 17 fallow species were listed throughout the whole study zone. The distribution of species providing wrapping materials was not uniform across the resource domains (chi-square test, d.f.=6, $P<0.0001$) with the Ebolowa villages being richer (11 species listed) than the Mbalmayo and Yaoundé resource domains (Table 5.5). Short-term fallows (of less than 6 years old) appeared to be the most important source of wrapping materials for local communities' use, providing about 76% of the total number of species in this category.

Table 5.5. Proportion (%) of total number* of fallow species providing wrapping materials across the three resource domains of southern Cameroon.

Fallow Class	Ebolowa area	Mbalmayo area	Yaoundé area	**Overall study zone**
Short fallows	41	24	29	**76**
Medium-term fallows	41	0	6	**47**
Long fallows	12	0	0	**12**
Total fallows	**65**	**24**	**35**	**100**

*Some species were recorded in one or more fallow class.

Furthermore, it appears that farmers in the Ebolowa area were able to identify about 65% of the total fallow species for this use category whereas only 24 and 35% were reported in the Mbalmayo and Yaoundé areas, respectively.

5.7.1. Species providing wrapping materials in short fallows

Wrapping materials collected in short fallows mostly consisted either of leaves or of resistant stems used as cords. Useful species in this category included cultivated plants such as *Musa paradisiaca*, *Xanthosoma sagittifolium* and *Musa sapientum* (Figure 5.13). Also mentioned in this use category were *Haumania danckelmaniana*, *Anthocleista schweinfurthii* and *Megaphrynium macrostachyum*, along with *Gnetum africanum* and *Chromolaena odorata* which stems are used as cords.

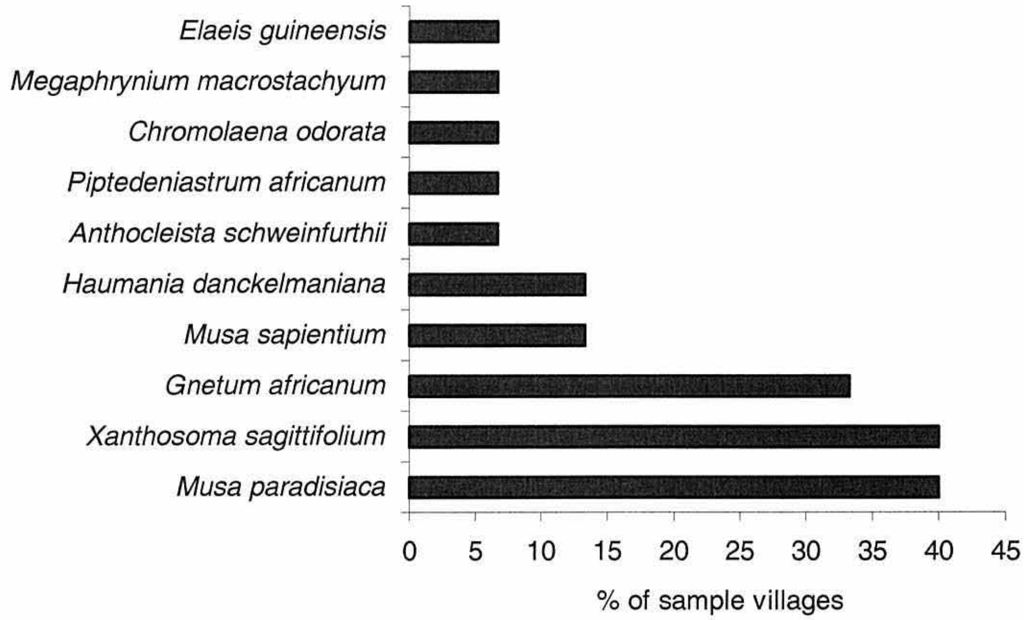


Figure 5.13. Popularity of the most important short fallow species providing wrapping materials in southern Cameroon

5.7.2. Species providing wrapping materials in medium and long-term fallows

From fallow lands aged 6 to 10 years, farmers identified only eight plants that provide wrapping materials (Table 5.5), mainly in the Ebolowa resource domain. Species reported included *Musa paradisiaca*, *Vernonia conferta*, *Piptadeniastrum africanum*, *Anthocleista schweinfurthii* and *Musa sapientum*, which leaves are used as packaging to wrap food (Figure 5.14). In addition to these plants, *Triumfetta cordifolia* was also listed in this category, with its stem used as cords.

From long fallow stands, only farmers of the Ebolowa area identified two plants that can provide wrapping materials. These were *Megaphrynium macrostachyum* and *Haumania danckelmaniana*.

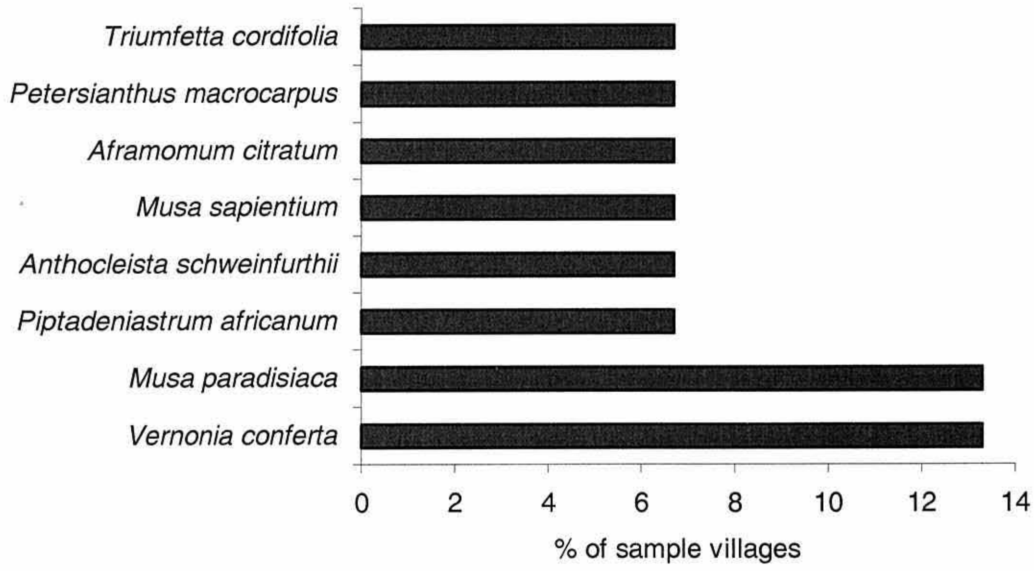


Figure 5.14. Popularity of the most important medium fallow species providing wrapping materials in southern Cameroon

5.8. Fallow species used as traditional medicines

The most important use category of fallow plants across the villages sampled for this study is certainly the one of traditional medicine. Not less that 128 different plant species were recorded as collected from fallow lands. The distribution of species used as traditional medicine was uniform across the three resource domains (chi-square test, d.f. = 6, P=0.136), and also across the three fallow classes (chi-square test, d.f. = 6, P=0.141).

Throughout the humid forest zone of southern Cameroon, fallow lands of all age-classes are valued as potential reservoirs of traditional medicines (Table 5.6). However, fallow lands of more than 6 years old appeared to be richer than short-term fallows. Moreover, for each fallow class, fallow species identified for this use category did vary across the study areas. Each fallow age-class seemed to provide specific medicinal products.

Table 5.6. Proportion (%) of total number* of fallow species used as traditional medicine recorded across the three resource domains of southern Cameroon.

Fallow Class	Ebolowa area	Mbalmayo area	Yaoundé area	**Overall study zone**
Short fallows	23	20	18	**41**
Medium-term fallows	27	20	19	**48**
Long fallows	17	14	1	**26**
Total fallows	**49**	**41**	**34**	**100**

*Some species were recorded in one or more fallow class.

Except for the Yaoundé area where only one species was identified in long fallows, farmers of the humid forest zone of southern Cameroon equally valued fallow lands of all age-classes as potential sources of medicinal species.

5.8.1. Medicinal species in short fallows

Taken as a whole, nearly 53 species used in traditional medicine and collected in fallows of less than 6 years old were recorded across the three study areas, with an average of about 25 plants mentioned per area. As for the previous use categories, farmers' listing of medicinal short fallow plants varied across the study resource domains. Nevertheless, plant parts used in traditional medicine were commonly tree barks, leaves and exudate for woody species, and the whole plant when the medicinal species was herbaceous.

Among the plants listed for this category, the oil palm tree *E. guineensis* and *Musa paradisiaca* were the most popular (Figure 5.15). Other most frequently mentioned medicinal plants found in short fallows included some cultivated species such as cassava (*Manihot esculenta*) and cocoyam (*Xanthosoma sagittifolium*). Some 'wild' yam species (*Discorea* spp.), *Spilanthes filicaulis*, *Costus afer*, *Alstonia boonei* and *Vernonia conferta* were also repeatedly listed as medicinal plants that farmers collect in short fallows.

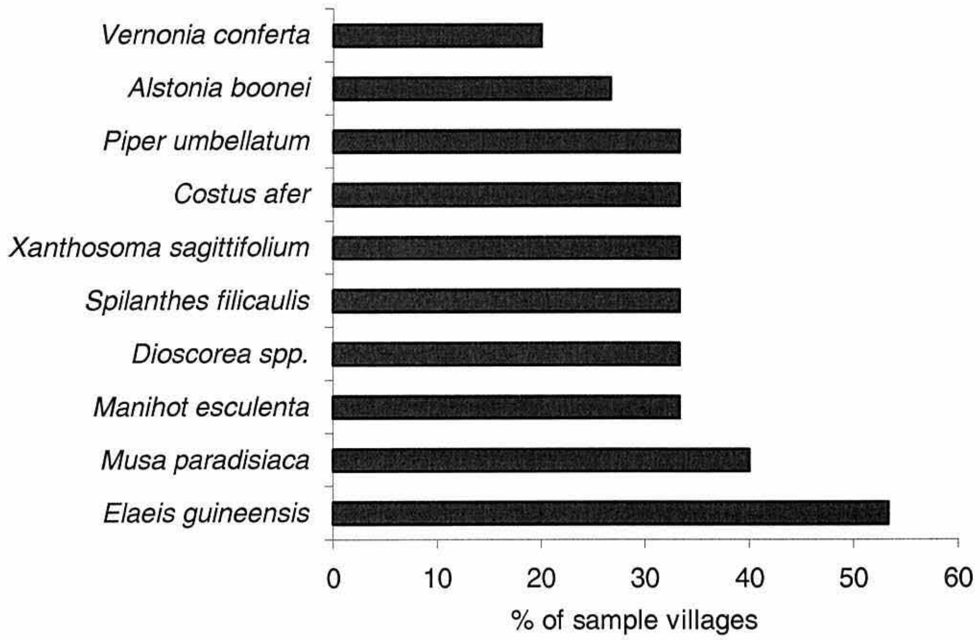


Figure 5.15. Popularity of the ten most important medicinal species collected in short fallows of southern Cameroon

5.8.2. Medicinal species in medium-term fallows

Fallow lands aged 6 to 10 years old appeared to be richer in medicinal species than other fallow age-classes, providing nearly 48% of the total number of species in this use category (Table 5.6). Apart for few exceptions, farmers' listing of medicinal plants in this fallow class did fluctuate across the study areas.

However, some species were regularly mentioned during group discussions with farmers throughout the study (Figure 5.16). Among these is the oil palm tree *E. guineensis*, for which bark, exudate and fruits (for their oil) were reported to be used in traditional medicine. Other frequently listed species were mainly trees, valued for their leaves, bark, grains (or fruits) or exudates, such as *Musanga cecropioides*, *Macaranga* spp., *Petersianthus macrocarpus*, *I. gabonensis* and *Terminalia superba*.

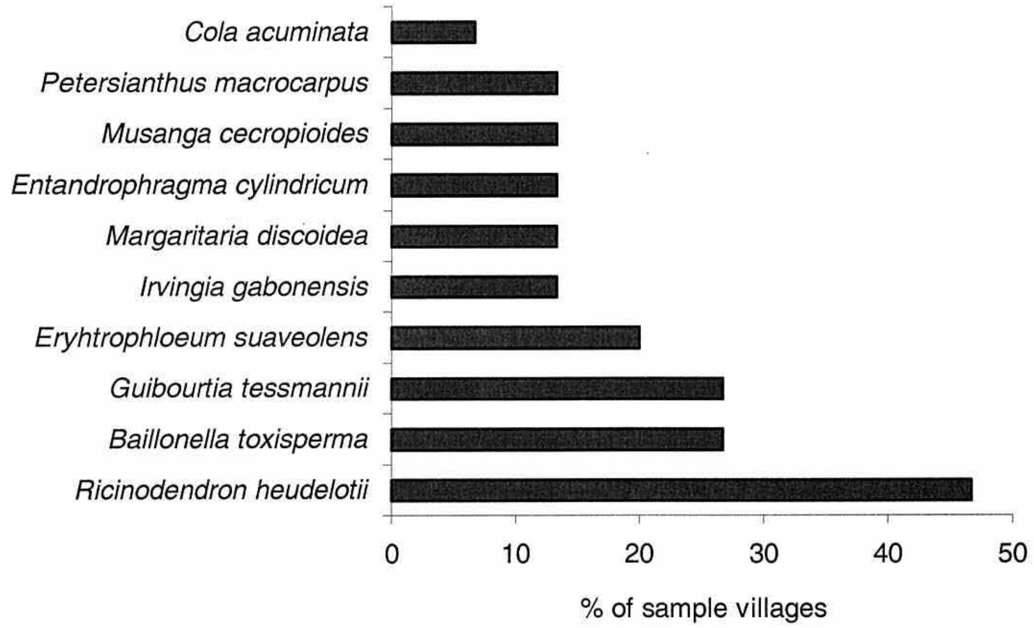


Figure 5.16. Popularity of the ten most important medicinal species collected in medium fallows of southern Cameroon

5.8.3. Medicinal species in long fallows

Across the study sites farmers listed up to 33 different medicinal species found in long fallows, from which *R. heudelotii* was the most frequently cited (Figure 5.17). The other most popular medicinal species in this fallow class were *B. toxisperma*, *Guibourtia tessmannii* and *Erythrophloeum suaveolens*. Although not listed in many sample sites, *Margaritaria discoidea*, *Irvingia gabonensis* and *Cola acuminata* were also reported to be of great value in traditional medicine.

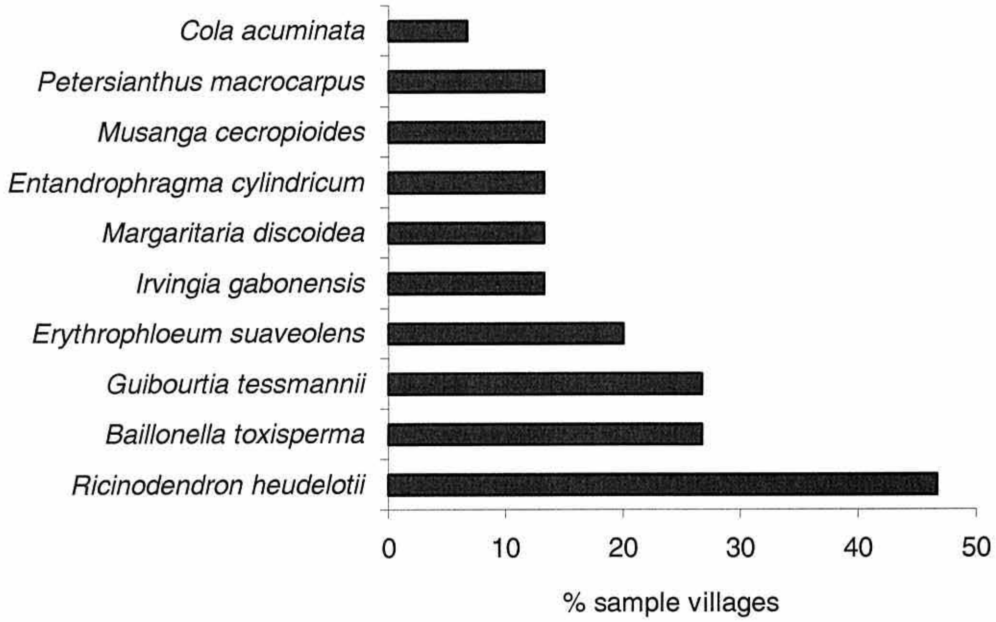


Figure 5.17. Popularity of the ten most important medicinal species collected in long fallows of southern Cameroon

5.9. DISCUSSION

5.9.1. Indigenous knowledge and importance of NTFPs

In all three resource domains of the FMBA, farmers consistently displayed an exceptional knowledge of the useful plants they collect from natural fallow lands, confirming the findings of previous studies in the region (Dounias, 1993; van Dijk, 1999 and Zapfack *et al.*, 2000).

Farmers identified more than 170 useful species of various life forms on farm lands of various age, from which about 58% are found in fallow lands of less than 10 years old (long fallows providing approximately 48% of plants used by farmers in the region). This result demonstrates the importance of short fallow systems and of NTFPs in the socio-economic and cultural lives of village people in the study region. As already outlined by Brocklesby & Ambrose-Oji (1997), local communities view fallow plots, including short fallows, as not-'resting' lands from where they collect specific products or resources.

The value of non-timber forest products for rural farmers has been widely recognized and extensively studied in Africa, and a review of the abundant literature available on the subject is given by Dounias *et al.* (2000). However, the recognition of fallow systems, especially shortened fallows, as important providers of useful NTFPs has been scarcely addressed. In Cameroon, the study of van Dijk (1999), although not targeting fallows in particular, demonstrated that about 40% of the most popular non-timber forest products are found in highest densities in habitats that are strongly influenced by agricultural activities (fallows, secondary forests and cocoa plantations).

The importance of agro-ecosystems as significant suppliers of non-timber resources was also reported by Davies and Richards (1991) whose study in Sierra Leone revealed that the Mende people harvest 25% of their food resources in fallows against only 14% in the forest. This farmers' preference of fallows for collection of useful plants might be due to the easier physical access or the better control over access prevailing in these anthropogenic land use systems as compared to forest stands (van Dijk, 1999).

5.9.2. Distribution of NTFPs within the study zone

Considering all fallow types, the number of useful plants listed by local farmers in the Yaoundé area was higher than the number recorded in the Mbalmayo and, particularly, the Ebolowa areas. This distribution pattern contradicts our working hypothesis, since it is actually the reverse of the current gradient of resource use intensity level reported in the region (Gockowski *et al.*, 1998a). Possible explanations to this include either the better knowledge of plants uses displayed by farmers of the Yaoundé area as compared to respondents from other areas, or the necessity derived from high land pressure.

The number of useful fallow species known to the local communities involved in this study varied across villages in the same area, with some villages different from the common trend reported in the area. Examples of this were the village Nkolfoulou II in the Yaoundé area, the village Ngat in the Mbalmayo area, the villages Akok and

Minsélé in the Ebolowa area. These discrepancies, already partially noted by Gockowski *et al.* (1998a), could be due to various factors among which are knowledge of plant uses and species availability in the site.

Community members, during the interviews, recognized that some species, particularly useful trees, were in decline or even no longer available in fallow lands. The main factors responsible for this situation might be increased land use pressure and resource use intensity, as well as unsustainable harvesting and logging activities (van Dijk, 1995; Vabi, 1996; Clark & Tchamou, 1998).

The ecological impact of unsustainable harvesting of non-timber resources in the area has already been addressed by Laird (1995), Guedje (1996) and van Dijk (1999). An increasing number of useful species, victims of their own popularity (economical, medicinal or social), are reportedly overexploited. Such over-valued products include, for example, bark of *Alstonia boonei* or *Guibourtia tessmannii* (used in traditional medicine), leaves of *Gnetum africanum* (of high local and international market value) and stem of *Petersianthus macrocarpus*, *Entandrophragma cylindricum* or *Triplochiton scleroxylon* which are widely used for building or furniture making (Ndoye, 1995; van Dijk, 1999).

Although various other uses (e.g. consumption, fuel, building and furniture making) were reported, farmers of the study region mostly make use of fallow species in traditional medicine. Even though the number of uses for a cited fallow species and the preference with regard to the species to use for a specific cure varied across the sample resource domains (possibly due to variation in knowledge of use), some species were reported to have multiple uses. Among those multipurpose species are the oil palm tree *Elaeis guineensis*, *Alstonia boonei*, *Ricinodendron heudelotii* and *Baillonella toxisperma*, of which fruits, bark, exudate and stem are all used by local farmers. Also valued in fallow lands of the study areas were wild fruit trees, such as *Dacryodes edulis*, *Coula edulis*, *Irvingia gabonensis* and *Garcinia kola*, for which an increasing market demand has been reported by numerous authors (Ndoye, 1995; Clark & Tchamou, 1998).

5.9.3. NTFPs and shortening fallow duration

A total of 101 useful species collected in fallow lands of less than 6 years old was reported across the study areas, whereas 100 and 84 were collected from medium and long fallows respectively. However, while useful species listed in short fallows were mainly herbaceous, secondary forest pioneer trees and later-successional trees were dominant among the useful species that farmers collect from older fallows.

However, it is noticeable that some medium-sized to very large forest trees are listed among useful species which farmers collect from short fallows. Examples of these are *Terminalia superba, Piptadeniastrum africanum* and *Picralima nitida.* As already stated by van Dijk (1999), a possible explanation to this relatively surprising finding might be found in the fact that the elimination of less useful trees, during field preparation activities before the cropping period, is selective. Moreover, although not widely practiced in the region, a few respondents have reported the planting of some NTFPs in their fields. However, it could be suggested that local communities reported a higher number of useful plants from shortened fallows because of the easier physical access to these land use systems (in areas of low land use intensity level).

Whereas some species were shared amongst two or three fallow types, others were unique to one. A subset of 37 out of the total 174 species was listed as collected from all three fallow classes against 100 species found only in one fallow class. The 'ubiquitous' fallow species (i.e. species collected in all fallow classes) used by farmers in the study areas consisted mainly of the most popular trees providing fuelwood and building materials. Their presence in short fallow lands denotes and confirms the selective elimination of plants that local farmers practice during clearing (Carrière *et al.*, 2002).

An important ubiquitous useful fallow species reported by farmers is the oil palm tree *Elaeis guineensis*. Numerous authors have reported the important value attached to this species by rural communities in the humid forest zone of southern Cameroon (Ndoye, 1995; van Dijk, 1999; Dounias *et al.*, 2000; Carrière *et al.*, 2002). For many people in the region, and in particular for men, tapping oil palm trees for wine is a considerable source of cash income.

Other important species protected by farmers in fallow lands of all classes include *Alstonia boonei* and *Guibourtia tessmannii* which value, as reported by van Dijk (1999), is not only medicinal (with many medicinal functions), but also mostly magic-religious. The three fallow classes shared a common pool of useful wild fruit trees with high market and nutritional values, such as *Coula edulis*, *Dacryodes edulis*, *Irvingia gabonensis* and *Ricinodendron heudelotii*.

Each fallow class carried some unique useful species, with fallows of less than 10 years old having the largest number (more than 50), most of which were herbaceous species. This could be explained by the decreasing proportion of herbaceous plants with increasing age of fallow already reported by Carrière *et al.* (2002) in the region. Most of the useful species that farmers collect only from fallows of more than 6 years old consisted of forest species such as *Pentaclethra macrophylla*, *Mitragyna stipulosa*, *Cissus aralioides* and *Caloncoba* spp.

5.9.4. Implications and perspectives for fallow management

This study confirms that local communities in the humid forest zone of southern Cameroon have valuable knowledge of the plants and their uses (identification and use categories). Moreover, although the human utilization of plant species varies between areas and fallow types, the results of this study also demonstrate the importance of fallows, and particularly of short fallows (of less than 10 years old) in the socio-economic and cultural lives of small-scale rural farmers. Additionally, it was shown that every fallow type constitutes a unique species pool for farmers' supply of NTFPs, with fallows of less than 6 years old having the most unique components.

These findings provide the major rationale for identifying shortened fallows as individual land use systems with high socio-economic, cultural and ecological potentials. The findings of this study also suggest possible disparities among the three fallow classes present in the region, in terms of plant species composition and vegetation structure, reflecting differences in management practices (as shown in Chapter 4).

Based on the results of this study, and building on recommendations of previous studies (particularly Brocklesby & Ambrose-Oji, 1997; van Dijk, 1999), there is a case to encourage more research on the ecological and economic performances of fallow systems in the forest zone of southern Cameroon.

Short fallows in particular must be targeted for future land use management studies, planning and practice. The high value of short fallow systems as a source of NTFPs widely used by local poor communities provides an important justification for the design of new vegetation management techniques to be applied within the framework of an appropriate management plan. An increasing number of alternatives and possible management 'prescriptions', to improve the productivity of short fallows, is being proposed and applied in many tropical areas (Mauray *et al.*, 2002a).

Although information on the density of useful resources is needed, this study hopes to contribute to the ongoing effort towards better management of shortened fallows that will be not only ecologically sustainable, but also economically viable for small-scale rural farmers of the region. Studies should therefore be developed to ensure that the conservation value of short fallows is maintained or enhanced, and considerable resources should be put into research on these anthropogenic land use types and appropriate monitoring should be designed. In that direction, this study represents a basis for the promotion of priority plant species for planting in fallows in order to increase their productivity and contribute to biodiversity conservation.

However, very little is known about the underlying ecological processes needed to devise a sustainable utilization of plants. As suggested by Peters (1996), van Dijk (1999) and Dounias *et al.* (2000), more studies must be initiated on the propagation, physiology, reproductive biology, productivity, population structure and phenology of priority species (i.e. species that can be valuable for local people, and species that merit special management in their own ecological right).

Moreover, for already 'over-exploited' species, conservation and domestication should be undertaken to save them from extinction. Furthermore, there is a need to develop studies for processing and marketing of some indigenous fruit trees that could be of great economic value to rural farmers in the region. However, the sustainable use of NTFPs, seen in the wider context of optimal environmental management, also questions territorial concepts, stakeholder and ownership, giving rise to serious disputes over genetic resource ownership and revenue distribution (Dounias *et al.*, 2000). For that reason, the role and status of indigenous knowledge experts should be recognized, and channels of authority clarified in the management of natural resources in the region. For management projects to have a high level of effectiveness and sustainability, farmers should be involved in all stages of project planning and implementation (Fischer & Vasseur, 2002).

Another recommendation emerging from the interviews with smallholders is the necessity for project staff to try to maintain the trust of farmers by following through on promise feedback and visits, and to listen to farmers' concerns and preferences.

A preliminary step before planning any innovative management of shortened fallow systems in the humid forest zone of southern Cameroon is the assessment of the status of the fallow sites and their potential for improvement. Management radically alters habitat structure and relative abundance of species in a site, but may have only minor effects on their presence or absence. Therefore, to assist management-planning decisions, it is important to detail the vegetation structure and relative abundance of plant species in short fallow sites (i.e. not just list the species present), in order to monitor major changes and detect long-term ecological changes that might need attention.

CHAPTER VI

PLANT COMMUNITY COMPOSITION, VEGETATION STRUCTURE AND DIVERSITY OF SHORT FALLOWS IN SOUTHERN CAMEROON

6.1. INTRODUCTION

Fallow lands of less than 10 years old form an important component of the agricultural landscape in the humid forest zone of southern Cameroon. These fallow types have been shown to be an essential part of local communities' life, as they are used not only for cropping, but also as key reserves of NTFPs. In addition to the reported effect of resource use pressure on shortening fallow duration in the benchmark area, previous studies of Weise (1995) and Weise & Tchamou (1999) revealed an invasion of these land use systems by the Asteraceous species *Chromolaena odorata* (L.) R. M. King & H. Robinson.

Although the weedy nature and associated problems of the invasive *C. odorata* have been recognized in cultivated lands (e.g. Weise, 1995; Weise & Tchamou, 1999), few studies have been conducted on its implications on fallow vegetation of the humid forest zone of southern Cameroon. Like many other invasive species, the extensive distribution of *C. odorata* in the region is associated with an increased intensity of disturbance.

The reported growing rate of resource use intensification in the study area (Kotto-Samè *et al.*, 2000), and the increasingly acknowledged need for more productive and environmentally friendly agricultural systems for resource-poor farmers have stimulated renewed interest in the mechanisms by which, among other functions, fallows restore ecosystem fertility. A better understanding of these mechanisms is necessary for the development of 'improved' fallows. From that perspective, most past research on fallow systems in the humid and sub-humid tropics addressed the effects of various crop-fallow sequences on crop yields, soil fertility and nutrient dynamics or nutrient accumulation in fallow vegetation (e.g. Nye and Greenland, 1960; Aweto, 1981; Uhl *et al.*, 1982; de Rouw, 1995).

However, of the limited number of studies focusing on vegetation-soil-management interactions in the fallow ecosystem, shortened fallow systems were seldom included. In the humid forest zone of southern Cameroon, apart from the reported studies of Gillison (2000) and Zapfack *et al.* (2000), very little quantitative information is available on the interactive effects of land use intensification and invasion of *C. odorata* on the plant biodiversity of shortened fallows.

The objective of this part of the study was to examine species diversity as impacted by fallow age and type in short fallow systems. The hypotheses tested in this study were built on the studies of Gillison (2000) and Zapfack *et al.* (2000) who have documented different fallow types based on the age of the fallow stand, the main vegetation type present on the stand, and the vegetation type that was present on the stand in the previous cropping cycle.

- The central hypothesis of this study was that the number of cropping cycles (reflecting the link to the forest) and the intensity of past land use (as reflected by its vegetation type) are likely to influence the plant community composition and characteristics of a stand (Szott *et al.*, 1999).
- Another hypothesis tested in this study concerned the relationship between fallow vegetation structure and plant community composition of the fallow. It was assumed that the plant community composition can be influenced by stand structural features (e.g. canopy height, basal area, crown cover of woody plants), because this diversity of structures provide a diversity of primary ecological factors that are relevant to basic plant requirements (Tilman, 1988).

It is hoped that information gathered would eventually contribute to a better understanding of the bio-physical changes associated with *C. odorata*-fallows in the forest margins, and would suggest strategies seeking decreases in rate of deforestation and biodiversity loss in the area. The functional and compositional approach used in this study, because it considers plants in regard to their autoecology, their morphology and physiological performances, will provide information on the underlying mechanisms of species assemblages (Gillison, 2000).

6.2. METHODOLOGY

6.2.1. Study area

This part of the study was conducted in Mengomo, a village located in the southern part of the Cameroonian humid forest zone, at the southern part of the Ebolowa resource domain (Figure 3.1). The main criterion for selecting that locality among others in the region was the possibility to get all the three fallow types considered for this study, which are representative for agricultural land uses and shortened fallow systems in the whole region. Thus, findings could be applicable to other areas of southern Cameroon having comparable agro-geo-climatic conditions.

Situated at 2°20'N and 11°03'E, Mengomo is a small village (598 inhabitants and 83 households) in the humid forest zone of southern Cameroon. It lies 52 kilometres south of the city of Ebolowa, along the national highway connecting Cameroon with Gabon and Equatorial Guinea. It is characterized by a hot and moist equatorial climate, with a minimum mean annual temperature of about 20°C and a maximum of 29°C (National Meteorological Station of Yaoundé: mean of 11 years: 1983-1994 *in* Santoir & Bopda, 1995). The climate is however moderated by the altitude (620 m above sea level, in average). The mean annual rainfall is about 1800 mm that has a bimodal pattern, which determines two rainy seasons and two dry (i.e. less rainy) seasons of unequal duration. The main natural vegetation is a mosaic of semi-deciduous tropical forest, fallow fields of various length and vegetation types (Letouzey, 1968). The farming system is one of the lowest intensified among villages of the area, and the production is highly oriented towards auto-subsistence. The site is also characterized by yellow ferralitic and highly desaturated soils that fall into the FAO class of Orthic Ferrasols (Koutika *et al.*, 2000).

6.2.2. Selected fallow types and sites

The investigations for this study were conducted over the rainy seasons of 1997-1998 and repeated in 1998-1999, on different fallow fields. For the purpose of this study, the ecological sample was stratified based on the results of previous work conducted in the area (Weise & Tchamou, 1999; Gillison, 2000; Zapfack *et al.*, 2000), and three types of fallows were distinguished and constituted the study treatments:

- Treatment 1 (referred to as 'frequently cropped' or Co-Co fallows): 5-7 years old *C. odorata*-dominated fallows that had also been 5-7 years old *C. odorata*-dominated fallows in the previous crop-fallow cycle.
- Treatment 2 (referred to as 'moderately cropped' or Co-Fo fallows): 5-7 years old *C. odorata*-dominated fallows that had been forest before the preceding cropping period.
- Treatment 3 (referred to as 'recently forest' or Bu-Fo fallows): 5-7 years old bush fallows (not dominated by *C. odorata*) that had been forest prior to the previous cropping phase.

An average number of 10 replications (thereafter referred to as plots or fields) were studied for each treatment.

The selection of 5-7 years old fallows for this study was based on a number of practical observations in the area. It was noticed that fallows of 2-3 years old are rarely used by local farmers for food crop production (apart from home gardens) because they are seen as refuges for pest and weed species that can invade subsequent adjacent food crop fields, and also because of the availability of fallow lands of longer duration in the area (Weise & Tiki-Manga, 1995). Moreover, fallow lands of more than 10 years old are also preferably avoided by local farmers for the establishment of food crop fields mainly because of the higher labour input required for field preparation before cropping (Gockowski *et al.*, 1998a). Therefore, the fallow duration of 5 to 7 years old that was used in this study actually reflects the common practice of agricultural land management in the study village. Following Weise & Tchamou (1999), the first treatment was defined as being representative of relatively high resource use intensity level, the second treatment being representative of moderate land use intensity and the third treatment represented low land use intensity level.

Land-use history and age of each fallow field were determined based on information gathered from the field owner, and visually checked by a rapid field inspection. Although it was impossible to identify fields with matching cropping histories, great attention was paid to include, in each fallow type, only sites for which differences in land use history were relatively small. In each selected field, uniformity of the vegetation was visually checked along with other considerations such as evenness of slope, similarity of the soil drainage and soil profile conditions. All plots consisted of a belt-transect of eight contiguous 5 m x 5 m quadrats (Figure 6.1).

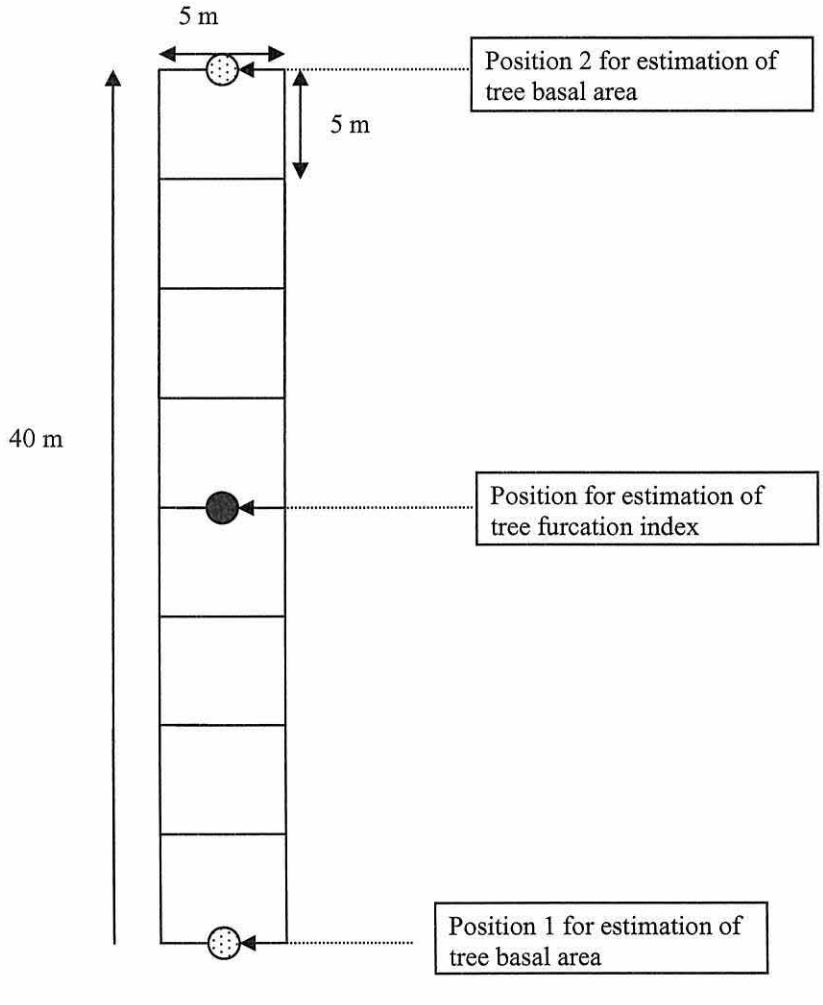


Figure 6.1. Lay out of a transect for fallow vegetation assessment at Mengomo (southern Cameroon)

6.2.3. Sampling strategy

At each site, vegetation was surveyed within a 200 m^2 grid transect, established in the centre of the fallow field and parallel to any visible topographic contour. All species of vascular plants rooting in each 5 m x 5m quadrat were identified, including both phanerophytes and ferns; but excluding mosses, liverworts and seedlings. A visual estimate of the leaf size, leaf chlorotype, life form and root type of each individual plant was recorded in each quadrat, and the combination of these four plant functional attributes (PFAs) was referred to as a *modus* (Gillison, 1988). Estimates of PFAs were done using templates (Appendix 6.1) and recorded on a presence-absence basis. Leaf size and leaf chlorotype were described according to templates, while life form and root type were described according to a modified Raunkiaerean classification (Appendix 6.1).

The theoretical basis for the plant functional approach used in this study is described formally by Gillison & Carpenter (1997). The method has been found useful for characterizing vegetation in a way that reflects its adaptation to environment. Therefore, because a *modus* describes an individual, not a taxon, a species may be represented by multiple *modi*, and a *modus* may represent multiple species.

Within each plot, the mean canopy height was visually estimated using the tallest and smallest canopy units as reference points. A visual estimate of total crown cover was also recorded in each plot, using the Domin cover-abundance scale (Table 6.1). Using the Bitterlich principle, which is independent of the plot size, basal area (in $m^2\ ha^{-1}$) of all woody stems was recorded using an optical prism, at three specific locations in the plot (Figure 6.1). Individual stems were recorded for multi-stemmed trees. The optical prism was used to record 'hits' when the image of a tree was not totally displaced, and depending on the magnification factor of the prism used, 'hits' were converted to values of basal area. For example, 10 'hits' with a factor of 1 indicates 10 $m^2\ ha^{-1}$.

To avoid the differences of opinion between surveyors in deciding what was a 'shrub' (typically described as 'a woody plant that branches at or near the ground') and what was a 'tree' (typically, 'a woody plant above two metres tall'), and to use a metric that allows a comparative measure of primary woody plant architecture, a 'furcation index' (as devised by Gillison, 1988) was assessed from a point in the centre of each plot, and recorded for the nearest twenty canopy trees. The furcation index is defined as the distance from the apex to the first break point (or fork) in the main stem of the linear axis of a woody stem, expressed as a percentage of total height (Figure 6.2). The utility of this parameter lies in the way the primary architecture of the main stem is influenced by the fate of the apical meristem (Gillison, 1988). Furcation indices have been found useful for providing a measure of site history.

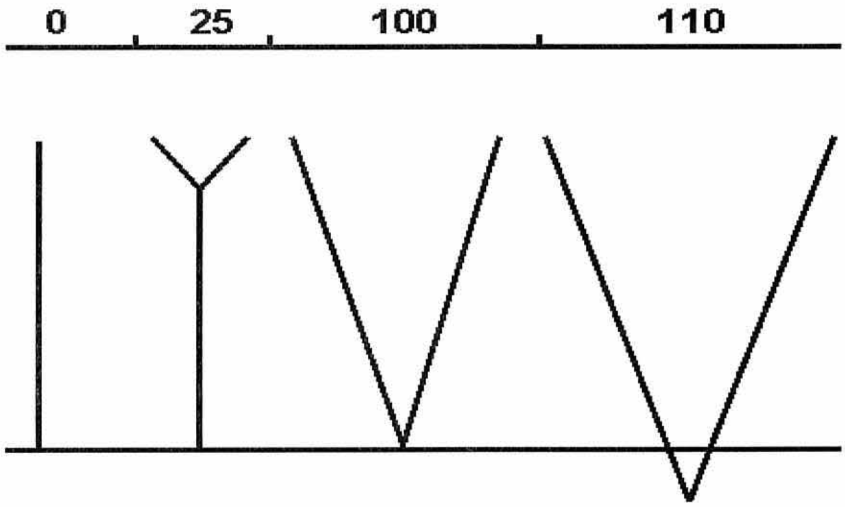


Figure 6.2. Furcation index (%) examples of continuous range 0–100% (from Gillison, 1988)

Table 6.1. Domin cover-abundance scale used in the fallow vegetation survey (Mengomo, southern Cameroon)

Cover-abundance (%)	**Scale**
About 100	10
> 75	9
50-75	8
33-50	7
25-33	6
Abundant: about 20	5
Abundant: about 5	4
Scattered: cover small	3
Very scattered: cover small	2
Scarce: cover small	1

Source: Gillison (1988).

In each plot, litter depth, referred to as the fallen plant material (leaves, stems, etc.) that covered the plot floor (Gillison, 1988), was recorded using a graduated stick and only where the material was dead or dying. Cultivated species that had persisted in, or had colonized, fallow sites were also recorded. Only presence-absence for species data were considered because when coupled with vegetation structure data and PFAs, they are assumed to provide most of the information needed (Gillison, 2000). Each vascular plant species was tentatively identified in the field by a botanical expert, and when necessary, by comparison with specimens at the Cameroonian National Herbarium. Plant species nomenclature follows, and relies upon, Hutchinson & Dalziel (1954-1972). When needed, names were updated using information from The Plant Names Project (1999) - International Plant Names Index, published on the Internet; http://www.ipni.org [accessed on June 2002].

6.2.4. Data analysis

The VegClass Version 1.6 software (CIFOR, 2000) was used to enter the data collected and to calculate mean values, per fallow type, of a set of variables. Data summarisation included the tabulation of:

- The number of unique *modi* per plot (the 'unique *modi*').
- The number of unique species recorded per fallow plot.
- Richness and diversity measures, which included the *modi* richness (i.e. the number of 'unique *modi*' per plot) and the species richness (i.e. the number of species per plot), the Shannon-Wiener's index (Shannon and Weaver, 1949), the Simpson's index (Magurran, 1988) and the Fisher's alpha index (Fisher *et al.*, 1943). These diversity indices were adapted to weight *modi* (or PFTs) instead of species (Gillison 2000).
- The mean basal area per fallow plot.
- The mean canopy height.
- Total crown cover percentage.
- Mean litter depth.
- Mean value and coefficient of variation of the furcation index per plot.

These response variables were used as parameters describing the diversity and richness of a fallow plot. Their mean values were subjected to analysis of variance

(Proc GLM, SAS, SAS Institute Inc., 1990) and compared between fallow types using LSD tests (at $\alpha = 0.05$). Inter-relationships among biodiversity parameters were checked, at the fallow type scale, by correlation (Pearson coefficients).

To select the linear combination of fallow structural features that maximizes the distribution of the species within and among the studied fallow types, and to assess the relative importance of these variables, the 1998 and 1999 floristic data were subjected to canonical correspondence analysis (CCA), using the CANOCO program Version 4.02 (ter Braak & Šmilauer, 1998). In the interpretation of the results, attention was restricted to the first two axes extracted from the CCA ordinations.

For all ordinations, the species matrices included presence-absence of each species in each plot. Only species with a frequency $\leq$75% and $\geq$ 4% across the total number of sampled sites were included in the ordination analyses. Fallow vegetation structural parameters considered in the ordination analyses are listed in Table 6.2. Spearman's rank correlation coefficients (using Proc CORR, SAS) were calculated between the positions of the fallow sites on the two axes of the CCA and fallow vegetation structural parameters (crown cover percentage, canopy height, litter depth and basal area) in order to help display and explore any possible relationships (Ola-Adams & Hall, 1987).

Table 6.2. Vegetation structural variables used in ordination analyses of short fallows (plot size: 40 m x 5 m) in Mengomo (southern Cameroon)

Explanatory variables	Symbol	1998*	1999
Mean basal area ($m^2 ha^{-1}$)	BASAREA	X	X
Mean canopy height (m)	CHEIGHT	n/r	X
Mean crown cover of woody plants (%)	CRCOVER	n/r	X
Mean litter depth (cm)	LITTER	n/r	X
Mean furcation index (%)	FURC	X	X
Coefficient of variation of furcation index (%)	FURCV	X	X

*n/r, not recorded.

The significance of each explanatory variable and of canonical ordination axes was assessed at the 5% significance level using 999 Monte-Carlo permutation tests. The ordinations are plotted as sites-species-explanatory variables triplots with scaling focused on interspecies distances (ter Braak & Šmilauer, 1998). Sites have been classified according to the experimental design, and explanatory variables are shown as lines emanating from the centre of the diagram. Their directions relative to each other and to the axes, species points and sites, indicate the coordinated gradients in the ecological space and the distribution of the species maxima with respect to them. The length of each line indicates the magnitude of the correlation between the variable and the ordination axes (ter Braak & Šmilauer, 1998). From the CCA analyses, hypothetical associations of species were identified (Šmilauer, 1992).

6.3. RESULTS

6.3.1. Biodiversity components

This vegetation survey of short fallow sites indicated a common trend among fallow types over the two years of the study. Considering all the measured biodiversity components, there is a consistent pattern of differences between recurrent *C. odorata*-dominated fallows and fallow sites that had been a forest prior to the cropping phase: increasing intensity of land management seemed to be a significant predictor of falling plant diversity (Tables 6.3 and 6.4). The average number of species per fallow type varied from 45 to 66 in 1998, and from 54 to 92 the following year. The fields with the highest diversity in each fallow type averaged about 65 species per 200 m^2, the mean species richness being similar for classes that had previously been a forest.

Differences between recurrent *C. odorata*-dominated fallow types and fallows that had been forests prior to the cropping phase were significant (at $P<0.05$) for almost all biodiversity components. Moreover, *C. odorata*-dominated fallows that had been forests were clearly distinct from recurrent *C. odorata*-dominated fallow stands, in all biodiversity components.

Table 6.3. Mean values of some biodiversity indicators recorded in three types of short fallow at Mengomo (southern Cameroon, 1998)*

	Frequently cropped**	Moderately cropped	Recently forest
Modi richness (200 m^2)	45.64 (2.04)b	51.44 (2.23)b	58.72 (2.59)a
Species richness (200 m^2)	54.73 (3.80)c	70.33 (4.16)b	92.59 (4.83)a
Modal*** Shannon index	3.695 (0.043)	3.762 (0.047)	3.823 (0.054)
Modal Simpson index	0.029 (0.002)	0.028 (0.002)	0.029 (0.002)
Modal Fisher's alpha	83.347 (5.247)a	66.539 (5.748)ab	55.488 (6.663)b
Mean canopy height (m)	3.13 (0.57)c	5.54 (0.63)b	7.31 (0.72)a
Crown cover (%)	82.27 (7.49)	74.77 (8.20)	78.52 (9.51)
Mean litter depth (cm)	0.73 (0.30)	1.18 (0.33)	1.45 (0.38)
Mean basal area (m^2 ha^{-1})	5.42 (1.34)b	11.13 (1.47)a	12.40 (1.70)a
Mean furcation index (%)	42.37 (4.64)	33.14 (5.08)	30.50 (5.89)

*S.E.M. values are in parentheses. Different letters following entries within a row indicate that the means were significantly different (at $P<0.05$).

**see text for treatment categories.

***Formulae for calculating these diversity indices have been modified to weight 'modi' instead of species (Gillison, 1988).

Over the two years, there were substantial differences between modal diversity indices in the ordering of fallow types. For example, while in 1998, fallow types dominated by *C. odorata* scored high on the modal Fisher's alpha index, the 1999 data show a completely reverse ranking. However, there was a consistent link between plant species richness and the structural diversity (indicated by the *modi* richness, the Shannon and Fisher's alpha indices for PFAs). A general tendency was that fallow types with high species richness (i.e. fallows that had been previously a forest) also had a variety of plant morphological (or functional) attributes.

A similar pattern of difference between recurrent *C. odorata*-dominated fallows and fallow fields that had been a forest prior to the cropping phase is seen in the analyses of stand structural features. Over the two study years, the fallow types were consistent in their ranks for mean canopy height, litter depth, basal area, and furcation index. Fallow types that had been forests displayed the highest values of stand structural parameters, except for the furcation index. There was no significant effect of fallow type on the crown cover as well as on the litter depth.

Table 6.4. Mean values of some biodiversity indicators recorded in three types of short fallow at Mengomo (southern Cameroon, 1999)*

	Frequently cropped**	Moderately cropped	Recently forest
Modi richness (200 m^2)	34.45 (1.57)b	44.30 (1.72)a	48.00 (1.86)a
Species richness (200 m^2)	45.55 (1.88)b	59.10 (2.31)a	65.56a (2.90)a
Modal*** Shannon index	3.324 (0.056)b	3.633 (0.038)a	3.713 (0.040)a
Modal Simpson index	0.048 (0.003)a	0.033 (0.002)b	0.029 (0.002)b
Modal Fisher's alpha	43.66 (4.69)b	63.15 (3.73)a	64.12 (4.29)a
Mean canopy height (m)	3.23 (0.50)c	5.40 (0.22)b	8.17 (0.39)a
Crown cover (%)	90.91 (2.76)	86.50 (1.67)	83.89 (2.32)
Mean litter depth (cm)	0.36 (0.03)	0.44 (0.03)	0.54 (0.07)
Mean basal area (m^2 ha^{-1})	4.18 (0.33)b	6.47 (0.79)a	7.78 (0.67)a
Mean furcation index (%)	47.03 (3.29)a	29.91 (2.79)b	35.37 (2.59)b

*S.E.M. values are in parentheses. Different letters following entries within a row indicate that the means were significantly different (at $P<0.05$).

**see text for treatment categories.

***Formulae for calculating these diversity indices have been modified to weight 'modi' instead of species (Gillison, 1988).

Except for mean litter depth, a significant positive correlation was found between plant biodiversity (as indicated by the number of *modi*, the number of species and the modal diversity indices; $0.48 < r^2 < 0.71$ at $P<0.05$) and fallow structural features (canopy height and basal area). Conversely, there was a negative significant correlation between plant species diversity and crown cover of woody plants as well as furcation index. Plant species richness was significantly correlated with plant structural diversity (as indicated by the *modi* richness and the modal Shannon diversity index), particularly in the recurrent *C. odorata*-dominated fallow type ($r^2=0.79$, $P<0.01$). However, there was no significant correlation between plant biodiversity and litter depth. Correlations between the various parameters are shown in Tables 6.5 and 6.6.

Within each fallow type, significant correlations were established between species diversity and functional diversity. In the recurrent *C. odorata*-dominated fallow type, there was a highly significant negative correlation ($r^2 = -0.78$, $P<0.01$) between species diversity and stand furcation index. In the fallow type III (bush fallow not dominated by *C. odorata* that had been forest), a significant negative correlation

(r^2=−0.70, P<0.05) was also found between species richness and crown cover of woody plants.

Table 6.5. Matrix of correlation coefficients for the investigated parameters in shortened fallows at Mengomo (southern Cameroon, 1998)

	Unique modi	Unique species	Species:modi ratio	Shannon index	Simpson index	Fisher's alpha	Basal area	Furc
Unique modi	1.00							
Unique species	0.83^{hs}	1.00						
Species:modi	0.34	0.80^{hs}	1.00					
Shannon	0.88^{hs}	0.51^{**}	-0.07	1.00				
Simpson	-0.41^{*}	-0.03	0.41^{*}	-0.71^{hs}	1.00			
Fisher'α	0.13	-0.37	-0.74^{hs}	0.52^{**}	-0.64^{***}	1.00		
Basal area	0.33	0.55^{**}	0.64^{***}	0.02	0.30	-0.36	1.00	
Furcation	-0.43^{*}	-0.46^{*}	-0.32	-0.30	0.02	0.28	0.07	1.00
Furc CV	0.30	0.40^{*}	0.34	0.09	0.27	-0.25	0.40	-0.35

$^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$; $^{hs}P<0.0001$.

Table 6.6. Matrix of correlation coefficients for the investigated parameters in shortened fallows at Mengomo (southern Cameroon, 1999)

	Unique modi	Unique species	Species:modi ratio	Shannon index	Simpson index	Fisher's alpha	Basal area	Furc
Unique modi	1.00							
Unique species	0.89^{hs}	1.00						
Species:modi	-0.16	0.31	1.00					
Shannon	0.96hs	0.78^{hs}	0.55^{**}	1.00				
Simpson	-0.85^{hs}	-0.6^{***}	-0.61^{***}	-0.94^{hs}	1.00			
Fisher'α	0.79hs	0.49*	0.82^{hs}	0.89^{hs}	-0.85^{hs}	1.00		
Basal area	0.49*	0.54^{**}	0.08	0.50^{*}	-0.47^{*}	0.33	1.00	
Furcation	-0.6^{***}	-0.6^{***}	-0.17	-0.61	0.48^{*}	-0.48^{*}	-0.28	1.00
Furc CV	0.51^{**}	0.49^{*}	0.03	0.45	-0.43^{*}	0.31	0.02	-0.7^{hs}

$^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$; $^{hs}P<0.0001$.

6.3.2. Plant community composition

In total, 224 and 225 species of vascular plants were recorded from the study sites in 1998 and 1999 respectively (Appendix 6.2). They belonged to 74 and 72 families, respectively. The most richly represented families were Euphorbiaceae, Fabaceae (=Papilionaceae) and Sterculiaceae, respectively with 23, 21 and 12 genera.

Although up to 85 plant species were common to all fallow types, about 67 plants were exclusive to stands that had been forests prior to the cropping phase (Table 6.7). Among the species most frequently found in all study sites were *Chromolaena odorata*, *Haumania danckelmaniana*, *Milletia* spp., *Dioscorea* spp., *Cissus* spp., *Cnestis ferruginea* and *Nephroplepis biserrata*, which were present in more than 70 percent of the sites.

Table 6.7. Total number of plant species recorded in three fallow types in the humid forest zone of southern Cameroon* (1998, 1999**)

Plant community composition	Frequently cropped*	Moderately cropped	Recently forest	Total fallows
Total species	111 (165)	58 (132)	171 (150)	224 (225)
Species with frequency of presence ≥70%	12	13	17	7
Species with frequency of presence ≥50%	26	33	47	27
Total families	54	37	64	74 (72)
Families with one species	31	25	33	34
Species exclusive to fallow type	4	33	34	-

*See test for treatment categories

**Values in parentheses were recorded during the 1999 survey.

6.3.2.1. Recurrent C. odorata-dominated fallows

Although only four species were found exclusively in recurrent *C. odorata*-dominated fallows, this fallow type displayed the highest species diversity (i.e. total number of different species recorded). The species exclusively encountered in this fallow type are *Calpolobia alba*, *Elephantopus mollis*, *Stachytarpheta cayennensis* and *Stephania* sp. The two *C. odorata*-dominated fallows shared about 103 species, whereas 134 plants species were recorded mutually in stands that had been previously forests. *C. odorata*-dominated fallow sites that had been *C. odorata*-dominated fallows in the previous cropping cycle were characterized by the abundance of *C. odorata*, *Albyzia zygia* and *Dioscorea* spp., which were found in all study sites (Table 6.8). The canopy, about two metres tall, showed from place to place some stems of the pioneer species *Alchornea cordifolia*. The under-storey was only characterised by few Poaceae (such as *Axonopus compressus*), and some Cyperaceae (such as *Cyperus* sp). Other species with a high frequency were *Haumania danckelmaniana*, *Clerodendrum* sp, *Desmodium adscendens* and *Triumfetta cordifolia.*

Table 6.8. Relative frequency (%) of the most common species found in short fallows at Mengomo (southern Cameroon), 1998 and 1999.

Species	Frequently cropped*	Moderately cropped	Recently forest
Aframomum sp	36	50	75
Agelaea sp	27	60	88
Alchornea cordifolia	82	60	63
Chromolaena odorata	100	100	63
Cissus sp	45	80	100
Clerodendrum sp	73	60	38
Cnestis ferruginea	73	80	63
Cyperus sp	82	30	50
Desmodium adscendens	73	60	50
Dichapetalum sp	73	70	63
Dioscorea sp	100	60	75
Haumania danckelmaniana	91	80	100
Microdesmis puberula	18	80	75
Milletia sp	82	80	88
Nephroplepis biserrata	45	90	88

Species	Frequently cropped*	Moderately cropped	Recently forest
Palisota hirsuta	64	80	63
Penianthus longifolius	36	80	63
Sabicea sp	36	90	88
Tabernaemontana crassa	73	50	88
Trichilia sp	27	60	88

*See text for treatment categories.

6.3.2.2. Chromolaena odorata-dominated fallows that had been forests

The vegetation in *C. odorata*-dominated fallows that had previously been forests was consistently the less diverse and rich of all study fallow types: 58 (and 132 in 1999) species belonging to 37 families (Table 6.7). Although *C. odorata* was still abundant (recorded in all sites), this fallow type was characterized by the importance of Commelinaceae and Marantaceae species (Table 6.9), represented by different species of *Palisota* and *Megaphrynium*. Species of the genus *Cissus* were found in 80% of the sample sites.

Table 6.9. Family frequency by species diversity (number of genera in each family) in shortened fallow systems at Mengomo (southern Cameroon), 1998 and 1999.

Family	Frequently cropped*	Moderately cropped	Recently forest
Annonaceae	1	2	4
Apocynaceae	4	1	7
Araceae	0	2	4
Asteraceae	3	3	4
Combretaceae	3	4	3
Commelinaceae	4	1	6
Costaceae	2	2	3
Ebenaceae	1	1	4
Euphorbiaceae	14	6	20
Leguminosae	6	3	11
Marantaceae	3	2	6
Olacaceae	3	0	5
Rubiaceae	4	1	6
Sapindaceae	2	1	4
Sterculiaceae	5	4	10

The canopy was co-dominated by *Alchornea cordifolia* and *Albizia* spp. which carried stems of *Cogniauxia podolaena*. Pioneer trees, such as *Musanga cecropioides* and *Macaranga* spp. (especially *M. barteri* and *M. spinosa*) were also dominating the canopy stratum (in more than 50% of the sample sites). There was more under-storey than in the previous fallow type, and comprised some forest herbaceous species like *Aframomum* spp., *Harungana madagascariensis* and *Haumania danckelmaniana*. In addition to *C. odorata* and *H. danckelmaniana*, other most frequently encountered species included *Alchornea cordifolia*, *Cogniauxia podolaena*, *Cnestis ferruginea*, *Microdesmis puberula*, *Palisota hirsuta* and *Rhektophyllum mirabile*.

6.3.2.3. Bush fallows (not dominated by C. odorata) that had been forests

A high number of species was recorded in this fallow type associated with a relatively low resource use intensity regime: 171 species belonging to 64 families in 1998, and 150 from 72 families in 1999. The vegetation in these fallows was clearly stratified in three distinguishable layers: an upper storey dominated by pioneer semi-woody species (of up to 6-8 m height), an intermediate stratum that comprised small individuals of mostly secondary or primary forest species, and a lower storey dominated by secondary forest herbaceous species. Although *Haumania danckelmaniana* and *Milletia* spp. were still recorded among the most frequent species, the floristic composition in this fallow type was very different from others (Table 6.8). *C. odorata* was not among the ten most frequent species in these sites. The most frequently found species were individuals of the genus *Cissus* and *H. danckelmaniana*. The families Euphorbiaceae, Fabaceae and Sterculiaceae were represented by more species in this fallow type as compared to the two others (Table 6.9): 20, 11 and 10, respectively (against 14:6:5 and 6:3:4 for *C. odorata*-dominated fallows).

Characteristic species of the mature secondary forest were consistently present in bush fallows (e.g. *M. cecropioides*, *Macaranga* spp., *Combretum* spp. and *Palisota* spp.). Of the 171 species (150 in 1999) recorded on fallow sites of this type, about 100 were present only in one or two plots, most of them being exclusive to that fallow class. Included in this category were species of the genera *Cola*, *Maesobotrya* and

Diospyros as well as some forest trees such as *Triplochiton scleroxylon* and *Uapaca* spp.

6.3.3. Patterns of plant functional diversity

In spite of the differences in terms of species diversity between the three study fallow types, there was also a number of general patterns in plant functional attributes that were recognised. The results from the Chi-square analysis indicated a significant difference (P=0.000) in the frequency of occurrence of plant functional attributes (leaf size, leaf chlorotype, leaf morphotype, life form and root type) between fallow types (Figure 6.3). More specifically, the fallow types defined for this study were significantly different (P=0.000) from each other in terms of leaf size and leaf chlorotype.

Fallow types dominated by *C. odorata* did not show significant difference in the frequency of distribution of life form attributes (χ^2 (*df*, 5) = 9.09, P=0.106). Fallow types that had been forests prior to the cropping phase were not significantly different in the frequency distribution of the attributes related to the root type (χ^2 (*df*, 1) = 2.881, P=0.09).

Leaf inclination attributes (i.e. vertical, lateral, pendulous or composite inclination) were equally distributed in all fallow vegetation types, as well as some functional attributes related to leaf size (nanophyll, microphyll, notophyll, mesophyll and platyphyll), leaf chlorotype, leaf morphotype (rosulate and succulent) and life forms (phanerophytes, chamaephytes, hemicryptophytes and lianas). The remaining PFAs showed some differences in their distribution across the fallow types (Figure 6.3).

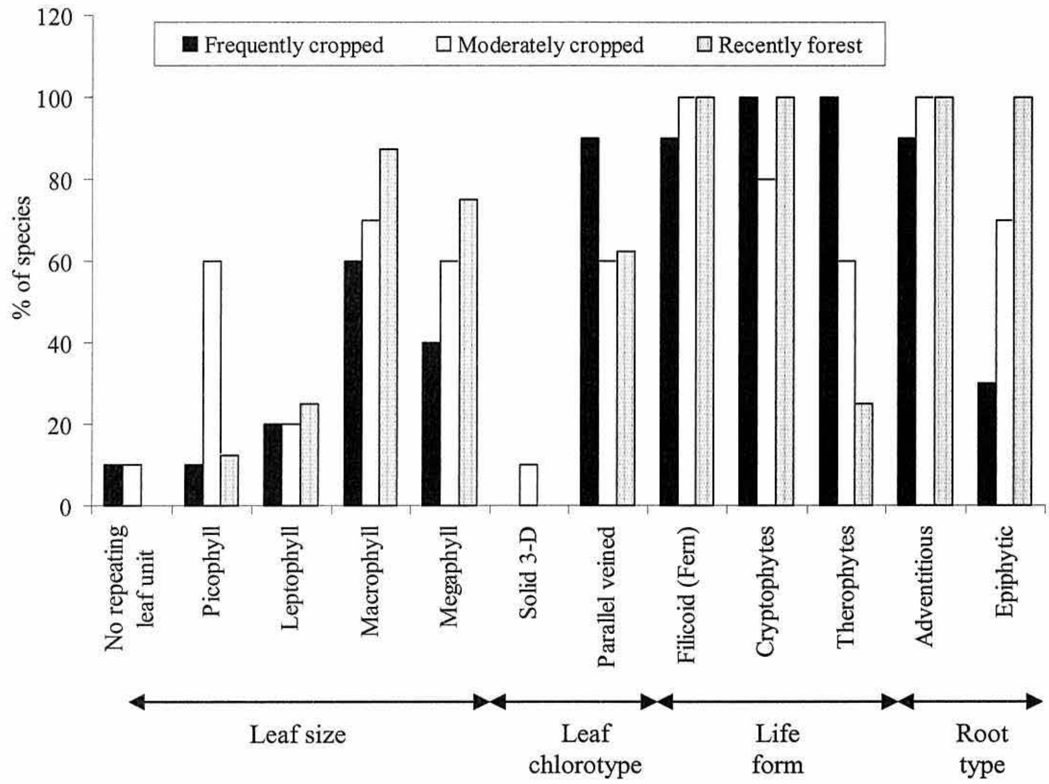


Figure 6.3. Variation in plant functional attributes (PFAs) among three types of short fallow at Mengomo (southern Cameroon)

6.3.4. Patterns of variation in species composition among fallow types

The total inertia (i.e. total variance in the species data) of CCA of the 1998-1999 combined vegetation data is 3.610 (Figure 6.4). Eigenvalues of the first four axes are respectively 0.229, 0.184, 0.087 and 0.069. The corresponding relative inertia values are respectively, 6.3, 5.1, 2.4 and 1.9%. Because of the small eigenvalues and the presumably little information that can be drawn from the third and fourth axes, we will concentrate on the first two axes. The overall ordination and axes 1-4 were significant (P=0.001), indicating the strength of the relationships between fallow species composition and the measured fallow stand structural parameters.

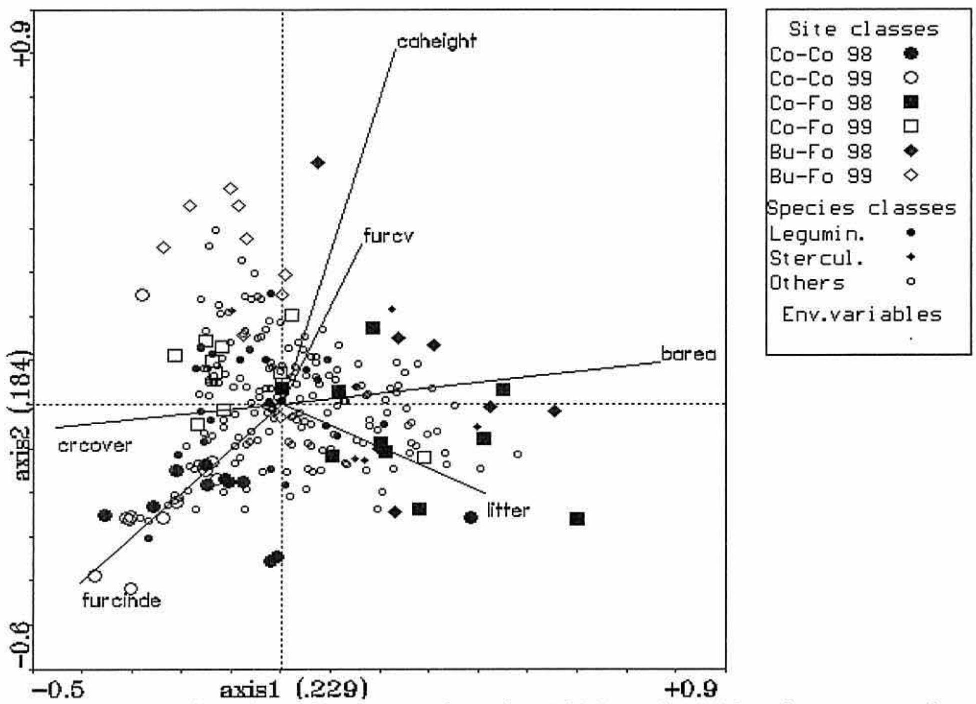


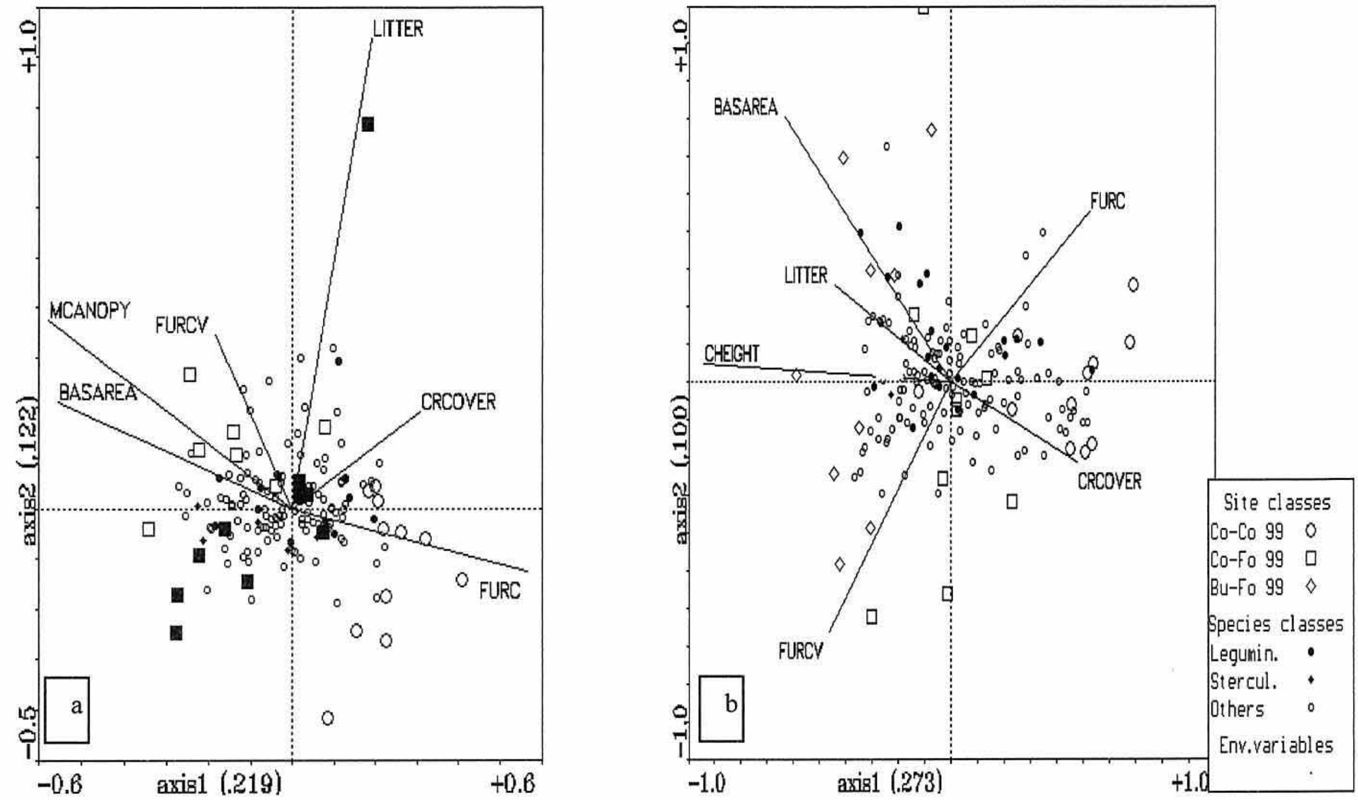
Figure 6.4. CCA ordination diagram using the 1998 and 1999 using vegetation data recorded in three types of short fallow at Mengomo (southern Cameroon). Vegetation structural variables are indicated by arrows, and coded as: barea, basal area; caheight, canopy height; crcover, crown cover; furcinde, furcation index; furcv, furcation index coefficient of variation; litter, litter depth. Species classes are labelled as: Legumi., Leguminosae; Sterc., Sterculiaceae and Others, other taxa. Fallow sites are coded as: circles, frequently cropped fallows; square, moderately cropped fallows; lozenge, recently forest fallows.

The site-conditional ordination diagrams based on the 1998 and 1999 data taken separately are shown in Figure 6.5. Using forward selection (Monte-Carlo permutation test), basal area, canopy height, canopy crown cover and litter depth were found to significantly explain the total variance in species distribution in fallow sites, at respectively, 0.001, 0.001, 0.014 and 0.046 significance levels. This combination of variables explained 68.5% of the total variance in species' distribution. The first axis of both ordination diagrams clearly indicates a clear gradient of land use intensity, with low intensity regimes to the left and higher regimes to the right. Sites on the left of Axis 1 correspond to fallow stands that had been a forest in the previous cultivation-fallow cycle, while those on the extreme right are recurrent *C. odorata*-dominated fallows.

When combining data from both years (Figure 6.4), axis 1 explained 33.4% of the total variance of the species data, and was positively correlated with basal area (ca. 0.8) and litter depth (ca. 0.4), and negatively correlated with canopy crown cover (ca. −0.4). The second axis explained an additional 26.9% of the species data, and was positively correlated with canopy height (ca. 0.8) and negatively with furcation index (ca. −0.4). The position of the fallow sites along the first axis suggests that recurrent *C. odorata*-dominated fallows differed systematically from fallows that had been a forest and have less tall and large tree species. *C. odorata*-dominated fallows that had also been *C. odorata*-dominated fallows in the previous cropping phase are characterised by plant species that exhibit recurrent branching from break-points on the main stem with resulting high furcation index values.

For the 1998 data, axis 2 opposes fallow sites dominated by *C. odorata* and bush fallows not dominated by that Asteraceous species, while for the 1999 data, it opposes recurrent *C. odorata*-dominated fallows and fallows that had been forests in the previous cropping cycle. Fallow sites that had been forest in the previous cropping cycle are being characterised by high coefficient of variation of the furcation index, and little amount of litter.

The influence of measured stand structural variables detected as significant by the CANOCO analysis on the distribution of fallow species was explored further (Table 6.10). The first point to note is that the ordination axes 1 and 2 are uncorrelated with each other (r_s=−0.025, P=0.85), indicating that they may reflect different sources of variation within the vegetation data. That table also reveals that relative positions of sites on the first and second axes in the CCA ordination relate, not only to the measured stand structural variables, but also to fallow type (P=0.009 and P<0.0001, respectively). The first axis appears to be very highly correlated (P<0.0001) with basal area, confirming the visual relationship described above. The second axis is significantly correlated with canopy height (r_s=0.750, P<0.0001), basal area (r_s=0.328, P=0.012) and canopy crown cover (r_s=−0.325, P=0.013). Except for the litter depth, all measured vegetation structural parameters are either positively or negatively (canopy crown cover) correlated to the fallow type.



Figures 6.5. Site-conditional triplots based on a CCA of the 1998 (a) and 1999 (b) short fallow vegetation study at Mengomo (southern Cameroon). The 'environmental' variables are abbreviated as in Figure 6.4, and eigenvalues of canonical axes are given in parentheses.

Table 6.10. Spearman's rank correlation coefficients between the site scores and the first two axes of the canonical correspondence analysis of the combined 1998/1999 fallow vegetation data and the environmental variables for canopy height, basal area, litter depth and canopy crown cover for those sites

	Fallow type	**Ordination axes**		**Canopy height**	**Basal area**	**Litter depth**
		1	2			
CCA axis 1	0.34^{**}					
CCA axis 2	0.77^{hs}	−0.03				
Canopy height	0.83^{hs}	0.27^{*}	0.75^{hs}			
Basal area	0.64^{hs}	0.63^{hs}	0.33^{**}	0.68^{hs}		
Litter depth	0.24	0.32^{**}	−0.06	0.25	0.34^{**}	
Canopy crown cover %	-0.41^{***}	-0.37^{**}	-0.33^{**}	-0.29^{*}	−0.24	−0.07

$^{hs}P \leq 0.0001$; $^{***}P \leq 0.001$; $^{**}P \leq 0.01$; $^{*}P \leq 0.05$.

In the CANOCO site-conditional CCA ordination of the floristic data (Figure 6.6, based on the same data as Figure 6.4), the species ordination relates to floristic gradients through the three studied fallow types. When subjected to a Monte-Carlo permutation test, the species distribution in the ordination was found to be highly significantly related to the measured stand structural variables (P=0.001).

As shown in the diagram, species lie within a circular belt around the centre of the diagram, and appear to be associated with the vegetation structural variables, which give rise to differences between species assemblages. Here again, as already noticed for the ordination of sites, the most distinct separation between the 1998 species scores was along Axis 1, which showed a gradient from lower to higher land use intensity; whereas in 1999, the separation was along Axis 2 which also showed a gradient of land use intensity from its negative to its positive pole. Therefore, species can be separated in three main groups: one at the lower left side of the diagram (Group 1), a second at the upper left (Group 2) and a third on the positive pole of Axis 1 (Group 3). This distribution corresponds well with that of the sampled fallow sites (Figure 6.4), with Group 1 species associated with recurrent *C. odorata*-dominated fallows (for both years), the 1999 fallow sites that had been previously a forest characterised by species of the Group 2, and the 1998 fallow sites that had previously been a forest associated with species of Group 3. Apart for some small trees (e.g. *Albizia* spp.) and shrubs (e.g. *Anthocleista schweinfurthii*), Group 1 mainly constituted of weedy species (e.g. *Axonopus compressus*, *Costus afer*, *Desmodium adscendens*, *Elephantopus mollis*, *Oplismenus burmannii*, *Sida rhombifolia*, *Triumfetta cordifolia* and *Vigna* spp.). Group 2 was mostly made of secondary rapidly growing woody (or semi-woody) pioneer species (such as *Alchornea floribunda*, *Carapa procera*, *Musanga cecropioides*, *Rothmannia* spp., *Stephania* sp, *Thalia welwitschii*, *Trichilia rubescens*), as well as of some long-lived pioneer species (e.g. *Distemonanthus benthamianus*, *Diospyros conocarpa*, *Tetrorchidium didymostemon*). Finally, species of Group 3 were mostly plants that are found in the under-storey of secondary forests in the area (e.g. *Bertiera* sp, *Cissus* sp, *Culcasia* sp, *Ficus* sp, *Leptonychia* sp, *Megaphrynium* spp., *Sarcophrynium* spp., *Smilax kraussiana*). Species at the left side of Axis 1 were most frequently found in relatively litter-rich fallows, where crown cover of woody plants was maximal but tree basal area and canopy height were lower. With regards to the vegetation structural parameters, species of Groups 2 and 3 appeared to be characteristic of fallow sites with taller and larger trees, as compared to species of Group 1. In the 1998 *C. odorata*-dominated fallows that had been a forest, some species appeared to be strongly associated with higher litter-rich sites. Such species included *Culcasia* sp, *Leptonychia* sp, *Meiocarpidium lepidotum* and *Renealmia* sp.

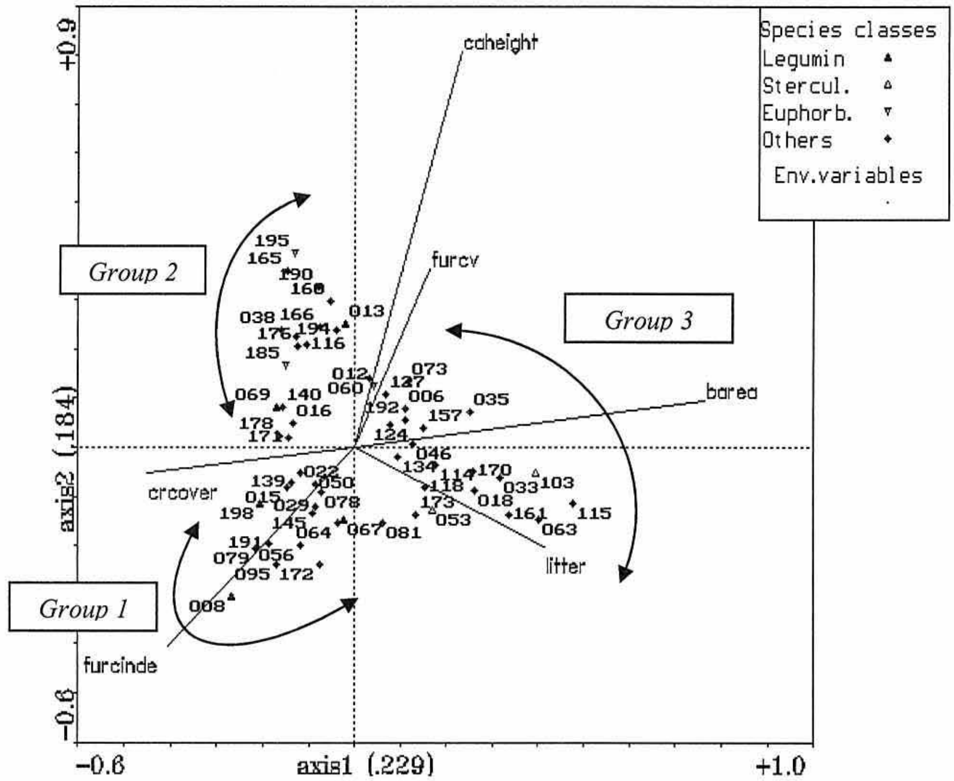


Figure 6.6. Site-conditional ordination, based on a CCA by CANOCO, of presence/absence species (4%<frequency<75%) in 58 sites from three different short fallow types at Mengomo (southern Cameroon, combined data of 1998 and 1999). Only selected species are displayed that have N2>14 (i.e. 68 species out of the 202 included in the CCA). Figures in the diagram identify species and are coded as follows: 006= *Agelaea* sp, 008= *Albizia* sp, 012= *Alchornea floribunda*, 013= *Albizia gummifera*, 015= *Albizia zygia*, 016= *Ampelocissus bombissina*, 018= *Anchomanes difformis*, 022= *Anthocleista schweinfurthii*, 029= *Axonopus compressus*, 033= *Bertiera* sp, 035= *Calamus deerratus*, 038= *Carapa procera*, 046= *Cissus* sp, 050= *Costus afer*, 053= *Cola* sp, 056= *Commelina* sp, 060= *Coelocaryon preuss*ii, 063= *Culcasia* sp, 064= *Cyperus* sp, 067= *Desmodium adscendens*, 069= *Distemonanthus benthamianus*, 073= *Diospyros conocarpa*, 078= *Elaeis guineensis*, 079= *Elephantopus mollis*, 081= *Ficus* sp, 095= *Ipomoea mauritiana*, 103= *Leptonychia* sp, 114= *Megaphrynium* sp, 115= *Meiocarpidium lepidotum*, 116= *Megaphrynium macrostachyum*, 118= Menispermaceae undetermined species, 124= *Microsorium punctatum*, 127= *Musanga cecropioides*, 134= *Nephrolepis biserrata*, 139= *Oplismenus burmannii*, *140= Palisota ambigua*, 145= *Paullinia pinnata*, 157= *Pteris* sp, 160= *Raphia montbuttorum*, 161= *Renealmia* sp, 165= *Rothmannia hispidum*, 166= *Rothmannia* sp, 170= *Sarcophrynium* sp, 171=

Scleria boivini, 172= *Sida rhombifolia*, 173= *Smilax kraussiana*, 176= *Stephania* sp, 178= *Strophantus* sp, 185= *Tetrorchidium didymostemon*, 190= *Thalia welwitschii*, 191= *Triumfetta cordifolia*, 192= *Trichilia* sp, 194= *Trichilia rubescens*, 195= *Uapaca guineensis*, 198= *Vigna* sp.

From Figure 6.6, it can also be seen that there seem to be more members of the Sterculiaceae family (such as *Cola* spp., *Leptonychia* sp) in fallow sites that had been a forest as compared to recurrent *C. odorata*-dominated fallows. Whereas, conversely, these more intensified land use types comprised more taxa of the Caesalpiniaceae, Mimosaceae and Papilionaceae (here grouped as leguminous species; e.g. *Albizia zygia*, *Desmodium adscendens*, *Vigna* sp). However, although not included in the CCA ordination, two other groups should be added to the three defined above groups.

The first group comprises 'generalist' species for which no fallow type affinity was found (i.e. species with an overall frequency of >75%), which included *C. odorata* (present in nearly 95% of the sampled sites), *Haumania danckelmaniana* (recorded in 93% of the sites), *Dichapetalum* sp (present in 74% of the fallow sites) and *Cnestis ferruginea* (with a frequency of about 71%). The second group, made of 'low frequency' species, comprised 119 species in total that were found in less than 3 fallow sites and included both herbaceous and woody plants.

6.4. DISCUSSION

6.4.1. Plant community composition

When the biodiversity parameters recorded in the sampled fallow types were compared with values obtained in various land use types in southern Cameroon, the structural features recorded in the 5-7years-old fallows sampled in this study broadly fall within the range found in other short fallows of about 8 years-old, but the species and functional richness appear to be lower than in fallows of 2-4 years-old dominated by *C. odorata* and much lower than in secondary forests (Table 6.11). This finding, added to the fact that the recurrent *C. odorata*-dominated fallow type displayed the highest total species and functional diversity in this study, emphasises the suggestion made by Gillison (2000) that *C. odorata* may contribute to increase total plant biodiversity, maybe by enhancing soil nutrient availability through increased litter deposition and reduced soil exposure.

Table 6.11. Biodiversity indicators values in 200 m^2 plots in various locations of southern Cameroon, from Gillison (2000)*

Location	Fallow type	Canopy Height	Crown Cover(%)	Litter Depth	Basal Area	Furc (%)	No. *Modi*	No. species
Awae	8-10 years MC**	3.5	95	12	4.7	65.5	35	54
Nkolfoulou	4 FC	2.6	95	1	2.2	100.0	22	30
Mengomo	Secondary Forest	1.8	70	6	20.7	37.5	42	93
Mengomo	2 MC	2.5	95	1	0.5	100.0	47	76
Akok	4 MC	3.5	95	2	1.0	58.6	66	100
Akok	2 FC	2.5	95	2	1.0	79.3	44	61

*Units for canopy height, litter depth and basal area are m, cm and m^2 ha^{-1}, respectively.

**MC, moderately cropped fallows dominated by *C. odorata*; FC, frequently cropped fallows dominated by *C. odorata*.

As in other studies of vegetation succession after agricultural abandonment in humid tropical conditions (Letouzey, 1968; Mitja & Hladik, 1989; Carrière *et al.*, 2002), establishment of woody fallow species was associated with sites where canopy height was greatest, and where crown cover and furcation indices were negligible. In their study of vegetation succession after cultivation in slash-and-burn agriculture, Uhl & Clark (1982) suggested that away from the crowns of long-lived fallow species, the establishment and abundance of large herbaceous monocotyledons (especially Marantaceae such as *Haumania danckelmaniana* and Commelinaceae) may be favoured by both lower seed rain and abiotic conditions beneath trees.

Crown cover and coefficient of variation percentage around the mean of the furcation index were also significant stand structural predictors of fallow species distribution. Although no significant difference was found among the three fallow types in terms of crown cover, recurrent *C. odorata*-dominated fallows displayed a slightly higher crown cover than the two other fallow types. This could be due to the effect of remnant trees (i.e. isolated trees that were selectively spared during field clearing activities) such as *Ceiba pentandra*, *Psidium guajava* or *Terminalia superba* (Carrière *et al.*, 2002).

The pattern of variation in fallow species composition showed that it was significantly correlated with the coefficient of variation of the furcation index, which can be a useful diagnostic for the disturbance level of these habitat types, as high furcation index coefficient of variation has been associated with more 'vulnerable' (for mechanical reasons) sites (Gillison, 2000). Therefore, the furcation coefficient percent associated with fallow types that had been forests raises the possibility that these fallows have experienced more frequent, small to medium scale disturbance, and thus could explain that they had a higher number of species per plot as compared to recurrent *C. odorata*-dominated fallows. Given the level of disturbance often associated with slash-and-burn agriculture practices, this explanation would then be consistent with the Connell's intermediate disturbance hypothesis (Ashton, 1990) that disturbance leads to species enrichment through its influence on the diversity of microhabitats for establishment and regeneration. According to that model, in less fertile sandy soils, nutrient status appears to be the main determinant of species richness.

However, the fact that all fallow types were dominated by a few number of species (e.g. *C. odorata*, *Dioscorea* spp., *H. danckelmaniana*) may confirm the 'non-equilibrium' hypothesis of Tilman (Ashton, 1990) that species richness is depressed by an increase in species dominance, as the dominant species tend to competitively exclude others from the ubiquitous resource, light. This situation, he argued, is however more likely to happen in habitats where soil resources are not limiting. Moreover, if assuming differences in soil nutrient status, the observed differences in species richness between recurrent *C. odorata*-dominated fallows and fallows that had previously been forests could also be attributed to differences in the number of rare species in each group (Ashton, 1990).

The pattern of basal area obtained in this study was substantially much higher than that found by Gillison (2000) and approaches the basal area of secondary logged-over forests (Table 6.11). This difference is likely to be a result of the abundance of remnant trees sampled in this study. However, as already mentioned by several studies conducted in the area (Mitja & Hladik, 1989; Carrière *et al.*, 2002), basal area in vegetation re-growth stages after cultivation is mostly contributed by woody species (trees and shrubs), thus explaining the higher basal area values obtained in bush fallows that had been forests. Individual trees and shrubs were larger and more frequent in this fallow type than elsewhere and belonged to rapidly growing pioneer species such as *Macaranga* spp., *Musanga cecropioides*, *Pycnanthus angolensis* and *Trema orientalis*. The measured litter depth was somewhat smaller than that reported by Gillison (2000) and is likely to result from the differing sampling size (Table 6.11).

Overall, it appears that fallow sites that had been forest in the previous fallow-cultivation cycle already show patterns of a young diversified forest with a heterogeneous structure already reported by Zapfack *et al.* (2000). However, the high values of furcation index coefficient of variation recorded in this study for all fallow types, suggest a land use with high level of disturbance (Gillison, 2000). The same pattern was reported by Moutsamboté *et al.* (2000) in their study of vegetation re-growth in early fallows in Mayombe (southwestern Congo).

Although canopy height was the best predictor of species richness and diversity, litter depth and basal area added significantly to the explained variability. Previous studies on the fallow species diversity (e.g. Aweto, 1981, 2001; Chinea, 2002; Le Coeur *et al.*, 2002) argued that, because of their very structure and position in the landscape, species diversity in fallow lands are likely to be significantly impacted by the surrounding semi-natural vegetation which can be highly variable from one site to another. Moreover, the small size of fallow lands as reported by Gockowski *et al.* (1998a) and the relatively short distances to other land use types (cocoa plantations, food crop fields and patches of secondary forest) are likely to reduce the importance of distance from seed sources in the colonization by species from adjacent lands. This argument draws attention to the magnitude of seed dispersal for the colonization of fallows (Chinea, 2002).

Therefore, the pattern of species diversity between fallows that had been a forest and recurrent *C. odorata*-dominated fallows observed in this study could also be due to differences in the type of vegetation present in the surroundings of the studied sites. Zapfack *et al.* (2000), following Gillison (2000), noted more species of introduced origin and weedy propensity in fallows directly adjacent to intensively farmed lands (such as recurrent *C. odorata*-dominated fallows) as compared to less intensively farmed habitats (bush fallows or forest patches). The high number of species per plot reported in fallows that had been a forest could also be explained by the frequency of presence of trees (in particular, wild fruit trees or shrubs such as *Carapa procera*, *Cola* spp., *Sarcophrynium* spp.) found in sites of this type, since these trees may provide for seed sources and perches for animals that disperse native species (Chinea, 2002).

The high number of species recorded in recurrent *C. odorata*-dominated fallows as compared to the less intensively farmed *C. odorata*-dominated fallows that had been a forest (an average number of 138 species identified over the two years, versus only 95 for the second fallow type) agrees with the result of Gillison (2000) who found that diversity in frequently farmed shortened fallows dominated by *C. odorata* seems to exceed that of old-growth secondary logged-over forest (Table 6.11).

In a comparative assessment of species diversity and richness within various habitats types in the Bipindi-Akom II region (south Cameroon), van Dijk (1999) recorded nearly 50 different species per hectare in young fallows (although the fallow age was not reported), and about 82 to 100 species per hectare in secondary forests. As in this study, van Dijk (1999) found high species diversity in fallows, which could be comparable to late secondary forests. One possible explanation to the unexpectedly high species diversity of the short fallow systems may be found in the high number of remnant trees that were recorded in the sites, confirming the selective weeding and tree felling practiced by local farmers (van Dijk, 1999; Carrière *et al.*, 2002).

The functional attributes spectra demonstrated that the percentages of macrophyll and megaphyll species declined with increasing land use intensity, whereas the percentages of therophytes (i.e. plant species that spend the unfavourable period of the year as seeds) and plants with solid tri-dimensional or parallel veined leaves followed the opposite gradient (i.e. were highest in highly farmed fallow types). Macrophyll and megaphyll leaf sizes were more frequently recorded in bush fallows that had been forests, thus confirming the relative similarity of these land use types with young forests of readily vertical stratification (Moutsamboté *et al.*, 2000; Zapfack *et al.*, 2000).

The importance of therophytes (many monocotyledons and some grass-like dicotyledons) as colonising species in highly farmed fallow types had already been reported by various studies conducted in other extreme habitat types, and appears to be a function of their life-form (Kent & Coker, 1992). Their ability to produce seeds during the unfavourable season (i.e. the dry season) enables them to survive when the soil is subjected to drought in the dry months, giving them an adaptive advantage over forest species. The importance of plants with parallel leaf venation in recurrent *C. odorata*-dominated fallow sites could be an indication that this fallow type is wetter than the two others, since this plant attribute is mostly found in graminoids or grass-like-dominated sites (Gillison, 1988). Plants with solid tri-dimensional leaves (e.g. *Eulophia* sp and *Vanilla africana*) were recorded exclusively in *C. odorata*-dominated fallows that had been a forest, and Gillison (1988) linked the occurrence of that plant attribute with a plant response to extreme conditions of soil moisture availability.

From the ordination analyses, it can be seen that there is a clear pattern of distribution of species along a gradient of resource use intensity: recurrent *C. odorata*-dominated fallows (reflecting high land use intensity) were clearly separated from fallow sites that had been forests in the previous cropping cycle (corresponding to relatively lower land use intensity). Stand structural factors (especially canopy height and crown cover) and past vegetation type significantly affected species composition in 5-7 years old fallows of southern Cameroon. Canopy height of the stand was the first factor selected by the forward selection feature of CANOCO. Very few species (*Calpolobia alba*, *Elephantopus mollis*, *Stachytarpheta cayennensis* and *Stephania* sp) were exclusively found in recurrent *C. odorata*-dominated fallows, which underscores the high intensity level of agricultural use of these habitats, resulting in the elimination of the original vegetation. It is also possible that the invasion of *C. odorata* induced changes in vegetation structure (particularly, woody plants) that affected the fallow species community in *C. odorata*-dominated fallow sites. Propagules of species colonizing fallow lands of this type necessarily have to disperse from the surrounding vegetation (Chinea, 2002).

However, the low frequency of occurrence (less than 10%) of species exclusively found in highly farmed *C. odorata*-dominated fallows in this study makes it difficult to look for a more accurate ecological explanation. In this fallow type were mostly present weedy plants (such as *Axonopus compressus*, *C. odorata*, *Cyperus* sp, *Desmodium adscendens*, *Triumfetta cordifolia*), residual crop species from the previous cropping period (such as *Dioscorea* spp., *Ipomoea involucrata*, *Manihot esculenta*) and light-demanding monocotyledonous herbs such as *Commelina* spp, *Harungana madagascariensis*. Pioneer species such as *Macaranga* spp., *Musanga cecropioides*, *Myrianthus arboreus* and *Trema orientalis* were present in less than 37% of the sites of this fallow type although Carrière *et al.* (2002) reported that this latter species usually dominates fallow sites cultivated over many cycles or burnt several times.

Fallows that had been a forest in the previous fallow-cropping cycle shared a great number of common species (about 134), of which 85 were also found in recurrent *C. odorata*-dominated fallows. A possible explanation to this high number of common species among the three fallow types could be the human influence (van Dijk, 1999). In fallow sites of this type (i.e. that had been a forest), one notices the appearance of 'new' species which, though not very frequent (such as *Carapa procera*, *Coula edulis*, *Dialium* sp, *Dichapetalum* sp., *C. odorata*), still dominated the flora (100% frequency of occurrence) in the fallow type II. In the fallow type III, *C. odorata* was recorded at a lower frequency (65.5%).

Weedy plants were also less frequent in this latter fallow type, whereas the frequency of occurrence of pioneer species (e.g. *Macaranga* spp., *Musanga cecropioides*, *Myrianthus arboreus* and *Trema orientalis*) increased. The consistent presence of these pioneer species confirmed the findings of previous studies of vegetation re-growth in fallows of Central Africa (Letouzey, 1968; Mitja & Hladik, 1989; van Dijk, 1999). From the CCA ordination of species, leguminous plants appeared to be separated from forest taxa of the Sterculiaceae family. This separation could be of interest since each group has been found to impact differently the fertility function of fallows during the post-fallow cropping phase; leguminous-based fallows performing better than fallows based on herbaceous species, particularly on low base status soils (Szott *et al.*, 1999).

The influence of vegetation composition and vegetation structure on species assemblages reported in this study concurs with similar studies on different land use types (Chinea, 2002; de Blois *et al.*, 2002; Huang *et al.*, 2002). The species assemblages along the first canonical axis, highly correlated with litter depth and basal area, suggest that there is a gradient of soil organic matter content and soil moisture from the less to the more intensively farmed fallow types. However, Szott *et al.* (1999) noticed that in fallows of less than 10 years old, the association with soil factors is not as strong as in long fallow systems, and in some cases, may be overridden by other factors such as the geographical situation of the sites (e. g. proximity to a river).

It is possible that the effects of vegetation structure on plant community composition reported in this study is an indirect one, through greater shading and water uptake by larger trees which in turn effect the soil moisture, humidity and the composition of the ground flora. Many forest species are associated with shady humid conditions, especially in the early stages of their development (de Rouw, 1991; 1995), while others are associated with drier more open conditions. A good example of these indirect effects can be seen in the distribution of *Calamus deerratus* and *Anchomanes difformis*: both species were more frequent in fallow sites with larger trees, suggesting a preference for shady and wetter habitat types, which is said to be the case for *C. deerratus*, described as a shade-bearer species preferring the specific conditions of valley bottoms (van Dijk, 1999). However, Figure 6.6 indicates that both species were influenced by a combination of increasing basal area and increasing litter depth. This has already been observed in other studies (van Dijk, 1999; Carrière *et al.*, 2002) where these species were more abundant in dense tracts of tall forest trees. These observations thus suggest that it is the shady and humid microclimate found under these conditions that both species are responding to, rather than the presence of larger trees *per se*. Also of interest were leguminous species (such as *Albizia* spp., *Distemonanthus benthamianus*, *Vigna* sp): they are associated with ferralitic soils (ferrasols, Ola-Adams and Hall, 1987)

The results of this study suggest that increasing land use intensity (reflected here by increasing number of fallow-cultivation cycles) will initially have little effect on the total diversity (as showed in table 6.11) of the shortened fallow plant community. However, as the link to the forest is reduced, altering the site vegetation structural characteristics and decreasing shade (leading to a more homogeneous microclimate), there will be an adverse effect and species richness will decline. Nevertheless, other studies have shown that increasing land use intensity result in the loss of some uncommon useful species of shortened fallow systems such as *Megaphrynium* spp., *Sarcophrynium* spp. (van Dijk, 1999; Aweto, 2001). Like in this study, there may be no replacement with uncommon weed species because they are being exposed to competition from 'generalist' species through habitat disturbance (Sutherland, 1996).

6.4.2. Weeds in shortened fallows

Because shortened fallows are by definition anthropogenic lands, we expect light-requiring species to flourish in these habitats; i.e. species known to be tolerant to open conditions (heliophytic species) are expected to be more competitive than forest shade-tolerant species (Fujisaka *et al.*, 2000). Our results show that increased level of land use intensity associated with increased level of disturbances in fallows correlate with the more intensive fallow type (i.e. the recurrent *C. odorata*-dominated fallows), and seem to facilitate the invasion by weeds, such as *Axonopus compressus*, *C. odorata*, *Costus afer*, *Cyperus* spp., *Desmodium adscendens*, *Oplismenus burmannii*, *Scleria boivini*, *Sida rhombifolia*, *Stachytarpheta cayennensis*, and *Triumfetta cordifolia*, characteristic of unstable habitats (Letouzey, 1968).

The proportion of weedy species in fallows that had been forests appeared to be lower than in the recurrent *C. odorata*-dominated fallow type, and corroborates the finding of Weise & Tchamou (1999) who studied the abundance of weeds in various fallow systems in the study area. In recurrent *C. odorata*-dominated fallows, 10 out of the 15 most frequent species were weeds. Both the direct intensive agricultural use of fallow lands of this type that contributes to reduce tree width and tree cover, and the indirect effect of weed propagules from adjacent fields could interact to increase opportunity for weed invasion (de Rouw, 1995; Floret & Pontanier, 2000; de Blois *et al.*, 2002).

Previous studies on floristic composition and diversity of habitats (e.g. French & Cummins, 2001; Chinea, 2002; de Blois *et al.*, 2002) have shown that sites directly adjacent to intensively farmed fields are likely to have more weeds as compared to sites adjacent to less intensively farmed habitats (such as forests or long duration fallows). This situation has been shown to affect species composition and community structure of fallow fields (Szott *et al.*, 1999; Gillisson, 2000). Therefore, it is important to suggest measures that aim to protect these land use types and sensitive species, which can contribute to reduce opportunities for weed invasion from adjacent vegetation.

CHAPTER VII

WEED POPULATION DYNAMICS AND CROP YIELD IN FIELDS ESTABLISHED AFTER SHORT-DURATION FALLOWS IN THE HUMID FOREST ZONE OF SOUTHERN CAMEROON

7.1. INTRODUCTION

Among the problems which farmers in tropical humid environment face, weeds are recognised as being of major importance (Nye & Greenland, 1960; Moody 1975; de Rouw, 1995). In fact, increasing weed infestation, leading to increased labour (for weeding activities), has led farmers in slash-and-burn farming systems under land pressure to attribute more importance to fallows as weed-break (Roder *et al.*, 1997). Throughout the study area, weeds were the main agricultural constraint cited by all farmers questioned (Chapter 5), especially when managing fallow lands of less than 7 years old (see also Weise & Tchamou, 1999).

With the shortening of fallow duration, apart from the socio-economic concern for the well-being of rural communities who depend on fallows to collect NTFPs, and the environmental concern of biodiversity losses, another global and no less important problem for short fallow systems has been widely expressed. Agriculturalists have been increasingly concerned about the degradation of tropical soils, the increasing weed infestation and the declining crop yields associated with short fallow duration (Nye & Greenland, 1960; Moody, 1975; Zimdahl, 1993; de Rouw, 1995; Alègre & Cassel, 1996; Brady, 1996; Sanchez & Leakey, 1996; Zimdahl, 1999). The effect of short-duration natural fallows on yields of subsequent crops has been reported to depend on fallow properties and the nature of crop limitations (Szott *et al.*, 1999). The magnitude of the yield benefit from the fallow is influenced by the species composition, the biomass accumulation during the fallow phase, the soil nutrient status and structure or other biophysical constraints. On another hand, the degradation of forest-structured fallow vegetation into thickets and shrubby lands, under the pressure of shortening fallow duration, also brings on a rapid development of weeds (de Rouw, 1995). When the weed-break function of the fallow phase is no longer effective or feasible, smallholder farmers often have to either shift fields (Nye & Greenland, 1960; Moody, 1975), limit the area they can cultivate (Adesina, 1996) or radically change their cropping practices (de Rouw, 1995).

Studies conducted on the role of fallows as weed-break show that the fallow period prevents weeds being carried over from the previous cropping phase, either as seeds or as vegetative re-sprouts (de Rouw, 1995). Additionally, during the fallow period, weeds are suppressed in the fallow vegetation (cf. Chapter 6), and the seed population progressively loses viability, depending on the quality and the duration of the fallow vegetation. In the process of weed suppression during the fallow period, de Rouw (1995) distinguished two main phases. The first phase, which takes about 5 years, is the period during which "the forest chokes the weeds" and eliminates arable weeds by shading them out. The second phase takes at least 10 years, and is the period during which weed seed banks are reduced to tolerable levels. Therefore, in shortened fallow systems (with fallows of 5-7 years old), the effectiveness of the fallow period to limit weed growth is considerably reduced. The success of the fallow phase as a weed-break will then depend on several factors such as the rapid development of overhead shade after crop harvest (which can prevent the germination of a second generation of weeds), the nutrient accumulation in fallow vegetation (which is closely associated with species diversity and inherent soil fertility) and the ability of the soil to retain and store nutrient elements in forms that are readily available to the plant (de Rouw, 1995; Juo & Manu, 1996).

Yield losses from weed competition and the effectiveness of control measures largely depend upon the weed species present (Kent *et al.*, 2001). Many factors affect the weed species composition during the cropping phase, among which are landscape position, soil fertility, water control, season and crop rotations (Moody, 1975). According to Zimdahl (1993; 1999), the levels of invasibility by weed species is an indirect consequence resulting from the effects of species richness on resource levels. This supports the hypothesis that the increased use of limiting resources occurring at higher levels of species richness is a mechanism inhibiting invasion by other plant species (Ashton, 1990). Furthermore, resource use intensification was also reported to

induce a shift in weed population through changing cultivation practices (Liebman *et al.*, 2001).
Since weed competition problems are not solved by removing weeds during the cultivation period (Zimdahl, 1993), shifts in weed species composition and associated factors need to be studied to allow smallholder farmers to manage weeds more efficiently. Knowledge on how shortened duration fallows affect crop production is useful to identify management interventions that maximize the restoration of ecosystem fertility (Szott *et al.*, 1999) and the development of an integrated weed management system approach (Swanton & Weise, 1991). Although work on weed control in small-scale farming systems is a priority activity in many research institutions in West Africa, little is known about the weed flora common in fields established after clearing short-duration fallows (Chikoye *et al.*, 2000; Ekeleme *et al.*, 2000; Chikoye & Ekeleme, 2001; and N'zala *et al.*, 2002). Moreover, little information is available on weed competition in cassava-maize-groundnut-based fields in the Cameroonian humid forest zone. Quantitative data on changes in weed species composition in fallow systems dominated by *C. odorata* are still needed to understand and develop appropriate management strategies for a better control of that species. De Rouw (1995) has stressed that *C. odorata* has a dramatic effect on species composition and species dynamics.

Based on response from female farmers in southern Cameroon, Weise & Tchamou (1999) reported shifts in weed communities during the cropping period, at the beginning of the cropping period (i.e. 6-8 weeks after planting) in mixed food crop fields. Additionally, although listed among the first three most common weed problems in mixed cassava-maize-groundnut fields in the area, *C. odorata* was assumed to positively contribute to the soil fertility of short fallow systems, especially through its ability to out-compete the grass weed *Imperata cylindrica* (L.) Raeuschel (see also Akobundu *et al.*, 1999; Chikoye *et al.*, 2000; Chikoye & Ekeleme, 2001).

Biological and ecological knowledge are necessary to design successful and sustainable weed management strategies, mostly because of the concomitant effects of the many other factors involved in crop management (Zimdahl, 1999). Such studies do provide useful working hypotheses that will determine the long-term dynamics of the weed flora during crop growth (Swanton *et al.*, 1999; Kent *et al.*, 2001). Such predictions could be used to design weed management approaches that are more proactive than reactive (Légère & Samson, 1999). Specifically, such studies could help identify associations between a particular weed species trait (life cycle or other) and a given fallow type, which could then allow the identification of plant species of potential weediness and the implementation of adapted strategies to prevent the development of weed populations beyond critical thresholds.

7.2. OBJECTIVE

This part of the study aimed to examine the composition of the weed flora and its dynamics during the cropping phase after three types of short fallow systems, and to assess how these fallow types influence crop yields in a mixed food crop agricultural system of southern Cameroon.

Specific objectives included:

- To study the weed species composition at three sampling dates during the cultivation period (determined based on crop life cycle), in order to evaluate the relative importance of dominant weed species and their development during crop growth.
- To evaluate how the weed species composition differs among food crop fields established after fallow types of different vegetation and different land use history.
- To evaluate the relative effect of soil properties on the weed flora, by identifying soil parameters involved in determining the presence or dominance of certain species (or group of species).
- To study the effect of three shortened duration fallow types on yields of subsequent crops (cassava, maize and groundnut in a mixed crop system).

7.3. MATERIALS AND METHODS

7.3.1. Study area and study sites

The experiment was conducted in 1998/1999, and repeated (on different sites) in 1999/2000 during the first cropping season at Mengomo (see Figure 3.1). Experimental plots were established after clearing previously assessed and characterised fallow fields (see Chapter 6). The study treatments were:

- Treatment 1: food crop fields established after clearing 5-7 years old *C. odorata*-dominated fallows that had also been 5-7 years old *C. odorata*-dominated fallows in the preceding crop-fallow cycle (referred to as Co-Co or frequently cropped system).
- Treatment 2: food crop fields established after clearing 5-7 years old *C. odorata*-dominated fallows prior to the previous cropping phase, after forest clearance (referred to as Co-Fo or moderately cropped system).
- Treatment 3: food crop fields established after clearing 5-7 years old bush fallows (not dominated by *C. odorata*) that had been forest prior to the preceding cultivation phase (referred to as Bu-Fo or recently forest system).

Precipitation was lower in the 1998/1999 cropping year as compared to the 1999/2000 (*cf.* Chapter 3, Figure 3.2). Additionally, some plots were excluded from evaluation due to excessive shade from surrounding vegetation or unscheduled weedings.

7.3.2. Plant material

Cassava cuttings, maize and groundnut seeds used were identical throughout all experimental units.

Cassava cuttings (20-30 cm long) used for the study belonged to the IITA cultivar 8034, which main characteristics are:

- a rapid growth of branches;
- an improved resistance to the 'brown leaf disease';
- although it is difficult to precisely determine the length of the life cycle, mature tubers can be harvested 12 months after planting.

The maize cultivar selected for the experiment was the composite CMS 8704, whose biological cycle is about 110 to 120 days. Characterised by yellow grains and an average number of leaves per individual of 8-10, this cultivar has a potential yield of 5-6 t ha^{-1}. The local groundnut cultivar (purchased from the local market) was used for the experiment. Among its main characteristics are a relatively short biological cycle of 90-100 days, red grains and individual plants with erect stems.

7.3.3. Experimental design

The experiment was set up as a randomized complete design with three treatments. All plots were laid out inside fields that had been assessed during the fallow phase, and consisted of eight 5m x 5m sample-squares arranged in two parallel strips separated by a 3-4 m alley and surrounded by a guard row of 1 m wide (Figure 7.1). Each sample-square included a 3m x 3m (i.e. 9 m^2) area for weed measurements and final crop harvest.

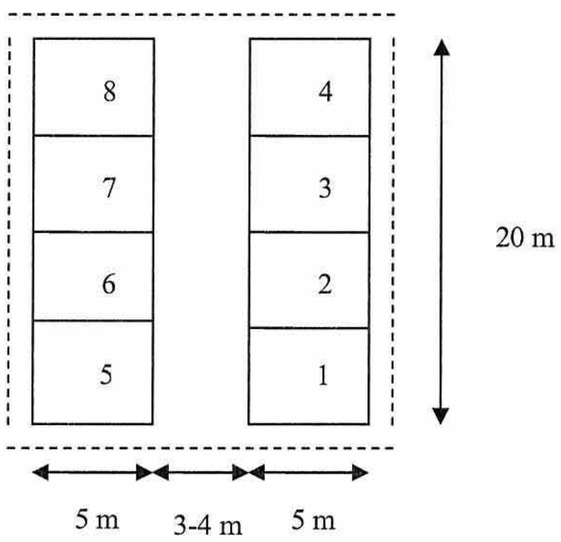


Figure 7.1. Lay-out of a study plot (numbers indicate sample-squares with the sampling order). The dash-line indicates the guard row of 1 m-wide.

7.3.4. Land preparation

On March 1998 and February 1999, the vegetation of each field was cleared following farmers' local practice; i.e. using a cutlass. Herbaceous species were cleared first, followed by shrubs whose stems were cut at about 1 m above ground level. Tree felling followed 2-3 weeks later (depending on the climatic conditions), followed by one overall burn in each field. However, particularly in 1998, because of late tree felling, the burning rate (i.e. the proportion of vegetation completely burnt) presented noticeable variation in the proportion of total field burnt (between 0 to 80 %). This low rate of burning considerably added to the cost of land clearing activities, which were mostly executed manually.

7.3.5. Cultural details

Following local farmers' agricultural practice, mixed food cropping was adopted in this experiment, with cassava (*Manihot esculenta* Crantz) intercropped with maize (*Zea mays* L.) and groundnut (*Arachis hypogaea* L., Table 7.1). Cassava cuttings (20-30 cm long each) were planted immediately after burning, at a density of 10,000 stems ha^{-1}, in rows that were 150 cm apart and at a within-row spacing of 150 cm. Plots were then slightly ploughed when groundnut seeds were planted between cassava rows. Finally, maize seeds were planted between cassava rows at a population of 40,000 plants ha^{-1}, in rows spaced 150 cm apart and within-row spacing of 50 cm, with three seeds per hill (Figure 7.2). Three weeks after planting (WAP), maize was thinned to 2 plants per mound. No herbicides or fertilisers were applied to the plots.

Table 7.1. Diary of cultural operations at Mengomo (1998-1999 and 1999-2000 cropping seasons).

	Year 1 1998-1999	**Year 2 1999-2000**
Cassava cuttings planted	Mid-April	Mid-March
Maize seeds sowed	April 22-May 02	2-7 April
Maize seeds re-sowed (3 plots)	May 10	Not needed
Groundnut seeds sowed	April 22-May 10	2-7 April
First weed assessment*	6 WAP**	6 WAP
Second weed assessment*	14 WAP	14 WAP
Maize and groundnut harvest	Late July (119 DAP**)	Late June (97 DAP)
Third weed assessment*	30 WAP	30 WAP
Cassava harvest	350 DAP (May 1999)	376 DAP (April 2000)

*All plots were hand-weeded and weeds removed from the fields after each weed assessment.

**DAP: days after planting, WAP: weeks after planting.

7.3.6. Weed assessments

Six weeks after planting, 14 WAP (i.e. at maize and groundnut harvest) and 30 WAP each year, data on weed vegetation was taken from three 0.25m x 0.75m quadrats in each 5 m x 5 m sample-square (Figure 7.2). Quadrats were set up in each sample-square (within the harvest area of 9 m^2) in such a way that weeds were assessed once beneath a cassava plant (position 'a'), and twice between two maize plants (position 'b'). The sampling strategy was adopted based on the assumption that cassava and maize plants will have different effects on the weed flora (de Rouw, 1991). However, to simplify the interpretation of the results, weed data were averaged for each sample-square before analysis.

For the purpose of this study, weeds were defined following Slaats *et al.* (1998), as all "invading species" that were present in a plot, but that were not specifically planted. This definition included native and exotic species, as well as crops that were not planted for the experiment. The dimensions of the quadrats (0.75m long and 0.25m wide) were chosen to represent half the distance between cassava rows and half the distance between maize within-rows, respectively (de Rouw, 1991).

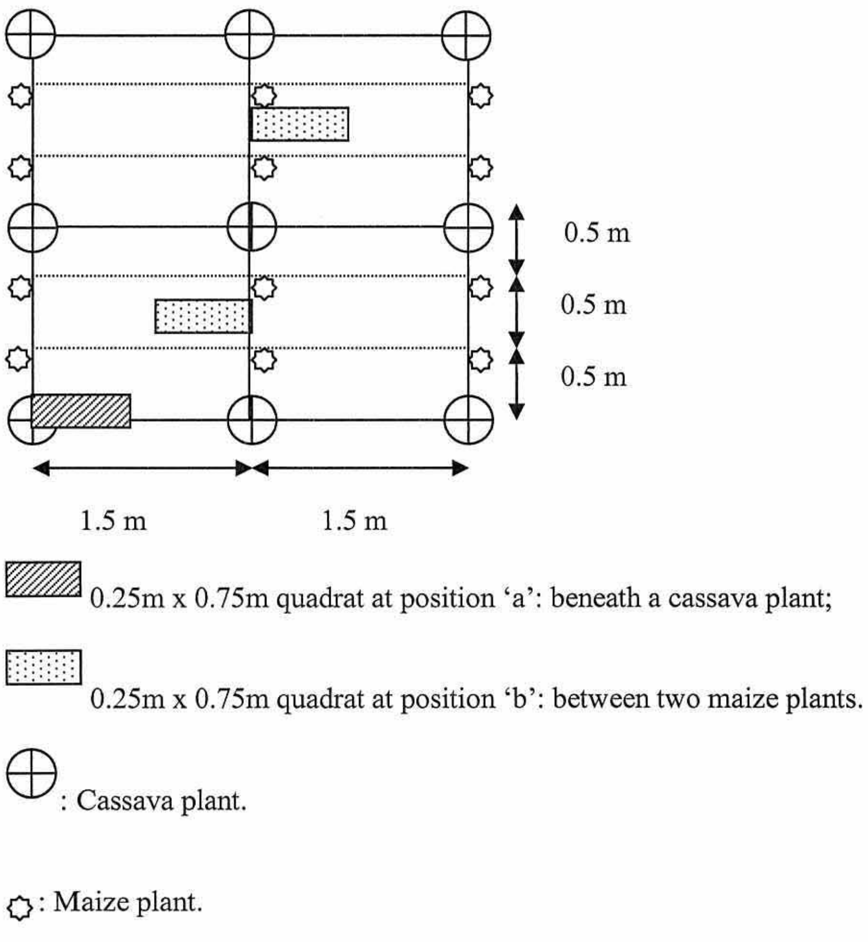


Figure 7.2. Lay-out of the experiment for weed assessments.

At each sampling time, recorded data within a quadrat included the number of individuals per species and the visual estimate of species percentage cover, with the total quadrat cover (i.e. overall cover of weed species, crops and bare soil) being 100%. Weed plants were identified to species or family (when identifiable plant traits such as flowers or buds were lacking). For stoloniferous or rhizomatous species, each upright stem crossing the quadrat was counted as an individual. Plant species nomenclature follows Hutchinson & Dalziel (1954-1972).

7.3.7. Soil sampling

Each year, 2-3 weeks after planting, soil was sampled in each plot at three depths (0-5, 5-10 and 10-15 cm), using a precision bucket auger of 5 cm diameter and 5 cm depth. For each 5 m x 5 m sample-square, six soil cores were collected and pooled for each soil depth, and used for soil analysis (resulting in a total of 48 cores and 8 soil samples per plot for each soil depth).

Soil samples were air-dried at room temperature and ground to pass a 2-mm sieve, and soil bulk density was measured from the pooled soil sample, for each soil depth. The percentage of sand, clay and silt was measured taking a sub-sample of 28 g of dry soil per sample-square and for each soil depth. Because of some missing samples, only bulk density was determined for the 1998 experiment. Soil samples were then sent to the IITA soil laboratory in Yaoundé for chemical analyses. Soil physical analysis was conducted at the IITA soil laboratory of Mbalmayo (Cameroon).

Soil total carbon was determined by Walkley-Black acid dichromate digestion. Total nitrogen was determined with an ammonium sensitive electrode method (Powers *et al.*, 1981). Soil pH was determined in H_2O. Ca^{2+}, Mg^{2+}, K^+ and total P were extracted by the Mehlich-3 procedure. Cations were then determined by atomic absorption spectrophotometry, and total P by the malachite green colorimetric procedure (Motomizu *et al.*, 1983). Al concentrations were determined by the exchange aluminium pyrocatechol violet (PCV) procedure.

7.3.8. Assessment of crop yields

Crop yields were determined in the eight sample-squares (9 m^2 harvest area for each) per plot, excluding the guard row of 1m around the plots. At 14 WAP in 1999, five maize plants were randomly harvested per sample-square. Marketable maize cobs were separated from non-marketable ones, and their fresh weight recorded. A sub-sample of five marketable cobs was then taken. Dry weight of grains was determined by shelling the cobs after drying (at 65°C to constant mass). In the 1998 experiment, maize yield was almost nil in all plots.

At the same period (i.e. 14 WAP in 1998 and 1999), all groundnut plants present in a sample-square (harvest area) were harvested for determination of total fresh weight. A sub-sample of about two handfuls was then oven-dried (24 h, 105°C), and weight of grains determined by shelling the pods after drying.

Approximately 12 months after planting each year, all cassava plants present in a sample-square (9 m^2 harvest area) were harvested for determination of total fresh weight. A sub-sample of about 700g was oven-dried and tuber dry weight determined per harvest area.

7.3.9. Data analysis

To assist and facilitate the ecological interpretation of changes in plant communities, weed species were subsequently grouped into six classes: Cyperaceae (or sedges), Poaceae (or grasses), other monocotyledons, *C. odorata*, other dicotyledons and Pteridophytes (or ferns). Weed data were averaged for each sample-square, and each year was analysed separately.

For each plot, mean weed density for each species in the weed flora was calculated by summing all densities from the 24 quadrats and dividing by 24. Similarly, weed density on a treatment basis was calculated by summing all mean weed densities from all plots in a given treatment, and dividing by the total number of plots per treatment. Weed frequency for each species per plot was calculated by tallying all quadrats in which the species was present and dividing by 24, and expressed as a percentage. In the same way, weed cover for each species per plot was the averaged cover percentage of that species within the plot.

In order to dampen the effects of single large individuals or infrequent species, and because more than one measure of abundance was recorded for each species, a synthetic value (the relative importance value, RIV) was computed as the mean of the relative frequency, relative density and relative cover percentage, for each species per treatment (Equations 7.1, 7.2 and 7.3) (Wentworth *et al.*, 1984; Bàrberi *et al.*, 1997; Swanton *et al.*, 1999; Ekeleme *et al.*, 2000). The relative frequency, relative density and relative cover for each species were calculated as follows:

$$\text{Relative frequency} = \frac{\text{Mean frequency within the plot}}{\text{Total frequency of all weeds for the plot}} x100 \qquad (7.1)$$

$$\text{Relative density} = \frac{\text{Mean density within the plot}}{\text{Total density of all weeds for the plot}} \text{x}100 \qquad (7.2)$$

$$\text{Relative cover} = \frac{\text{Mean cover within the plot}}{\text{Total cover of all weeds for the plot}} x100 \qquad (7.3)$$

RIV accounts for species number (density), species distribution patterns (frequency) and species contribution to the weed community (cover), thus limiting problems arising from weed patchiness (Bàrberi *et al.*, 1997; Rew & Cousens, 2000). The RIV values were used to rank each species in the weed flora in order of importance: the higher the RIV, the more important a given weed (Swanton *et al.*, 1999; Chikoye & Ekeleme, 2001). Weed species with relative frequency values < 4% were considered rare and subsequently excluded from further analysis and discussion.

Variation between plots in species richness and species density of the weed flora in the three treatments were assessed with ANOVA (Proc GLM SAS, SAS Institute Inc., 1990), for each sampling time. Comparisons of mean values between treatments were done by LSD, at $\alpha = 0.05$. Before analysis, weed density values were transformed as x= log 10 (x+1) whereas cover values were transformed as $y=\arcsin (y)^{-0.5}$ to down-weight large numbers and increase homogeneity of variance (Sokal & Rohlf, 1995).

Repeated ANOVA (Proc GLM SAS) was conducted to test within plot effects of time and between plots effects of treatments, and the time by treatment interaction.

The effect on weed species composition of soil parameters (texture, structure and nutrient status) was tested using Canonical Variate Analysis (CVA) within the computer programme CANOCO version 4.0 (ter Braak & Šmilauer, 1998). CVA is a widely used multivariate techniques (along with Principal Component Analysis, PCA, and Canonical Correlation Analysis, COR). CVA was used in this study because sites were grouped into classes, and the objective was to determine how the weed species composition differs among sites of different classes. Because CVA seeks a weighed sum of the species abundances that maximises the ratio of the between-class sum of squares and the within-class sum of squares of the sites along the first ordination axis, the differences between classes are clearer than is possible on the basis of the abundance values of species taken separately (Jongman *et al.*, 1995). A Monte Carlo test, using 199 permutations, was used to assess the importance of the ordination on the first and second axes, at the 0.05 significance level (ter Braak & Prentice, 1988). Ordinations were plotted as site-environment biplots with focus on inter-species distances and Hill's scaling. In the CVA ordination diagrams, distances between site classes means represent Mahalanobis distances (ter Braak & Šmilauer, 1998). Separate analyses were performed for the 1998 and 1999 experiments, for each sampling date, considering only the upper 0-5 cm soil depth for environmental data.

Scores of the first two CVA axes were subjected to ANOVA (Proc GLM SAS), and relations between CVA sample scores on these axes and soil parameters were examined by correlation (Spearman correlation coefficients). Stepwise selection of soil parameters that were highly correlated with the derived ordination axes was used for selection of soil variables to incorporate in the final models, using a cut-off point of $P = 0.10$ (ter Braak & Šmilauer, 1998). For all data sets, analyses were confined to those species with relative frequency values of 4% or more. Relative density values of each species were used in the ordination (Chikoye & Ekeleme, 2001). These were transformed as log (x+1) before analysis (ter Braak, 1995).

Furthermore, a Redundancy Analysis (RDA) was performed on all data sets, for each sampling time, with scaling focussed on inter-species distances and species data centered and standardized. The species-environment tables obtained were examined to determine strength of association between particular species and a given soil parameter. Species were considered to be correlated to a particular soil parameter when $r > 0.30$, and to be strongly correlated when $r > 0.40$ (Tabachnick & Fidell, 2001).

Maize grain dry weight, groundnut grain dry weight and cassava tuber dry weight were subjected to ANOVA (Proc GLM SAS) to test for the effect of treatments, and mean values were compared by LSD, at α=0.05. Relationships between crop yield and weed density ($\log_{10}$ of average value across each cropping season) were explored through regression analysis (Proc REG, SAS).

7.4. RESULTS

7.4.1. Weed species composition

A total of approximately 200 species (209 in 1998 and 200 in 1999), belonging to 61 families, was recorded across all treatments (Appendix 7.1). Grasses and sedges were minor (with about 3% and 2% of the weed spectrum, respectively), but broadleaved weeds (accounting for more than 80%) and monocotyledons other than sedges (nearly 13%) dominated the total weed spectrum. Leguminous species consistently dominated the weed community (with about 37 genera), followed by Euphorbiaceae (with 16 genera), Asteraceae (with 14 genera) and Rubiaceae (with 9 genera).

Mean species richness (i.e. mean number of weed species per plot) was similar across treatments, 6 WAP (Figure 7.3). Toward the end of the cultivation period (i.e. at 14 and 30 WAP), treatment 3 was significantly (at $P<0.05$) different from the other two treatments. There was a clear trend over the two years of study showing that, irrespective of the time of observation, fields established after clearing a short fallow that had been a forest in the precedent cultivation cycle had more weed species than plots established after recurrent *C. odorata*-dominated fallows: 103 species in Co-Fo and Bu-Fo plots against 93 for Co-Co plots. The range for species richness was 6-33 (14-30 in 1999) for frequently cropped fields, 11-37 (9-30 in 1999) and 12-36 (11-42 in 1999) for Co-Fo and Bu-Fo fields, respectively. Weed species richness significantly

(P<0.001, ANOVA Repeated Measures) varied over time during the cultivation phase. While in 1998, the total number of weed species was lower toward the end of the cultivation period in Co-Co and Co-Fo fields, a completely reverse trend was observed during the 1999 experiment (Figure 7.3).

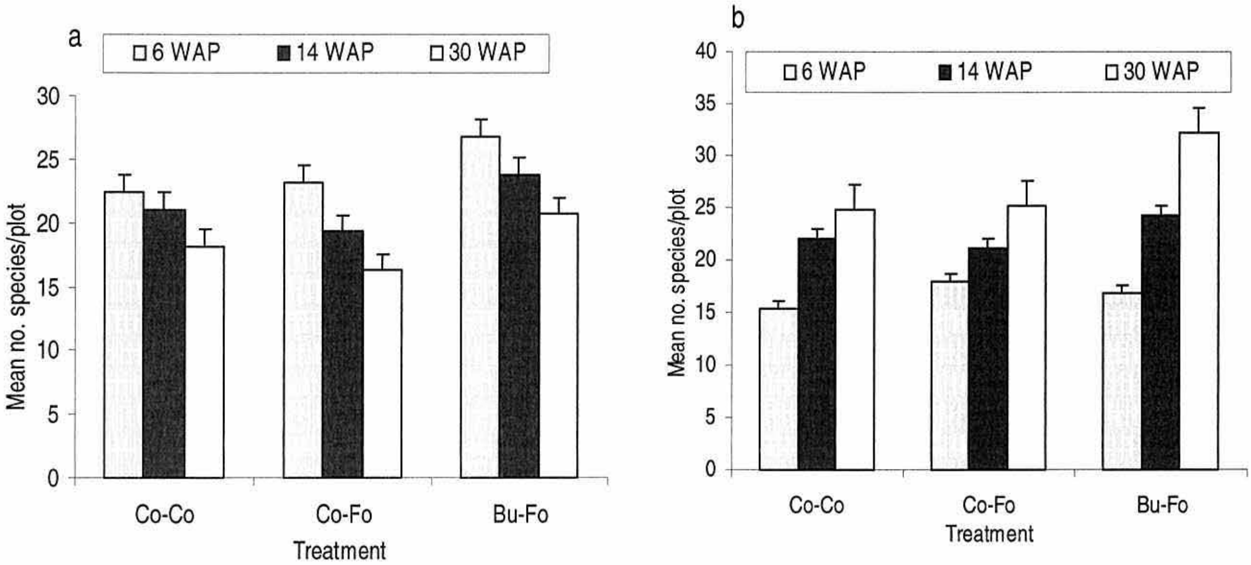


Figure 7.3. Mean species richness in mixed food crop fields after three fallow types at Mengomo (southern Cameroon: a, in 1998, and b, in 1999). Bars are ± standard error of the mean.

There was no significant difference (at P=0.05, Canonical Discriminate Analysis, Proc CANDISC SAS) among treatments in species composition of the weed flora (Table 7.2). However, the Mahalanobis squared distance was slightly higher between Co-Co and Bu-Fo fields, as compared to the distance between Co-Fo and Bu-Fo fields, and Co-Co and Co-Fo plots.

Table 7.2. Mahalanobis squared distance (D2) differences in weed species composition between food crop fields established after three short fallow types at Mengomo (southern Cameroon).

	1998			1999		
Treatments[a]	**6 WAP**	**14 WAP**	**30 WAP**	**6 WAP**	**14 WAP**	**30 WAP**
Co-Co vs. Co-Fo	0.0013	0.0003	0.0006*	$3.5\ 10^{-6}$	$1.2\ 10^{-7}$	$1.9\ 10^{-6}$
Co-Co vs. Bu-Fo	0.0060	0.0022	$6.7\ 10^{-7}$	$2.5\ 10^{-6}$	0.0007*	$1.4\ 10^{-6}$
Co-Fo vs. Bu-Fo	0.0017	0.0008	0.0006	$9.8\ 10^{-6}$	0.0006	$3.56\ 10^{-7}$*

[a] See text for treatment categories. *Significant at $P < 0.05$.

7.4.2. Dominant weed species

C. odorata had the highest RIV (Relative Importance Value) and, was by far the most important weed in terms of density, frequency and cover across all treatments (Table 7.3a and 7.3b, for 1998 and 1999 experiments, respectively). Dominant weeds associated with *C. odorata* differed with treatments over time. For treatment 1, the most important weeds, in decreasing order of importance, after *C. odorata* (RIV = 30-51) were *Sida rhombifolia* (RIV = 6-12), *Stachytarpheta cayennensis* (RIV = 6-12), *Triumfetta cordifolia* (RIV = 5-11) and *Ageratum conyzoides* (RIV = 4-7).

Table 7.3a. Relative Importance Value (%) of weed flora in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon, 1998). Taxa are ordered alphabetically by family and within each family.

		Growth	6 WAP			14 WAP			30 WAP		
Family	Taxa	form*	1**	2	3	1	2	3	1	2	3
Asteraceae	*Ageratum conyzoides*	ABL	-	-	-	4.6	-	-	6.7	5.7	-
	C. odorata	PBL	38.4	49.1	30.1	40.6	45.7	34.7	50.9	50.9	35.2
	Mikania cordata	PBL	-	-	-	-	-	-	-	5.8	8.7
Commelinaceae	*Aneilema beninense*	AM	-	-	-	-	-	4.4	-	-	-
Cucurbitaceae	*Cogniauxia podolaena*	ABL	-	-	-	-	5.8	8.4	-	-	-
Malvaceae	*Sida rhombifolia*	PBL	12.7	-	-	6.3	-	-	-	-	-
Poaceae	*Oplismenus burmannii*	PG	-	-	-	-	-	-	-	-	4.7
Tiliaceae	*Triumfetta cordifolia*	PBL	-	-	-	5.4	-	-	-	-	-
Ulmaceae	*Trema orientalis*	PBL	-	6.9	18.6	-	4.6	7.1	-	-	-
Verbenaceae	*Stachytarpheta cayennensis*	PBL	6.4	-	-	12.3	-	-	8.8	-	-

-, RIV < 4%.

*ABL, annual broadleaved; AM, annual monocotyledon; PBL, perennial broadleaved; PG, perennial grass. **1, treatment Co-Co; 2, treatment Co-Fo; 3, treatment Bu-Fo: see text for treatment categories.

In Co-Fo plots, *T. orientalis* (RIV = 5-7), *C podolaena* (RIV = 6) and *M. cordata* (RIV = 6) ranked highest in association with *C. odorata* (RIV = 46-58). The most important species in the weed flora of Bu-Fo fields were *C. odorata* (RIV = 30-50), *C. podolaena* (RIV = 8), *T. orientalis* (RIV = 7-10) and *M. cordata* (RIV = 9). Only few weeds had a RIV greater than 10. These included *C. odorata* (far the most important weed), *S. cayennensis*, *S. rhombifolia* and *T. cordifolia*. All these species were most frequent and more dominant in fields established after clearing *C. odorata*-dominated fallows (i.e. Co-Co and Co-Fo fields). Grasses did not play an important role in the weed flora of all treatment plots, except towards the end of the cropping period in Co-Co and Bu-Fo plots.

Table 7.3b. Relative Importance Value (%) of weed flora in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon, 1999). Taxa are ordered alphabetically by family and within each family.

Family	Taxa	Growth form*	6 WAP 1**	6 WAP 2	6 WAP 3	14 WAP 1	14 WAP 2	14 WAP 3	30 WAP 1	30 WAP 2	30 WAP 3
Asteraceae	*Ageratum conyzoides*	ABL	4.2	-	-	5.3	-	-	6.5	-	-
	C. odorata	PBL	30.2	49.9	49.9	44.7	55.2	50.7	36.8	58.3	50.0
	Mikania cordata	PBL	-	-	-	-	-	-	-	-	4.2
Cyperaceae	*Cyperus rotundus*	PS	6.7	-	-	3.3	-	-	-	-	-
Euphorbiaceae	*Plagiostyles africana*	PBL	-	-	-	-	-	-	-	-	4.2
Poaceae	*Oplismenus burmannii*	PG	-	-	-	-	-	-	12.2	4.8	-
	Paspalum conjugatum	PG	-	-	-	-	-	-	12.0	5.7	-
Portulacaceae	*Talinum triangulare*	PBL	-	4.6	-	-	4.3	-	-	-	-
Tiliaceae	*Triumfetta cordifolia*	PBL	11.8	-	-	5.8	-	-	-	-	-
Ulmaceae	*Trema orientalis*	PBL	-	5.3	10.0	-	-	-	-	-	-
Verbenaceae	*Stachytarpheta cayennensis*	PBL	9.5	-	-	8.1	-	-	8.4	-	-

Family	Taxa	Growth form*	6 WAP 1**	2	3	14 WAP 1	2	3	30 WAP 1	2	3
Zingiberaceae	*Costus afer*	AM	-	7.0	-	-	8.1	-	-	-	

- RIV < 4%.

*ABL, annual broadleaved; AM, annual monocotyledon; PBL, perennial broadleaved; PG, perennial grass; PS, perennial sedge. **1, treatment Co-Co; 2, treatment Co-Fo; 3, treatment Bu-Fo: see text for treatment categories.

7.4.3. Weed density

Weed densities in each study plot were 28-665 plants m^{-2} for Co-Co fields, 49-342 plants m^{-2} for treatment 2, and 60-278 plants m^{-2} for treatment 3 (Figures 7.4a and b). *C. odorata* consistently had the highest density in all plots sampled (mean 96.61 ± 15.67 plants m^{-2} in 1998 and 126.22 ± 29.18 plants m^{-2} in 1999).

The mean number of weed species (particularly grasses and sedges) per square metre was higher (though not significantly) in Co-Fo and Bu-Fo plots as compared to Co-Co plots (Tables 7.4a and b). However, fields established after clearing recurrent *C. odorata*-dominated fallows showed an increased weed density towards the end of crop growth. In 1999, there was a significant difference in the total number of weeds (P=0.001), the number of sedges (P=0.03) and the number of other monocotyledonous weeds (P=0.006) among treatments at the beginning of the cropping period. At the beginning of the cropping phase, density of *C. odorata* and other dicotyledonous weeds was significantly higher (P<0.01) in fields established after clearing fallows that had been forest, but towards the end of crop growth, a reverse pattern was observed. Over the two study years, there was no significant (at P=0.05) time effect of weed density across all treatments. In 1998, mean density of grasses and of *C. odorata* were significantly higher (P<0.05) in Co-Fo and Bu-Fo fields than the densities recorded in Co-Co plots, 14 and 30 WAP.

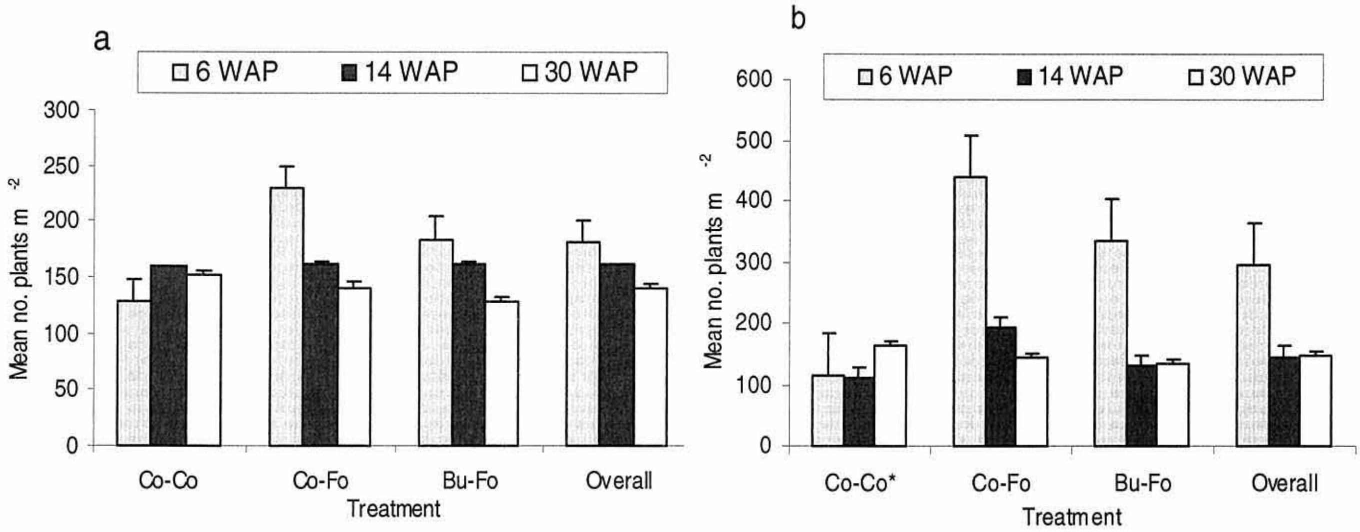


Figure 7.4. Weed density in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon. a: in 1998 and b: in 1999). Bars are ± standard error of the mean.

Problem weeds (such as grasses and sedges) were more abundant in treatments 2 and 3 than in treatment 1. In 1998, *C. odorata* had the highest density in fields established after *C. odorata*-dominated fallows (i.e. Co-Co and Co-Fo fields). Whereas in 1999, fields established after clearing recurrent *C. odorata*-dominated fallows had the lowest number of *C. odorata* plants m^{-2}. There was no significant difference in weed species density among treatments at 14 and 30 WAP over the two years. Except for treatment 1, there were almost twice as many weeds in the 1999 plots than in plots sampled in 1998 at the beginning of the cropping period (Figure 7.4).

Table 7.4a. Weed density in mixed food crop fields after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1998). Mean ± 1 standard error.

Weed	6 WAP			14 WAP			30 WAP		
category*	Co-Co	Co-Fo	Bu-Fo	Co-Co	Co-Fo	Bu-Fo	Co-Co	Co-Fo	Bu-Fo
Sedges	2.3±1.1	3.7±2.7	1.6±0.7	3.5±0.8	2.4±1.0	6.8±2.5	2.1±0.7	3.9±2.6	3.5±2.0
Grasses	4.0±1.6	2.8±0.9	8.2±4.8	1.7±0.4	2.9±0.8	9.9±3.2	3.8±1.7	5.6±2.9	17.0±7.7
Other monocot.	1.2±0.6	2.4±0.5	12.8±5.1	2.5±1.1	6.9±2.4	8.8±1.7	2.5±0.7	5.4±2.2	7.3±1.0
C. odorata	70.8±13.1	165.6±55.7	82.9±45.8	91.3±13.8	113.3±26.8	86.8±31.0	99.3±15.6	89.3±12.5	65.0±21.5
Other dicots	49.1±15.8	54.7±19.3	76.3±27.4	59.2±14.8	36.1±11.2	45.5±9.7	43.2±8.4	35.8±10.6	33.5±7.5
Pteridoph.	0	0	0	0.6±0.4	0.4±0.3	1.3±1.2	0.7±0.4	0.2±0.1	1.5±1.2
Total	127.8±19.4	229.5±72.9	183.3±49.4	159.2±22.0	162.4±30.7	162.3±26.3	151.6±22.0	140.6±20.8	127.9±16.6

*See text for weed categories.

Table 74b. Weed density in mixed food crop fields after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1999). Mean ± 1 standard error.

Weed	6 WAP			14 WAP			30 WAP		
category*	Co-Co	Co-Fo	Bu-Fo	Co-Co	Co-Fo	Bu-Fo	Co-Co	Co-Fo	Bu-Fo
Sedges	1.7±1.7	25.6±23.7	4.3±1.8	5.7±1.6	5.1±3.3	2.9±1.0	5.2±0.9	4.1±2.7	4.1±1.9
Grasses	4.9±1.1	6.3±1.7	3.5±0.9	4.5±1.5	3.7±1.0	3.3±1.0	48.7±17.1	13.0±3.6	8.7±4.9
Other monocot.	2.3±0.6	36.1±15.7	11.3±4.1	2.6±0.8	16.0±7.0	6.1±1.2	2.6±0.9	6.5±1.9	4.9±0.8
C. odorata	41.7±6.0	284.4±66.0	251.3±95.0	69.7±16.1	149.4±28.0	95.0±21.2	66.5±5.7	97.4±9.6	80.6±15.2
Other dicots	89.5±7.4	328.7±64.6	306.9±93.3	97.0±18.4	168.4±29.5	116.9±22.0	98.1±5.8	108.7±8.6	103.9±12.0
Pteridoph.	0	0.1±0.1	0.3±0.3	0.8±0.8	0.1±0.1	0.1±0.1	0.2±0.1	1.3±0.8	1.2±0.6
Total	115.6±8.5	439.6±89.2	334.5±94.7	110.9±19.8	193.4±30.0	129.7±21.8	164.9±16.2	144.1±10.5	133.9±11.7

*See text for weed categories.

7.4.4. Weed cover

In general, the cover percentage of weeds significantly ($P<0.05$) increased with time across all treatments, but the increase was greater in Bu-Fo plots (Table 7.5). Total weed cover was significantly different between Co-Co and Co-Fo fields ($P=0.003$), between treatments Co-Co and Bu-Fo fields ($P<0.0001$), but not between treatments Co-Fo and Bu-Fo plots.

Table 7.5. Cover of weed species (expressed as percentage of total ground cover) in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon).

	1998			1999		
Treatment*	6 WAP	14 WAP	30 WAP	6 WAP	14 WAP	30 WAP
Co-Co	19.1±1.3	21.1±0.7	52.6±1.6	27.4±1.3	20.2±0.8	61.5±1.2
Co-Fo	21.2±1.5	22.1±0.7	59.2±1.9	38.8±1.6	24.8±1.2	60.3±1.7
Bu-Fo	19.8±1.4	23.4±0.9	63.0±2.1	36.9±1.6	24.7±1.1	79.1±1.1
LSD (α=0.05)	3.05	1.85	4.22	4.03	2.66	3.66

*See text for treatment categories.

At the beginning of the cropping period (i.e. 6 WAP), all weed species covered about 20-30% of ground soil, while crops covered 20% in 1998 and 20-30% in 1999. Fourteen weeks after planting, the weed cover percentage did not change, but the cover of crops increased to nearly 50%. Finally, 30 WAP, weeds were covering almost the whole area (60-80% of ground soil) while cassava covered only 10-30% (Figures 7.5 and 5.6).

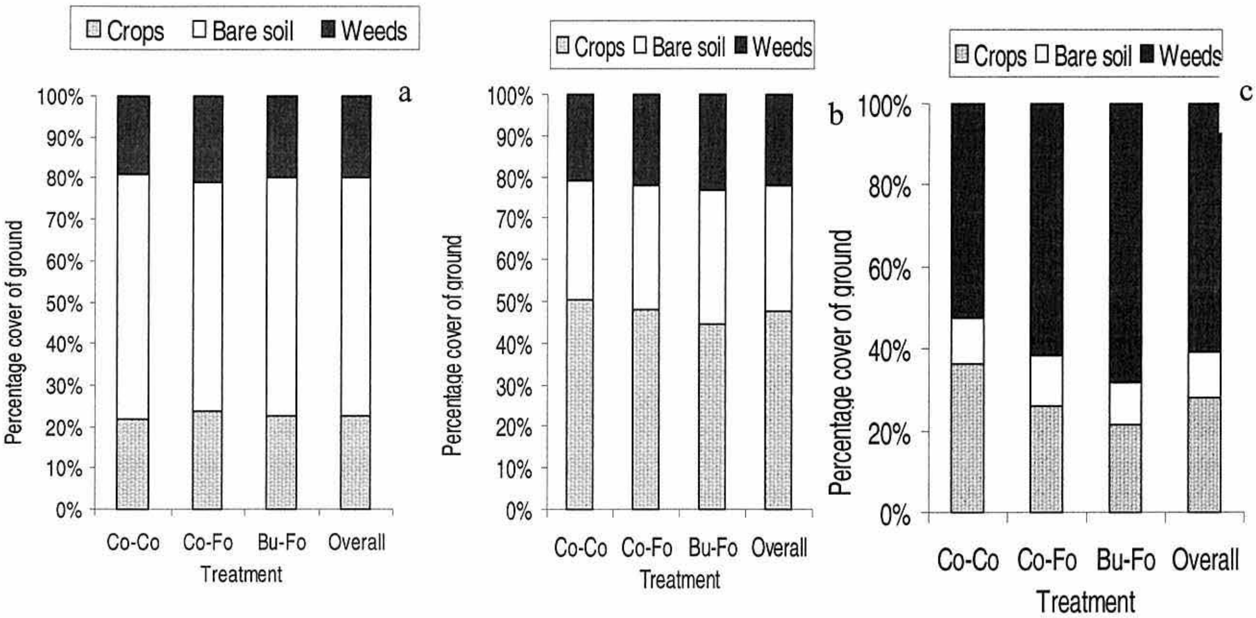


Figure 7.5. Cover percentage in mixed food crop fields established after clearing three fallow types at Mengomo (southern Cameroon in 1998; a: 6 WAP; b: 14 WAP and c: 30 WAP).

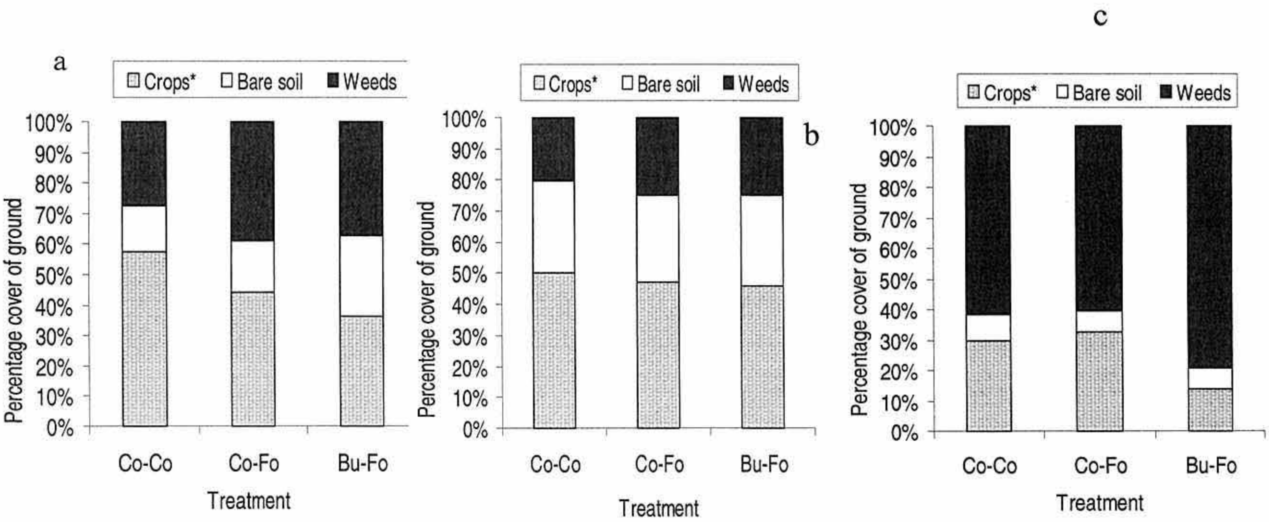


Figure 7.6. Cover percentage in mixed food crop fields established after clearing three fallow types at Mengomo (southern Cameroon in 1999; a: 6 WAP; b: 14 WAP and c: 30 WAP).

7.4.5. Soil properties

7.4.5.1. Soil physical properties

Fields established after clearing recurrent *C. odorata*-dominated fallows (treatment 1) showed significantly lower clay and silt content than Co-Fo and Bu-Fo fields ($P<0.05$, Tables 7.6 for the 1999 experiment, the 1998 soil data not presented here). The lowest bulk density values were obtained in Co-Co plots.

Table 7.6. Average values for soil physical parameters measured in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1999). Figures in parentheses are ± standard error of mean.

Treatment*	Bulk density (g cm^{-3})	Sand (%)	Clay (%)	Silt (%)
Depth 0 – 5 cm				
Co-Co	0.99 (0.02)	50.09 (1.59)	39.36 (1.43)	10.56 (0.49)
Co-Fo	1.12 (0.03)	39.70 (1.95)	49.83 (2.13)	10.48 (0.26)
Bu-F0	1.04 (0.05)	41.92 (1.55)	45.48 (1.97)	12.60 (0.61)
LSD (α=0.05)	0.10	4.99	5.36	1.37
Depth 5 – 10 cm				
Co-Co	1.24 (0.02)	45.22 (1.73)	45.51 (1.56)	9.28 (0.21)
Co-Fo	na	36.49 (1.50)	53.73 (1.66)	9.79 (0.23)
Bu-Fo	na	38.93 (1.41)	49.09 (1.96)	11.99 (0.73)
LSD (α=0.05)	-	4.59	4.99	1.23
Depth 10 – 15 cm				
Co-Co	na	42.86 (1.56)	47.84 (1.51)	9.31 (0.16)
Co-Fo	na	35.48 (1.50)	55.04 (1.60)	9.48 (0.19)
Bu-Fo	na	37.90 (1.22)	51.30 (1.82)	10.80 (0.90)
LSD (α=0.05)	-	4.26	4.75	1.42

*See text for treatments codes. na: data not available due to errors during laboratory analyses.

7.4.5.2. Soil nutrient status

Except for Al content, soil nutrient status in the upper 0-5 cm depth was significantly ($P<0.05$) higher than in the lower depths (Table 7.7 for the 1999 experiment). In general, the difference in soil nutrient content between treatments 2 and 3 was not significant. There was a significant difference among treatments in relation to soil chemical parameters. Soils under treatment 1 were less acidic than soil under other treatments, especially in the upper 0-10 cm.

Table 7.7. Average values for soil chemical parameters measured in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1999). Figures in parentheses are ± standard error of mean.

Treatment*	pH (H_2O)	Total N (g kg^{-1})	Total C (g kg^{-1})	C:N ratio	P (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	Al (cmol kg^{-1})
0 – 5 cm									
Co-Co	5.49	0.17	2.65	15.47	28.89	4.20	1.25	0.29	0.05
	(0.10)	(0.00)	(0.08)	(0.21)	(2.02)	(0.32)	(0.06)	(0.02)	(0.02)
Co-Fo	4.96	0.21	3.14	14.84	21.59	4.46	1.08	0.33	0.38
	(0.19)	(0.01)	(0.22)	(0.31)	(2.72)	(1.19)	(0.11)	(0.02)	(0.12)
Bu-Fo	4.39	0.24	3.49	14.73	21.95	2.41	0.75	0.32	0.71
	(0.11)	(0.01)	(0.18)	(0.17)	(1.18)	(0.33)	(0.05)	(0.02)	(0.16)
LSD (α=0.05)	0.41	0.03	0.49	0.70	6.18	2.15	0.23	0.06	0.32
5 – 10 cm									
Co-Co	4.65	0.10	1.53	15.02	7.18	1.46	0.47	0.17	0.38
	(0.08)	(0.00)	(0.04)	(0.26)	(0.62)	(0.44)	(0.03)	(0.01)	(0.06)
Co-Fo	4.31	0.12	1.64	13.95	5.42	1.15	0.37	0.17	1.08
	(0.10)	(0.01)	(0.06)	(0.64)	(0.55)	(0.20)	(0.05)	(0.01)	(0.24)
Bu-Fo	4.08	0.15	1.84	12.26	6.73	0.74	0.28	0.16	1.36
	(0.07)	(0.01)	(0.09)	(0.30)	(0.56)	(0.10)	(0.03)	(0.01)	(0.16)
LSD (α=0.05)	0.25	0.02	0.18	1.26	1.69	0.46	0.11	0.04	0.49
10 – 15 cm									
Co-Co	4.71	0.10	1.32	12.71	3.49	0.98	0.30	0.12	0.22
	(0.03)	(0.00)	(0.03)	(0.13)	(0.67)	(0.13)	(0.03)	(0.01)	(0.04)

Treatment*	pH (H_2O)	Total N (g kg^{-1})	Total C (g kg^{-1})	C:N ratio	P (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	Al (cmol kg^{-1})
Co-Fo	4.36	0.11	1.57	14.32	2.12	0.70	0.24	0.10	0.58
	(0.06)	(0.01)	(0.07)	(0.35)	(0.21)	(0.12)	(0.04)	(0.01)	(0.12)
Bu-Fo	4.32	0.12	1.70	14.67	2.90	0.55	0.18	0.12	1.11
	(0.06)	(0.01)	(0.08)	(0.27)	(0.38)	(0.08)	(0.02)	(0.01)	(0.10)
LSD (α=0.05)	0.15	0.01	0.18	0.76	1.42	0.08	0.08	0.04	0.27

*See text for treatment categories.

Total N and C concentrations showed contrasting trends among treatments over the two years of study. In 1998, soil under Co-Co and Co-Fo plots had higher N and C content that soil samples taken from Bu-Fo plots. A reverse pattern was observed in 1999, where soils taken from Bu-Fo plots had the highest concentrations of total N and total C. Consequently, in 1998, the C:N ratio was significantly higher in Co-Co and Co-Fo soils as compared to soils from Bu-Fo plots.

Available P concentrations also showed a variation among treatments, being significantly lower in 1998 and higher in 1999 in Co-Co soils as compared to other treatments, particularly in the upper 0-10 cm depth. There was very little difference in K concentration among treatments, but Bu-Fo plots had higher values than the two others. Ca and Mg concentrations were significantly higher ($P<0.05$) in soils taken from Co-Co and Co-Fo plots compared to soils under Bu-Fo. Although there was little variation over the two study years, the mean Al concentration was higher in treatment 3 plots than in fields established after clearing *C. odorata*-dominated fallows.

7.4.6. Weed species composition in relation to soil parameters

7.4.6.1. At the beginning of the cropping period

The variation of weed species composition and abundance during the cropping phase was studied in relation to soil physical and chemical characteristics measured after crop planting. Site association with soil variables can be ascertained from the position of the centroid and by the direction and length of the vector in the ordination diagram.

For reason of clarity of the diagram, and to make the interpretation easier, only the site-environment biplots from the CVA carried out on data recorded at 6 WAP are presented in Figure 7.7.

The first two axes of the ordination accounted for most of the variation in the weed species data, with eigenvalues of 0.27 and 0.16 in 1998, and 0.29 and 0.13 in 1999, for axis 1 and 2, respectively. The total variation in the data was 1.94 and 1.57, in 1998 and 1999, respectively; and the first two ordination axes explained about 22.5% and 26.8% of this variation, in 1998 and 1999, respectively.

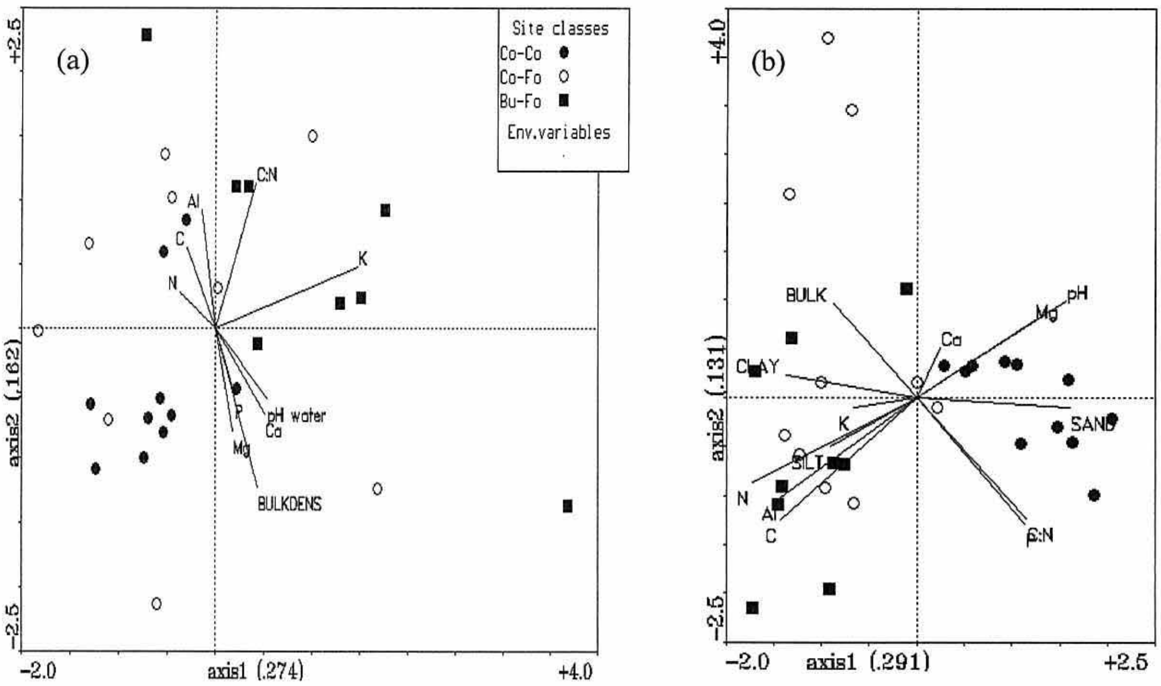


Figure 7.7. CVA ordination diagrams of weed communities in relation with soil physical and chemical parameters in mixed food crop fields established after three different fallow types in (a) 1998 and (b) 1999 at Mengomo (southern Cameroon), 6 WAP. Soil variables are represented as vectors and study plots as symbols (circles: Co-Fo plots, solid circles: Co-Co plots and solid squares: Bu-Fo plots). Direction of vectors shows the maximum variation for a soil variable and their length indicates the strength of the correlation with the ordination axes.

The first axis of the ordination (both years) corresponds to the most important gradient in the species data (Monte Carlo test: P=0.04, F=2.63 in 1998 and P=0.005, F=3.86 in 1999). There is a significant (P<0.05, ANOVA on CVA sample scores in

1998 and 1999) separation of Co-Co plots from the other two treatments. Thus, Axis 1 corresponds to a gradient of land use intensification, where fields established on intensively cropped fallow lands are positioned on one side of the diagram (negative loadings on Axis 1 in 1998, and positive loadings on Axis 1 in the 1999 experiment), and less intensively managed fields are on the other side (positive loadings on Axis 1 in 1998 and negative loadings in 1999).

In 1998, sample scores on the first ordination axis were correlated with the C:N ratio and K concentration (Spearman rank correlation; $P=0.04$ and $P=0.02$, respectively. Table 7.8) so that sites located to the left in the ordination diagram (Figure 7.7a) had low C:N ratio and K concentrations. The second CVA axis did not significantly ($P>0.05$) correlate with any soil parameter, but it was most strongly related to soil bulk density (Spearman rank correlation $r_s = -0.37$). In 1999, sample scores on the first ordination axis were significantly correlated with almost all soil parameters, most particularly with N content ($P<0.0001$), sand percentage and soil pH ($P=0.001$), Al and Mg concentrations ($P=0.001$ and $P=0.01$, respectively). Therefore, plots that loaded positively on the first axis had low total N and Al concentrations, were sandier, less acid and had high Mg concentrations. However, contrasting with the 1998 experiment, those plots had high C:N ratios. The second axis was significantly correlated with pH ($P=0.001$), total N, total C and total N contents ($P<0.001$ and $P=0.003$, respectively), and some cations (Ca, Mg and Al) concentrations in the soil.

Table 7.8. Spearman rank correlations between sample scores on CVA first axes (1 and 2) and soil parameters (6 WAP at Mengomo, southern Cameroon)[a]

		Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
1998														
	Axis 1				-0.03	0.02	-0.19	-0.17	0.40 *	0.14	-0.03	-0.04	0.45 *	-0.02
	Axis 2				-0.37	-0.13	-0.10	0.07	0.44	-0.10	-0.16	-0.19	0.35	0.15
1999														
	Axis 1	0.57 **	-0.48 **	-0.24	-0.32	0.57 **	-0.68 ***	-0.42 *	0.44 *	0.42 *	0.27	0.45 *	-0.28	-0.59 **
	Axis 2	0.22	-0.16	-0.21	0.31	0.58 **	-0.53 **	-0.70 ***	-0.33	-0.26	0.50 *	0.49 *	-0.15	-0.56 **

[a] ***Significant at $P<0.001$, **Significant at $P<0.01$, *Significant at $P<0.05$.

Based on the strength of their correlation (RDA ordination) with each soil parameter, *Aneilema beninense*, *Eremospatha* sp, *C. odorata*, *Cogniauxia podolaena* and *Trema orientalis* were most strongly associated with soil K content in 1998, which was the only soil parameter that significantly (P=0.015) explained weed species composition (Tables 7.9 and 7.10). *Rhektophyllum mirabile* was strongly positively correlated with soil bulk density, but negatively correlated with soil N and C concentrations. *C. odorata* occurred more abundantly in clay plots with lower pH, lower value of bulk density and Ca concentrations in the soil, but higher value of Al content than the other weed species.

Table 7.9. Correlation coefficients between species density variables and soil parameters, and significance levels from Monte Carlo test (cut-off point P=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (6 WAP, southern Cameroon, 1998). Only coefficients > 0.30 are reported.

Weed species[a]	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Sedges										
Scl boi	-0.36									
Monocots										
Ane ben			-0.33		0.40				0.44	
Eremosp							0.32		0.48	
Hau dan						-0.32				
Pal hir					0.32					
Rhe mir	0.41		-0.34	-0.36						
Dicots										
Age con		0.32					0.37	0.32		
Chr odo		-0.39					-0.38		-0.53	0.33
Cog pod									0.48	
Cya pro	0.34									
Dissotis					-0.35					
Dio sca	-0.32			0.33						
Mus cec	0.32								0.39	
Phy ama	0.33									
Sid rho					-0.39					
Tal tri		0.35					0.39	0.39		
Tre ori									0.48	
Tri cor										-0.34

Weed species[a]	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
					CVA forward selection results					
P value	0.07	0.64	0.83	0.70	0.25	0.87	0.63	0.96	0.02	0.14
F-ratio	1.59	0.85	0.67	0.74	1.29	0.58	0.81	0.41	2.43	1.33
Significance	ns	ns	ns	ns	ns	ns	ns	ns	*	ns

[a]Weed species: Age con, *Ageratum conyzoides*; Ane ben, *Aneilema beninense*; Chr odo, *Chromolaena odorata*; Cog pod, *Cogniauxia podolaena*; Cya pro, *Cyathula prostrasta*; Dissotis, *Dissotis* sp; Dio sca, *Diodia scandens*; Eresmop, *Eremospatha* sp; Hau dan, *Haumania danckelmaniana*; Mus cec, *Musanga cecropioides*; Pal hir, *Palisota hirsuta*; Phy ama, *Phyllanthus amarus*; Rhe mir, *Rhektophyllum mirabile*; Scl boi, *Scleria boivinii*; Sid rho, *Sida rhombifolia*; Tal tri, *Talinum triangulare*; Tre ori, *Trema orientalis*; Tri cor, *Triumfetta cordifolia*.

* indicates significance at the 0.10 level. ns, nonsignificant.

Over the two years of study, *Ageratum conyzoides* had opposite soil preferences to *C. odorata*, except for bulk density, total N and total C content. Similarly, *C. odorata*'s soil preferences were opposed to those of the sedges *Cyperus rotundus* and *Mariscus alternifolius*, except for K concentrations. Sedges were strongly correlated with sandy plots poor in total N and total C. Grasses mostly occurred in plots with low soil Al content, but high value of Ca, Mg and K.

Table 7.10. Correlation coefficients between species density variables and soil parameters and significance levels from Monte Carlo test (cut-off point P=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (6 WAP, southern Cameroon, 1999). Only correlation coefficients > 0.30 are reported.

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Grasses													
Opl bur	0.45							0.35					
Pas con					0.34				0.40	0.61	0.49	0.33	
Sedges													
Cyp rot	0.46	-0.37	-0.33		0.38	-0.54	-0.40	0.47	0.37				-0.39
Mar alt	0.37	-0.36			0.40	-0.33					0.42		-0.33
Scl boi			0.31										
Monocots													
Ane ben				0.37				-0.50					
Cos afe				0.44				-0.53	-0.60				
Hau dan	0.39	-0.31				-0.44	-0.47						
Pal hir													
Rhe mir				0.46						0.40			

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Dicots													
Age con	0.44	-0.35	-0.33		0.32		-0.31						
Chr odo	-0.56	0.50				0.57	0.56					0.33	0.35
Cog pod			0.33										
Cya pro	-0.37	0.39			-0.32	0.36	0.33					0.31	
Dio sca						0.34							
Dissotis								0.35					
Har mad				0.48						0.43			
Mac ass					-0.40	0.34	0.35				-0.38		
Mik cor			0.37								-0.32		
Mus cec	-0.46	0.47							-0.32				
Phy ama													
Pou gui					0.42		-0.37	-0.42		0.43	0.45		-0.34
Ric bra	0.38	-0.36		-0.36	0.37	-0.35	-0.34						-0.34
Sid rho	0.34	-0.32			0.49	-0.44	-0.33	0.42	0.38		0.37		-0.37
Sta cay	0.57	-0.50			0.55	-0.53	-0.46		0.31		0.41		-0.45
Tal tri						-0.35	-0.33					-0.49	
Tre ori	-0.37		0.46		-0.56	0.61	0.60				-0.43		0.61
Tri cor	0.48	-0.45				-0.39	-0.32		0.45				
CVA forward selection results													
P value	0.37	0.42	0.98	0.07	0.65	0.01	0.30	0.54	0.01	0.39	0.05	0.23	0.66
F-ratio	1.06	1.11	0.33	1.52	0.86	3.80	1.18	0.91	2.26	1.04	1.58	1.19	0.78
Significance	ns	ns	ns	*	ns	*	ns	ns	*	ns	*	ns	ns

[a] See Table 7.9 plus: Cyp rot, *Cyperus rotundus*; Cos afe, *Costus afer*; Har mad, *Harungana madagascariensis*; Mac ass, *Macaranga assas*; Mar alt, *Mariscus alternifolius*; Mik cor, *Mikania cordata*; Pou gui, *Pouzolzia guineensis*; Ric bra, *Richardia brasiliensis*; Sta cay, *Stachytarpheta cayennensis*.

* indicates significance at the 0.10 level. ns, nonsignificant.

Pouzolzia guineensis, *Sida rhombifolia*, *Stachytarpheta cayennensis*, *Talinum triangulare* and *Triumfetta cordifolia* occurred in fallow types with almost similar soil features: sandy, less acid soils with low N, C and Al concentrations, but high Mg content. *Cyathula prostrata* and *Trema orientalis* showed similar soil preferences as *C. odorata*.

Canonical variate analysis of the 1998 data showed that all measured soil parameters explained only 38.3% of the inertia (i.e. the total variance), the remaining 61.7% being unexplained. K content significantly explained about 86% of the variance explained by all measured soil variables. In 1999, the measured soil variables together explained 51.1% of the inertia in weed species data. Four variables significantly influenced the weed species composition, and were retained in the CVA forward selection of the thirteen soil parameters. These variables were total N content, P and Mg concentrations, and bulk density; which together were responsible of about 27.8% of the inertia explained by all measured soil parameters. Thus, the final models explained 14.5% and 27.8% of the variation in weed species abundance, in 1998 and 1999 respectively, and the resulted ordinations were significant (at P=0.005, Monte Carlo test).

7.4.6.2. At maize and groundnut harvest

As shown in Figure 7.8, there were marked differences among the soil characteristics of the three treatments 14 WAP (i.e. just before maize and groundnut harvest).

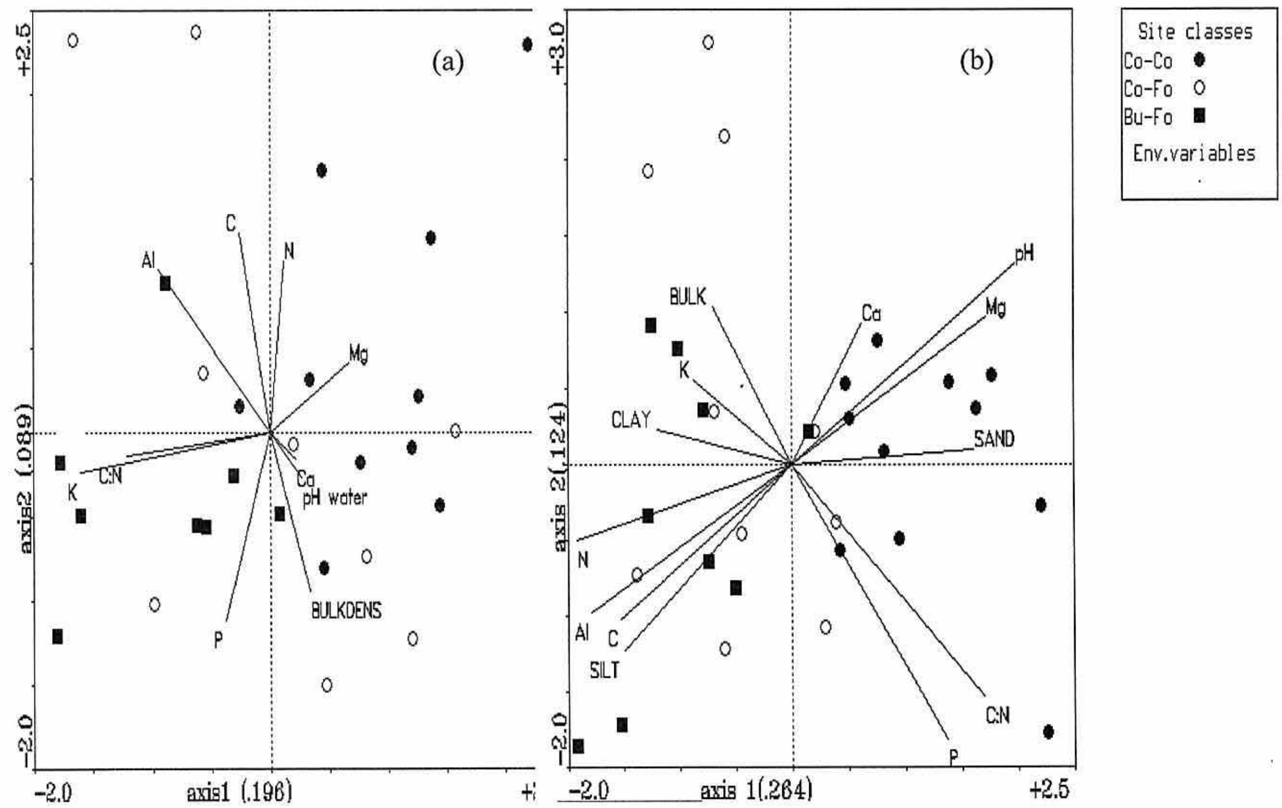


Figure 7.8. CVA ordination diagrams of weed communities in relation with soil physical and chemical parameters in mixed food crop fields established after three different fallow types in (a) 1998 and (b) 1999 at Mengomo (southern Cameroon), 14 WAP. Soil variables are represented as vectors and study plots as symbols. Direction of vectors shows the maximum variation for a soil variable and their length indicates the strength of the correlation with the ordination axes.

Each study year, weed species composition was correlated with soil variables. In 1998, they explained 37.2% of the variance in species data, and 51.9% in 1999. The first axis (eigenvalues 0.20 and 0.26 in 1998 and 1999, respectively) was consistently stronger than the second one as a discriminating factor, as plots were better separated according to their loadings along the first canonical variable, particularly in 1999 (P=0.005, F=3.74, Monte Carlo test). In 1998, Axis 1 can be explained in terms of C:N ratio and K concentration in the soil, while in 1999, it was mostly correlated with pH (positively) and with Al and N content (negatively, Table 7.11). There is a significant separation of Co-Co plots from the other fallow types (P<0.001, ANOVA on CVA sample scores on the first axis). As at the beginning of the cropping phase, Axis 1 corresponds to a gradient of land use intensification, where fields established on intensively managed fallow types are positioned on the right side of the diagram (Co-Co and Co-Fo cropping systems), and less intensively farmed fields are on the other side (Figure 7.8).

Table 7.11. Spearman rank correlations between sample scores on CVA first axes (1 and 2) and soil parameters (14 WAP at Mengomo, southern Cameroon)[a]

		Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
1998														
	Axis 1				0.20	0.12	0.10	0.02	-0.46 *	-0.22	-0.13	0.14	-0.52 *	-0.15
	Axis 2				-0.09	0.03	0.06	0.14	0.14	-0.45 *	-0.04	0.13	-0.08	0.12
1999														
	Axis 1	0.49 *	-0.38 *	-0.28	-0.36	0.60 **	-0.62 ***	-0.38 *	0.52 **	0.42 *	0.36	0.54 **	-0.26	-0.61 ***
	Axis 2	0.15	-0.08	-0.28	0.25	0.47 *	-0.29	-0.43 *	-0.31	-0.37 *	0.48 *	0.34	0.19	-0.43 *

[a] ***Significant at P<0.001, **Significant at P<0.01, *Significant at P<0.05.

The second axis of the ordination (eigenvalues 0.09 and 0.12 in 1998 and 1999, respectively) can mostly be explained in terms of soil K content and C:N ratio in 1998, whereas in 1999, it was more strongly correlated with soil pH, total C, Ca and Al concentrations.

Based on the strength of their correlation with each soil variable, monocotyledonous weeds (*A. beninense* and *R. mirabile*, in particular) were most strongly associated with soil K content (Tables 7.12 and 7.13). *C. odorata* remained associated with clay soils, where pH, Ca and K concentrations were low.

Table 7.12. Correlation coefficients between species density variables and soil parameters and significance levels from Monte Carlo test (cut-off point P=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (14 WAP, southern Cameroon, 1998). Only correlation coefficients > 0.30 are reported.

Weed species[a]	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Grasses										
Opl bur									0.43	
Monocots										
Ane ben						0.43	0.32		0.48	
Cos afe	-0.33									0.39
Hau dan									0.33	
Pal hir									0.31	
Rhe mir							0.34		0.47	
Dicots										
Brill sp									0.32	
Chr odo		-0.34					-0.33		-0.41	
Cog pod	0.48								0.55	
Des adc	0.35		0.34	0.31				0.36		
Dissotis	0.47		-0.41	-0.43						
Ipo sp					0.35				0.38	
Maran sp					0.42				0.60	
Mus cec					0.33				0.63	
Pip umb		-058					-0.53	-0.58		0.51
Pou gui	-0.43									
Sid rho					-0.31					
Tre ori					0.35				0.40	
Tri cor	0.34								-0.31	-0.33
CVA forward selection results										
P value	0.11	0.72	0.88	0.91	0.96	0.65	0.95	0.26	0.02	0.03
F-ratio	1.40	0.76	0.59	0.62	0.46	0.83	0.52	1.21	2.10	1.77
Significance	ns	ns	ns	ns	ns	ns	ns	ns	*	*

[a] See Tables 7.9 and 7.10 plus: Brill sp, *Brillantaisia* sp; Des adc, *Desmodium adscendens*; Ipo sp, *Ipomoea* sp; Maran sp, *Marantochloa* sp; Pip umb, *Piper umbellatum*.

* indicates significance at the 0.10 level. ns, nonsignificant.

The weed species *Piper umbellatum* appeared to be associated with similar soil parameters as *C. odorata*, with higher correlation coefficients with soil pH and Ca content.

Table 7.13. Correlation coefficients between species density variables and soil parameters and significance levels from Monte Carlo test (cut-off point *P*=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (14 WAP, southern Cameroon, 1999). Only correlation coefficients > 0.30 are reported.

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Sedges													
Cyp rot					0.39	-0.38			0.52		0.43		-.35
Cyperus sp					0.38	-0.33	-0.34			0.46			
Scl boi			0.35		-0.35						-0.37		
Monocots													
Ane ben			0.51		-0.35			-0.49			-0.38		
Cos afe				0.42				-0.63	-0.58				
Pal hir			0.55		-0.54	0.35					-0.53		0.41
Dicots													
Age con	0.41	-0.34			0.32		-0.30						
Chr odo	-0.34	0.31				0.33	0.41						
Har mad													0.32
Mac ass			0.41	-0.45	-0.41	0.38	0.39				-0.32		0.31
Mik cor			0.53		-0.46				-0.33	-0.33	-0.46		
Mus cec					-0.37	0.30			-0.31		-0.41		
Phy ama		-0.33											
Pla afr								-0.35					
Sid rho					0.39	-0.33		0.43	0.44		0.38		
Sta cay	0.54	-0.45	-0.31		0.40	-0.50	-0.43	0.32					-.36
Tal tri	0.32					-0.35	-0.33					-.50	
Tre ori					-0.37	0.49	0.42				-0.32	0.41	0.50
Tri cor			-0.34			-0.32							
					CVA forward selection results								
P value	0.05	0.14	0.97	0.28	0.01	0.17	0.78	0.01	0.11	0.14	0.82	0.63	0.19
F-ratio	3.21	1.37	0.35	1.20	3.21	1.31	0.72	2.41	1.51	1.46	0.69	0.87	1.30
Significance	*	ns	ns	ns	*	ns	ns	*	ns	ns	ns	ns	ns

[a] See Tables 7.9 and 7.10 plus: Pla afr, *Plagiostyles africana*.

* indicates significance at the 0.10 level. ns, nonsignificant.

Here again, *S. cayennensis*, *T. triangulare* and *T. cordifolia* occurred in plots with similar soil characteristics: high sand content, low N, C and Al concentrations. Meanwhile, *C. odorata*, *Mikania cordata*, *Macaranga assas*, *Musanga cecropioides* and *Trema orientalis* were more abundant in plots with low pH and high N, C and Al concentrations.

Canonical variate analysis of the 1998 and 1999 data revealed that all measured soil variables explained 37.2% and 51.9%, respectively, of the variance in weed species abundance across the three treatments. In 1998, of the ten measured soil parameters, only two significantly influenced the weed species abundance (Table 7. 12). These were K and Al concentrations, which together accounted for 14.1% of the variance explained by all soil variables. In 1999, sand percentage, pH and C:N ratio were the only soil variables that significantly influenced the abundance of weed species across the treatments, accounting together for 22.4% of the total variance explained by all soil parameters (Table 7.13). The final models thus explained 14.1% and 22.4% of the variation in weed species abundance across the study treatments in 1998 and 1999, respectively, and the ordination after selection of significant soil variables was significant (P=0.005, Monte Carlo test).

7.4.6.3. Towards the end of the cropping phase

As in the previous sampling dates, weed composition and abundance at the end of the cultivation period was also correlated with soil variables (Figures 7.9a and b). In 1998, soil variables explained 41.3% of the variation in the composition and relative density of weed species; the remaining 58.7% being unexplained. The first axis of the ordination (eigenvalue 0.251) was significantly correlated with soil K concentration and C:N ratio (at P=0.004 and P=0.03, respectively, Spearman rank correlation. Table 7.14 and Figure 7.9a). The second axis (eigenvalue 0.108) was not significantly correlated with any soil variable.

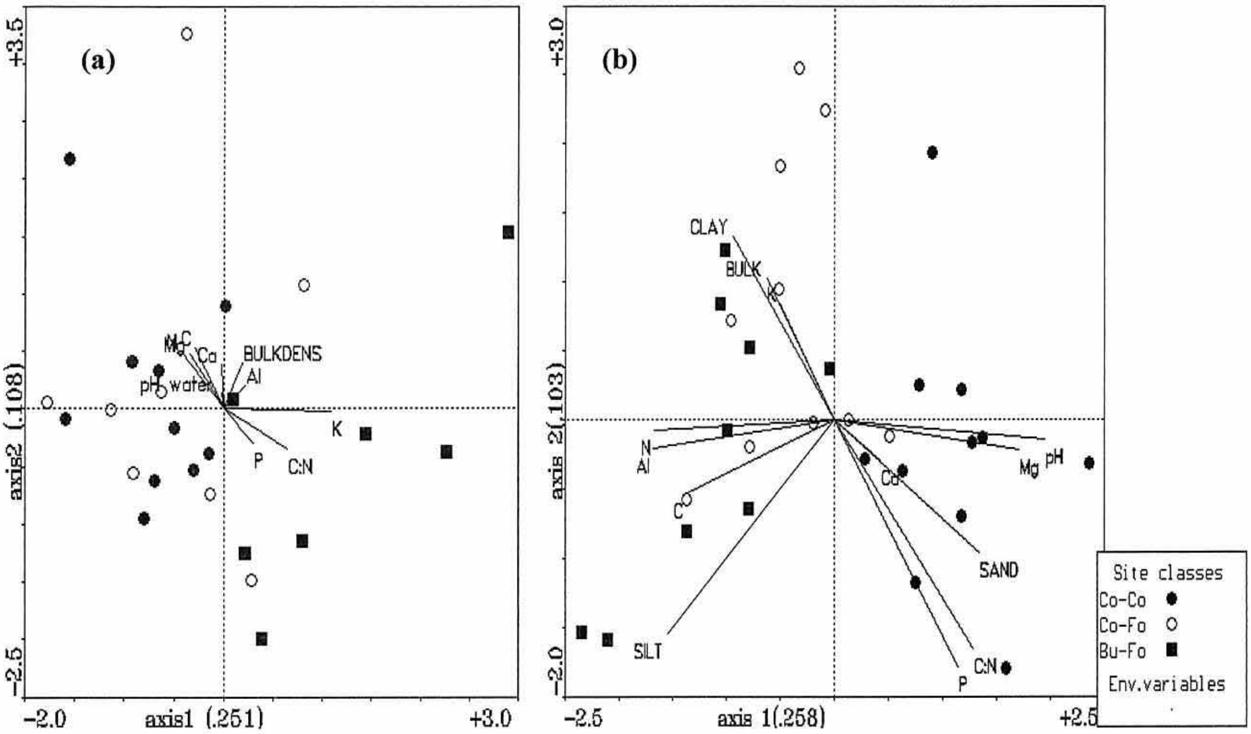


Figure 7.9. CVA ordination diagrams of weed communities in relation with soil physical and chemical parameters in mixed food crop fields established after three different fallow types in (a) 1998 and (b) 1999 at Mengomo (southern Cameroon), 30 WAP. Soil variables are represented as vectors and study plots as symbols. Direction of vectors shows the maximum variation for a soil variable and their length indicates the strength of the correlation with the ordination axes.

The first two axes explained 20.2% of the variance in the species data. In 1999, the discriminating power of the first two canonical axes (eigenvalues 0.258 and 0.103, respectively) was slightly higher than in the previous year (27.7% of the total variance in the species data), because of lower variability within treatments. The first 1999 ordination axis can be explained mostly in terms of Al, pH and C variation, with samples positioned on the right side of the diagram (i.e. Co-Co and Co-Fo plots) having less acidic soils, but low Al and C concentrations (Figure 7.9b).

Table 7.14. Spearman rank correlations between sample scores on CVA first axes (1 and 2) and soil parameters (30 WAP at Mengomo, southern Cameroon)[a]

		Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
1998														
	Axis 1				-0.19	-0.04	-0.10	-0.04	0.44*	0.20	-0.04	-0.11	0.56**	0.00
	Axis 2				0.30	0.11	0.19	0.17	-0.08	-0.16	0.17	0.22	-0.12	0.15
1999														
	Axis 1	0.49*	-0.39*	-0.29	-0.33	0.60***	-0.62***	-0.39*	0.42*	0.35	0.36	0.50*	-0.18	-0.69****
	Axis 2	-0.41*	0.49*	-0.49*	0.31	-0.09	0.06	-0.19	-0.40	-0.48*	-0.00	0.00	0.39*	0.17

[a] ****Significant at *P*<0.0001, ***Significant at *P*<0.001, **Significant at *P*<0.01, *Significant at *P*<0.05.

Overall, the first axis corresponded to the most important gradient in the weed species data in 1998 (Monte Carlo test: *P*=0.05, F=2.30 in 1998, and *P*=0.005, F=4.19 in 1999). There is a significant (ANOVA on CVA sample scores on the axis: *P*<0.0001 and *P*=0.0001 in 1998 and 1999, respectively) separation of Bu-Fo plots from the other two treatments. Thus, as at 6 and 14 WAP, Axis 1 corresponds to a gradient of land use intensification. However, of all soil parameters measured, only few significantly influenced weed species abundance across the three treatments. In 1998, only K content, Ca concentration and bulk density significantly explained species data (Table 7.15). The CVA ordination was significant (Monte Carlo test: *P*=0.005, F=1.83), and the final model accounted for 20.7% of the variance in weed species abundance. Whereas in 1999, five soil variables were retained as significant in the CVA with forward selection of the thirteen variables. These variables were pH, Ca, P, silt content and C:N ratio, shown in order they were entered in the model (Table 7.16). This final model in 1999 accounted for 30.0% of the variation in weed species abundance, and the ordination was significant (*P*=0.005, F=1.63, Monte Carlo test).

Table 7.15. Correlation coefficients between species density variables and soil parameters and significance levels from Monte Carlo test (cut-off point P=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (30 WAP, southern Cameroon, 1998). Only correlation coefficients > 0.30 are reported.

Weed species[a]	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Grasses										
Opl bur		0.50	-0.41	-0.38					0.44	-0.45
Pas con	0.34									
Sedges										
Scl boi		0.36	-0.31							-0.36
Monocots										
Ane ben									0.31	
Com ben		0.31					0.34		0.37	
Rhe mir					0.41					
Dicots										
Ant sch			-0.37		0.50				0.61	
Asy gan							0.34			
Cel tri	0.32									
Chr odo		-0.48					-0.48			
Coc gra									0.33	
Combretum			0.32	0.45						
Dav cha		-0.41					-0.41	-0.43		0.33
Des adc									0.46	
Dis rot		0.56				0.34	0.60	0.38	0.62	-0.38
Har mad			0.31	0.39						
Hyp ari									0.52	
Man esc	0.34								-0.41	
Mik cor									0.46	
Mit sca	0.43									
Mus cec									0.60	-0.34
Phy ama						-0.38				
Sap ell					0.31				0.45	
Sta cay									-0.36	
Tal tri							0.31	0.38		
Tre ori	0.31		-0.33							
Tri cor	0.32			-0.41						-0.34
Ver fro			-0.31						0.33	

Weed species[a]	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
CVA forward selection results										
P value	0.06	0.82	0.70	0.93	0.90	0.74	0.05	0.89	0.02	0.13
F-ratio	1.48	0.73	0.78	0.52	0.58	0.78	1.66	0.61	2.19	1.34
Significance	*	ns	ns	ns	ns	ns	*	ns	*	ns

[a] See Table 7.9 plus: Ant sch, *Anthocleista schweinfurthii*; Coc gra, *Coccinia grandis*; Com ben, *Commelina bengalensis*; Dav cha, *Davallia chaerophylloides*; Hyp ari, *Hypoestes aristata*; Mit sca, *Mitracarpus scaberulus*; Sap ell, *Sapium ellipticum*; Ver fro, *Vernonia frondosa*.

* indicates significance at the 0.10 level. ns, nonsignificant.

Based on the strength of their correlation with soil parameters, the density of more than ten weed species was strongly influenced by K concentrations in the soil, particularly in 1998 (Tables 7.15 and 7.16). In 1999, soil pH, total N and total C influenced mainly the abundance of *Oplismenus burmannii*, *Scleria boivini*, *Dissotis rotundifolia*, *Trema orientalis* and *Triumfetta cordifolia*.

Table 7.16. Correlation coefficients between species density variables and soil parameters and significance levels from Monte Carlo test (cut-off point P=0.10) in CVA forward selection for weed density data collected from mixed food crop fields established after clearing three different fallow types at Mengomo (30 WAP, southern Cameroon, 1999). Only correlation coefficients > 0.30 are reported.

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Grasses													
Opl bur									0.34			-0.37	
Pas con					0.42	-0.41	-0.36		0.38		0.37		-0.35
Sedges													
Cyp rot									0.34				
Cyperus sp	0.33		-0.43			-0.43	-0.45						
Scl boi			0.66		-0.46	0.35					-0.47		0.44
Monocots													
Ane ben							-0.32	-0.50					
Cos afe								-0.62	-0.66				
Hau dan	-0.43	0.40				0.47	0.48						0.39
Dicots													
Age con	0.48	-0.41			0.40	-0.41	-0.34					-0.42	-0.34
Chr odo						0.33	0.31		-0.35			0.44	
Ipo inv													0.35
Mik cor			0.49		-0.34						-0.34		
Phy ama	0.43	-0.34	-0.32		0.40			0.39					

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Pip umb				0.38				-0.33	-0.41				
Pla afr					-0.42	0.36	0.33				-0.34		0.37
Sid rho									0.34		0.33		
Sta cay	0.35	-0.36			0.49	-0.37		0.46	0.35		0.48	-0.32	-0.42
Tal tri												-0.37	
Tre ori													
Tri cor				-0.43					0.52		0.34		
Ver con			0.57		-0.40						-0.39		
CVA forward selection results													
P value	0.70	1.0	0.01	0.20	0.01	0.48	0.53	0.07	0.01	0.01	0.14	0.39	0.68
F-ratio	0.76	0.001	2.05	1.31	3.55	0.92	0.93	1.55	2.11	2.29	1.44	1.04	0.76
Significance	ns	ns	*	ns	*	ns	ns	*	*	*	ns	ns	ns

[a] See Tables 7.9 and 7.10.

* indicates significance at the 0.10 level. ns, nonsignificant.

Ageratum conyzoides, *Paspalum conjugatum*, *Phyllanthus amarus* and *Stachytarpheta cayennensis* were strongly associated with high soil pH, while *Mikania cordata*, *Plagiostyles africana*, *Scleria boivini* and *Vernonia conferta* were more abundant in sites with low soil pH. Species that were associated with sites with high soil bulk density were *Costus afer*, *Haumania danckelmaniana* and *Mikania cordata*. *C. odorata*, *H. danckelmaniana*, *Plagiostyles africana* and *Scleria boivini* were more abundant in sites with high percentage of clay, high nitrogen and carbon content. No species was correlated with soil Ca content, and very few with bulk density.

7.4.7. Maize, groundnut and cassava yield

Overall, there was a significant difference between treatments in all crops yield (Table 7.17). In 1998, maize grain yield was almost nil in all plots, probably due to the severe drought that occurred at the beginning of crop growth. However, in 1999, maize grain yield was similar across fields established after clearing *C. odorata*-dominated fallows (i.e. Co-Co and Co-Fo systems, mean 3.70 ± 0.52 t ha^{-1}), but significantly lower in Bu-Fo plots (mean 1.78 ± 0.29 t ha^{-1}).

Table 7.17. Effect of different short fallow types on maize, groundnut grains and cassava tuber yields in mixed crop fields at Mengomo (southern Cameroon).

	Maize (t ha^{-1})		Groundnut (kg ha^{-1})		Cassava (t ha^{-1})	
Treatment*	1998	1999	1998	1999	1998	1999
Co-Co	0	3.88±0.51a	49.15±3.30a	296.68±15.25a	7.60±0.52a	3.32±0.29a
Co-Fo	0	3.52±0.53a	28.34±2.90b	180.37±18.78b	2.76±0.28b	2.96±0.47a
Bu-Fo	0	1.78±0.29b	40.60±4.66a	67.72± 6.17c	2.20±0.27b	1.20±0.13b
LSD (α=0.05)		1.24	10.09	39.73	1.11	0.93

See text for treatment categories. Vaues with the same letter within a column are not significantly different at *P*=0.05.

Groundnut grain yield was significantly higher in 1999 than in the previous year (mean total 39.68 kg ha^{-1} and 189.22 kg ha^{-1}, in 1998 and 1999, respectively). However, in all years, Co-Co plots had the highest yield (mean 49.15 ± 3.30 kg ha^{-1} and 296.68 ±15.25 kg ha^{-1} in 1998 and 1999, respectively. Figure 7.10). The within treatment effect was significant (P<0.05) in all treatments. The analysis of pod yields produced similar findings to those of grain yields: Co-Co plots had the highest pod yield as compared to the other two treatments (mean values 24.60, 13.44 and 18.56 kg ha^{-1} in 1998; and 133.96, 80.00 and 30.23 kg ha^{-1} in 1999 for Co-Co, Co-Fo and Bu-Fo fields, respectively).

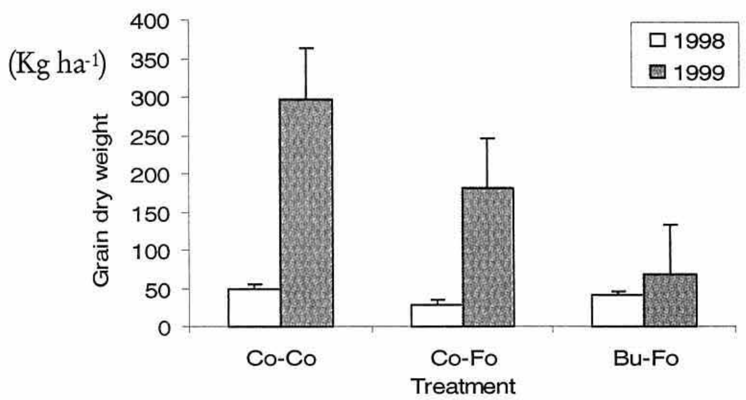


Figure 7.10. Groundnut grain yield in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1998 and 1999). Vertical bars indicate standard errors of the mean.

Cassava tuber yield in all treatments showed a fluctuating trend that was highest in 1998, but decreased in 1999. Co-Co plots also consistently performed better (*P*<0.05) than the two other treatments, with tuber dry weight of 7.60±0.52 t ha^{-1} in 1998, and 3.32±0.29 kg ha^{-1} in 1999 (Figure 7.11). Bu-Fo plots consistently had lowest cassava tuber yield over the two years.

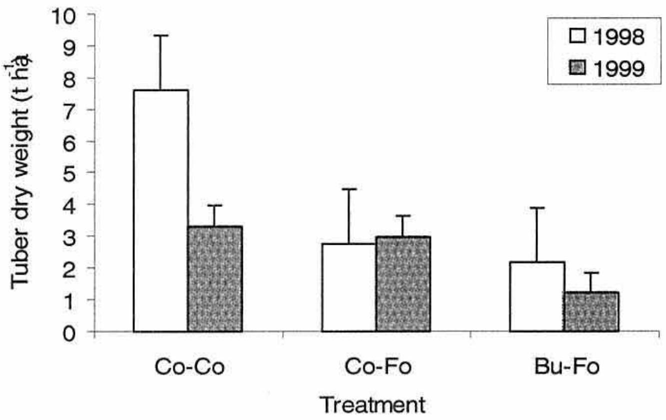


Figure 7.11. Cassava tuber yield in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1998 and 1999). Vertical bars indicate standard errors of the mean.

7.4.8. Soil properties and their relationship with crop performance

Based on Pearson correlation coefficients, and although less obvious in the 1998 experiment, there was a highly significant (*P*<0.0001) positive relationship between crop yield and soil pH, Mg, sand percentage, bulk density and Ca concentration (Table 7.18). Crop yield was strongly negatively correlated (at *P*<0.0001) with clay percentage, Al, total N and total C concentrations in the soil. However, apart for the relationship between maize, groundnut grain yield and soil pH, the correlation coefficients between soil properties and crop yield were low (< 50%), particularly in the 1998 experiment.

Table 7.18. Pearson correlation coefficients between crop production (maize, groundnut and cassava) and soil properties in mixed food crop fields established after three short fallow types at Mengomo (southern Cameroon)[a].

	1998		1999		
	Groundnut grain	Cassava tuber	Maize grain	Groundnut grain	Cassava tuber
Sand %	na	na	0.33****	0.41****	0.28****
Clay %	na	na	0.44****	0.47****	0.34****
Silt %	na	na	-0.40****	-0.45****	-0.27****
Bulk density	-0.06 ns	0.04 ns	-0.13*	-0.05 ns	-0.24***
pH	0.03 ns	0.15*	0.61****	0.52****	0.37****
Total N	0.01 ns	-0.06 ns	-0.33****	-0.44****	-0.23***
Total C	0.01 ns	-0.11 ns	-0.29****	-0.38****	-0.19**
Ratio C:N	0.04 ns	-0.08 ns	0.07 ns	0.13 ns	0.08 ns
P	-0.07 ns	-0.07 ns	0.20**	0.14*	0.14*
Ca	0.01 ns	0.09 ns	0.35****	0.28****	0.37****
Mg	0.02 ns	0.24***	0.49****	0.29****	0.23***
K	0.05 ns	-0.23**	0.13 ns	-0.15*	0.14*
Al	0.01 ns	-0.17*	-0.45****	-0.46****	-0.21**

[a] ****Significant at $P<0.0001$, ***Significant at $P<0.001$, **Significant at $P<0.01$, *Significant at $P<0.05$. ns, nonsignificant; na, not available.

7.4.9. Crop yield as influenced by weed density

Over the two years of study, groundnut grain yield decreased with increasing weed density in Co-Fo plots (significantly in 1999: $P=0.008$), and in Bu-Fo plots (not significantly, $P>0.05$). Groundnut production also decreased with increasing weed density in Co-Co and Bu-Fo plots, but the relationship was weak ($P>0.05$) (Table 7.19, Figure 7.12).

Regression analysis also revealed that, in general, there was a relationship between cassava production and overall weed density (Figure 7.13), but the relationship was significant only for Co-Co plots in 1998 (P=0.014) and Co-Fo plots in the 1999 experiment (P<0.0001: Table 7.20), with the highest yield recorded in plots with lowest weed density.

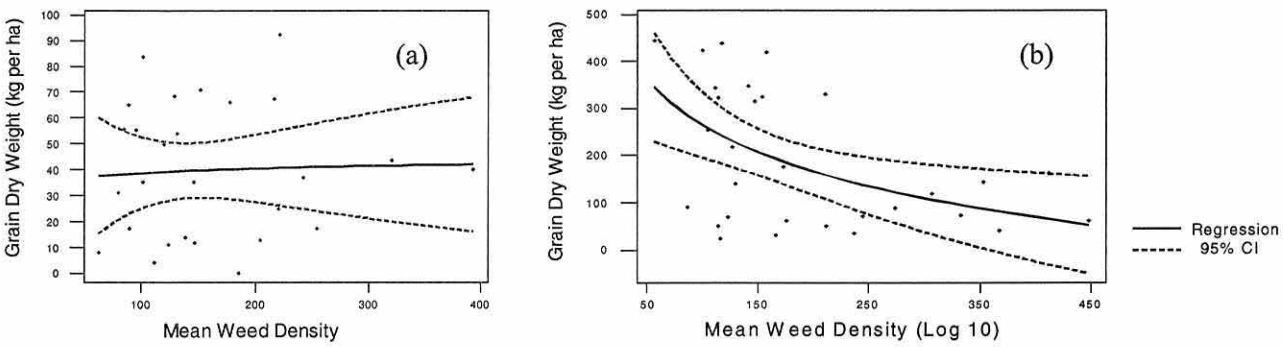


Figure 7.12. Effect of weed density on groundnut grain production in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon: a, 1998 and b, 1999). CI, confidence intervals.

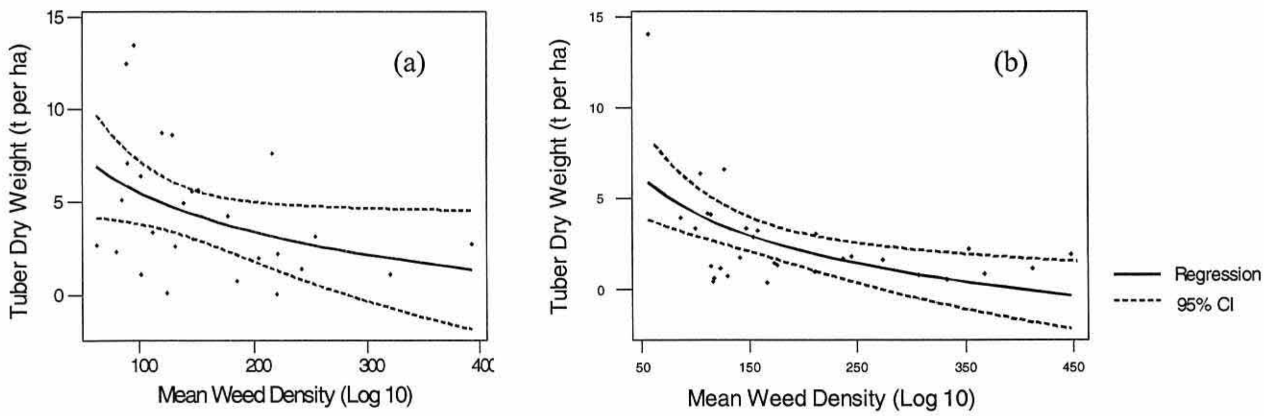


Figure 7.13. Effect of weed density on cassava tuber yield in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon: a, 1998 and b, 1999). CI, confidence intervals.

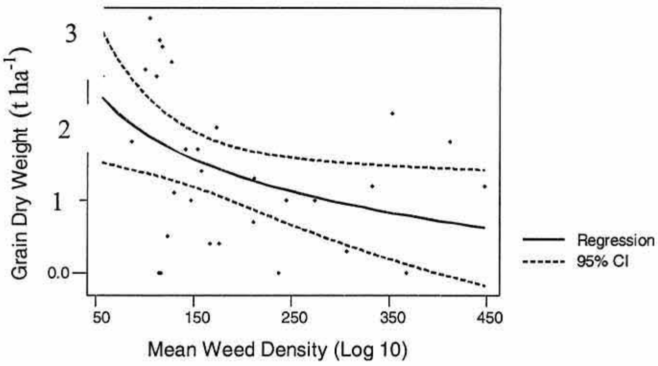


Figure 7.14. Effect of weed density on maize production in mixed food crop fields established after three fallow types at Mengomo (southern Cameroon, 1999). CI, confidence intervals.

With the exception of Co-Co plots in 1999, weed density did not significantly ($P<0.05$) have an effect on maize production (Table 7.21). However, plots with highest weed density generally had the lowest production, except in treatment 3 plots where the reverse trend was observed (Figure 7.14).

Table 7.19. Groundnut grain production and weed species density (average value of all three observations) in mixed food crop fields established after clearing three different short fallow types at Mengomo (southern Cameroon).

Treatment*	Regression coefficient	*P*-value[a]	Linear regression equation
1998			
Co-Co	0.28%	0.885 ns	Yield = 63.7584 – 3.0002 log10 (Density)
Co-Fo	8.30%	0.489 ns	Yield = -11.6537 + 8.2510 log10 (Density)
Bu-Fo	0.31%	0.905 ns	Yield = 4.1007 + 7.4838 log10 (Density)
1999			
Co-Co	0.91%	0.780 ns	Yield = 98.3167 + 41.3273 log10 (Density)
Co-Fo	60.95%	0.008*	Yield = 1424.7591 – 235.1124 log10 (Density)
Bu-Fo	2.85%	0.664 ns	Yield = -146291 + 16.2744 log10 (Density)

* See text for treatment categories.

[a] *Significant at $P<0.05$.

Table 7.20. Cassava tuber yield and weed species density (average value of all three observations) in mixed food crop fields established after clearing three different short fallow types at Mengomo (southern Cameroon).

Treatment*	Regression coefficient	*P*-value[a]	Linear regression equation
1998			
Co-Co	54.92%	0.014*	Yield = 36.8848 – 6.0158 log10 (Density)
Co-Fo	14.59%	0.350 ns	Yield = 7.5407 – 0.9068 log10 (Density)
Bu-Fo	20.61%	0.306 ns	Yield = 19.3806 – 3.4199 log10 (Density)
1999			
Co-Co	28.43%	0.091 ns	Yield = 24.7293 – 4.4608 log10 (Density)
Co-Fo	88.52%	<0.0001****	Yield = 40.9326 – 7.1709 log10 (Density)
Bu-Fo	23.83%	0.182 ns	Yield = -4.0083 + 1.030 log10 (Density)

* See text for treatment categories.

[a] *Significant at $P<0.05$, ****Highly significant at $P<0.0001$.

Table 7.21. Maize grain production and weed species density (average value of all three observations) in mixed food crop fields established after clearing three different short fallow types at Mengomo (southern Cameroon, 1999).

Treatment*	Regression coefficient	*P*-value[a]	Linear regression equation
Co-Co	37.87%	0.044*	Yield = 1.3667 - 0.2366 log10 (Density)
Co-Fo	23.77%	0.153 ns	Yield = 0.5585 - 0.0810 log10 (Density)
Bu-Fo	36.07%	0.087 ns	Yield = -0.3213 + 0.0749 log10 (Density)

* See text for treatment categories.

[a] *Significant at $P<0.05$.

7.5. DISCUSSION

7.5.1. Weed species composition

There were differences in species composition (richness and abundance) of the weed community in relation to the type of short fallow that preceded the cultivation phase, and in relation to the number of cultivation cycles since forest clearing. With the exception of the observation at 6 WAP in 1999, weed density values observed in this study are consistent with previous studies on weed communities in mixed food crop fields in tropical Africa (Akobundu *et al.*, 1992; de Rouw, 1995; Akobundu *et al.*, 1999; N'zala *et al.*, 2002). The higher species diversity in Co-Fo and Bu-Fo plots at the end of the cropping period can be due to an increased abundance of re-sprouting forest plants (Marantaceae and Zingiberaceae in particular, such as *Haumania danckelmaniana* and *Costus afer*) that survived the cultivation phase either because they were present in the seed bank or because of the selective weeding practiced by farmers (de Rouw, 1995). In those plots, although *C. odorata* was covering about 50% of the canopy, its cover remained patchy because the distribution of re-sprouting plants over a field was not uniform. Subsequently, the open spaces between stumps were filled by new generations of weeds, resulting in higher species diversity in plots of these treatments. The ability of sprouting species to out-compete and suppress weeds has already been used in some intensively managed shifting cultivation systems (e.g. Aweto, 1981: Nigeria and de Rouw, 1995: the Taï area, Côte d'Ivoire). The large leaves and vigorous growth of the re-sprouting plants assure a rapid ground cover, which averts the spread of heliophytic weeds (such as grasses, sedges and annual dicotyledons). However, as already reported by de Rouw (1995), the ability of sprouting species to out-compete weeds does not suppress the development of pioneer trees (such as *Trema orientalis*) or the growth of *C. odorata*.

In addition to the high weed infestation observed in all study fields, another disadvantage of cropping after short fallows was the low weed:forest species ratio. Although the few forest species present in the field after crop harvest can provide shade to avert a massive germination of a second generation of weeds, it is still sparse enough to allow the invasion of *C. odorata* (de Rouw, 1995). Slaats (1992) has reported a degeneration of much secondary forest to *C. odorata* thickets in the Taï region (Côte d'Ivoire). The low rate of reforestation, described by the low weed: forest plants ratio, observed in frequently cropped plots (i.e. Co-Co plots), can be due to a succession of short fallow periods, which had eliminated the seed and seedling bank of forest plants, and had provided the opportunity for annual weeds to produce several crops of seeds and the persistence of weedy seed and seedling bank (de Rouw, 1995). A succession of short fallow periods (as with the Co-Co fields) is reported **to** eliminate the seed and seedling bank of most forest species, leaving little overhead shade after crop harvest, and allowing annual weed species to produce several crops of seeds (de Rouw, 1995). These trends suggest a more serious delay in reforestation after Co-Co fields compared to recently forested fields.

According to Mohler *et al.* (2001), the composition of a weed community is also determined by inter-specific interactions among weeds, especially in agricultural systems where farmer resources are limited, crop value is low and weed biomass is high. In such systems, one species may competitively have negative effects on the abundance of other weeds (Johnson & Kent, 2002). This may explain the low number of weed species observed in Co-Co and Co-Fo plots, where *C. odorata* was particularly abundant. This effect was reported to be useful in the weed management if easily controlled weeds can be used as living mulches to suppress more competitively harmful ones, and may be responsible of the total absence of important problem weeds such as *Imperata cylindrica* in all study plots.

Weed community composition showed some constant and some changing features over the sampling dates. At 6 weeks after planting, over the two years of study, *C. odorata*, *Stachytarpheta cayennensis*, *Triumfetta cordifolia* and *Sida rhombifolia* were the most abundant species in frequently plots (accounting for more than 50% of the weed flora), whereas recently forested plots (i.e. Co-Fo and Bu-Fo) were dominated by *C. odorata*, *Trema orientalis*, *Costus afer* and *A. beninense*. At 14 weeks after planting, a similar weed flora was recorded, but some grasses (e.g. *O. burmannii* and *Paspalum conjugatum*) were already among the six most important weeds in Co-Co fields. Towards the end of the cultivation period, grasses and sedges became more predominant in the weed flora, more abundantly in fields established after clearing recurrent *C. odorata*-dominated fallows. Although Chikoye & Ekeleme (2001) reported a weak relationship between the species from the seedbank and those from the weed flora, differences in weed species composition between frequently cropped fields and recently forested plots observed in this study may be due to dissimilarity in weed seed composition. However, studies to evaluate the impact of short fallows on the germination of seeds of the dominant weed species identified in this study are recommended.

The increasing abundance of grass weeds in frequently disturbed agro-ecosystems (such as Co-Co plots) has been reported by Froud-Williams (1986) who suggested that, increased land use would generally be associated with communities largely composed of annual and perennial grass species, fewer annual dicotyledons, and increased wind-disseminated and volunteer crop species. In accordance with the findings of this study, de Rouw (1995) found that fallows infested by *C. odorata* had more arable weeds (e.g. sedges and grasses) remaining in the vegetation of the subsequent cropping phase, for a longer period. However, contrasting with findings of previous studies on weed community composition in humid tropical zones (e.g. Akobundu *et al.*, 1999; Chikoye & Ekeleme, 2001; N'zala *et al.*, 2002), grasses did not play an important role in the weed flora of the study zone across all treatments.

Some of the weed successions reported in this study have clear implications for labour, production costs and yield losses in crop production by small-scale farmers of southern Cameroon. For example, one of the farmers' most important constraints to crop production in short duration fallow systems, *C. odorata*, was not only consistently abundant throughout the cropping period, but it was also dominant in fields established after clearing less intensively farmed fallow types. One of the world's most widespread and problematic weeds, *C. odorata* is ranked as the most important weed problem by more than 75% of farmers in southern Cameroon (Weise & Tchamou, 1999) and one of the widely distributed common weeds of the wet tropics (Slaats, 1992). Its rapid multiplication and the re-sprouting ability of established plants make it impractical to control infestations by manual means alone. Therefore, the abundance of *C. odorata* in mixed food crop fields established after short duration fallows represents a serious predicament for resource-poor farmers.

An increase in *Stachytarpheta cayennensis* (especially in intensively farmed short fallow types) also signifies a problem trend for small-scale farmers. This species has become a widespread weed of cassava-based cropping systems in the region (Weise & Tchamou, 1999). It poses a major challenge in food crop fields, where it is capable of vigorous growth, early seeding and a rapid increase in population. In a survey of farmers' perceptions of different weeds in the study area, *S. cayennensis* was ranked among the five most problem weeds by more than 50% of farmers (Weise & Tchamou, 1999). The deep-penetrating rooting system of this species and its re-sprouting ability makes weeding more tedious, thus representing another serious predicament for resource-poor farmers. The fact that *Stachytarpheta cayennensis* and *Sida rhombifolia* occupied a major portion of the weed flora (especially at the early stages of crop growth) suggests that these species were able to compete with *C. odorata*. In frequently cropped plots (i.e. Co-Co fields), the increase in perennial grasses and sedges is likely to have resulted from the combination of repeated cultivation cycles and dominance of the vegetation by *C. odorata*, which gave those species a substantial advantage over perennial dicotyledons (Légère & Samson, 1999). Recently forested fields (Co-Fo and Bu-Fo plots) supported a wider range of species than the treatment 1 environment.

The changes in the dominant species have a greater significance for weed management questions than the more subtle shifts in species composition (Johnson & Kent, 2002). In intensively cropped short fallow systems (i.e. Co-Co and Co-Fo plots), particularly towards the end of the cultivation phase, the relative shift in dominance from perennial dicotyledons *Stachytarpheta cayennensis* and *Triumfetta cordifolia* to the very difficult to remove sedges *Cyperus* spp. and *Scleria boivini* also presents a worrying trend for farmers. The rapid multiplication of these weeds, the very sharp edges of their leaves and the ability of tubers to lie dormant make it impractical to control infestations by manual means alone. For example, an established population of *Cyperus rotundus* in West Africa rice-based systems is reported to accumulate 40 t ha^{-1} roots, tubers and rhizomes (Johnson & Kent, 2002). Thus, the presence of sedges in mixed cassava-maize-groundnut fields represents a serious constraint for small-scale farmers in the study area. The increase in perennial grasses and sedges was matched by a decline in the abundance of pioneer species such as *Trema orientalis*. This suggests that pioneer species were unable to compete with invading fast-growing and more shade-tolerant weed species such as *C. afer*, *A. beninense*, *Vernonia* spp., *Tristemma mauritiana* and *Mikania cordata*. However, the greater relative importance of species such as *Desmodium adscendens* 30 WAP, and the decrease in importance of others such as *A. conyzoides* (known as a major problem weed in the study area: Weise & Tchamou, 1999) were unexpected, and may have been stimulated by environmental factors.

7.5.2. Influence of soil parameters on weed species composition and abundance

The results of this study indicate that soil physical and chemical properties were significantly correlated with the weed species composition across the three study environments, accounting for up to 30% of the variation in weed species distribution and abundance. This may be attributed to interactions between site characteristics and the form of disturbance provided by the study fallow systems, which is a balance of positive effects of the vegetation present in the fallow prior to the cropping phase on soil fertility, negative effects of competition for light, water and nutrients, and a potential effect via microclimate (Bazzaz, 1996; Légère & Samson, 1999; Chikoye & Ekeleme, 2001).

Confirming the findings of previous studies on weed ecology (Zimdahl, 1999), the results of this study demonstrated that nitrogen, phosphorus and potassium are the primary soil nutrients that can significantly influence weed species composition. Different weed communities in soils with different texture reported here have also been reported elsewhere (Phillips, 1992; Chikoye & Ekeleme, 2001). Weed species such as *Ageratum conyzoides*, *C. odorata* and *Talinum triangulare* were influenced by soil pH. However, unlike Chikoye & Ekeleme (2001), *Ageratum conyzoides* was found to be associated with sites with low clay and silt, and grass weeds (*Oplismenus burmannii* and *Paspalum conjugatum*) were associated with sites with low nitrogen and carbon concentrations. Liebman *et al.* (2001) reported that certain weeds were specific to certain intercrop systems. For example, perennial weeds such as *C. odorata* are likely to be more abundant in perennial crops such as cassava because they synchronize their growth and reproduction with that of the crop. Chikoye *et al.* (1997) reported an abundant mixture of annual and perennial weeds in crop fields established after rotational cropping-fallowing cycles of 2 or more years, whereas continuous cropping resulted in annual weeds being dominant. However, it is noticeable that some common weed species associated with cassava in mixed crop fields (such as *Imperata cylindrica*, *Smilax anceps*, *Mucuna pruriens* or *Mimosa invisa*) were either completely absent or not important in the weed flora of the study environments. Similarly, weed species commonly interfering with maize (such as *Rottboellia cochinchinensis*, *Euphorbia* spp., *Digitaria* spp. or *Eleusine* spp.) were not important in the weed community. However, weeds frequently associated with groundnut (e.g.

Cyperus rotundus, *Ageratum conyzoides* or *Mariscus alternifolius*) were well represented in the weed community, especially of fields established after *C. odorata*-dominated short fallows.

The higher number of species recorded in recently forested plots that were not dominated by *C. odorata* may be caused by the importance of the seed bank of forest plants present in those plots, as compared to more intensively farmed fallow types. Forest plants often improve soil fertility, and the increased nutrients after fallow can support the survival and growth of several weed species (Szott *et al.*, 1999). Lower species richness in Co-Co and Co-Fo plots may be related to depletion of the seedbank through repeated cycles of clearing and burning activities, which affect soil nutrient status and texture.

At the treatment level, differences in species composition may reflect the adaptation of weeds to specific soil conditions. A high abundance of *P. africana*, *A. beninense*, *C. afer* and *P. umbellatum* was observed in clay soils with relatively high bulk density and K concentration. *T. cordifolia*, *S. cayennensis*, *S. rhombifolia* and *T. triangulare*, which were among the most dominant species in intensively farmed systems (Co-Co and Co-Fo fields), are adapted to growing in sandy environments with high pH and Mg concentrations. The low abundance of these latter species on clay soils suggests that they do not grow well on heavy soils. Growth of rhizomes, a major means of regeneration, may be restricted under clay soils as indicated by thin rhizomes and lack of buds on the rhizomes (Chikoye & Ekeleme, 2001). The centroids for *C. odorata* were located near the centres of the ordination diagrams, indicating that the abundance of this species was influenced by many environmental parameters, and confirming results from previous studies (Chikoye *et al.*, 2001; N'zala *et al.*, 2002). Ability to survive under a diverse set of growing conditions is one of the attributes responsible for the biological success of this weed (Slaats, 1992).

However, the soil parameters measured in this study significantly accounted for only up to 30% of the variation in the weed species composition and abundance, the remaining being unexplained. This relationship between weed data and some soil characteristics is likely to result from the important site-to-site variation observed in the study, particularly in the 1999 experiment. Moreover, the relatively tenuous correspondence between weed community composition and soil factors across the study treatments may also suggests that other aspects of weed biology (such as seed size, dispersal, production, germination requirements, seedbank, longevity, seed dispersal at harvest) should be invoked in trying to explain the presence and dominance of certain weed species with regard to short fallow management type (Mortimer & Cousens, 1995).

Several studies have also demonstrated or suggested the role of crop rotation, tillage and weed management practices, water status, date of planting, date of burning, shading period and intensity, seed cleaning before planting (Swanton & Weise, 1991; Légère & Samson, 1999; Swanton *et al.*, 1999; Zimdahl, 1999).

7.5.3. Effect of short fallow type on crop performance

Data collected in this study showed that the type of short fallow prior to the cultivation phase had a significant influence on cassava tuber, maize and groundnut grain yields. In the present study, the fact that fields established after clearing *C. odorata*-dominated short fallows (which had the highest weed densities) had the highest crop yield is a surprising finding that contradict those of various studies on crop performance-weed pressure (e.g. de Rouw, 1995; Akobundu *et al.*, 1999; Zimdahl, 1999). This situation may however be attributed to the effect of *C. odorata* on soil properties, which confirms the hypothesis developed by Weise & Tchamou (1999) and Gillison (2000) and substantiates the suggestion of Szott *et al.* (1999) and Kent *et al.* (2001) that yield losses from weeds largely depend upon the types of plant present during the fallow prior to the cultivation phase, and upon the weed species present during crop growth. According to Gautier (1996), *C. odorata*'s long deep roots are capable of extracting nutrients elements that have been leached into the deeper soil layers. The rapid decomposition of the roots later releases high nutrient content within 8 months. By incorporating the plant in the soil, it was demonstrated that the quantity and quality of the organic matter are substantially improved (Gautier, 1996). According to Szott *et al.* (1999), increased crop yields following short-duration fallows are often attributed to greater amounts of plant-available N in soil. Therefore, following these authors, results from this study suggest that *C. odorata* is a good fallow species for fertility improvement, and crop production can be sustained by planting fields after clearing a *C. odorata*-dominated fallow.

Better performance after clearing a *C. odorata*-dominated fallow may also be due to the fact that *C. odorata* is tolerant to low soil fertility (Szott *et al.*, 1999), and partly because this perennial dicotyledon may have contributed nitrogen and carbon to the soil. Moreover, the highest correlations reported in this study between soil C and N content and some weed species (in particular *C. odorata*, *Cyathula prostrata* and *Plagiostyles africana*) more abundant in fields established after clearing *C. odorata*-dominated fallows, may indicate the positive effect of *C. odorata*-dominated fallows on soil fertility amelioration.

However, the lack of significance in the relationship between weed density and crop yield in this study, and the poor correlation between crop yields and soil properties suggest the presence of multiple nutrient limitations or other biophysical constraints or moreover, facet of inherent soil fertility, which seems very low (Szott *et al.*, 1999). Fields established after clearing *C. odorata*-dominated fallows may have better overcome multiple nutritional constraints than fields established after clearing bush fallows. According to previous studies, reduction in crop production can be primarily attributed to reduced light intensity (Zimdahl, 1999) or excessive shading by surrounding vegetation. Although not reported in this study, treatment plots established after clearing bush fallows that had been forest were generally surrounded by secondary forest lands.

Soil bulk density was generally lower under fields established after clearing *C. odorata*-dominated fallows than under fields established after clearing bush fallows, at the beginning of the cropping period. An increase in soil bulk density, indicating soil compaction, and resulting in reduction in soil moisture and soil organic matter concentration has been reported during the cultivation phase after forest clearance (Alègre & Cassel, 1996; McDonald *et al.*, 2002).

Maize yield (or absence of maize yield in 1998) shows that this crop is sensitive to drought (especially at the early stages of crop growth). The lowest maize grain yield (1.5-4.3 t ha^{-1}) observed in recently forested fields established after bush fallows not dominated by *C. odorata* also suggests that this crop is more sensitive to weed competition as compared to the two other crops (i.e. groundnut and cassava). These findings are consistent with those from previous studies in similar environmental conditions (Akobundu *et al.*, 1999). Although the values reported in this study are lower than those from previous yield studies in wet tropic zones with mixed crop farming system (e.g. Akobundu *et al.*, 1999), fields established after recurrent *C. odorata*-dominated fallows consistently had higher crop production that the other treatments. Given that these plots had the highest weed densities throughout the cropping period, this result could be due to higher soil fertility conditions in this fallow type as compared particularly to recently forested plots (which yielded almost twice less than frequently cropped fields).

However, as emphasized by Roder *et al.* (1997), in small-scale farming systems with land use pressure, shortening of fallow duration, by increasing labour requirements (for weeding essentially), has directed farmers to attribute more importance to the function of fallow as weed-break than upon soil fertility. Recent studies have demonstrated a weak or an absence of measurable correlation between crop yield and changes in soil parameters in slash-and-burn agriculture, suggesting that too much emphasis should not be placed on the role of fallow for soil fertility restoration (Roder *et al.*, 1997; Szott *et al.*, 1999).

This study provided a useful description of the weed flora associated with three different types of short fallows in a mixed crop fields farming system, and its association with soil physical and chemical properties. The study also provided the opportunity to examine the relationship between short fallow type and crop yield. The time series illustrated a succession by problem weed species with land use intensification, and supports the theory that weed pressures are a significant factor influencing farmers' decisions to fallow in slash-and-burn agriculture (Johnson & Kent, 2002; Mertz, 2002). In frequently cropped short fallow systems, ingression by species such as *C. odorata*, *Stachytarpheta cayennensis* and *Sida rhombifolia* that are capable of rapid vegetative growth and multiplication would greatly increase the labour requirements for weeding. Given the fact that sufficient labour is not available to farmers in the study area (Gockowski *et al.*, 1998a), increased crop losses due to weed infestation would result. This study also indicated an ongoing decline in plant diversity, particularly in frequently cropped short fallow systems. These results emphasize the urgent need to design and implement an adaptive management programme that would improve the productivity and sustainability of shortened fallow systems in the study area, and improve local farmers' livelihoods.

CHAPTER VIII

PRODUCTIVITY OF SELECTED HIGH-VALUE SPECIES IN SHORTENED FALLOWS OF SOUTHERN CAMEROON

8.1. INTRODUCTION

Current efforts to develop the productivity and sustainability of intensively managed farming systems with crop-fallow cycles of shortened duration in the wet tropics are directed almost exclusively on the development of management interventions that have promise for improving fallow productivity (Nair, 1993; Leakey & Simons, 1998; Szott *et al.*, 1999). Such interventions include the enrichment of short-duration fallows with long-lived, useful tree species that eventually form productive agroforests (van Noordwijk, 1999). Where socio-economic conditions permit, it is believed that the evolution of such managed, 'improved' fallows toward long rotation semi-commercial fallow-based systems will result in land use that will benefit the environment and improve small-scale farmers' livelihood.

However, the inherent problem with this form of management is that tree species that could be used to improve the productivity and sustainability of short-duration fallows are traditionally most abundant in forest lands (Peters, 1990; Leakey & Simons, 1998). Given the existing rates of deforestation and land use intensification in the humid forest zone of southern Cameroon, alternative management strategies are urgently required.

Although the fact is seldom emphasized in most of the literature on Cameroonian non-timber forest products (NTFPs), many multipurpose species occur naturally in fallow lands (see Chapter 6; Ndoye, 1995). Tropical fallow lands contain mostly wild fruit trees, which local farmers retain on farmlands primarily because of the benefits derived from their comestible fruits or seeds (Irvine, 1961; White, 1994; de Rouw, 1995; Leakey & Simons, 1998; Carrière *et al.*, 2002). The major indigenous key productive fruit trees identified by farmers throughout the humid forest zone of southern Cameroon include *Coula edulis* Baill., *Dacryodes edulis* H. J. Lam, *Irvingia gabonensis* Baill. and *Ricinodendron heudelotii* (Baill.) Pierre (*cf.* Chapter 6).

The occurrence of such key productive species in fallow lands offers a unique opportunity to integrate the utilization and conservation of shortened-duration fallow lands in the humid forest zone of southern Cameroon. Nevertheless, as stated by Peters (1990) and Peters & Hammond (1990), before promoting the increased exploitation of wild fruit trees, some fundamental questions need to be addressed, such as:

- How abundant are the selected species in the farming system?
- Is each species regenerating itself *in situ*?
- When do the species flower and fruit?
- How much fruit is produced by natural populations?

Preliminary results of phenological observations conducted by Bibani-Mbarga *et al.* (1998) on *C. edulis* and *R. heudelotii*, and by Kengue (1990) on *D. edulis* suggest a continuous pattern of leaf-fall, flowering and fruiting, with seasonal peaks during the rainy period. However, although the general characteristics of these species have been described in the classics of Irvine (1961), Letouzey (1968), Hutchinson-Dalziel (1954-1972) and Aubréville (1963-1983), few data are available to quantify their density, phenology or productivity patterns in the area.

This study was undertaken to characterize the phenology of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* in a fallow farming system of southern Cameroon, and to examine the phenological patterns in relation to land use. Leaf flushing, flowering and fruiting phenology of each study species were investigated and patterns of fruit production monitored.

8.2. SPECIES DECRIPTIONS

8.2.1. Coula edulis Baill. (Olacaceae)

Coula edulis is a medium-sized tree commonly known as "African walnut", which is especially abundant in evergreen and deciduous forests of the Congo Basin (Irvine, 1961). It is known locally as "noisettier" (in French), and in the humid forest zone of southern Cameroon, as "ewomèn" or "komol" (in local languages: Bëti and Bassa, respectively).

Individual plants of *C. edulis* may attain a height of 17-19 m and a diameter of 2-3 m. The bark is fairly smooth and thin, and of brownish-green colour in adult trees. Leaves are simple, alternate, 6-12 cm in length, with a long-caudate-acuminate tip. Flowers are perfect, with five fairly thick brown petals and 10 stamens. Fruits are elliptical drupes, brown when mature, of up to 3.8 cm in diameter with a hard and rough nut-shell, difficult to break.

C. edulis trees are very popular in southern Cameroon because of the multiple benefits derived from their fruits, timber and bark. Kernels are an important local and marketable product, which are eaten fresh, boiled in shell or roasted. Nearly half the weight of the kernel is made of edible oil, containing 87 per cent oleic acid (Irvine, 1961; Ndoye, 1995). The timber is hard, heavy, resistant to water and immune to insects, thus very suitable for construction. The bark (powdered or in decoctions) is used in traditional medicine for dysentery, for dressing sores, to stimulate appetite or to counteract anaemia (Zapfack *et al.*, 2000). The species is occasionally cultivated in cocoa plantations and in home gardens with the fruit as a by-product (Sonwa *et al.*, 2002).

8.2.2. Dacryodes edulis (Pierre) H. J. Lam. (Burseraceae)

Dacryodes edulis is a medium-sized tree originating from Equatorial Africa (south of Nigeria, Congo and maybe Cameroon), but is currently widely distributed throughout the deciduous, dry deciduous and fringing forests of the Congo Basin and Gulf of

Guinea, from Sierra Leone to Gabon, Uganda and Angola (Irvine, 1961; Aubréville, 1963-1983; Letouzey, 1968; Kengue, 1990). Commonly known as "African plum" or "African pear", the tree species' local name throughout southern Cameroon is "safoutier" (its fruits are called "safou") or "assa" (Kengue, 1990; van Dijk, 1999).

Adult trees reach heights of 18 m and diameters of up to 100 cm when cultivated in open lands, and heights of up to 45 m and diameters of 150 cm in forests (Irvine, 1961; Kengue, 1990). The leaves are alternate, imparipinnately compound, with 4 to 12 pairs of leaflets (Kengue, 1990). *D. edulis* is a dioecious species, whose flowers, born in terminal panicles, fragrant and larger than leaves, are of three types: female, male or hermaphrodite (Kengue, 1990). Female trees generally bear exclusively female flowers, whereas male-and-hermaphrodite individuals bear both male and hermaphrodite flowers in proportions that vary considerably from year to year (from 5 to 95%). Kengue (1990) reported that *D. edulis* populations in south Cameroon are dominated by male-and-hermaphrodite individuals, in a ratio of 4:1. The fruits are drupes of various forms and dimensions: ellipsoid, oblong or globular, 4-12 cm in length and 3-6 cm wide (Kengue, 1990). Mature fruits are commonly eaten raw, boiled or roasted, with cassava and maize. Edible oil is also extracted from the fruits (pulp and seeds) and constitutes up to 61% of the weight of the fruit (Sonwa *et al.*, 2002). Chemical analyses have shown that *D. edulis* fruits are very rich in palmitic and oleic acids. There is an important local and regional market for *D. edulis* fruits (Ndoye, 1995). Other useful products from the species include fuel wood, timber and medicinal products (resin, bark) used to treat yellow fever, dysentery and anaemia (Zapfack *et al.*, 2000; Sonwa *et al.*, 2002). The species is frequently cultivated in cocoa plantations and in home gardens, or used as a living fence.

8.2.3. Irvingia gabonensis Baill. (Irvingiaceae)

Irvingia gabonensis, colloquially known as "bush mango" or "dika nut", is an economically important fruit tree native to moist lowland tropical forests in central and west Africa (Mollet *et al.* 1995; Atangana *et al.*, 2002). The species' natural habitat is the evergreen forest and mixed deciduous forest (Irvine, 1961). Its geographic range is from Nigeria to Congo (Atangana *et al.*, 2002). The common name for the species in southern Cameroon is "ando'o" (van Dijk, 1999) or "ndoga". Okafor (1990) identified two varieties of *I. gabonensis*, one with sweet, edible nuts and the other with bitter nuts.

The species is a large tree of up to 35 m or more, with a grey trunk slightly buttressed (Aubréville, 1963-1983). The bark is smooth and greyish-brown, and leaves are simple and thin, with a length of up to 22 cm (Irvine, 1961). Flowers are yellowish-white and fragrant. The fruit is yellow, mango-like with over 5 cm in diameter and a yellowish-orange pulp on maturity.

The pulp, although slightly bitter and acrid, is eaten fresh or made into juice drinks. Rich in oil (54-67%), the kernels (or seed cotyledons) are a more important source of human food because of their use as a food thickening agent in various local soups (Irvine, 1961). Following Okafor (1990), the taxonomy of the species has been revised by Harris (1996), and the bitter variety was subsequently called *Irvingia wombolu* Vermoesen. The kernels of *I. gabonensis* are rich in a polysaccharide (which forms the glutinaceous thickening agent) and oil (Ladipo *et al.*, 1996). The market for *I. gabonensis* seeds is very well developed, locally and regionally (Ndoye, 1995; Eyebe *et al.*, 1999). The hard and heavy wood, said to be immune to termites, is used for house posts and household utensils. The bark is used in traditional medicine and for palm-wine fermentation (Irvine, 1961). Despite being economically valuable, *D. edulis* is not widely planted in Cameroon, and fruits are still harvested mainly from wild forest trees.

8.2.4. Ricinodendron heudelotii (Baill.) Pierre ex Pax (Euphorbiaceae)

Ricinodendron heudelotii is a fast-growing pioneer tree commonly encountered in fringing, deciduous and secondary forests of East, West and Central Africa (Irvine, 1961; Kyereh *et al.*, 1999). It is commonly known in southern Cameroon as "ezezang" or "njansang" (van Dijk, 1999).

The species is a tall tree of up to 30 m or more in height and up to 2.5 m in diameter, with very short buttresses (Irvine, 1961). *R. heudelotii* is a typical dioecious species whose individuals are either female or male. Fruits are 2- or 3-celled, 2.5-4 cm in diameter, with a hard endocarp containing prolific seeds, rich in oil.

Almost every part of *R. heudelotii* is used in some manner by local people in south Cameroon. Although the thick shell is hard to remove, dried ground kernels are much used to thicken and flavour soups, and there is high commercial demand for the species in the local and regional market (Ndoye, 1995; van Dijk, 1999). Soft and perishable, light and easily carved, the wood is commonly used for making masks and kitchen utensils. The bark is used in traditional medicine as a cure for elephantiasis, dysentery, constipation or to relieve labour pains and prevent abortion (Irvine, 1961; Zapfack *et al.*, 2000).

8.3. METHODS

8.3.1. Identification of the study area

Preliminary information on the distribution and abundance of the study species was gathered through an extensive botanical survey conducted in the three resource domains of the IITA benchmark area (data not presented) to complement information gathered from interviews with village farmers (Chapter 3 and Chapter 5). In the botanical survey, the assessment focussed on the determination of the supply of the selected fruit trees in different land use systems. The main objective of the survey was to identify a location within the benchmark area, where the abundance of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* was sufficient to have a substantial sample for the phenological monitoring.

From the three locations surveyed (Kaya in the Mbalmayo domain, Nkometou in the Yaoundé domain and Akok in the Ebolowa domain, Figure 3.1), Kaya had the highest number of adult trees of the selected species, distributed across the three defined land use types, and was therefore selected for this study.

8.3.2. Study area

Kaya watershed is a transition forest-savanna zone, which extends from 3°33' - 3°40'

N latitude to 11°02' - 11°06' E longitude (ASB Summary Report, 2001 unpublished). Located to the southwest of Yaoundé city, Kaya is populated with *Bassa*, unlike the other Benchmark domains that are populated with *Bëti* (Santoir & Bopda, 1995).

Situated at 700 m above sea level, Kaya presents a climate typical of the humid forest zone, with rainfall and temperature peaking twice a year, the first in September and the second between March and April (Figure 8.1). Monthly climatic data for the five years prior to this study were obtained from the nearest meteorological station, located at Eséka, about 75 km from Kaya, at the same altitude. Climatic variables during the two years of monitoring were not recorded. Mean annual rainfall is around 1500 mm, falling in a bimodal pattern, delimiting two rainy seasons (April-May and July-October) and two dry seasons (November-March and May-June). Temperature peaks in March (with 28.7° C), and the lowest temperatures occur in February (22.6° C). There is little rainfall from December to February, with precipitation of less than 50 mm.

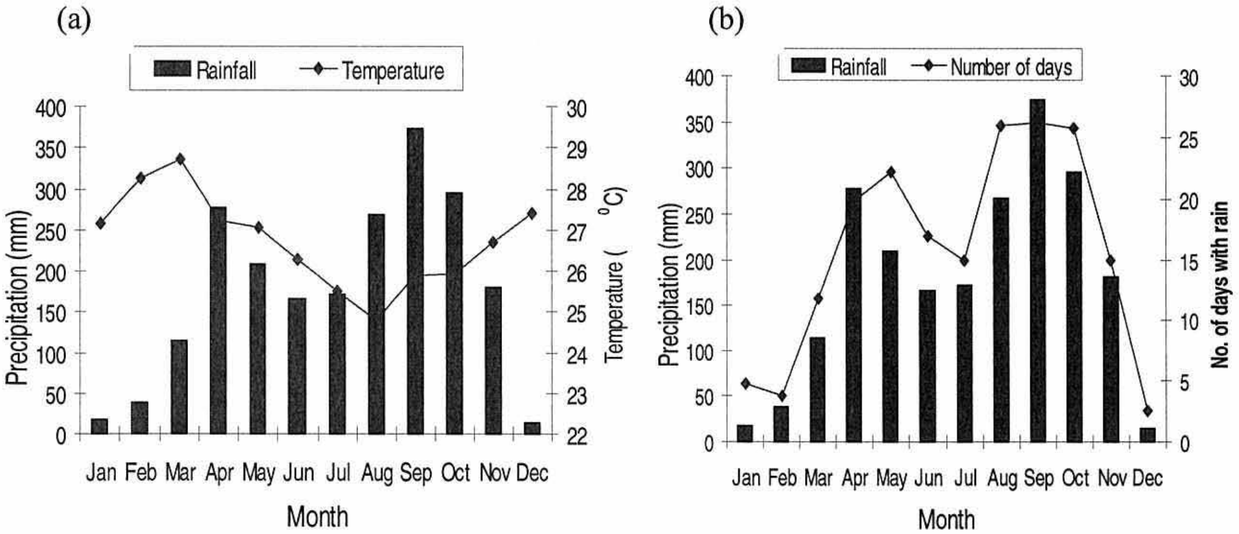


Figure 8.1. Climatic parameters at Kaya, south Cameroon, for (a) mean monthly rainfall and temperature and (b) mean monthly rainfall and mean number of days with rain (means 1996-2000). Source: Meteorological station of Éséka (Cameroon).

The soils of Kaya have high sand (44-72%) and clay (17-44%) contents, are acid and have low values of organic carbon (1-2%), total nitrogen (0.08-0.14%), available phosphorus (2.17-7.50 mg kg^{-1} in the topsoil) and exchangeable basic cations (ASB Summary Report, 2001). The base saturation varies widely between soil depths and between land use types.

8.3.3. Courtesy and protocol

Meeting and consultations were held with local farmers at Kaya, in collaboration with the Institut de Recherche Agricole pour le Développement (IRAD, the national agricultural research institute) research team working in the village. A large meeting involving a wide number of the local community was held in August 2000, and the objective of the research was explained, linking it as much as possible to the ongoing ASB research project carried out throughout the Kaya watershed (ASB Summary Report, 2001). The species selected for this study are key NTFPs in the area, and gaining support for the implementation of the research was therefore not problematic. Consequently, access to the forest and farm lands of Kaya was obtained. Guides were subsequently selected for the botanical inventory of the selected species in the village in order to select individual trees for the monitoring.

8.3.4. Survey methods

8.3.4.1. Distribution and abundance of the study species

Formal method to assess the abundance of sparsely distributed tree species are scarce and only recently, researchers have started to develop methods to inventory these resources (Peters, 1989; Hall, 1991; Hall & Bawa, 1993; Lämås, 1996; van Dijk, 1999). The sample design used in this study was adopted from van Dijk (1999). The sample plots covered an area of 4.9 ha, in the form of four transects with a length of 1.15-1.25 km and 10 m wide (Figure 8.2). The first three transects were laid out so as to bypass the various land use types present in the area (i.e. fallows, forests, food crop fields, cocoa plantations, oil palm plantations, etc.). A fourth transect was laid out in the vicinity of the village and settlements because a visual observation indicated a relatively higher abundance of the target species in the surrounding of the village houses.

8.3.4.2. Phenological sequences

For this part of the study, three land use types were defined: short fallows (of less than 7 years old), medium-term fallows (of 7-10 years old) and long-term fallows (of more than 10 years old). For each of these land use types and across the sample area (4.9 ha), an average number of 10 individuals per species was selected for phenological observations. Following interviews with local farmers, who were owners of the selected trees, only mature individuals that were reported to have fruited the year preceding the study were retained. Tree selection was limited to individuals growing in fallow lands defined for the experiment, and to healthy individuals whose crown did not overlap with other conspecific adults.

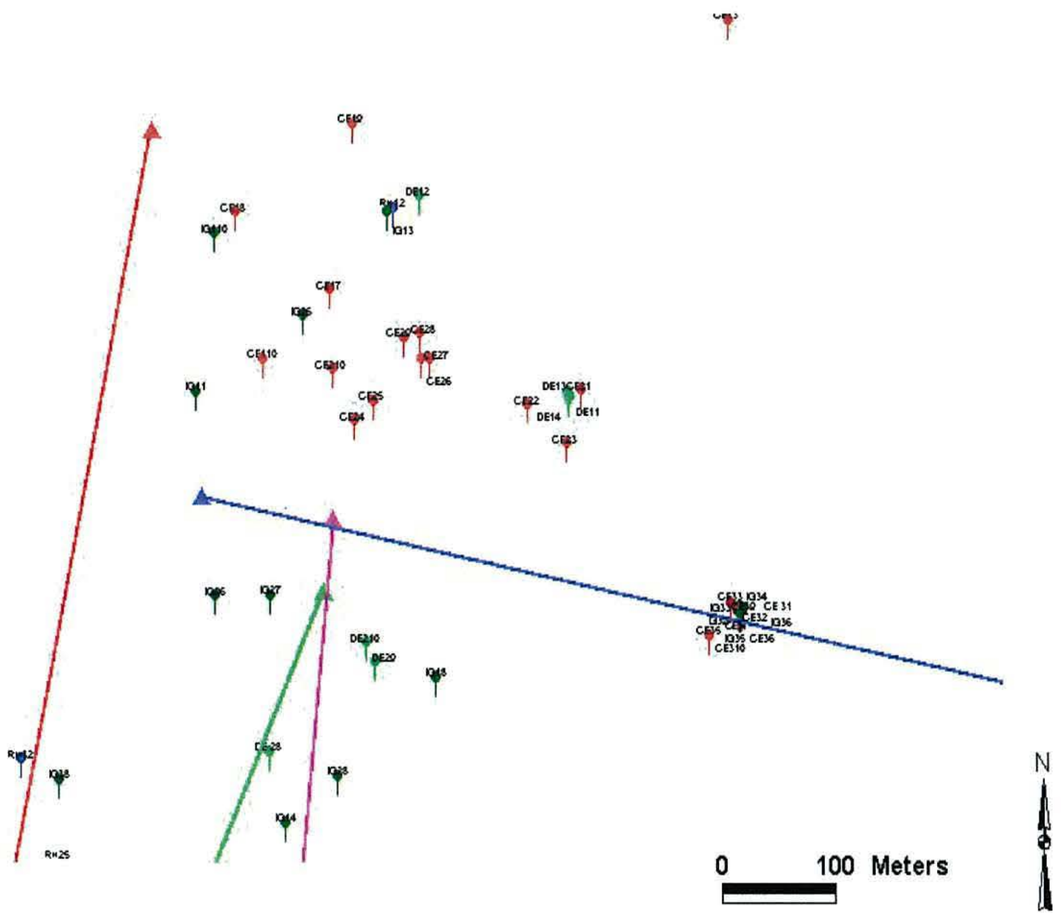


Figure 8.2. GIS map showing the location of all transects and trees sampled at Kaya (south Cameroon, 2001) for the phenological monitoring. Blue trees represent *R. heudelotii* (RH); Green, *I. gabonensis* (IG); Light green, *D. edulis* (DE) and Red, *C. edulis* (CE). T1-T4, transect numbers.

Individuals were also selected to have clusters of trees that could be visited and assessed within 15 days by one person. Selected individuals of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* were then measured for height and diameter at breast height (dbh), and their position was precisely mapped using GPS instrumentation. Each selected individual was permanently numbered with a metal tag.

In each fallow type, 10 individuals of each of the chosen species (if present) were selected. For *D. edulis*, due to the low density of the target species, additional individuals were located out of the four transects sampled. Moreover, because of the difficulty to find individuals of *D. edulis* and *R. heudelotii* in long fallows, the total number of individuals observed varied (Table 8.1). Flowering, leafing and fruiting patterns were observed on the 103 individuals twice per month (i.e. every 15 days) over a period of 19 months (from February 2001 to August 2002).

Table 8.1. Number of trees sampled, per land use type, for phenological observations at Kaya (southern Cameroon, 2001-2002).

Fallow type	*C. edulis*	*D. edulis*	*I. gabonensis*	*R. heudelotii*
Short-term fallows	10	10	10	10
Medium-term fallow	10	10	10	10
Long-term fallow	10	0	10	3

For each tree species, the pattern of leaf flushing, leaf falling, flowering and fruiting was recorded as the percentage of canopy in each phenophase (adapted from Law *et al.*, 2000). Estimates for each phenophase were made by categorising the canopy area of each individual in four quarters, and the following stages were distinguished:

(0) Completely absent: 0% of canopy.

(*f*) Present in less than one quarter: < 12.5% of canopy.

(0.5) Present in half of one quarter: 12.5% of canopy.

(1.0) Present in one of the four quarters of the canopy: 25% of canopy.

(1.5) Present in one of the four quarters of the canopy plus half of a second quarter: 37.5% of canopy.

(2.0) Present in two of four quarters: 50% of canopy.

(2.5) Present in two of four quarters plus half of a third quarter: 62.5% of canopy.

(3.0) Present in three of four quarters: 75% of canopy.

(3.5) Present in three of four quarters plus half of the fourth quarter: 87.5% of canopy.

(4.0) Present in all four quarters: 100% of canopy.

8.3.4.3. Fruit production

Except for *D. edulis*, the basic procedure used to estimate fruit yield was identical for all study species and adapted from Peters & Hammond (1990). Only fruiting individuals were selected for this part of the study. Based on their flowering phenology, it was anticipated that some *D. edulis* trees would produce no fruit during the ensuing fruiting season. Therefore, additional individuals were located in the farm land and subsequently included in the sample, in order to get an average number of 10 trees per land use type, when possible.

Two weeks prior to fruiting (which generally occurs for the target species between July and January: Irvine, 1961), the ground beneath the crown of each individual was cleaned of vegetation and debris. The vertical projection of the crown of each sample tree was then determined by measuring out from the trunk to the outmost branches along four radii. The main characteristics of all trees sampled for this recording are presented in Appendix 8.1. Fruit collections were conducted over two fruiting seasons (2001 and 2002), the same individuals being measured each year (when fruiting).

8.3.4.3.1. Sampling procedure for *C. edulis*, *I. gabonensis* and *R. heudelotii*

The vertical projection of the crown of each sample tree determined, four litter traps were positioned within this area under the crown, using random bearing and distances from the trunk. Each trap consisted of a 1 m x 1 m wood quadrat supported by four 1.0 m wooden stakes. Nylon net bags (perforated to prevent collection of rain water) were sewn inside each quadrat to collect any material falling from the crown.

Each trap provided a sample area of 1 m^2, thus providing an approximate sampling intensity of 5% (based on the mean crown area of one individual: Appendix 8.1). All quadrats were emptied weekly during the fruiting season. For each tree, the total number of mature fruits was recorded, and their weight determined using an electronic scale. Following Peters & Hammond (1990), total fruit production for each individual, per year, was estimated by summing the number of fruits collected and their weight during each sampling period and by extrapolating the result by the percent of the crown area sampled. Only mature intact fruits (i.e. fruits that were not rotten or dried up) were considered.

8.3.4.3.2. Sampling procedure for *D. edulis*

Weekly censuses of selected fruiting individuals were used to quantify the rates of fruit production for *D. edulis* trees. Another methodology was used for this species mainly because its fruits rarely fall when ripe (unless they are already rotten). Before the beginning of the fruiting season, 1/8 of the crown area was delimited for each individual, by a climber, using nylon ribbons. Then, at each census, all mature fruits produced within the delimited sampling area were harvested (using climbers), counted and their fresh weight determined. However, it was noticed that parrots were eating some fruits directly from the canopy.

8.3.5. Data analysis

LSD tests (at $\alpha = 0.05$) were used to compare the intensity of each phenophase among fallow types (PROC ANOVA, SAS, SAS Institute Inc., 1990). The annual flower abundance of each species was calculated by averaging the percentage of foliage in flower across the 19 months of monitoring for each species. All variables were transformed as $x = \log_{10}(x + 1)$ before analysis to normalize data distribution.

The relationship between tree size parameters (dbh and crown area) and fruit number and fruit yield was examined through regression analysis (Proc REG, SAS). Fruit number was $\log_{10}$-transformed before analysis. Each fruiting season was treated separately.

8.4. RESULTS

8.4.1. Land use and distribution of tree populations

The farmland of Kaya appeared to be mainly dominated by fallow lands of more than 7 years old (about 35% of the total area sampled, Figure 8.3) and logged-over secondary forests (24% of the total area sampled).

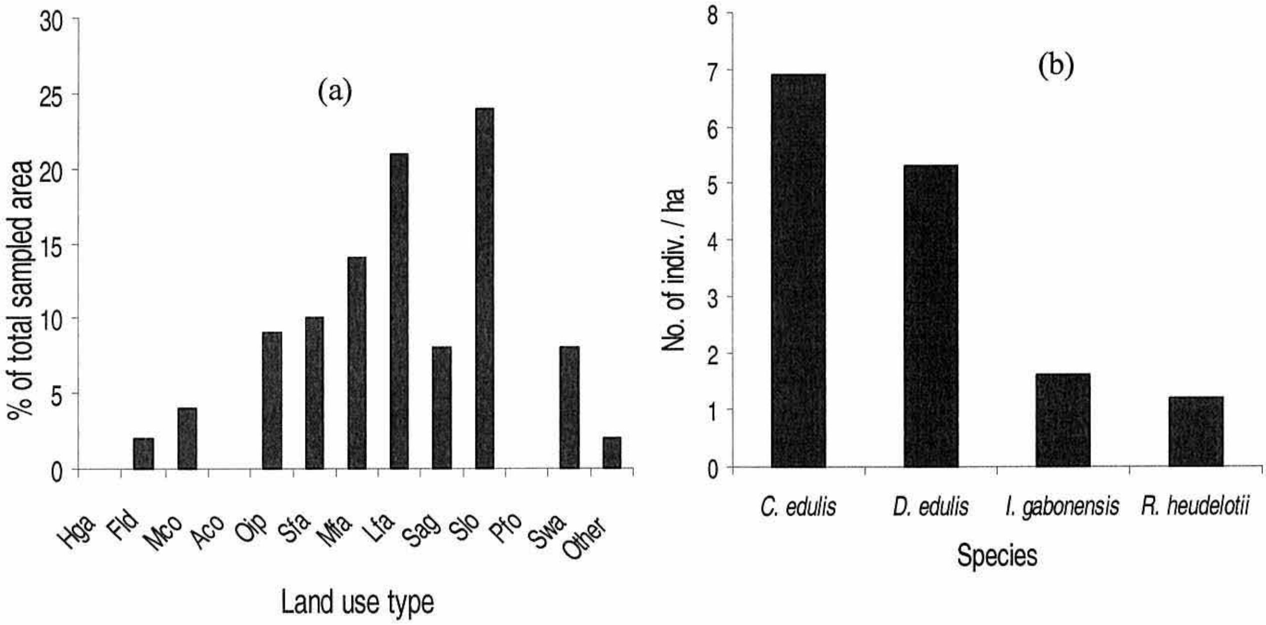


Figure 8.3. Pattern of land use (a) and tree population density (b) at Kaya (south Cameroon, 2000). Enumeration in 4.9 ha of individuals with a dbh > 10 cm. Hga, Home gardens; Fld, food crop fields; Mco, maintained cocoa plantations; Aco, abandoned cocoa plantations; Oip, oil palm plantations; Sfa, short-term fallows (< 7 years old); Mfa, medium-term fallows (7-10 years old); Lfa, long-term fallows (> 10 years old); Sag, secondary forest after agriculture; Slo, secondary forest damaged by logging; Pfo, primary forest; Swa, swamps.

Overall, 151 individuals of the four study species were inventoried throughout the four transects, with *C. edulis* and *D. edulis* being the most abundant (49 and 30 individuals, respectively. Table 8.2).

Table 8.2. Size-class distribution of individuals in *Coula edulis*, *Dacryodes edulis*, *Irvingia gabonensis* and *Ricinodendron heudelotii* natural populations at Kaya (south Cameroon, 2000). Enumeration in 4.9 ha.

DBH Class (cm)	DBH Range (cm)	*C. edulis*	*D. edulis*	*I. gabonensis*	*R. heudelotii*
1	(0-10)	15	4	2	22
15	(11-20)	10	10	3	0
25	(21-30)	0	10	1	1
35	(31-40)	4	4	2	0
45	(41-50)	7	2	0	1
55	(51-60)	3	0	1	0
65	(61-70)	3	0	0	0
75	(71-80)	1	0	0	2
85	(81-90)	1	0	0	0
95	(91-100)	5	0	1	1
105	(101-110)	0	0	0	1
Total		49	30	10	28
Total[a]		34	26	8	6
Mean height[b] **(m)**		12.3 (0.8-25.0)	9.6 (3.0-15.0)	12.3 (2.5-28.0)	6.7 (0.7-28.0)

[a] Number of trees with over 10 cm diameter at breast height on 4.9 ha.

[b] Parentheses show minimum and maximum values.

The four species differed greatly in terms of population density (i.e. number of individuals per hectare) and in terms of distribution across land use types (Figure 8.3b). *C. edulis* had the highest density with 10 individuals of dbh > 10 cm per ha, followed by *D. edulis* (with 5.3 individuals of dbh > 10 cm per ha). Except for *R. heudelotii*, all the diameter distributions of the study species are characterised by a greater number of individuals in the smaller size-classes than in the larger ones. Regression analyses revealed that the size structure of the *C. edulis* (r^2 = 0.31; P=0.073), *D. edulis* (r^2 = 0.73; P=0.001), *I. gabonensis* (r^2 = 0.50; P=0.015) and *R. heudelotii* (r^2 = 0.13; P=0.277) populations approximate a negative linear distribution, the reduction in number from one diameter class to the next being significant for all species except for *C. edulis* and *R. heudelotii* (Figure 8.4).

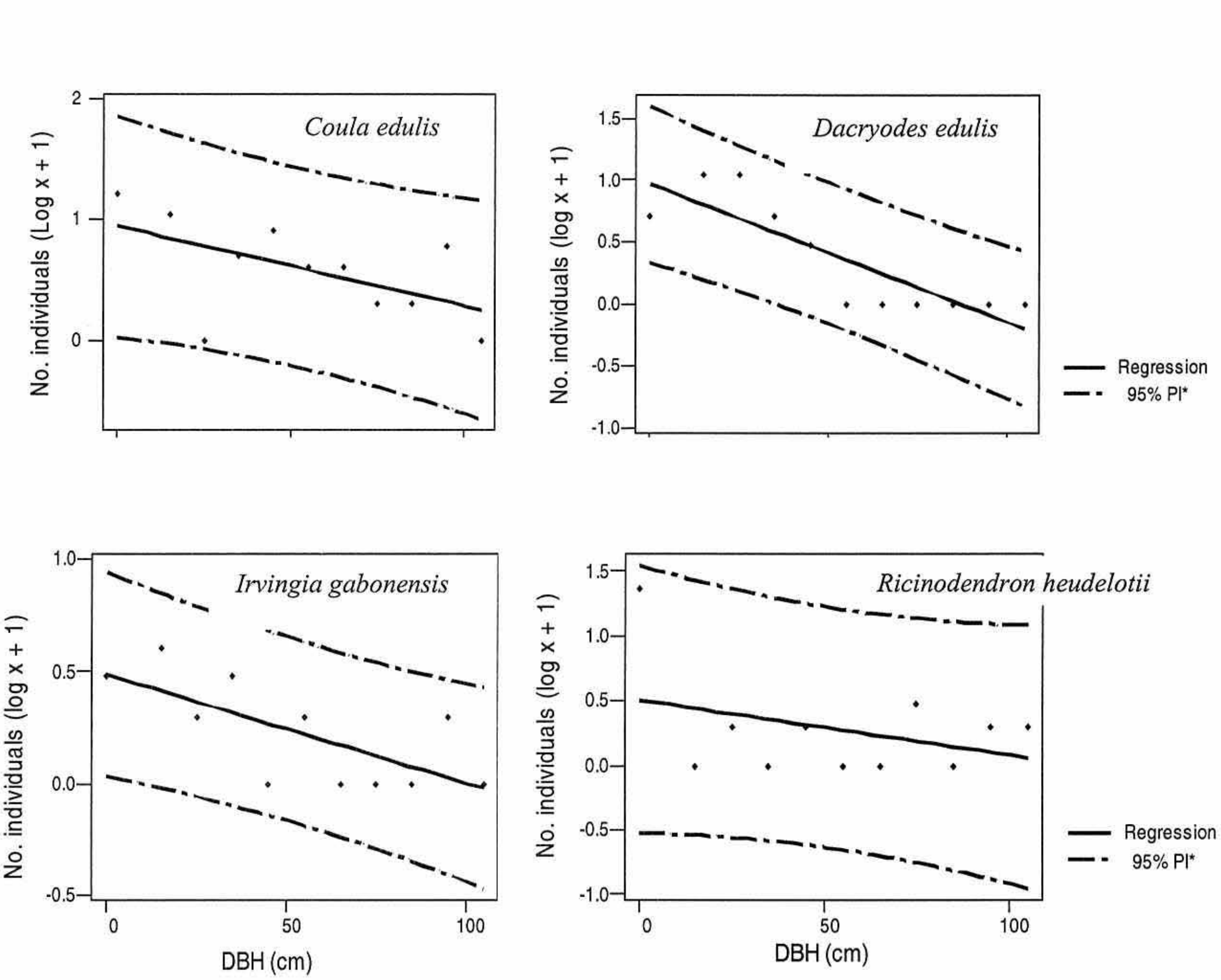


Figure 8.4. Size-class distribution of individuals in C. edulis, D. edulis, I. gabonensis and R. heudelotii natural populations at Kaya (southern Cameroon). Note $\log_{10}(x + 1)$ on y-axis. Sample area = 4.19 ha. *PI, Prediction band intervals (at 95.0 confidence level).

8.4.2. Fallow type and tree size

There was no significant difference among fallow types in terms of the height, diameter at breast height and crown area of *D. edulis* individuals (Figure 8.5). *C. edulis* trees growing in short fallows were significantly taller and larger than individuals found in fallows of more than 10 years old (LSD = 1.98, 18.54 and 0.94, respectively, $P<0.05$), but had the smallest crown area.

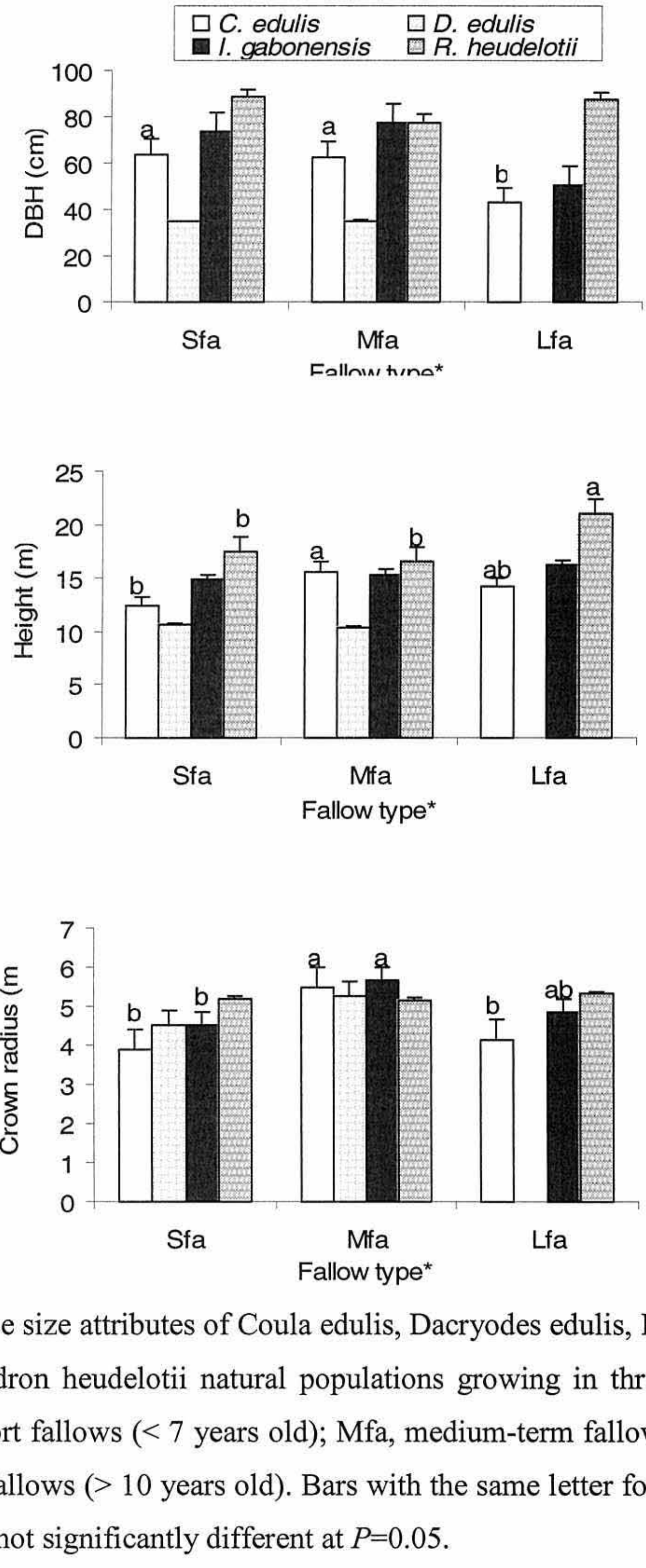


Figure 8.5. Tree size attributes of Coula edulis, Dacryodes edulis, Irvingia gabonensis and Ricinodendron heudelotii natural populations growing in three different fallow types: *Sfa, short fallows (< 7 years old); Mfa, medium-term fallows (7-10 years old) and Lfa, long fallows (> 10 years old). Bars with the same letter for a species indicate values that are not significantly different at P=0.05.

I. gabonensis trees growing in fallows of more than 7 years old had the highest height, dbh and crown area as compared to individuals found in younger fallows, but the difference was statistically significant only for the crown area (LSD = 1.08, P<0.05).

Individuals of *R. heudelotii* present in long fallows were significantly taller than individuals found in short and medium-term fallows (LSD = 3.15, $P<0.05$).

8.4.3. Tree phenological sequences

8.4.3.1. Foliar phenology

Except for *R. heudelotii*, all the study species are essentially evergreen, as they retain their leaves year-round. The peak of leaf flush (i.e. production of new leaves) occurred between February and March for all species, at the end of the major dry season (Figure 8.6a). A second peak of leaf flush for *C. edulis*, *D. edulis* and *I. gabonensis* occurred during the dry month of October and part of November, with a reduced number of *C. edulis* individuals participating. *R. heudelotii* had a peak of leaf loss (most or all leaves, depending on individuals) between November and January, during the long dry season.

8.4.3.2. Flowering

All four species exhibited a consistent seasonal pattern of flowering over the two years of monitoring. Based on the duration (length) of flowering and time of peak flowering corresponding to the season, two groups were identified. The first group consisted of *D. edulis*, *I. gabonensis* and *R. heudelotii*, which had their peak flowering in March (i.e. at the end of the major dry season but just before the short rainy period). For these three species, the flowering period lasted 2-3 months (from February to April) with brief bursts (of two weeks) for two individuals of *D. edulis* later in July and November (Figure 8.6b). *C. edulis* showed a different flowering pattern. Found in flowers for greater than six months (from February to July the first

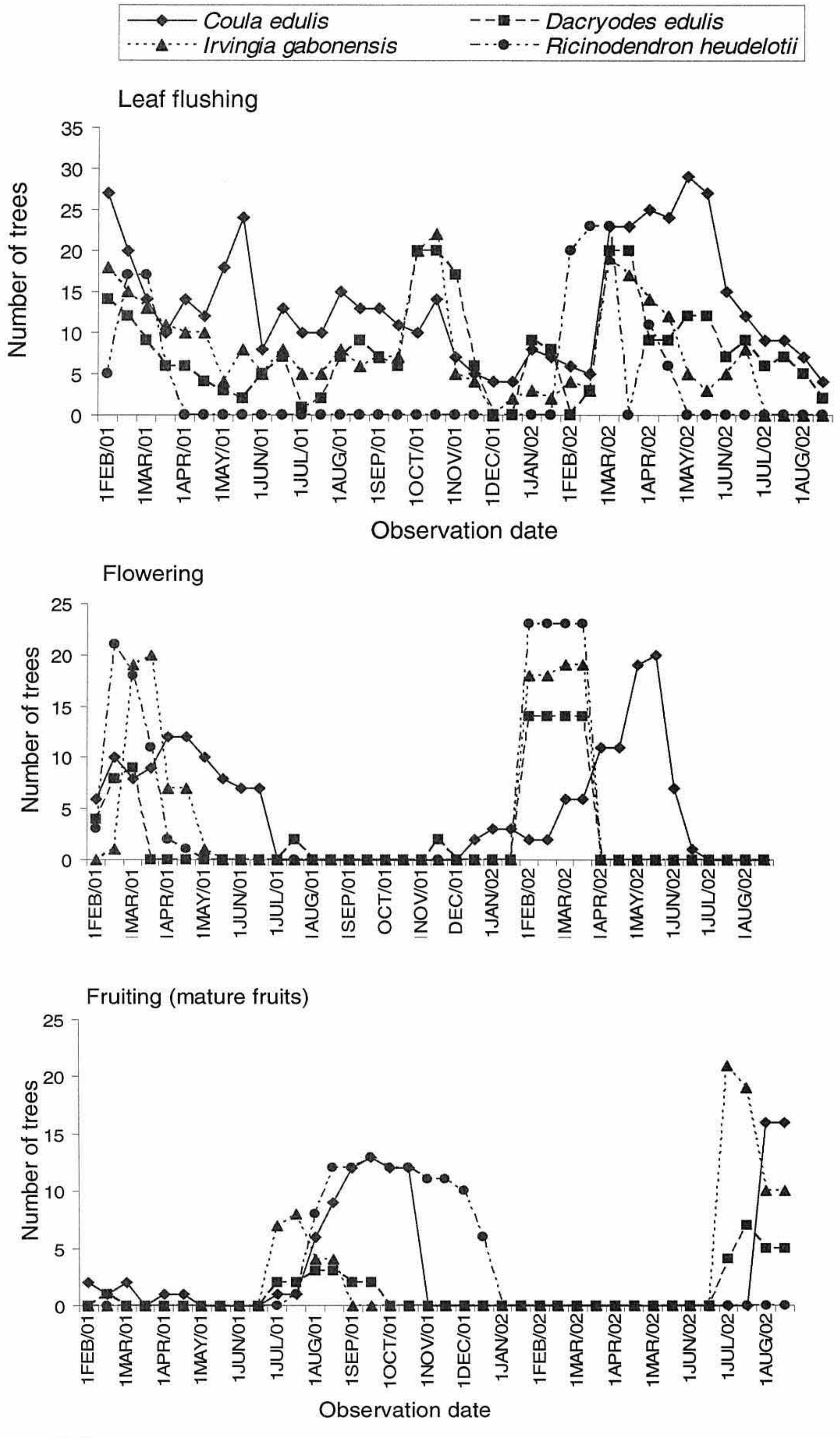


Figure 8.6. Phenology of leaf flushing, flowering and fruiting by *C. edulis*, *D. edulis*, *I. gabonensis* and *R.heudelotii* natural populations growing in fallow lands at Kaya (southern Cameroon).

year and from mid-December to July the second year), it can be described as an extended flowerer.

8.4.3.3. Fruiting phenology

Fruiting was concentrated between July and October (and up to January for *R. heudelotii*), coinciding with the rainy season (Figure 8.6c). Although a small number of *C. edulis* trees were encountered with fruits almost year-round, seasonal fruiting was the most common pattern for the study species. The peak in fruiting for *R. heudelotii* trees extended for more than four months (from August to December).

For *D. edulis* and *I. gabonensis*, the peak in fruiting occurred one month prior to the peak of the major rainy season. The time between flowering and fruiting differed: 1 to 2 months for *C. edulis* and *I. gabonensis*, and 3 to 4 months for *D. edulis* and *R. heudelotii*.

8.4.4. Fallow types and phenological patterns

There was a significant effect of the fallow type on the intensity of leaf flushing, flowering and fruiting of *C. edulis*, and on the intensity of fruiting of *I. gabonensis* trees (Table 8.3). Averaged over the 19-months period of the study, the percentage of canopy in each phenological phase (leaf flushing, flowering and fruiting) was significantly higher ($P<0.05$) for *C. edulis* trees found in short fallows as compared to individuals growing in fallows of more than 7 years old. Similarly, individuals of *I. gabonensis* growing in medium- and long-term fallows showed a poorer fruiting intensity as compared to trees found in short fallows.

Table 8.3. Intensity of leaf flushing, flowering and fruiting (measured as the percentage of canopy in each phenological phase) by four tree species growing in three fallow types (of different ages), at Kaya (south Cameroon)[a]. Minimum and maximum values are in parentheses.

Fallow type	*C. edulis*	*D. edulis*	*I. gabonensis*	*R. heudelotii*
Leaf flushing				
Short fallows	14.5 (3.5-4.0)a	9.6 (1-46)	9.4 (1-75)	24.4 (3-100)
Medium fallows	9.7 (1-50)b	9.0 (1-31)	12.1 (1-38.5)	23.3 (1-100)
Long fallows	9.4 (1-35.8)b	na	5.0 (1-25.5)	25.9 (3.3-100)
LSD ($\alpha = 0.05$)	0.18	0.21	0.23	0.29
Flowering				
Short fallows	21.7 (1-46)a	12.3 (1-33.8)	19.4 (1-33.8)	34.2 (5-72.5)
Medium fallows	6.3 (1-19.5)b	12.1 (2.5-21.3)	14.7 (1-28.8)	39.9 (13-61.3)
Long fallows	3.3 (1-9.5)b	na	10.1 (1-18.8)	42.7 (12.5-62.5)
LSD ($\alpha = 0.05$)	0.23	0.26	0.26	0.34
Fruiting				
Short fallows	10.8 (1-21.3)a	9.0 (1-33.8)	19.1 (2.5-33.8)a	20.6 (6.5-40)
Medium fallows	8.8 (1-26.3)ab	7.5 (2-21.3)	14.7 (2-33.8)ab	21.7 (2.5-34.5)
Long fallows	5.7 (1-20)b	na	9.8 (1-18.5)b	14.0 (3.3-25)
LSD ($\alpha = 0.05$)	0.24	0.24	0.29	0.26

[a]For each species, the percentage of canopy flushing, in flower and fruiting was averaged across individuals over the 19-months (38 observation dates) period.

For each phenophase and within a column, values followed by the same letter are not significantly different at $P = 0.05$. na, data not available.

8.4.5. Total fruit production

Table 8.4 presents the estimates of the total number of fruits produced per tree and their fresh weight, for each species, calculated separately for each year. In general, fruit production was higher in 2002 as compared to 2001. Except for *R. heudelotii*, for which mature fruits were collected during four months (end August to end December in 2001), the peaks in mature (ripe) fruit production for the monitored species occurred during the long rainy season each year (from July to September), with a peak around the last week of July and mid-August.

An individual tree of *C. edulis* produced, on average, nearly 236 mature fruits (9.6 kg) in 2001 and 335 fruits (11 kg) the following year. However, there was great variability among individuals of that population, with the highest fruit production of 668 fruits (31 kg) in 2001 and 1509 fruits (49 kg) in 2002 recorded from different trees each year. Of the 30 *C. edulis* trees selected for the experiment in 2001, only 14 fruited again the following year.

The mean annual production of an individual of *D. edulis* was 235 mature fruits (12.5 kg) (with a maximum production of 840 fruits and a minimum of 8) and 801 fruits (51 kg) in the 2002 year (with a minimum of 24 and a maximum of 2160). The fruiting period lasted roughly only one month (from mid-August to mid-September each year). From the nine trees that produced fruits in 2001, only six fruited again the following year, and one tree fruited in 2002 that did not produce any fruit the previous year. The fruit production was not consistent at the individual level. There was also great variability in the weight of a single fruit, reflecting inconsistency in fruit size.

Table 8.4. Annual fruit production of individual trees of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* growing in fallow lands at Kaya (south Cameroon, 2001-2002). N is the number of adult trees assessed per year. Mean ± standard error.

	C. edulis	*D. edulis*	*I. gabonensis*	*R. heudelotii*
2001	N = 15	N = 10	N = 8	N = 12
Number of fruits	236.27±48.41	235.20±93.79	547.0±211.90	2018.50±466.76
Fruit yield (kg)	9.61±2.14	12.48±5.05	71.84±24.87	72.22±16.39
2002	N = 27	N = 9	N = 22	*
Number of fruits	334.88±88.37	801.78±245.51	1886.64±424.74	*
Fruit yield (kg)	10.90±2.86	51.40±16.01	133.28±30.00	*

*Assessment undergoing.

Over the two years of the experiment, *I. gabonensis* had the highest fruit production, with about 547 mature fruits produced in 2001 (72 kg) and more than 1800 fruits in 2002 (133 kg) per tree. The minimum fruit production in 2001 was 32 fruits (9.6 kg) and 16 fruits (0.5 kg) in 2002, whereas the maximum tree production was 1550 fruits (194 kg) and 9729 fruits (659 kg) in 2001 and 2002, respectively (Table 8.4). From the 30 individuals selected in 2001 for the experiment, only eight fruited in 2001, and

14 in 2002 (from which seven had produced fruits the previous year). Similar to the pattern noticed for the other study species, there was no consistency in fruit production at the individual level, similar trees displaying different yield over the two years.

Ripe fruits from *R. heudelotii* trees were recorded from the end of August to the end of December in 2001, and fallen mature fruits were sampled from mid-September in 2002. The total fruit production per tree in 2001 was estimated at 2018 fruits (72 kg), with a minimum of 214 fruits (5 kg) and a maximum of more than 4000 fruits (176 kg). Of the 23 individuals included in the experiment, only 12 fruited in 2001. Apart from one tree which was not fruiting in 2001, the same individuals produced fruits during the two years of the experiment. Fruit production data for 2002 are not presented here as the assessment is still underway.

8.4.6. Tree size and fruit production

Relationships were established between tree parameters and fruit production using regression analysis. Significant relations were established for size parameters of *C. edulis* trees with fruit number (P=0.03) and fruit yield, and between size attributes of *I. gabonensis* trees and fruit yield (P=0.0003) in 2002 only (Table 8.5). Although the 2002 data showed higher r^2 values than the 2001, the regression equations revealed that tree size parameters generally do not explain an important part of the production data ($r^2 < 60\%$).

There was a significant relationship between tree dbh and fruit production for *D. edulis* and *R. heudelotii* in 2002 (P=0.029 and P=0.031, respectively). The data of the 2001 assessment did not show any significant relations between fruit production and tree parameters.

Table 8.5. Relationships between fruit production and tree size parameters for *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* growing in fallow lands at Kaya (south Cameroon, 2002). The total number of fruits per tree was $\log_{10}$-transformed before analysis. Only significant relationships are presented.

Independent variable	Dependent variable	Regression coefficient (r^2)	*P*-value	Linear regression equation
C. edulis				
Number of fruits	DBH	0.40	0.007	Number = 1.405 + 0.015 DBH
	Crown area	0.30	0.024	Number = 1.727 + 0.007 Crown area
	DBH + Crown area	0.49	0.025	Number = 1.405 + 0.002 Crown area + 0.012 DBH
Fruit yield	DBH	0.31	0.020	Yield = -8.984 + 0.332 DBH
	Crown area	0.59	0.0003	Yield = -9.435 + 0.235 Crown area
	DBH + Crown area	0.59	0.002	Yield = -8.954 + 0.242 Crown area + 0.018 DBH
D. edulis				
Number of fruits	DBH	0.52	0.029	Number = 4.463 – 0.045 DBH
I. gabonensis				
Number of fruits	Crown area	0.22	0.028	Number = 2.384 + 0.005 Crown area
Fruit yield	Crown area	0.56	<0.0001	Yield = -79.913 + 1.807 Crown area
	DBH + Crown area	0.57	0.0003	Yield = -51.809 + 1.917 Crown area – 0.552 DBH
R. heudelotii				
Number of fruits	DBH	0.39	0.031	Number = 2.324 + 0.009 DBH

8.5. DISCUSSION

The data collected in this study represent the first available estimates of total fruit production for *C. edulis*, *I. gabonensis* and *R. heudelotii* in the humid forest zone of southern Cameroon, in particular for individuals growing in fallow lands. The little information related to the reproductive biology of these species in the area was collected from the forest (Bibani Mbarga *et al.*, 1998), and from *C. edulis* plantations established by IRAD (Kengue, 1990). Therefore, in the absence of comparative studies in the same area, it is difficult to assess the accuracy of the findings of this study.

Except for *R. heudelotii*, no leafless state was observed on any individual of the study species. Trees showed an indistinguishable transition from old to new foliage. New leaves were observed throughout the year, but at a lower intensity during the dry season of December to February. This pattern has been reported for many wet forest species (e.g. Bibani Mbarga *et al.*, 1998; Funch *et al.*, 2002), where there is little annual variation in solar radiation or mean temperature. The peak of leaf loss observed for *R. heudelotii* in January, at the peak of the dry season, is consistent with findings of Bibani Mbarga *et al.* (1998) in the rain forest of Ebom (south Cameroon). Although a clear linkage between leaf fall and rainfall patterns has not been clearly established, previous studies on the foliar phenology of humid forest species have shown that the peak of leaf flush often occurred in synchrony with the beginning of the rainy season (Funch *et al.*, 2002), which is March-April in this study area.

Except for *D. edulis* which flowered in May-June, all the study species concentrated flowering near the start of the rainy season (February-March), followed two months later by fruit production. This pattern is similar to that of various studies on mesophilic semi-deciduous and deciduous forest trees, for which seedfall were shown to coincide with the onset of the rainy season (Peters & Hammond, 1990; van Schaik *et al.*, 1993).

Fruit production rates varied from one year to another. This situation has already been reported by Peters & Hammond (1990) when assessing the productivity of three forest species in the Peruvian Amazonia. The magnitude of such variation is likely to be better determined through long-term studies. At the individual tree level, there was great variability in fruiting and fruit production in all species, probably due to variation in many bio-physical factors such as climate, pollinator abundance, and proximity of competitors (Peters & Hammond, 1990).

In terms of fruit production, based on the few work conducted in similar environments, *D. edulis* individuals assessed in 2002 compared favourably with individuals from IRAD plantations, with a maximum yield of 52 kg per tree (156 kg in 2002), as compared to the reported maximum value of 32 kg (Tchio & Kengue, unpublished). However, these authors noticed that male-hermaphrodite trees of *D.*

edulis had lowest production when compared to female trees, as most flowers of the male-hermaphrodite trees are male.

The significant allometric relationships found between fruit production and tree size parameters for all study species do not explain completely the variability in fruit productivity among individuals. Similarly, Peters & Hammon (1990) found that an increase in diameter can result in an increase in the number of fruits produced by some tree species growing in the Peruvian Amazonia. However, Law *et al.* (2000), assessing the flowering intensity of some Myrtaceous trees in Australia, found no significant difference between small-size and large-size individuals.

The results of this study provide evidence that natural populations of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* are present in fallow lands (of various age), but at very low density (≤ 10 individuals ha^{-1}), and with few large trees. This situation is likely to be a result of repeated farming activities, which could have modified environmental conditions (light, water and nutrient supply, pests and diseases attacks). However, given the relatively small area sampled for this study, this conclusion should be treated with caution. A more rigorous experimental approach, using fallow lands of different ages and types, is required to formally test the effect of land use intensification on the abundance and distribution of these resources.

The effects of shortening fallow duration on the phenology of the study species are likely to be complex. Although the results of this experiment are limited by the study not being designed to test for the effect of environmental conditions, previous studies conducted on other humid forest trees indicated a correlation between fruit production and previous rainfall (White, 1994), but no correlations were detected between fruit availability or flowering intensity and climatic parameters (White, 1994; Law *et al.*, 2000). These findings suggested that local site conditions are not a strong determinant of the inert-site variation in flowering and fruiting performance of the study species. Over the two years of monitoring, the percentage of canopy in flower or fruit was generally greater in individuals growing in shortened fallows as compared to long fallow trees, possibly because of better bio-physical conditions (Devineau, 1999).
Because phenology data must be collected over long periods, some findings from this 19-month data set may not be warranted. Nevertheless, data collected in this study

provide a general idea of the productivity potential of these important forest resources. Detailed studies of the market prices coupled with the yield data from this study can be used to estimate the economic value of fruits produced by natural populations in fallow lands, and in shortened fallows in particular. Ndoye (1995) has already established that the economics of exploiting natural populations of these species in southern Cameroon is favourable. Therefore, there is an urgent need to develop options and management strategies that will integrate these key productive species in shortened fallow systems, with the objective to propose an alternative to deforestation while securing sustainable livelihoods for resource-poor farmers in the area.

CHAPTER IX

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

9.1. INTRODUCTION

The present study was initiated as a participatory field research and carried out with local farmers to characterize the traditional fallow system throughout the humid forest zone of southern Cameroon, and to determine the mechanisms through which plant diversity and productivity components are affected in some shortened fallow systems. Many studies of slash-and-burn agriculture in the humid tropics have shown that shortening fallow duration often results in biodiversity losses, negative changes in soil properties leading to increased weed infestation and reduced crop yield (e.g. Nye & Greenland, 1960; Ruthenberg, 1980; de Rouw, 1995). That theoretical assumption has been adopted by many scientists, and had led to some resentment by governments towards short fallow-based farming practices (Mertz, 2002). However, very little research has been conducted to provide detailed scientific foundation to this theory, and empirical data to support it are rather limited, particularly concerning the wet lowlands of southern Cameroon.

Many studies have taken the relationship between shortened fallow and ecosystem diversity and productivity for "granted" and have applied it to their analysis without seeking solid evidence of its validity (Mertz, 2002). This is particularly the case of various studies conducted on the impact of shortening fallow systems in the humid zones of tropical Africa. Although the studies by Roder *et al.* (1995) found no correlation between fallow duration and crop yield, various authors (e. g. Mishra & Ramakrishnan, 1981; Tony & Ramakrishnan, 1981; de Rouw, 1995; Juo & Manu, 1996; Szott *et al.*, 1999) have provided indications of a positive relationship. However, as emphasized by Mertz (2002), because most of the reported studies did not address bio-physical factors other than the fallow length that may influence ecosystem productivity, general conclusions were impossible to draw in the study cases. Moreover, based on these studies, it was not possible to deduct whether a threshold or lower limit for effective fallow length exist.

Yet some studies provided evidence of a positive correlation between shortened fallow and ecosystem productivity. For instance, in northeast India, Mishra and Ramakrishnan (1981) reported increased maize, pumpkin (*Cucurbita maxima* Wall.) and cabbage (*Brassica oleracea* L.) yields with decreasing fallow duration. Similarly, when studying a system with short *C. odorata*-dominated fallows in Côte d'Ivoire, Slaats *et al.* (1998) found that the overall crop yield and labour productivity was not different between two years and a four year fallow systems.

However, studies on the relationship between shortened fallow and ecosystem productivity have rarely addressed the impact of previous land use history. Moreover, despite frequent reference to invasive fallow species in the wet forest zone of Africa, few studies have provided quantitative data on the impact of *C. odorata* invasion on the ecosystem species diversity, both during fallow and during subsequent crop growth.

9.2. INDIGENOUS CHARACTERISTIZATION OF NATURAL FALLOWS

Using fallow length as the main criterion, farmers of the study area broadly distinguished three fallow classes which have specific targeted agricultural uses. Contrary to what has been reported by Gockowski *et al.* (1998b), there was no difference in the distribution and abundance of long fallows between Mbalmayo and Ebolowa areas. Short fallows were the most abundant throughout the study zone (34-55% of overall fallow farmland), whereas long fallows occupied only 2-23%. This result, consistent with findings of previous studies in the area (e.g. Gockowski *et al.*, 1998b), provides evidence that an appropriate land use management in the region should recognize and integrate farmers' typology of fallows in order to enhance the trust-building process between local communities and researchers or land managers.

Confirming findings of Gockowski *et al.* (1998a) and Weise (1995) among others, and substantiating results of studies conducted in other tropical regions (e.g. de Rouw, 1995; Roder *et al.*, 1997; Mertz, 2002), it was shown that local farmers in the study area view weeds as the most limiting factor for sustainable crop production in all fallow classes, followed by labour burden associated with the clearing of fallows of more than 6 years old. Therefore, management strategies seeking to improve the productivity of natural fallows in the area must be designed to address those issues for a better adoption by local populations.

9.3. NTFPs IN FALLOW: FARMERS' PRIORITIZATION

More than 100 useful species were recorded as collected by local populations in fallows of various ages, with young fallows being particularly valued for herbaceous medicinal species and older fallows for useful timber or fruit trees. This finding once more illustrates the exceptional ethnobotanical knowledge of farmers in the humid forest zone of southern Cameroon, contrasting, for example, with the relative lack of awareness of farmers from the Mount Cameroon area, as reported by Nouhou Ndam (1998). Given this surprising high number of NTFPs valued in natural fallows by local farmers and following Brocklesby & Ambrose-Oji (1997) and van Dijk (1999), it could be anticipated that management strategies associated with improved agroforestry technologies and promotion of volunteer species will benefit from the existing good local practice of selective clearing and weeding.

Farmers in the study area identified some priority high-value species that could be used in improved agroforestry practices, among which are the fruit trees *Baillonella toxisperma*, *Cola acuminata*, *Coula edulis*, *Dacryodes edulis*, *Garcinia kola*, *Irvingia gabonensis* and *Ricinodendron heudelotii*. This finding is consistent with those of previous screening conducted in the study area in order to identify priority species for genetic improvement and domestication studies (Leakey & Jaenicke, 1995; Mollet *et al.*, 1995; Ladipo *et al.*, 1996; Atangana *et al.*, 2002). The identification of farmers' preferred products and species represents an important step towards the implementation of multipurpose tree systems in the area (Franzel *et al.*, 1996). For this technology to be successful in the humid forest zone of southern Cameroon, an integrated land use policy that combines increases in productivity and income generation, together with environmental benefits must be developed in keeping with the particular needs of the local communities.

9.4. IMPACTS OF SHORT FALLOW TYPES ON PLANT DIVERSITY

Among the issues for conservation management programmes of shortened fallow lands is the preservation of biodiversity, given the low species diversity observed in these habitats (Gillison, 2000). About 187 species per hectare were recorded in this study, contrasting with the 50 and 82-100 species per hectare counted in young fallows and secondary forests, respectively, of the Bipindi-Akom II region (south Cameroon) by van Dijk (1999). Short fallows dominated by *Chromolaena odorata* had the lowest number of species per unit area compared to fallow lands that had been through only one cropping cycle since forest clearance. This finding is consistent with results of previous biodiversity assessment studies conducted in the area by Gillison (2000) and Zapfack *et al.* (2000). Moreover, another negative contribution of short fallows dominated by *C. odorata* to biodiversity reported in this study was the reduced forest species:weedy plants ratio recorded in frequently farmed short fallows as compared to bush fallows not dominated by *C. odorata*. These observations may indicate that high cropping frequency impacts the species composition in short fallow systems, by altering the proportion of shade-bearer and light-demanding species within the community, thus reducing the number of species per unit area. However, based on the results of this study, it is not possible to draw conclusions at the long-term impact of intensively cropped short fallows dominated by *C. odorata* on biodiversity both at the local and regional levels.

Ordination analyses of fallow data revealed that species associated with intensively managed short fallow types were mostly weedy plants and were frequently found in relatively litter-rich sites where canopy crown cover of woody plants was high, but tree basal area and canopy height were lower. This observation is consistent with the hypothesis proposed by de Rouw (1995) and others that the success of a fallow as weed-break depends on the rapid development of overhead shade which can prevent the germination of a second generation of weeds.

This finding may explain the lower weed species richness observed in fields established after recurrent *C. odorata*-dominated short fallows as compared to fields after bush fallows. It was also shown that the abundance of *C. odorata* in the weed flora during crop growth resulted in a decline in the number of grasses and sedges in the weed flora of fields established after clearing frequently farmed *C. odorata*-dominated fallows. These findings agree with those of Slaats *et al.* (1998), and may indicate that, in spite of its reputation as a problem weed, *C. odorata* may be used to out-compete some more harmful weeds such as grasses. However, frequently farmed *C. odorata*-dominated short fallows were also characterized by an increased number of problem weeds such as *Sida rhombifolia* and *Stachytarpheta cayennensis*, grasses and sedges, which represent a serious worrying trend for resource-poor farmers of the study area (Weise & Tchamou, 1999). These species appeared to be better adapted to growing in sandy sites with high soil acidity and Mg concentrations. However, the weak correlation between the soil parameters measured in this study and the abundance of weed species across the three short fallow types suggests the intervention of other bio-physical factors in the relationship fallow-weed composition.

9.5. IMPACTS OF SHORT FALLOW TYPES ON CROP YIELD

The pattern of the responses of maize, groundnut and cassava to the three short fallow types did not differ over the two years of the study, all crops producing higher yield in fields established after clearing *C. odorata*-dominated fallows than in fields following bush fallows. Moreover, the values of crop yields recorded in this study approximated yields recorded in crop fields established after fallows of longer duration or after fallows planted with some leguminous species. These findings were not expected, as it was hypothesised that shortening fallow duration and high densities of *C. odorata* in the weed flora during crop growth lead to reduced yields (Nye & Greenland, 1960; de Rouw, 1995; Zimdahl, 1999).

However, improvement of crop yield after *C. odorata*-dominated short fallows has already been reported by Slaats *et al.* (1998) in Côte d'Ivoire, and suggested by de Foresta (1991) and Obatolu & Agboola (1993). According to Szott *et al.* (1999), increased crop yields following short-duration fallows should be often attributed to greater amounts of plant-available N in soil. However, it was observed that soil under fields established after frequently farmed *C. odorata*-dominated fallows had the lowest values of total N, total C and K concentrations, suggesting lower soil fertility as compared to short fallows following one cropping cycle since forest clearance. Nevertheless, based on the strong correlation observed in this study between *C.*

odorata and soil nitrogen and total carbon content, it can be suggested a positive relationship between the abundance of *C. odorata* in frequently disturbed short fallows and soil fertility. Nevertheless, as already stated by Mertz (2002), no definite conclusions can be reached without taking into account the various other bio-physical factors that can affect the relationship fallow length-yield, and special care must be taken when developing models to predict that relationship.

9.6. GENERAL CONCLUSIONS

Key conclusions emerging from this present research in relation to the impact of short fallows on ecosystem biodiversity and productivity show that:

- Fallows of less than 10 years old are an important component of the natural landscape in the humid forest zone of southern Cameroon.

- Despite the shortening of their duration, fallow lands continue to be a major source of NTFPs which farmers collect for many purposes, among which indigenous fruit trees *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* were recognized as priority high-value species by local communities.

- Based on their impact on plant diversity, both during fallow and during crop growth, frequently farmed *C. odorata*-dominated short fallows must be distinguished from bush fallows of the same duration.

- Although frequently cropped short fallow systems showed a lower forest species:weedy plants ratio, they had a more positive relationship with maize, groundnut and cassava yields during the subsequent cropping phase as compared to bush fallow systems.

- Frequently farmed *C. odorata*-dominated short fallows were also characterized by higher litter and crown cover, but lower tree basal area and canopy height compared to bush fallows that had been a forest in the preceding cropping cycle.

- The three short fallow study types also differed in terms of plant community composition during both the fallow and the subsequent cultivation phases. Short fallows dominated by *C. odorata* were dominated by heliophytic weedy species during fallow, and had more problem weeds (e.g. *C. odorata*, *S. cayennensis*, *S. rhombifolia*, grasses and sedges) during crop growth, as opposed to bush fallows, which were characterized by more shade-tolerant forest species during both the fallow and the cropping periods.

- Difference in soil properties among the three short fallow types compared in this study explained only up to 30% of the variation in the species data, thus suggesting the need for more analysis of the relationship between fallow type-ecosystem productivity and biodiversity.

- *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* were recorded at very low density values in fallow lands of the study area, suggesting that management strategies to promote the integration of these key productive fruit trees should include domestication practices or preferential management of regeneration.

- Apart from leaf flushing, flowering and fruiting phenology of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* are seasonal, with irregular flowering/fruiting observed for some *D. edulis* and *I. gabonensis* individuals over the two years of monitoring.

- The study gives some preliminary estimates of the annual fruit production of these selected species per year and allometric relations have been established between tree size parameters (dbh and crown area in particular) and fruit yield. These relations can be used in future research to help predict annual fruit production of individuals in natural populations.

- This study demonstrates that the relationship between length of fallow and ecosystem productivity and biodiversity is more complicated than the literature on slas-and-burn agriculture generally suggests, with a particular emphasis on the presumed declined in soil fertility commonly associated with reduced fallow duration.

- Moreover, from the relatively little effect of soil parameters measured in this study on the weed flora and crop production after short fallows, it is clear that other factors are important in the relation fallow length-ecosystem productivity, most notably a combined effect of soil, water and light.

- This study also demonstrates that a major constraint in managing short fallow systems in southern Cameroon is the cost of weeding. Therefore, to maximize agricultural production, given that constraint, and when land pressure is relatively low, resource-poor farmers of the area have the only option to shift and clear new fields, thus adding more pressure on forests.

9.7. SPECIFIC RECOMMENDATIONS

Despite advances produced by the present research, some aspects merit further investigation in order to get a fuller understanding of the mechanisms involved in the relationship between short fallows and ecosystem productivity.

- To encourage the establishment or maintenance of more forest species on short fallow lands, farmers could be encouraged to selectively leave more forest trees in farm sites during land clearing activities, in order to rehabilitate degraded short fallow lands. Additionally, the maintenance of forest trees during the cropping phase should also be encouraged or introduced, along with management techniques (such as pruning) that will increase soil nutrient status, weed control while providing off-farm revenue to farmers.

- Land management policies that encourage collaboration with better-organized local communities should be promoted before committing capital or energy to develop alternative strategies to short fallow systems.

- An analysis of the relationship between fallow duration and ecosystem productivity needs to be continued and extended, both in time and space, in order to include various combinations of fallow types present in the study area and other ecosystem parameters that can influence that relationship.

- Phenology monitoring of *C. edulis*, *D. edulis*, *I. gabonensis* and *R. heudelotii* needs to be widened both in time and space in order to confirm the consistency of the patterns observed in the present study. Such studies should be based on designed methodologies that will enable more accurate determination of ecological behaviour of these target species.

- Bio-physical parameters should also be monitored in order to assess their impact on the biology and ecology of the study species. This would help identify factors causing the variation in changing abundance and distribution of these species, and spot 'best' niches for their survival.

- Comparisons of population distribution and abundance of key productive NTFPs across the land use mosaic should be undertaken in order to assess the effects of changing land use mosaics on the characteristics of the study species in terms of genetic diversity, productivity, income and social value.

- The development of improved agroforestry practices suitable for increasing the survival and productivity of these species while preserving the dynamics of the land use mosaics in the area should be encouraged.

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APPENDIX 3.1

Characteristics of the 16 study villages.

No.	Province	Division	Sub-division	**Village Name**	Resource domain*	Distance from Yaoundé (km)	Pop.
1	South Province	Vallée du Ntem	Ambam	**Minsélé (or Esseng)**	EBOL	265	82
2	South Province	Vallée du Ntem	Ambam	**Mekoe**	EBOL	245	87
3	South Province	Vallée du Ntem	Ambam	**Mengomo**	EBOL	215	303
4	South Province	Mvila	Ebolowa	**Akok**	EBOL	202	176
5	South province	Mvila	Ngoulema-kong	**Obang II**	EBOL	110	335
6	Centre Province	Mefou & Afamba	Soa	**Nkolfoulou II**	YAOU	17	158
7	Centre Province	Lékié	Okola	**Etoud**	YAOU	18	302
8	Centre Province	Lékié	Sa'a	**Nkolmelok**	YAOU	65	736
9	Centre Province	Lékié	Monatélé	**Nkong-messe**	YAOU	93	n/a
10	Centre Province	Mefou & Afamba	Mfou	**Nkometou III**	YAOU	22	n/a
11	South Province	Dja & Lobo	Zoétélé	**Mvoutessi**	MBAL	123	369
12	Centre Province	Nyong & So'o	Awae	**Ngat-Bane**	MBAL	68	141
13	Centre Province	Mefou & Afamba	Awae	**Awae II**	MBAL	50	267
14	Centre Province	Nyong & So'o	Mbalmayo	**Nkolmetet**	MBAL	105	837
15	Centre Province	Mefou-Akono	Bikok	**Evindissi**	MBAL	80	876
16	Centre Province	Nyong & Kelle	Makak	**Kaya**	MBAL	60	602

*EBOL, Ebolowa; YAOU, Yaoundé and MBAL, Mbalmayo domains.

APPENDIX 4.1

QUESTIONNAIRE FORM FOR CHARACTERIZATION OF FALLOW SYSTEMS IN THE FMBA: Date ....Village ....

Enquêteur (s): ....

Nombre de personnes présentes: .... Femmes: .... Hommes: ....

Heure début: ....Heure fin: ....

Types de Jachères (FT):

FT1. Quels types de jachères sont présents dans votre village (nom en langue locale)? Et quel âge ont, respectivement, ces jachères (en années)?

FT1.1... Age: ....

FT1.2... Age: ....

FT1.3... Age: ....

FT1.4... Age: ....

FT1.5... Age: ....

FT2. Répartissez ces différents types entre 20 jachères prises dans le village. (Assimilez ces jachères à des billes, puis procédez à la répartition).

Type de jachère	Proportion/20
FT1.1	....
FT1.2	....
FT1.3	....
FT1.4	....
FT1.5	....

Végétation des jachères (FV)

FV1. D'une manière générale, quelle est la végétation dominante de ces jachères?

(Utilisez les codes: 1='Nkodengui' ou 'Dongmo'; 2=Brousse; 3=Jeune forêt; 4=Forêt mature; 5=Autre, à préciser).

	Type de jachère	Végétation dominante*
FT1.1		....1 ....2 ....3 ....4 5
FT1.2		....1 ....2 ....3 ....4 5
FT1.3		....1 ....2 ....3 ....4 5
FT1.4		....1 ....2 ....3 ....4 5
FT1.5		....1 ....2 ....3 ....4 5

*Mettre une croix devant le choix correspondent.

FV2. Quelles sont les principales plantes utiles (pour vous) présentes dans la flore de chaque type de jachère?

FV2.1. Liste des plantes utiles présentes dans le type FT1.1? Sur cette liste, classes par ordre d'importance décroissante, les 10 plantes les plus utilisées par vous (metre les rangs, 1, 2, etc, devant les plantes concernées).

Pour chacune des 10 plantes ci-dessus énumérées, répondez aux questions suivantes:

- FV2.1.1. Quelle est la fréquence de présence de la plante dans chaque type de jachère présent dans le village?
- FV2.1.2. Quelle est la fréquence d'utilisation de cette plante dans le village?
- FV2.1.3. Quelle est (ou quelles sont) la (ou les) partie(s) de la plante utilisée(s)?
- FV2.1.4. Quelles sont les utilisations principales de la plante?

Nom local	Nom scientifique	Fréquence de présence dans les jachères de ce type (1=dans quelques jachères; 2=dans la moitié des jachères; 3=dans la plupart)	Fréquence d'utilisation (1=rarement; 2=detemps-en-temps; 3=fréquemment)	Parties de la plante utilisée (1=feuilles; 2=tige; 3=écorce de l'arbre; 4=racines; 5=sève; 6=fruit ou graine; 7=fleurs ou inflorescences; 8=autre)	Utilisations (1=combustible; 2=alimentation ou boisson; 3=artisanat; 4=emballage; 5=papier hygiénique; 6=construction; 7=outillage; 8=médicine traditionelle; 9=autre)	Commentaires
	.....	.....		.....	.....	
	.....	.....		.....	.....	
	......	.....		.....	.....	

FV2.2. à FV2.5: Répétez FV2.1 pour chaque type de jachère.

Gestion des jachères (FM)

FM1. Quesl sont les usages agricoles les plus courants pour chaque type de jachère défini en FT1?

Donnez, pour chaque type de jachère, la proportion sur 20 jachères, de parcelles réservées à ces usages.

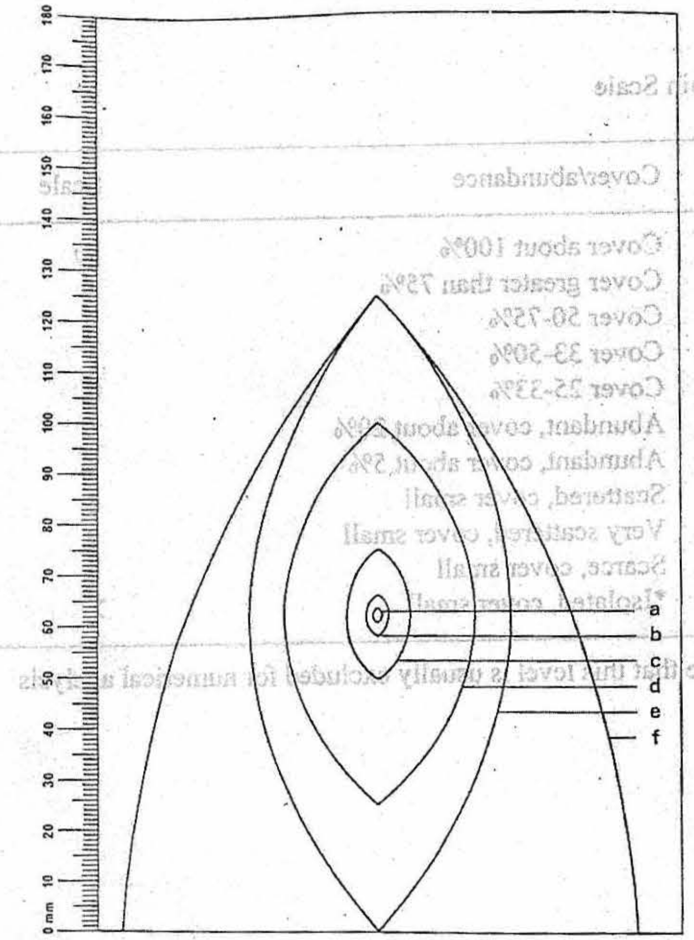
Type de jachère	Cultures vivrières	Cultures pérennes	Autres (Préciser)
FT1.1			
FT1.2			
FT1.3			
FT1.4			
FT1.5			

Contraintes liées à la gestion des jachères (FC)

FC1. Quelles sont les 3 principales contraintes agricoles liées à la gestion de chaque type de jachère? Classez-les par ordre d' importance décroissante (1=3ème contrainte; 2=2ème contrainte; 1=1ère contrainte).

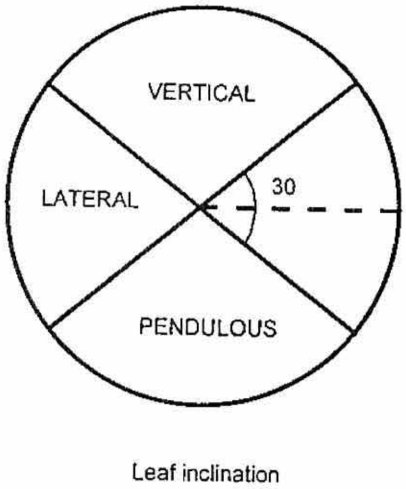
Type de jachère	Difficile à défricher	Difficile à brûler	Adventices nombreuses	Rongeurs nombreux	Ravageurs et maladies	Fourmis abondantes	Fertilité faible	Autre (Préciser)
FT1.1								
FT1.2								
FT1.3								
FT1.4								
FT1.5								

APPENDIX 6.1

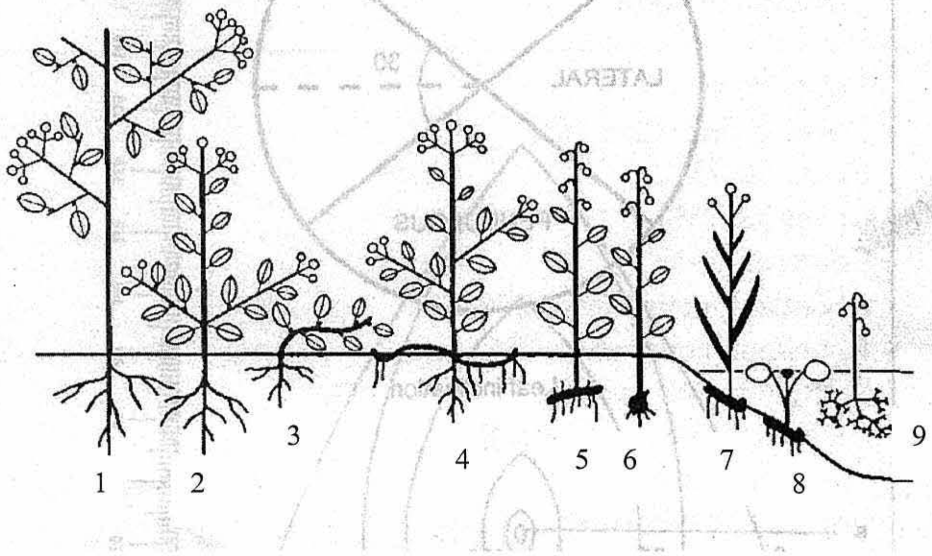


Leaf size class	Approximate length of lanceolate leaf (mm)	Approximate area (mm^2)
<a = picophyll	<2	<2
<b = leptophyll	2 - 8	2 - 25
<c = nanophyll	8 - 25	25 - 225
<d = microphyll	25 - 75	225 - 2025
<e = notophyll	75 - 125	2025 - 4500
<f = mesophyll	125 - 250	4500 - 18 200
f to 2xf = platyphyll	250 - 360	18 200 - 36 400
2f to 8x rectangle = macrophyll	360 - 830	36 400 - 18×10^4
>8x rectangle = megaphyll	>830	>18×10^4

Appendix 6.1.1. Range of leaf size classes from template (From Gillison, 1988).



Appendix 6.1.2. Leaf inclination classes from template (From Gillison, 1988).



Appendix 6.1.3. Life form classes: (1) Phanerophytes, (2-3) Chamaephytes, (4) Hemi-cryptophytes and (5-9) Cryptophytes. (From Gillison, 1988)

APPENDIX 6.2

Species identified in three shortened fallow types of the humid forest zone of southern Cameroon.

One species unidentified at the family level have been omitted

	Co-Co‡	Co-Fo	Bu-Fo
ACANTHACEAE			
*Asystasia gangetica**T. Anders.	x	x	
*Asystasia macrophylla**Benth.ex Lindau			x
Asystasia sp	x	x	x
Clesotopholis patens Engl. & Diels		x	x
Whitfieldia sp		x	
ADIANTACEAE			
Adiantum sp		x	x
AMARANTHACEAE			
Celosia trigyna L.		x	
Celosia sp	x		x
*Cyathula prostrata** Blume	x		
ANACARDIACEAE			
Antrocaryon kamerunensis		x	
*Trichoscypha arborea**A. Chev.	x		
ANNONACEAE			
Artabotrys sp			x
Meiocarpidium lepidotum Engl. & Diels		x	x
Polyalthia suaveolens Engl. & Diels		x	
Xylopia abyssinica		x	
Xylopia parviflora A. Chev.		x	
Xylopia sp	x	x	x
ANNONACEAE			
Polyalthia suaveolens Engl. & Diels		x	
APOCYNACEAE			
Alstonia boonei De Wild.	x	x	x
Baissea calophylla Stapf	x		
Baissea sp	x	x	x
Funtumia africana Stapf	x	x	x
Funtumia elastica Stapf	x	x	x
Landolphia sp		x	x
Rauwolfia macrocarpa Standl.		x	x
Rauwolfia vomitoria Afz.	x	x	
Strophanthus sp*	x	x	x
Tabernaemontana crassa Benth.	x	x	x
Tabernaemontana penduliflora K. Schum.			x
ARACEAE			
Anchomanes difformis Engl.	x	x	x
Cercestis sp**			x
Culcasia sp		x	x
Raphidophora africana N. E. Br.		x	
Rhektophyllum mirabile N. E. Br.	x	x	x
Rhektophyllum sp			x

	Co-Co[‡]	Co-Fo	Bu-Fo
*Stylochiton zenkeri***Engl.	x	x	x
*Xanthosoma sagittifolium***(L.) Schott	x	x	x
ASCLEPIADACEAE			
Asclepia sp**	x	x	x
ASTERACEAE			
*Ageratum conyzoides***L.	x		
Chromolaena odorata (L.) R.M. King & H. Rob.	x	x	x
Elephantopus mollis H. B. & K.	x		
*Mikania cordata***B. L. Rob.	x		
Vernonia amygdalina Delile	x		
Vernonia conferta Benth.	x	x	x
BEGONIACEAE			
Begonia sp		x	x
BIGNONIACEAE			
Markhamia lutea K. Schum.	x	x	x
Markhamia tomentosa K. Schum. Ex Engl.	x		
Fernandoa adolfi-fridericii (Gilg & Mildbr.) Heine		x	
Spathodea campanulata Beauv.		x	
BOMBACACEAE			
Ceiba pentandra Gaertn.	x	x	x
Ceiba sp	x		
BROMELIACEAE			
Renealmia africana Benth.			x
Renealmia sp	x	x	x
BURSERACEAE			
*Dacryodes edulis** H. J. Lam		x	
COMBRETACEAE			
Combretum hirsuta		x	
Combretum hispidum Laws.	x	x	x
Combretum puberum Rich.		x	
Combretun racemosum P. Beauv.	x	x	
Combretum sp	x	x	x
*Terminalia superba**Engl. & Diels	x	x	x
COMMELINACEAE			
Aneilema beninense Kunth	x	x	x
Aneilema sp		x	x
Commelina benghalensis Wall.	x		
Commelina diffusa Burm.f.	x		
Commelina sp	x	x	
Floscopa sp**	*		
Palisota ambigua C. B. Clarke	x	x	x
Palisota hirsuta K. Schum. ex C. B. Clarke	x	x	x
Palisota mannii C. B. Clarke		x	x
Palisota sp	x	x	x
CONNARACEAE			
Agelaea sp	x	x	x
Cnestis ferruginea DC.	x	x	x

	Co-Co‡	Co-Fo	Bu-Fo
CONVOLVULACEAE			
Ipomoea batatas (L.) Lam.	x		
Ipomoea involucrate Beauv.	x	x	
Ipomoea mauritiana Jacq.	x		x
Ipomoea sp	x	x	x
COSTACEAE			
Costus afer Ker-Gauwl.	x	x	x
Costus englerianus K. Schum.	x	x	x
Costus sp	x	x	x
CUCURBITACEAE			
Cogniauxia podolaena Baill.	x	x	x
CYPERACEAE			
Cyperus alternifolius Steud.	x		
Cyperus sp	x	x	x
Mapania sp**			x
*Scleria boivini***Steud.	x	x	x
DAVALLIACEAE			
Nephrolepis biserrata (Sw.) Schott	x	x	x
DICHAPETALACEAE			
Dichapetalum sp	x	x	x
DILLENIACEAE			
Tetracera alnifolia DC.		x	x
Tetracera triceras Thou. ex. Baill.		x	
DIOSCOREACEAE			
Dioscorea bulbifera L.	x	x	
Dioscorea sp	x	x	x
DIPTEROCARPACEAE			
*Lophira alata**Banks ex Gaertn.f.	x	x	x
EBENACEAE			
Diospyros cinnabarina (Gürke) F. White	x	x	x
Diospyros conocarpa Gürke ex K. Schum		x	x
Diospyros similes Craib			x
Diospyros sp	x	x	x
EUPHORBIACEAE			
Alchornea cordifolia Muell. Arg.	x	x	x
Alchornea floribunda Muell. Arg.	x	x	x
Bridelia ferruginea Benth.	x		
Bridelia micrantha Baill.	x	x	x
Erythrococca sp*	x	x	
Hymenocardia lyrata Tul.	x	x	x
Jatropha jateorhiza	x		
Jatropha micrantha Muell. Arg.	x	x	
Macaranga assas A. Amougou		x	x
Macaranga barteri Muell. Arg.	x	x	x
Macaranga sp	x	x	x
Macaranga spinosa Muell. Arg.	x	x	x
Maesobotrya dusenii Hutchinson			x
Maesobotrya sp			x
Manihot esculenta Crantz	x	x	x

	Co-Co‡	Co-Fo	Bu-Fo
Manniophyton fulvum Muell. Arg.	x	x	x
Manniophyton sp	x		
*Mareyopsis longifolia**Pax & K. Hoffm.			x
*Margaritaria discoidea***(Baill.) Webster	x		
Microdesmis puberula Hook.f.	x	x	x
Microdesmis sp	x	x	x
Phyllanthus amarus Schum. & Thonn.	x		
Phyllanthus discoides Muell. Arg.	x	x	x
Phyllanthus sp	x	x	x
*Plagiostyles africana**Prain ex De Wild.			x
Ricinodendron heudelotii (Baill.) Pierre ex Heckel	x	x	x
*Sapium ellypticum** Pax	x	x	
Tetrorchidium didymostem Pax ex K. Hoffm.	x	x	x
Uapaca guineensis Muell. Arg.			x
Uapaca paludosa Aubev. & Leandri			x
FLACOURTIACEAE			
Caloncoba glauca Gilg	x	x	x
Caloncoba welwitschii Gilg	x	x	x
Caloncoba sp		x	x
*Homalium le-testui**Pellegr.	x	x	x
GLEICHENIACEAE			
Gleichenia linearis C. B. Clarke			
GNETACEAE			
*Gnetum africanum***Welw.	x		x
GUTTIFERAE			
*Allanblackia floribunda***Oliver	x	x	
*Garcinia mannii***Oliver			x
Garcinia sp**			x
HYPERICACEAE			
Harungana madagascariensis Poir.	x	x	x
ICACINACEAE			
*Lasianthera africana**Beauv.	x	x	
LAURACEAE			
Persea Americana Mill.	x	x	x
LECYTHIDACEAE			
Napoleonaea sp**		x	x
*Petersianthus macrocarpus***(P. Beauv.) Liben	x	x	x
LEGUMINOSAE-CAESALPINIACEAE			
*Cassia mimosoides***DC.	x		
Cynometra hankei Harms*			x
Cynometra sp*		x	
Dialium sp*		x	x
*Distemonanthus benthamianus***Baill.	x	x	x
Duparquetia dewevrei Baill.	x	x	
Duparquetia orchidacea Baill.	x		
Duparquetia sp	x	x	x
Erythrophleum suaveolens Brenan		x	x
Hylodendron gabunense Taub.		x	x

	Co-Co‡	Co-Fo	Bu-Fo
LEGUMINOSAE-MIMOSACEAE			
Acacia kamerunensis Gandoger			x
Acacia sp	x		
Albizia ferruginea Benth.	x	x	x
Albizia gummifera C. A. Smith		x	x
Albizia zygia Macbride	x	x	x
Albizia sp	x		
Anthonotha fragrans Exell & Hillc.		x	
Anthonotha lamprophylla J. Leonard	x	x	x
Calpocalyx sp*		x	x
*Cylicodiscus gabunensis***Harms	x		
*Mimosa invisa***	x		
Pentaclethra macrophylla Benth.	x	x	x
Piptadeniastrum africanum (Hook.f.) Brenan	x	x	x
LEGUMINOSAE-PAPILIONACEAE			
*Abrus precatorius**L.	x	x	
Abrus sp*	x	x	x
Angylocalyx pynaertii De Wild.			x
Angylocalyx sp	x	x	x
*Arachis hypogaea***L.	x		
*Baphia nitida***Lodd.	x	x	x
*Centrosema pubescens***Steud.	x		
Centrosema sp**	x		
Dalbergia hostilis Benth.	x	x	x
Dalbergia sp	x	x	x
Desmodium adscendens DC.	x	x	x
Indigofera sp*		x	
Milletia barteri (Benth.) Dunn	x	x	x
Milletia laurentii			x
Milletia sp	x	x	x
*Mucuna flagellipes***Hook.f.		x	x
*Mucuna pruriens***DC.	x		
Mucuna sp**	x		
*Pterocarpus soyauxii**Taub.		x	
Vigna sp**	x	x	x
LILIACEAE			
Dracaena sp**			x
Smilax kraussiana Meissn.	x	x	x
LINACEAE			
*Lepidobotrys staudtii**Engl.		x	x
LOGANIACEAE			
Anthocleista schweinfurthii Gilg	x	x	x
Anthocleista vogelii Planch.	x	x	x
*Strychnos canthioides**Leeuwenb.			x
Strychnos sp*		x	x
LOMARIOPSIDACEAE			
Lomariopsis palustris Mett.			x
Lomariopsis sp			x
MALVACEAE			
Sida rhombifolia L.	x	x	x
*Triplochiton scleroxylon**K. schum.			x
Urena cameroonensis L.		x	x
Urena lobata L.	x		

	Co-Co‡	Co-Fo	Bu-Fo
Urena repens L.		x	
MARANTACEAE			
Haumania danckelmaniana MilneRedh.	x	x	x
*Hypselodelphys violacea***Milne-Redh.		x	x
Megaphrynium macrostachyum Milne-Redh.	x	x	x
Megaphrynium megaphylla Milne-Redh.		x	x
Megaphrynium sp	x	x	x
Sarcophrynium sp	x	x	x
Thalia welwitschii Ridl.		x	x
Thalia sp	x	x	x
MELASTOMATACEAE			
*Dissotis braziliense***	x		
Dissotis sp**	x		
MELIACEAE			
Carapa procera DC.		x	x
Trichilia rubescens Oliver		x	x
Trichilia sp	x	x	x
MENISPERMACEAE			
Undetermined	x	x	x
*Jateorhiza macrantha***Exell & Medonça		x	x
Penianthus longifolius Miers	x	x	x
Stephania abyssinica Walp.	x	x	x
Stephania sp	x	x	x
MORACEAE			
Ficus exasperata Vahl	x	x	x
Ficus mucuso Welw. ex Picalho	x	x	x
Ficus sp	x	x	x
Milicia excelsa (Welw.) C. C. Berg	x	x	x
*Morus mesozygia**Stapf		x	
Musanga cecropioides R. Br. apud Tedlie	x	x	x
MYRISTICACEAE			
Coelocaryon preussii Warb.		x	x
*Pycnanthus angolensis***(welw.) Warb.	x	x	x
MYRTACEAE			
*Psidium guajava***L.	x		
Syzygium sp**	x	x	x
OCHNACEAE			
Campylospermum elongatum (Oliv.) Tiegh.			x
Campylospermum sp		x	
OLACACEAE			
Coula edulis Baill.			x
Lavigeria macrocarpa Pierre	x	x	x
Lavigeria sp	x	x	x
Olax subscorpioides Oliver	x	x	x
Olax sp	x	x	x
*Strombosiopsis tetrandra**Engl.			x
OLEANDRACEAE			
Arthropteris cameroonensis Alston	x	x	x
Arthropteris sp	x	x	x

	Co-Co‡	Co-Fo	Bu-Fo
*Oleandra distenta**Kunze		x	
ORCHIDACEAE			
Eulophia sp**	x		
*Vanilla africana**Lindl.		x	
PALMAE			
*Calamus deërratus**Mann & H. Wendl.		x	x
Elaeis guineensis Jacq.	x	x	x
*Oncocalamus deërratus***H. Wendl.			x
*Raphia monbottorum***Drude		x	x
PANDANACEAE			
*Panda oleosa**Pierre			x
PASSIFLORACEAE			
Adenia sp*	x	x	x
Barteria fistulosa Mast.	x	x	x
Barteria sp			x
*Deidamia clematoides**Harms			x
Deidamia sp*		x	
PIPERACEAE			
*Piper guineense***Schum. & Thonn.			x
*Piper umbellatum**L.	x	x	
POACEAE			
Axonopus compressus (Sw.) P. Beauv.	x	x	x
*Brachiaria lata***C.E. Hubbard	x		
*Leptaspis cochleata***Thw.	x		
*Olyra latifolia***L.			
Oplismenus burmannii (Retz.) P. Beauv.	x		x
*Paspalum conjugatum***Berg	x		
*Saccharum officinarum***L.	x		
POLYGALACEAE			
Carpolobia alba G. Don	x		
POLYPODIACEAE			
Microsorum punctatum (L.) Copel.	x	x	x
PTERIDACEAE			
Pteris sp		x	x
RHAMNACEAE			
Gouania longispicata Engl.	x	x	x
Gouania sp	x	x	x
RUBIACEAE			
Bertiera sp*		x	x
Cephaëlis pedoncularis Salisb.		x	x
Cephaëlis sp		x	x
Coffea sp*	x		x
*Craterispermum laurinum***Benth.	x		
*Diodia scandens***Benth.	x		
*Massularia acuminata***Bullock ex Hoyle		x	x
Massularia sp**	x		
Morinda lucida Benth.	x	x	x
Morinda morindoides Milne-Redh.	x	x	x

	Co-Co[‡]	Co-Fo	Bu-Fo
Morinda sp		x	
Mussaenda sp**		x	x
Oxyanthus sp**	x		
Psychotria sp	x	x	x
Rothmannia hispida (K. Schum.) Fagerlind	x		x
Rothmannia sp			x
Sabicea sp1	x	x	x
Sabicea sp2**	x		
Sabicea sp3**	x		
Uncaria sp**	x		
RUTACEAE			
Teclea sp*			x
SAPINDACEAE			
*Cardiospermum halicacabum**L.			x
Cardiospermum sp*		x	
Chytranthus sp	x	x	x
*Eriocoelum macrocarpum**Gilg			x
*Pancovia pedicellaris**rzdlk. & Gilg ex Gilg		x	
Paullinia pinnata L.	x	x	x
SCITAMINAE			
Maranthochloa sp*		x	x
*Musa paradisiaca***L.	x	x	x
Musa sapientum L.	x	x	x
SIMAROUBACEAE			
Irvingia sp**	x		x
*Desbordesia glaucescens**Van Tiegh		x	x
SOLANACEAE			
Solanum torvum Sw.	x		
Solanum sp			x
STERCULIACEAE			
Cola chlamydantha K. Schum.		x	
Cola cordifolia R. Brown			x
Cola lepidota K. Schum.			x
Cola lateritia K. Schum.			x
Cola nitida Schott & Endl.	x	x	x
Cola pachycarpa K. Schum.	x	x	x
Cola sp	x	x	x
Leptonychia sp*		x	x
Pterygota sp*		x	x
Sterculia rhinopetala K. Schum.	x	x	x
Sterculia tragacantha Lindl.	x	x	x
Sterculia sp			x
Theobroma cacao L.		x	x
TILIACEAE			
*Desplatsia dewevrei**Burret		x	
*Glyphaea brevis**(Spreng.) Monach.			x
*Grewia coriacea**Mast.		x	
Grewia sp*	x	x	
Triumfetta cordifolia A. Rich.	x	x	
ULMACEAE			
Trema orientalis (L.) Blume	x	x	x

	Co-Co‡	Co-Fo	Bu-Fo
URTICACEAE			
Celtis mildbraedii Engl.		x	x
Celtis zenkeri Engl.		x	x
Myrianthus arboreus Beauv.	x	x	x
*Pouzolzia guineensis***Benth.	x		
VERBENACEAE			
*Clerodendron hispidum**M. R. Henderson			x
Clerodendrum sp	x	x	x
Stachytarpheta cayennensis Vahl	x		
Vitex grandifolia Gürke		x	
Vitex thyrsiflora Baker		x	x
VIOLACEAE			
Rinorea sp		x	x
VITACEAE			
*Ampelocissus bombycina***(Baker) Planch	x	x	x
Ampelocissus sp**			x
Cissus abyssinica L.			x
Cissus quadrangularis L.		x	x
Cissus sp	x	x	x
ZINGIBERACEAE			
Aframomum longiscapum K. Schum.	x	x	x
Aframomum sp	x	x	x

* Recorded only during the 1998 survey; ** Recorded only during the 1999 survey.

‡ Co-Co, *Chromolaena odorata* –dominated fallows that had been *C. odorata*-dominated fallows prior to the preceding cropping phase; Co-Fo, *C. odorata*-dominated fallows that had been forests prior to the preceding cropping phase; Bu-Fo, bush fallows (not dominated by *C. odorata*) that had been forests prior to the preceding cropping phase.

APPENDIX 7.1

List of weed species recorded in mixed food crop fields established after clearing short fallows at Mengomo (southern Cameroon)

SPECIES	6 WAP* Co-Co**	6 WAP* Co-Fo	6 WAP* Bu-Fo	14 WAP Co-Co	14 WAP Co-Fo	14 WAP Bu-Fo	30 WAP Co-Co	30 WAP Co-Fo	30 WAP Bu-Fo
Cyperus sp (CYPERAC.)	x	x		x	x		x	x	x
Mallotus alternifolius (EUPH.)	x	x		x	x	x	x	x	
Scleria boivini (CYPERAC.)	x	x	x	x	x	x	x	x	x
Acalypha ciliata (EUPH.)	x	x	x			x	x		x
Acacia kamerunensis (MIMOS.)		x	x		x				
Ageratum conyzoides(CONNAR.)	x	x	x	x	x	x	x	x	x
Ageratum sp (CONNAR.)							x	x	x
Albizia adianthifolia (MIMOS.)								x	
Alchornea cordifolia (EUPH.)				x			x		x
Albizia ferruginea (MIMOS.)							x	x	x
Alchornea floribunda (EUPH.)									x
Albizia sp (MIMOS.)	x	x		x	x	x	x		
Albizia zygia (MIMOS.)				x				x	
Amaranthus sp (AMARANTH.)			x						
Anthocleista schweinfurthii(LOGA.)		x	x		x	x	x	x	x
Asystasia gangetica (ACANTH.)			x	x	x	x	x	x	x
Asclepia sp (ASCLEPIAD.)			x	x		x	x		
Bartiera sp (PASSIFL.)								x	x
Bridelia micrantha (EUPHORB.)							x	x	
Brillantaisia sp (ACANTHACAC.)		x			x	x		x	
Carpolobia alba (POLYGALAC.)							x	x	
Capsicum frutescens (SOLANAC.)	x								
Caloncoba sp (FLACOURTIAC.)	x						x		
Carica papaya (PASSIFLORAC.)	x	x							
Undetermined							x		
Celtis mildbraedii (URTICAC.)								x	
Ceiba pentandra (BOMBACAC.)		x	x	x		x			
Celosia trigyna (AMARANTHAC.)				x			x	x	x
Chromolaena odorata (ASTERAC.)	x	x	x	x	x	x	x	x	x
Chytranthus sp (SAPINDAC.)						x		x	
Cissus sp (VITACEAE)	x								x
Cleome ciliata (CAPPARACEAE)							x		
Clerodendron hispidum (VERBEN.)								x	x
Clerodendron racemosum(VERBEN.)							x		x
Clerodendron sp (VERBENAC.)		x					x	x	
Cnestis ferruginea (CONNARAC.)			x	x	x	x	x		x
Combretum hispidum (COMBRET.)	x	x	x				x		
Cogniauxia podolaena	x	x	x	x	x	x	x		x

Cogniauxia sp (CUCURBITACEAE)	x	x	x	x	x	x	x	x	x
Cyathula prostrata (AMARANTH.)	x	x	x	x	x	x		x	x
Desmodium adscendens (PAPIL.)	x	x		x	x	x	x	x	x
Distemonanthus benthamianus					x			x	x
Dioscorea bulbifera (DIOSCOR.)							x		
Dichrocephala sp (ASTERACEAE)								x	
Diospyros conocarpa (EBENAC.)									x
Dichapetalum sp (DICHAPETAL.)			x					x	
Diplazium sp (WOODSIACEAE)				x	x	x			
Dissotis rotundifolia (MELASTOM.)							x	x	x
Diodia scandens	x	x	x	x	x	x	x	x	x
Dissotis sp	x	x	x	x	x	x	x	x	x
Dracaena sp (LILIACEAE)									x
Elytraria marginata (ACANTHAC.)						x	x	x	x
Elephantopus mollis (ASTERAC.)	x			x		x	x		
Emilia coccinea (ASTERACEAE)			x			x			
Eremospatha sp (PALMAE)			x						
Erythrococca sp (EUPHORB.)		x							
Papilionaceae sp							x	x	
Ficus exasperata (MORACEAE)		x			x			x	x
Fluerya sp				x	x	x			
Funtumia africana (APOCYNAC.)							x		
Funtumia elastica (APOCYNAC.)			x	x			x	x	
Gleichenia linearis (GLEICHENIAC.)				x		x			
Gouania longispicata (RHAMNAC.)								x	x
Harungana madagascariensis(HYP.)		x	x	x	x	x	x	x	x
Hymenocardia lyrata (EUPHORB.)		x	x	x	x				
Hypselodelphis sp (MARANTAC.)				x	x	x			
Ipomoea batatas (CONVOLV.)		x		x	x		x		
Ipomoea involucrata (CONVOLV.)	x	x					x	x	x
Ipomoea mauritiana (CONVOLV.)	x	x							
Ipomoea sp (CONVOLVULACEAE)	x	x	x	x	x	x			
Jatropha jateorhiza (EUPHORB.)						x			
Lavigeria macrocarpa (OLACAC.)							x	x	x
Djaji		x							
Landolphia sp (APOCYNAC.)						x	x	x	
Lomariopsis sp (LOMARIOPSIDAC)						x			
Macaranga assas (EUPHORB.)								x	
Manihot esculenta (EUPHORB.)	x	x	x	x	x	x	x	x	x
Manniophyton fulvum (EUPHORB.)			x						
Markhamia lutea (BIGNONIAC.)		x							
Marantochloa sp (MARANTACEAE)	x		x		x	x	x	x	x
Menispermaceae sp		x	x					x	
Mikania cordata (ASTERACEAE)							x	x	x
Milicia excelsa (MORACEAE)							x		
Milletia laurentii (PAPILIONAC.)									x
Microdesmis puberula (EUPHORB.)								x	
Microdesmis sp (EUPHORB.)						x	x		

Morinda lucida (RUBIACEAE)									x
Musanga cecropioides (MORAC.)		x	x		x	x	x	x	x
Mucuna pruriens (PAPILIONAC.)		x			x				
Myrianthus arboreus (URTICAC.)							x		
Occimum sp (LABIATAE)				x					
Olax subscorpioidea (OLACAC.)		x							
Oxyanthus sp (RUBIACEAE)							x		
Paulinia pinnata (SAPINDACEAE)	x					x	x		
Penianthus longifolius (MEANISP.)							x		
Pentaclethra macrophylla(MIMOS.)								x	
Phyllanthus amarus (EUPHORB.)	x	x		x	x	x	x	x	x
Pycnanthus angolensis(MYRISTIC.)	x	x	x	x	x			x	
Phyllanthus sp (EUPHORB.)								x	
Piper umbellatum (PIPERACEAE)			x	x	x	x	x	x	x
Pouzolzia guineensis (URTICAC.)	x	x		x	x	x	x	x	x
Portulaca oleracea (PORTULAC.)									x
Psychotria sp (RUBIACEAE)							x	x	x
Pueraria phaseolides (PAPILION.)								x	
Rauwolfia vomitaria (APOCYNAC.)							x		
Richardia brasiliensis(ARACEAE)						x			
Rinorea sp (VIOLACEAE)				x	x	x	x	x	
Rubiaceae sp									x
Sapium ellypticum (EUPHORB.)									x
Sabicea sp (RUBIACEAE)		x			x			x	x
Scottellia sp (FLACOURTIACEAE)									x
Setaria sp (POACEAE)						x			
Sida alata (MALVACEAE)							x	x	x
Sida rhombifolia (MALVACEAE)	x	x	x	x	x	x	x		
Solanum sp (SOLANACEAE)	x	x	x	x	x				x
Solenostemon monostachyus(LAB.)							x	x	
Solanum torvum (SOLANACEAE)		x		x	x			x	x
Stachytarpheta cayennensis (VER.)	x	x	x	x	x	x	x	x	x
Synedrela nodiflora (ASTERAC.)	x	x	x					x	
Tabernaemontana crassa(APOCY.)				x				x	x
Talinum triangulare (PORTULAC.)	x	x	x	x	x	x	x		
Tetrorchidium didymostemon(EUP.)			x				x		x
Terminalia superba (COMBRET.)			x						
Triumfetta cordifolia (TILIACEAE)	x	x	x	x	x	x	x	x	x
Trema orientalis (ULMACEAE)	x	x	x	x	x	x	x	x	x
Trichilia sp (MELIACEAE)							x	x	
Urena cameroonensis (MALVAC.)								x	x
Vernonia amygdalina (ASTERAC.)		x	x		x	x		x	
Vernonia conferta (ASTERACEAE)				x	x	x		x	x
Vernonia frondosa (ASTERAC.)							x	x	x
Vigna sp (PAPILIONACEAE)					x				
Vitex grandiflora (VERBENACEAE)									x

Voacanga africana (APOCYNAC.)				x					
Xylopia sp (ANNONACEAE)								x	x
Axonopus compressus (POAC.)	x	x				x	x	x	x
Brachiaria lata (POACEAE)	x	x		x					
Oplismenus burmannii (POAC.)	x	x	x	x	x	x	x	x	x
Paspalum conjugatum (POACEAE)	x	x	x	x	x	x	x	x	x
Paspalum paniculatum (POACEAE)							x	x	x
Aframomum longiscapum (ZINGIB.)		x	x				x		x
Aframomum sp (ZINGIBERACEAE)		x	x		x	x			x
Aneilema beninense (COMMEL.)	x	x	x	x	x	x	x	x	x
Costus afer (COSTACEAE)	x	x		x	x	x	x	x	x
Commelina benghalensis(COMME.)	x	x	x	x	x	x	x	x	x
Costus englerianus (COSTACEAE)			x						x
Commelinaceae sp								x	
Commelina sp (COMMELINAC.)				x				x	x
Costus sp (COSTACEAE)								x	x
Culcasia sp (ARACEAE)									x
Elaeis guineensis (PALMAE)	x	x	x	x	x	x	x	x	
Haumania danckelmaniana(MARANTAC.)	x	x	x	x	x	x	x	x	x
Megaphrynium macrostachyum	x	x	x		x	x			
Palisota hirsuta (COMMELINAC.)	x	x	x	x	x	x	x	x	x
Rhektophyllum sp (ARACEAE)								x	
Rhektophyllum mirabile (ARAC.)			x		x	x		x	x
Sarcophrynium brachystachys		x	x		x	x	x		x
Smilax kraussiana (SMILACAC.)				x	x	x	x		
Xanthosoma sagittifolium (ARAC.)	x	x	x	x	x	x	x	x	
Gleichenia linearis								x	
Nephrolepis biserrata (DAVALLIAC)							x	x	x
Pteris caudata (PTERIDACEAE)							x		
Pteris sp (PTERIDACEAE)							x		x

*WAP, weeks after planting.

** Co-Co, *Chromolaena odorata* –dominated fallows that had been *C. odorata*-dominated fallows prior to the preceding cropping phase; Co-Fo, *C. odorata*-dominated fallows that had been forests prior to the preceding cropping phase; Bu-Fo, bush fallows (not dominated by *C. odorata*) that had been forests prior to the preceding cropping phase.

APPENDIX 7.2

Average values for soil parameters measured in mixed food crop fields established after clearing three short-duration fallow types at Mengomo (southern Cameroon, 1999). Figures in parentheses are ± standard error of mean.

Treatment *	Bulk density (g cm^{-3})	pH	N	C	C:N	P	Ca	Mg	K	Al
Depth 0 – 5 cm										
Co-Co	1.04	5.31	0.20	2.55	13.15	8.74	3.23	0.89	0.07	0.11
	(0.02)	(0.05)	(0.00)	(0.04)	(0.14)	(1.15)	(0.19)	(0.05)	(0.00)	(0.03)
Co-Fo	0.91	4.76	0.23	2.96	13.08	11.72	2.67	0.62	0.08	0.39
	(0.02)	(0.06)	(0.01)	(0.08)	(0.15)	(0.76)	(0.25)	(0.05)	(0.00)	(0.04)
Bu-F0	1.04	5.36	0.17	2.36	14.17	9.13	3.26	0.69	0.12	0.15
	(0.04)	(0.10)	(0.00)	(0.05)	(0.18)	(0.84)	(0.30)	(0.05)	(0.01)	(0.03)
LSD (α=0.05)	0.07	0.20	0.01	0.16	0.44	2.72	0.68	0.15	0.01	0.10
Depth 5 – 10 cm										
Co-Co	1.19	4.94	0.12	1.57	13.00	2.54	1.24	0.43	0.07	0.48
	(0.02)	(0.04)	(0.00)	(0.03)	(0.14)	(0.11)	(0.07)	(0.03)	(0.00)	(0.04)
Co-Fo	1.11	4.52	0.13	1.78	13.50	4.97	0.79	0.24	0.07	1.50
	(0.02)	(0.03)	(0.00)	(0.05)	(0.19)	(0.37)	(0.07)	(0.02)	(0.00)	(0.10)
Bu-Fo	1.36	4.98	0.10	1.49	14.55	4.71	1.35	0.34	0.08	0.64
	(0.15)	(0.06)	(0.00)	(0.03)	(0.23)	(0.24)	(0.14)	(0.02)	(0.00)	(0.08)
LSD (α=0.05)	0.22	0.12	0.01	0.10	0.51	0.72	0.26	0.07	0.01	0.19
Depth 10 – 15 cm										
Co-Co	1.17	4.72	0.10	1.47	15.49	2.29	0.78	0.29	0.04	1.04
	(0.02)	(0.03)	(0.00)	(0.02)	(0.22)	(0.07)	(0.05)	(0.03)	(0.00)	(0.06)
Co-Fo	1.11	4.51	0.10	1.41	14.11	3.85	0.52	0.17	0.04	1.53
	(0.02)	(0.02)	(0.00)	(0.04)	(0.38)	(0.35)	(0.05)	(0.01)	(0.00)	(0.07)
Bu-Fo	1.26	4.83	0.08	1.03	13.08	3.52	0.81	0.26	0.08	0.68
	(0.05)	(0.05)	(0.00)	(0.04)	(0.26)	(0.27)	(0.11)	(0.02)	(0.01)	(0.07)
LSD (α=0.05)	0.10	0.10	0.01	0.09	0.83	0.70	0.19	0.06	0.01	0.18

APPENDIX 8.1

Main characteristics of trees monitored for phenology and fruit production of selected high-value species at Kaya (south Cameroon, 2001-2002).

Species	Land use type*	Tree Tag No.	Mean radius (m)	DBH** (cm)	Height (m)	Owner
Coula edulis						
	Sfa	CE11	3.5	82.80	14	Nguimbous
	Sfa	CE12	4	79.62	12.5	Ndjock
	Sfa	CE13	4.5	81.53	12.5	Bissohong
	Sfa	CE14	4	41.08	8.5	Nken
	Sfa	CE15	3.5	21.98	11	Alhadji
	Sfa	CE16	3.5	38.22	11.5	Alhadji
	Sfa	CE17	5.5	95.54	16	Mathias
	Sfa	CE18	3.5	65.61	12	Mathias
	Sfa	CE19	4.5	79.62	14	EPC
	Sfa	CE110	3.5	71.34	13	Mathias
	Sfa	CE121	2.9	46.5	11	Mathias
	Mfa	CE21	4	38.22	11.5	Mathias
	Mfa	CE22	4	47.77	11	Mathias
	Mfa	CE23	7	95.54	18	Mathias
	Mfa	CE24	6.5	65.61	17	Mathias
	Mfa	CE25	6	57.96	17.5	Mathias
	Mfa	CE26	4.5	60.51	15	Mathias
	Mfa	CE27	4.5	61.15	15.5	Mathias
	Mfa	CE28	6.5	63.06	17	Mathias
	Mfa	CE29	6	71.98	18	Mathias
	Mfa	CE210	6	63.69	15	Mathias
	Lfa	CE31	3.5	38.85	14	Tonyè
	Lfa	CE32	3.5	27.71	11	Tonyè
	Lfa	CE33	4	23.89	14.5	Tonyè
	Lfa	CE34	4	51.59	16	Tonyè
	Lfa	CE35	5.5	25.80	13	Tonyè
	Lfa	CE36	6	50.96	17.5	Tonyè
	Lfa	CE37	3.5	49.36	16	Tonyè
	Lfa	CE38	2	16.56	11	Tonyè
	Lfa	CE39	4.5	43.31	13	Tonyè
	Lfa	CE310	3.5	33.76	12.5	Tonyè
Dacryodes edulis						
	Sfa	DE11	6.5	46.50	12	Mathias
	Sfa	DE12	4	35.03	11	Mathias
	Sfa	DE13	3.5	41.72	9	Mathias
	Sfa	DE14	5.5	47.77	10	Mathias
	Sfa	DE15	4.5	29.30	11.5	Nken
	Sfa	DE16	3.5	23.57	9.5	Nken
	Sfa	DE17	3.5	22.61	9.5	Nken
	Sfa	DE18	4.5	28.66	9.5	Nken
	Sfa	DE19	2.5	13.69	6	Nken
	Sfa	DE110	4	28.66	7.5	Nken
	Sfa	DE111	4	25.5	11.5	

Species	Land use type*	Tree Tag No.	Mean radius (m)	DBH** (cm)	Height (m)	Owner
	Sfa	DE121	3.8	49.12	15	
	Sfa	DE122	5.5	49	12.5	
	Sfa	DE123	7.8	47.77	16	
	Mfa	DE21	4	17.83	7.5	Nguimbous
	Mfa	DE22	4.5	18.15	9.5	Nguimbous
	Mfa	DE23	7	24.20	8.5	Nguimbous
	Mfa	DE24	5.5	44.27	15	Bissohong
	Mfa	DE25	5.5	47.45	11	Bissohong
	Mfa	DE26	4	27.71	9	Ndjock
	Mfa	DE27	6	56.05	12	Ndjock
	Mfa	DE28	4	26.43	8	Tonyè
	Mfa	DE29	6	47.45	10	Tonyè
	Mfa	DE210	4.5	40.13	8.5	Tonyè
	Mfa	DE221	6.5	54.5	12.5	
	Mfa	DE222	6.5	44.5	13.5	
Irvingia gabonensis						
	Sfa	IG11	5.5	95.54	16	
	Sfa	IG12	4.5	43.31	12	
	Sfa	IG13	4.5	25.16	12	
	Sfa	IG14	7	68.47	14	Mathias
	Sfa	IG15	4.5	51.59	13	Tonyè
	Sfa	IG16	3.5	21.66	8.5	Nken
	Sfa	IG17	2.5	38.85	11.5	Nken
	Sfa	IG18	4.5	100.32	25	Alhadji
	Sfa	IG19	1.5	92.36	13.5	Tonyè
	Sfa	IG110	5	97.13	15	Tonyè
	Sfa	IG111	4.75	36	14	
	Sfa	IG121	6.38	95.54	23.5	
	Mfa	IG21	5	74.52	15	Nguimbous
	Mfa	IG22	5.5	46.18	14	Nguimbous
	Mfa	IG23	5.5	66.88	16	Ndjock
	Mfa	IG24	6.5	73.25	17	Ndjock
	Mfa	IG25	4	26.43	11	Mathias
	Mfa	IG26	6	89.17	13.5	Tonyè
	Mfa	IG27	6	130.57	16	Tonyè
	Mfa	IG28	5.5	85.99	14	Tonyè
	Mfa	IG29	6	98.73	19	Alhadji
	Mfa	IG210	6.5	81.53	18	Alhadji
	Lfa	IG31	4.5	44.90	20	Alhadji
	Lfa	IG32	5.5	76.43	15	Tonyè
	Lfa	IG33	5	30.57	17	Tonyè
	Lfa	IG34	3	21.34	14	Tonyè
	Lfa	IG35	6.5	109.87	22	Tonyè
	Lfa	IG36	6.5	78.98	21	Tonyè
	Lfa	IG37	4.5	22.93	11	Tonyè
	Lfa	IG38	5	32.80	13	Tonyè
	Lfa	IG39	3	23.89	14	Tonyè
	Lfa	IG310	5	65.61	16	Tonyè
Ricinodendron heudelotii						
	Sfa	RH11	5	95.54	20	Nguimbous
	Sfa	RH12	6.5	130.57	19	Mathias
	Sfa	RH13	4.5	46.82	13.5	Alhadji
	Sfa	RH14	5.5	98.73	18	Mandeng
	Sfa	RH15	5.5	100.32	19	Aladji

Species	Land use type*	Tree Tag No.	Mean radius (m)	DBH** (cm)	Height (m)	Owner
	Sfa	RH16	6.5	127.39	22	Aladji
	Sfa	RH17	4.5	66.24	15	Aladji
	Sfa	RH18	4.5	70.06	16	Aladji
	Sfa	RH19	5	79.62	15	Aladji
	Sfa	RH110	4.5	70.06	17	Aladji
	Mfa	RH21	4	24.84	16	Nguimbous
	Mfa	RH22	5	46.18	15	Bissohong
	Mfa	RH23	6	101.91	20	Bissohong
	Mfa	RH24	5	98.73	17	Ndjock
	Mfa	RH25	6.5	100	18	Tonyè
	Mfa	RH26	5	89.17	16	Alhadji
	Mfa	RH27	4.5	88.54	17	Alhadji
	Mfa	RH28	5.5	80.26	16.5	Alhadji
	Mfa	RH29	5.5	95.54	18	Tonyè
	Mfa	RH210	4.5	51.50	12	Tonyè
	Lfa	RH31	6.5	108.28	24	Tonyè
	Lfa	RH32	6	84.08	22	Tonyè
	Lfa	RH33	3.5	70.06	17	Tonyè