Alternatives to Slash-and-Burn

Summary Report and Synthesis of Phase II in Cameroon

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About ASB

This report is one of a series detailing results from the Alternatives to Slash-and-Burn (ASB) Programme, a global consortium founded in 1994 as a system-wide programme of the Consultative Group on International Agricultural Research (CGIAR). ASB is convened by the Nairobi-based World Agroforestry Centre (ICRAF) and is governed by a global steering group of 12 representatives from participating national and international institutions. At its inception, ASB was financially supported by the Global Environment Facility (GEF), with sponsorship from the United Nations Development Programme (UNDP). Additional funding for ASB global work is provided by the Governments of the Netherlands and the USA, through the United States Agency for International Development (USAID).

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Introduction

The Alternatives to Slash-and-Burn programme (ASB) involves a global consortium of national and international research institutes and is a system-wide initiative of the Consultative Group on International Agricultural Research (CGIAR). ASB's origins lie with the Rio de Janeiro Environmental Conference of 1992. The programme's purpose is to develop and test strategies for reducing environmental degradation and improving rural livelihoods along the forest margins of the tropics. Its objectives are the development of improved land-use systems and policy recommendations capable of alleviating the pressures on forest resources that are associated with slash-and-burn agricultural techniques. Research is conducted in benchmark sites across the pan-tropics. For the recently completed Phase II of the project, research was mainly concentrated in three global sites—the western Amazon of Brazil, the diptocarp forests of Sumatra in Indonesia, and the Atlantic and Congolese forests of southern Cameroon. This report presents a synthesis of findings from Phase II in Cameroon.

In Central Africa, ASB research efforts are focused on slash-and-burn agriculture in the Congo basin and the six countries–Congo-Brazzaville, Congo-Kinshasa, Gabon, CAR, Equatorial Guinea and Cameroon–whose borders encompass the world's second largest contiguous rainforest. FAO (1997) estimates a deforestation rate of 0.6% yr^{-1} (1,142,000 ha yr^{-1}) for the Congo basin. By comparison, other ASB benchmarks in Indonesia and Brazil are tackling estimated forest losses of 1.0% yr^{-1} (1,084,000 ha) and 0.5% yr^{-1} (2,554,000 ha), respectively. In Cameroon, the rate of deforestation is estimated at 0.6%, with about 100,000 ha of closed canopy forest lost annually.

Unlike Indonesia and Brazil, where large-scale agricultural operations play an important role, most of the deforestation in the Congo basin is attributed to smallholder agriculturalists using extensive slash- and-burn techniques. In Cameroon, over 85% of deforestation is attributed to smallholder agriculture. Thus, rural population density plays a significant role in determining the extent of closed canopy forest and the stock of woody biomass in a given area, but the relationship is far from linear and depends on a complex assortment of factors.

Measures of land and labor productivity in the Congo basin are low and have shown little growth. The low productivity of agriculture, in combination with rapid population growth, results in the continual extension of the forest margins. To alleviate the situation, Serageldin (1991) and others have called for a doubling of agricultural productivity at the household level. To achieve this ambitious goal, farmers will require access to disease-resistant varieties that are better at exploiting the relatively high levels of nutrients that characterize the first year of cropping, following the medium to long fallow periods of the region. Where rural population densities are high and fallow periods have shortened, farmers are forced to intensify their production. In these areas, the use of soil amendments (organic and chemical fertilizers, leguminous green manures, kitchen wood ash), in conjunction with better varieties, are suggested. Implementing an intensification strategy to increase agricultural productivity will require strengthening of agrarian services such as extension, plant and seed multiplication, farmer organizations, rural credit and savings organizations, and rural infrastructure.

The biophysical context of the Forest Margins Benchmark of southern Cameroon

ASB technological interventions and policy recommendations for the Congo basin are based on research conducted in the Forest Margins Benchmark Area of southern Cameroon (Figure 1). Covering 1.54 M ha, the benchmark spans a gradient of population density and also encompasses significant spatial variation in market access, soils and climate (Annex 1) for population gradient). For the analysis in the report, three blocks of the benchmark are distinguished and can be ordinally ranked (high to low) with respect to intensity of resource use as follows: the Yaounde block, the Mbalmayo block and the Ebolowa block. The range of socio-economic and biophysical conditions in the benchmark permit the study and targeting of short, medium and long fallow agricultural systems over areas with population densities ranging from 4 to 100 persons km^{-2}.

The red and red-yellow soils in the benchmark fall mainly into the broad FAO soil class of Orthic Ferrasols, which are suitable for cocoa, coffee, oil palm and rubber, if clay content is high. Four soil profile classes—Saa, Yaoundé, Mbalmayo and Ebolowa--with distinctive physicochemical properties, form a north- south fertility gradient. Annual precipitation falls in a bimodal pattern and ranges from 1350 mm to 1900 mm, with an increasing precipitation gradient from the northwest to the southeast.

Cameroon's National Environmental Management Plan (NEMP) divides the country into 4 major ecological regions—the Sudano-Sahelian zone in the far north, the savanna zone, the coastal-marine zone and the tropical forest zone. Within these regions, NEMP further subdivides the tropical forest zone into the degraded forests of the Center and Littoral Provinces and the dense humid forests of the Southwest, South and East Provinces. Lettuce (1985) provides a more disaggregated classification of the humid forest, dividing the zone into 16 evergreen types and 4 semi-deciduous types. An intermediate classification, used by Garland (1989) and building on Lettuce's divisions, groups the humid forest zone into 4 types of climax vegetation:

1. dense moist evergreen Atlantic forest, which is further subdivided into the coastal and Barren forests,
2. Cameroon-Congolese forest,
3. semi-deciduous forest, and
4. mangrove forests.

For the purposes of this study we choose to use this latter classification because of the important distinctions in biodiversity richness across these classifications (Table 1).

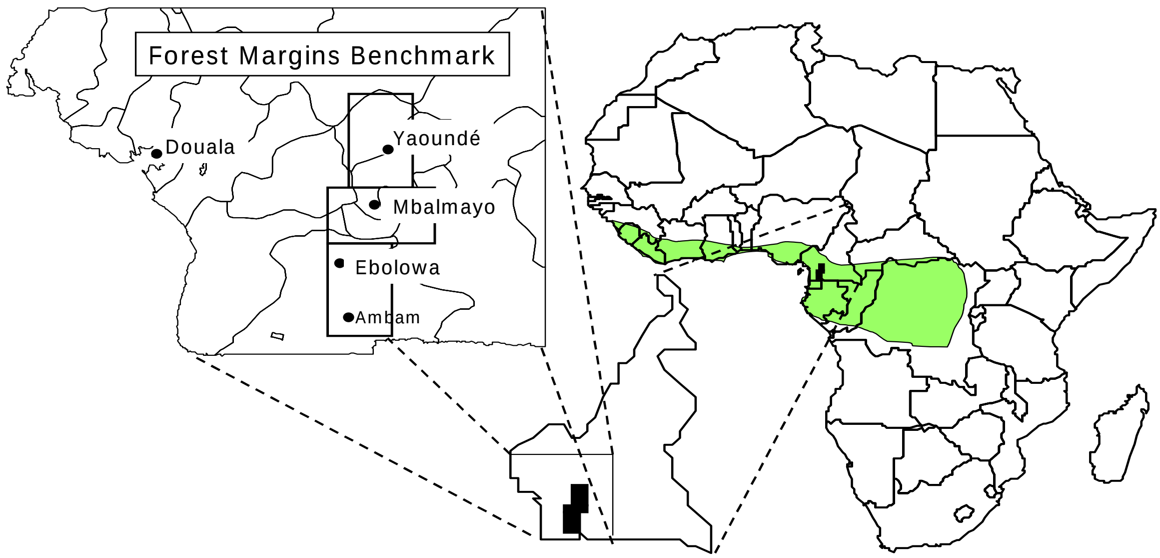

Fig. 1: **ASB forest margins benchmark in southern Cameroon.**

The coastal forests lie between the mangrove forests and the Barren forests and are characterized by an abundance of the dense hardwood *Lophira alata* (Azobé),
+ which is one of the most important commercial timber species. The abundance of this species is tied to human influence, as it thrives in clearings. Because of relatively easy access to the Douala port, these coastal forests have been logged several times and are a now relatively depleted source of timber resources.

In terms of floral diversity, the most important of these forest ecotypes is the Barren forest. Over 200 plant species have been counted within a 1 000 m^2 transect of the Barren forest, which purportedly represents a higher plant diversity than any other forest in Africa or Southeast Asia and is greater than most South American forests (Garland 1989). The Barren forest is a center of genetic diversity for important genera such as *Cola* spp., *Diospyros* spp. (ebony) and *Garcinia* spp. (which includes the bitter cola). These forests, which were Pleistocene refuges, are also characterized by a high number of endemic species.[1] There are also certain plant species that show affinities to the forest communities found along the Atlantic coast of South America. These forests are under high human population pressures. The most important conservation reserve of this forest ecosystem is the Korup National Park in the Southwest Province.

[1] During the Pleistocene ice age, the climate of central Africa was much drier and large areas that are now forested were covered by savanna.

Table 1. Floristic characteristics and extent of moist forest ecotypes in Cameroon.

Type of forest ecosystem	*Area km²*	*Biological characteristics*
Afromontane	725	Height 15-25 m, evergreen, high endemism but relatively low species diversity, important reserve of Prunus africanus.
Guineo-Congolian	267 000	
A. Submontane forest	3 775	Lies between 800-2200 m in elevation, increasing diversity of epiphytic flora with elevation, Prunus africanus found at higher elevations, biology of ecosystem not well known compared to lowland and montane forest systems.
B. Dense humid evergreen Atlantic forest (Barren)	54 000	Very high floristic diversity with marked endemism, flora with affinities to South American forests, and center of diversity for various plant taxa including the genera *Cola, Diospyros, Garcinia* and *Dorstenia.* Barren forest type characterized by gregarious associations of Caesalpiniaceae.
C. Dense humid Cameroon-Congolese forest	81 000	Intermediate in floristic diversity between the Atlantic forest and the semi-deciduous forest, flora affinities with Congo basin forests. Important ecosystem for large primates and elephants.
D. Dense humid semi-deciduous forest	40 000	Often fragmented, subject to fire during the dry season, particularly rich in commercial timber species although less biologically diverse than other tropical forest types.
Mangrove	2 434	Dominated by red mangrove *Rhizophora racemosa* with lesser occurrence of white mangrove *Avicennia nitida,* found on the coast to the east and west of Mount Cameroon, some ecological damage (eutrophication) as a result of large scale industrial plantation fertilizers and pesticides. Tree growth is correlated with rainfall. In coastal areas to the north of Douala red mangrove heights can reach 25 m.

Source: UICN 1994

The Cameroon-Congo and the semi-deciduous forest, which are widespread in the southeast of the country, have a much lower rate of plant endemism than Barren forest, but they are especially important in terms of charismatic faunal diversity in the southeast corner of the country, where large tracts are uninhabited. Most of Cameroon's estimated 25,000 elephants reside in these forests. Densities of 2.8 elephants km^{-2} and 3.2 gorillas km^{-2} were estimated within the 225 000 ha proposed park of Boumba-Bek, with park populations estimated at 6 524 ± 2 586 elephants and 7 233 ± 2 097 gorillas (Ekobo 1995). These are among the highest densities reported for the Congo basin.

As with plants, the amount of diversity with regard to fauna and fish species is, in general, higher in the humid forest zone of Cameroon than elsewhere in the country. Of the 250 mammalian species in Cameroon, 162 exist in the moist forests, with 132 of these species found only in this habitat. Similarly, of the 542 fish species identified, 294 exist in the freshwater resources of the moist forest zone, of which 78 are endemic to Cameroon (Vivian, 1974). The number of fish species in Cameroon is greater by twofold than the total in all of Europe.

The climax vegetation in the Forest Margins Benchmark is of two main types: the dense semi-deciduous forests characteristic of the Yaoundé block extending southwards into the Mbalmayo block, and the dense, humid, Congolese forest in the southern reaches of the Mbalmayo block extending to the Ebolowa block. In addition, there are small pockets along the western border of the Ebolowa and Mbalmayo block that are characterized by the biologically diverse, moist, evergreen, Atlantic forest.

Agricultural systems in the Forest Margins Benchmark

The most important food cropping system in the benchmark is the groundnut/cassava-based mixed food field, which largely guarantees household food security, and, in areas with market access, generates marketable surpluses. Women farmers manage this system, which is typically planted twice—in March-April and again in August-September. The next most important system and the largest source of household agricultural revenues are cocoa plantations. Men mainly manage these systems, although, in certain instances, widowed household heads also manage such systems. The third most frequently encountered field system (70 % of surveyed households) is the plantain/banana field. In the southern portion of the benchmark where population pressures are low, the plantain/melon-based (*Cucumeropsis mannii)* field is frequently encountered. Both the plantain- and plantain/melon-based fields are generally targeted to longer period fallow fields and secondary forests. Input intensive, monocrops of horticultural crops and maize for the fresh market are frequently encountered in the Yaoundé block, which has the best access to urban markets of the three blocks. These horticultural systems have spread rapidly within the last 20 years. Another process associated with increasing resource use intensification and farming systems diversification is the differentiation of field types (Gockowski and Baker 1996). ASB survey results reveal that 62% of the households in the Yaounde block had 5—8 distinct field types, versus only 28% and 44% in the Mbalmayo and Ebolowa blocks, respectively.

Farms in the benchmark are generally small and fragmented. The average number of annual crop fields is slightly more than 4. The mixed groundnut field, which is the most predominant annual food field, has an average size of slightly over 1,300 m^2, according to the unpublished Ministry of Agriculture field measurements conducted in the 1980s. The mean annual land cover in productive agricultural land use (does not include fallow fields) was 2.6 ha per household in the Yaounde block, 2.4 ha in the Mbalmayo block, and 3.6 ha in the Ebolowa block. Roughly fifty percent of this area is accounted for by complex cocoa agroforests.

The livestock sector is not well developed in the benchmark. Cattle raising is practically non-existent because of the tsetse fly, and smallstock and poultry production is generally practiced in a free range and extensive fashion. The only significant commercial production occurs in the urban peripheries of Ebolowa, Yaounde and Mbalmayo, where intensive and semi-intensive commercial pork and poultry farms are found. In high population density areas, crop damages from free-range smallstock are not tolerated, and fencing of home gardens or tethering of animals occurs.

Farmer-elicited production constraints vary systematically with the level of resource use intensification. In the high intensity Yaounde block, grassy weeds, maize stemborers and poor soils are the most frequently cited farmer problems. The increased citation of poor soils in the Yaoundé block reflects the lower level of woody biomass available in these farming systems as ash fertility input following slash-and-burn techniques, although in terms of CEC, pH, and soil structure, these soils are generally much better than those of the Ebolowa block. In the lower intensity Ebolowa and Mbalmayo blocks, rodents and other animal pests, broadleaf weeds and grassy weeds are more frequently cited (Gockowski et al. 1998a).

Using ASB household survey results and secondary data, land cover and land planted in 1994 were estimated (Gockowski et al. 1998a). Across the benchmark, 24.8% of the total land area is estimated to be in some agricultural use (including fallow fields), with significant differences across blocks. Slightly over 100,000 ha of fallow were cleared annually to create food crop fields, representing approximately 3.3% of the total land area. The predominant productive land use system was cocoa, accounting for 3.8% of total land area in the benchmark and representing 48% of total productive agricultural land use. Food crop systems accounted for the rest of the productive land use, led by the groundnut-cassava mixed crop field followed by the melon-based and plantain-based systems. Remote sensing estimates found 58.9% of land in the Ambam area of the Ebolowa block still in primary forest cover, versus 22.0% around Ebolowa, 5.3% around Mbalmayo and only 3.7% around Yaoundé (Thenkbail 1999). The remote sensing images also revealed the invasion of *Imperata* grasslands in portions of the Yaounde area.

The socio-economic context of farming systems in the Forest Margins Benchmark

Institutions and infrastructure are in general much better developed in the Yaoundé block, where population densities are higher, than in the Mbalmayo or Ebolowa blocks. The remote sensing estimates indicate a rural road density in Yaounde that is three times the density in the Ambam area. Institutional development is also more evolved in the Yaoundé block, where traditional customary land tenure institutions are evolving gradually towards individualistic, legally-recognized land ownership characterized by cadastral surveys and an increased incidence of land titling (IITA unpublished data). Among the important institutional cross block differences is the development in the Yaoundé block of a fairly competitive marketing system for both outputs and inputs. Farmers, in general, have easy access to purchased inputs, which are heavily applied by both cocoa (fungicides and insecticides) and horticultural (fungicides, insecticides and fertilizers) producers.[2] In the rest of the benchmark, farmers can spend more than a full day in acquiring inputs.

Institutional constraints in the Ebolowa and Mbalmayo blocks have major implications for agricultural intensification, which will require innovative policy-led interventions to overcome. The weakness of technology generation and diffusion institutions are also a major institutional problems that affects almost all the benchmark. The national agricultural research system has had no operational budget for over 14 years, and, as a result, the flow of innovations has slowed considerably. The seed technology diffusion system is underdeveloped, with almost no private sector involvement (with the exception of imported horticultural seeds and imported hybrid maize from South Africa). The most important crops at the household level are vegetatively propagated (cassava, plantains, cocoyams, yams, and sweet potatoes), which inhibits private sector involvement in varietal development and diffusion. The extension service has recently been reinvigorated through a World Bank-sponsored training and visit program, but there are major questions about sustainability once project funds are no longer available, as well as concern over a lack of appropriate technologies.

One of the most rapid changes affecting the agricultural sector throughout the Congo basin has been the tremendous growth in urban populations. Both Douala and Yaoundé have grown at rates of over 6% in the years since independence, which means that the number of urban consumers is doubling roughly every 12 years. The most important single market in the benchmark is Yaoundé, with over a million inhabitants. The largest food commodity markets in terms of value are plantains, cassava and cocoyams. Approximately 80 % of the total

[2] A recent survey of tomato producers in one of the IITA research villages in the Yaoundé block found that 76% purchased their pesticides and 82% their fertilizers from a farm chemical supply store located within the village limits (IITA 1999 unpublished data).

tonnage sold in Cameroon of these three crops is produced in the humid forest zone (MINAGRI survey statistics, 1984-1990). The rapid evolution in urban food demand is increasing income opportunities from food crops and encouraging the diversification process, especially in areas where market access and infrastructure are adequate. Nonetheless, food crop revenues are still dwarfed by cocoa and robusta coffee revenues across the forest zone. Prior to the collapse in coffee and cocoa prices in the late 1980s, revenues from these two crops were estimated to be three times larger than all combined food crop sales from the humid forest provinces of Cameroon. They still tend to comprise the largest portion of household income, although their relative share has probably fallen.

In general, households in the Yaoundé block face higher land pressures (as measured by the ratio of annual crop fields to fallow fields) and have intensified their production systems to a much greater degree than households in the Mbalmayo or Ebolowa blocks. This is a result of high population densities, good rural infrastructure resulting in excellent urban market access, and the greater development of market institutions. The intensification process in the Yaoundé block is comprised of numerous elements, including an augmentation of purchased inputs (agrochemicals and labor), increased tillage practices such as ridging and mounding, crop management strategies (planting in rows, use of improved varieties, mulching, new crop sequences), and an increasing differentiation in field types targeted to specific spatial and temporal niches (Gockowski et al., 1998a). Commercialization strategies across households are also a function of the intensification process. Intensively managed horticultural production systems are an important strategy for households in the Lekie division of the Yaoundé block. At the opposite end of this dimension are households which pursue an extensive production strategy, using almost no purchased inputs or management innovations to produce plantains and cocoyams for the market. These households tend to be located in areas of abundant land and long fallow resources. Increasing the land and labor productivity of extensive plantain/cocoyam systems would deflect smallholder pressures on the forest margin, as this is one field type that is often targeted to converted secondary forest. Another cross block difference in livelihood strategies is the decreasing time allocated to natural resource-based activities such as non-timber forest product gathering, fishing, and hunting, as forest resources degrade. Households in the Yaoundé block devote a much smaller portion of their effort to such activities. Conversely, there are increases in non-farm employment in the Yaoundé block, where the non-agricultural rural economy is better developed.

Sectoral and macroeconomic policy reforms since the late 1980s have had important impacts on slash-and-burn agricultural systems. Most of these reforms occurred in the cocoa and coffee sectors, with the state disengaging and liquidating the national marketing board for these crops during this period. At the same time, fertilizer and pesticide subsidies (ranging from 60 to 100%) were removed. Most of these reforms were driven through as part of a structural adjustment package with the World Bank and the IMF, in an effort to help the Cameroon government diminish massive internal and external deficits. Unfortunately, these reforms took place in the context of, and, indeed, were necessitated by, an overvalued FCFA and depressed world commodity markets. As a result, cocoa and coffee producers in Cameroon faced historically low producer prices and, in response, neglected their plantations and shifted resources into the production of plantain, cocoyams and horticultural production, in order to make up for the declining profitability of coffee and cocoa. This put significant additional pressure on the forest margins as new forest lands were cleared and brought into annual food crop production (Gockowski et al., 1998b).

Domain definition and problem identification in southern Cameroon

The Cameroon benchmark encompasses a gradient in resource use intensity (see Fig. 1). At one end is the Ebolowa block, with a low population density (around 5 people/sq. km) and large tracts of intact primary forest (59% of land cover). Cocoa is the primary source of farm income, with food crops mainly grown to meet subsistence needs. There is still significant reliance on natural resource-based activities, e.g. bushmeat hunting and gathering of non-timber forest products. Local agricultural markets are comparatively small, agricultural input markets are underdeveloped, and road infrastructure is poor and not maintained. During the rainiest period of the year, roads can become impassable. At the other end of the resource use gradient is the Yaoundé block, with an average spatial population density of around 80 persons km^{-2} and most of the land in some phase of an agricultural cycle; only 4% of land remains covered by primary forest. Land constraints at the household level result in shorter fallow periods. Proximity to the Yaoundé market, better-developed market institutions, and rural infrastructure have led to a process of agricultural intensification, diversification and commercialization. At the same time, the stock of forest resources has been seriously degraded (declines in carbon stocks, biodiversity and watershed functions). The southern and northern parts of the benchmark area represent distinct resource use domains shaped by the significant differences in farmer, village and regional circumstances, with great variation in the opportunities for and constraints to environmental protection and income generation.

In areas of low population density, such as the southern benchmark area, where large tracts of forest still exist, policies and practices should be geared towards sustainable utilization and conservation of forested land to improve rural livelihoods and environmental values. A multi-level and multi-sectoral approach is needed. At the household level, policies to encourage agricultural intensification are needed to overcome the divergence between the farmer's valuation of forest woody biomass resource as a fertility input and the societal value of a forest (timber revenues, environmental values, and intrinsic value). The low use of fertilizers in most of the Congo basin reflects, in part, this divergence. Macro-policies should also try to encourage households to adopt land-use practices such as the cocoa agroforestry that minimize environmental degradation and reduces poverty. Intensification of existing cocoa agroforests rather than further expansion of these systems is also indicated. At the village/clan/community level, the improved management of common pool resources and community forestry can improve livelihoods and generate communal benefits. Village-level multiplication of improved varieties of vegetatively propagated crops such as plantains, cassava and cocoyams could rapidly increase returns to land and labor. Policies to intensify production and increase land productivity at the household level must be supplemented by industrial policies that provide employment opportunities which are more attractive than agriculture along the forest margins. Migration policies need to guard against an influx of migrants into forested areas. This is a particular threat with the rapid increase in tropical logging in the East Province, which is opening up previously uninhabited forest tracts to human influence (mainly still restricted to logging and game poaching). Maintaining these tracts for sustainable timber production is high on the list of government priorities and will require supportive policies to limit the intrusion of agricultural migrants.[3]

Policy-led intensification at the household level should focus on the two major components of farming systems: perennial crop agroforests and slash-and-burn food crop production systems. Intensifying food production in the low population domain requires focusing first of all on

[3] Timber exports are now the leading agricultural export and are projected to surpass oil revenues as the principal source of foreign exchange within the next 5 to 10 years.

constraints and opportunities at the household and community level. In general, farmers in Ebolowa do not perceive soil fertility to be a major constraint for food crop production because they operate extensive crop-fallow rotations in which the fallow period is still sufficiently long for restoring fertility. However, for many households this increase in fertility comes at the cost of additional labor input for clearing. Innovations such as planted improved fallows which can maintain fertility may have a niche if the labor for clearing these fallows is significantly lower than for natural fallow; this niche may be especially attractive among widowed household heads and households with a lack of youthful male labor for clearing. The primary emphasis in this domain should be on perennial crop production systems. They not only protect the fragile topsoil but can also contribute to maintaining intermediary levels of carbon stocks and biodiversity. The institutional support for perennial crop systems needs to be improved.

The issues in the high population pressure domain typified by the northern part of the benchmark area are different. Ways have to be found to increase already low carbon stocks and biodiversity in a land-constrained situation. Income is already diversified through more specialized annual cropping systems. Soil degradation and crop protection urgently need to be addressed. Annual crop systems have to be made more productive and sustainable. If this can be achieved, then it may be possible to put aside land for specialized perennial systems (e.g. cocoa-fruit agroforests) and to protect pockets of forest in order to increase carbon stocks and maintain a minimum of biodiversity across the landscape.

Environmental concerns are not foremost among most small farmers in the benchmark. Increasing income and wellbeing are their primary goals. Global concerns with conservation and restoration of carbon stocks and biodiversity are only possible to achieve if they are linked to adequate income-generating opportunities and appropriate institutional support. Since farmers' private costs of using slash-and-burn farming techniques does not include environmental costs, corrective policies including subsidies for the intensification process, may be required.

Land use systems and evaluation methodology

In order to conduct the tradeoff analysis between environmental and development concerns, ASB tabulated measures of the performance of the major land use systems as well as several emerging alternatives with respect to a number of ecological, agronomic, social, economic and institutional parameters. A matrix table of land-use systems (rows) by performance parameters (columns) was the result. (Table 21.)

The predominant land use systems in the benchmark (including extant alternatives to slash-and-burn systems such as cocoa agroforests) were evaluated in terms of environmental parameters, agronomic sustainability, and socio-economic performance. The environmental parameters measured were carbon stocks, plant diversity, soil fauna diversity, and greenhouse gas emissions. Agronomic sustainability focused on soil structure, nutrient balances, and crop protection issues. The socio-economic performance included measures of profitability, labor intensity, food security issues, institutional requirements and equity biases. More details on specific methodologies are included with the discussion below.

Seven "alternative to slash-and-burn" land use systems (LUS) were evaluated and compared to the two dominant slash-and-burn crop-fallow rotations in the benchmark area. The alternatives included 4 variants of the widespread cocoa agroforests (an estimated 75% of households in the benchmark have these systems, with the mean area per household estimated at 1.3 ha) and two variants of hybrid oil palm plantations, which are gaining in importance as a smallholder option across the benchmark.

The alternatives considered, their distinguishing characteristics and the assumptions made for purposes of analysis are:

1. **Intensive cocoa with mixed fruit tree shade canopy planted to short fallow.** The level of management, fungicides and insecticides in this cocoa production system represents the higher end of the existing intensification gradient found within cocoa agroforests in southern Cameroon; these systems tend to be in areas of more pronounced land pressures and are associated with good market access. A description of this and other cocoa agroforests can be found in (Duguma and Gockowski 1998) and (Gockowski and Dury 1999). The cocoa shade canopy includes a productive component of fruit trees composed of avocado, mango, African prune (*Dacryodes edulis*), and mandarin oranges. Cocoa yields are assumed equal to 500 kg ha^{-1} at maturity and total fruit off-take equal to 920 kg ha^{-1}. For purposes of evaluation, it was assumed that this system was established in a *Chromolaena odorata* fallow of 4 years duration with intercropping of groundnuts, maize, leafy vegetables, plantains and cocoyams during the first three years of establishment.

2. **Intensive cocoa with shade canopy planted to short fallow.** This is the same land use as above, with the exception that fruit trees are not a commercial component due to limited market access.[4]

3. **Extensive cocoa with mixed fruit tree shade canopy planted to forest land or long fallow.** This system represents the extensive cocoa production systems more characteristic of the less populated areas of the benchmark, that are, however, characterized by relatively good market access.[5] Fruit tree composition and use were assumed the same as (1) above. Fungicide use was assumed to be 50% of the intensive cocoa systems with no control of capsid bugs.[6] Cocoa yields were assumed equal to 265 kg ha^{-1} at maturity and total fruit offtake equal to 920 kg ha^{-1}. This system was assumed to be established from forested land or a long fallow with intercropping of plantain, cocoyam and melonseed during the first three years of establishment.

4. **Extensive cocoa with shade canopy planted to forest land or long fallow.** The same as No. 3 with the exception that fruit trees are not a commercial component.

5. **Improved *Tenera* hybrid oil palm system planted to short fallow.** Hybrid "*Tenera*" variety of oil palm is produced in a monoculture at a planting density of 143 trees ha^{-1}. *Chromolaena odorata* fallow of 4 years duration is converted with intercropping of groundnuts, maize, leafy vegetables, and cocoyams during the first year of establishment. Yield per hectare was assumed to be 7500 kg ha^{-1} at maturity.

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[4] It was pointed out during a country working group discussion that although fruit trees are almost always a component of cocoa agroforests, it is only in areas with easy market access that they assume commercial importance (due to their relatively bulky nature and low value to weight ratio).

[5] Many producers with more intensive systems shifted to these more extensive types of systems when cocoa prices collapsed in 1989.

[6] The two major agronomic constraints for cocoa production in southern Cameroon are cocoa blackpod disease (caused by *Phytophthora megakarya*) and capsids (plant sucking bugs belonging to Miradeae); without control they typically reduce yields by more than 50%.

6. **Improved *Tenera* hybrid oil palm system planted to forested land or long fallow.** The hybrid "*Tenera*" variety of oil palm is produced in a monoculture at a planting density of 143 trees ha^{-1}. Forested land is converted with inter-cropping of plantain, cocoyam and melonseed during the first two years of oil palm establishment. Oil palm nut yield per hectare was assumed to be 8000 kg ha^{-1} at maturity.

7. **Community-managed forest.** The concept of community forests in the forest margins benchmark is amorphous and a function of availability (high to low) and the condition of the forest (virgin to degraded) and the governing institution. A statutory definition is in the process of evolving, following the 1994 forestry law which defined a procedure through which communities can gain legal tenure to forest tracts of 5,000 ha. This tenure permits a community to legally harvest and sell timber (it is currently illegal for a farmer to cut down and sell timber growing on his land even if he has legal title to the land; he may, however, harvest it for his own construction purposes). Another concept of the community forest is found in the community's livelihood dependence on the common property resources in forested land. The forest and the local institutions governing the exploitation of its natural resources (wild fruits, honey, building materials, rattan, fish, game, and medicinal plants) are the defining parameters of this alternative concept.

The above perennial *alternatives to slash-and-burn* systems were compared to the two predominant annual food crop systems:

8. **Intercropped food field planted in a short fallow.** This is the typical mixed food crop system of southern Cameroon that is managed by women. The chief role of this crop system is to feed the household by marketing of food surpluses which are increasing in importance as market access improves. Surplus revenues tend to be controlled by women. The two dominant crop are groundnuts and cassava; other crops in lower densities that are often associated include cocoyams *(Xanthosoma sagitiilium)*, maize, leafy vegetables *(Solanum nigrum* complex, *Corchorus spp.*) and plantains for purposes of analysis. The field was assumed to be converted from a four year *Chromolaena odorata* fallow and yields to be representative of typical farmer results.

9. **Intercropped food field planted in a long fallow**. Melonseed (*Cucumeropsis mannii*), plantain, maize and cocoyam are planted into a 15 year fallow field. Although both male and female labor are used in this field system, the cash income from this field tends to be controlled by men. This field type became a major commercial alternative for cocoa farmers when cocoa prices collapsed in 1989.

Together these last two cropping systems account for an estimated 75% of all annual and biennal cropland in the benchmark area (Gockowski et al. 1998a).

There are several other important land use systems that were not evaluated by ASB Cameroon. These include shaded robusta coffee systems, industrial plantations of oil palm and rubber, horticultural cropping systems, and various inland valley systems.

Shaded robusta coffee *(Coffea canephora*) systems are very important in the Congo basin, especially in the Democratic Republic of the Congo where there are over 230,000 ha of smallholder plantations. Unfortunately, robusta coffee is very limited in extent within the Forest Margins Benchmark, and environmental measures from these systems were not obtained. These systems resemble shaded cocoa systems in terms of their environmental parameters. The yield is typically low, on the order of 200 to 300 kilograms ha^{-1} of green coffee annually. A major limiting factor in these systems is the lack of improved genetic materials. Most of the tree stock has been produced from highly variable seedling. Improved clonal material developed by research in the region is capable of producing 1,500 tons when fertilized and grown in full sun conditions. Farmers, however, have very limited access to these materials because of government failures in distribution and the lack of private sector initiative.

Industrial plantations of rubber (*Hevea brasiliensis)* and oil palm (*Elaeis guineensis*) are found around Mount Cameroon in the Southwest Province and along the coast in the South Province. These systems were not included in the study largely because they are no longer expanding their operations to any significant degree and are no longer a driving force of deforestation. In the last 15 years, small and medium sized plantations of rubber have developed in northern Gabon in the area around Oyem. While it would have been interesting to compare these systems with the rubber systems of Sumatra, the logistics and expense of traveling to Oyem were prohibitive. With the declining production in Malaysia, and as industrialization continues in Indonesia, it is likely that African producers of *Hevea* will find the economics of production to be increasingly attractive.

Horticultural cropping systems are an important land use in the Lekie Division within the Yaoundé block of the benchmark, with an estimated 10,000 to 12,000 ha planted annually. An adoption study of intensive horticultural production within the urban periphery of Yaoundé (radius < 90 km) found that 65% of households had adopted input intensive, monocrop systems of tomatoes, okra, hot peppers, green maize production and, in the immediate urban periphery (radius < 25 km), highly perishable leafy vegetables (*Solanum nigrum, Corchorus olitorus,* and *Amaranthus hybridus*) (Gockowski and Ndoumbé, forthcoming). These systems are subject to high pest and disease pressures, and fungicides and insecticides are sprayed up to two times weekly. These commodities tend to be high value vis-à-vis staple food crops and have replaced cocoa as the most important source of revenues in many villages close to Yaounde. However, their importance in the rest of the benchmark is extremely limited by the underdeveloped input supply sector and market access.

Inland valley land-use systems were also neglected. The predominant crop in these systems is inland maize, produced in the dry season when prices can more than triple for fresh maize in urban markets. Other usage of these valleys include lowland rice cultivation, aquaculture, and dry season cropping of horticultural crops. Relative to the uplands, inland valleys are underexploited and offer potential for development. The reasons that have limited their exploitation by the farmers of the region merit investigation.

Global environmental parameters of the ASB land use systems

This section summarizes the findings on environmental parameters of global concern—namely biodiversity and global climate change variables. Measures of plant diversity and below-ground micro- and macrofaunal diversity, carbon stocks, and greenhouse gas emissions were made for each of the predominant land-use systems. Because sample sizes were limited and the typology of cocoa agroforests used to evaluate economic returns was not included explicitly in the sampling frame, the environmental parameters are only reported for a generic cocoa agroforest, based on a random sample of six cocoa agroforests across the benchmark. Ongoing work at the IITA Humid Forest Ecoregional Center on these complex systems is revealing a great deal of variation in biodiversity and carbon values. The results presented here, while probably capturing the mean difference across land use systems, need to be augmented with further measures within systems to better understand the causes of variation (management, biophysical, landscape ecology) and its consequences for the productivity of the system. In the case of cocoa agroforests for instance, the more heavily shaded systems are likely to be more affected by cocoa blackpod disease, while less affected by capsid insects. Both are major pests of cocoa that reduce yields. However, cocoa blackpod only reduces yields, while capsids can caused a significant deterioration/depreciation of the farmer's tree stock investment by destroying the plant. The more heavily shaded agroforests are more likely to have higher environmental parameters. The prelimary findings of ASB presented here have served to catalyze this line of research in Cameroon.

Carbon stocks

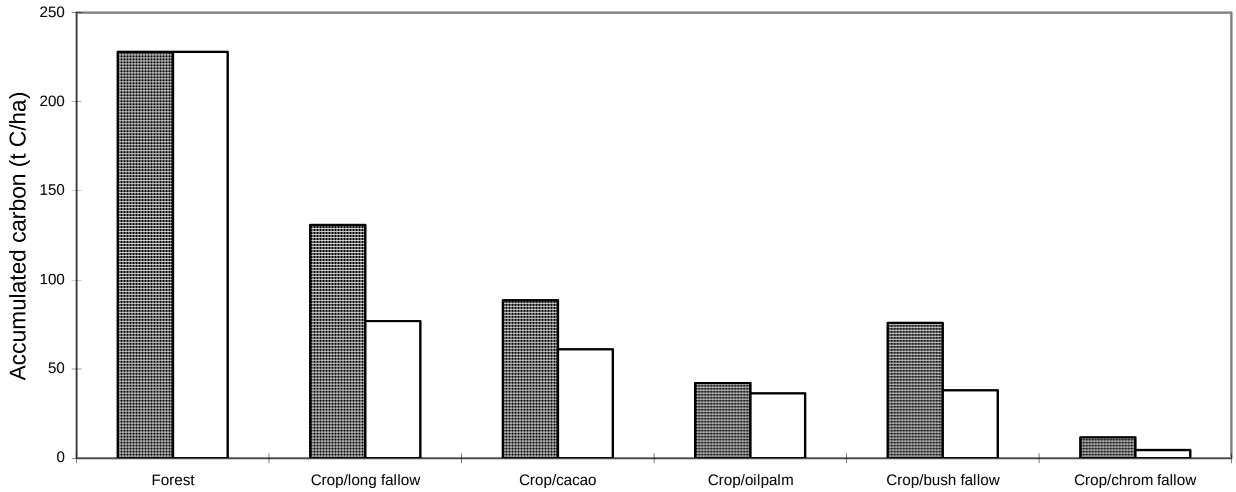
Carbon stocks were sampled using the methods described in the Climatic Change Working Group final report, Phase II (ref). Forests were used as the basis for comparison. The Carbon stocks (above-ground vegetation and litter) of the 6 selectively logged forests sampled in Cameroon averaged about 228 t C ha^{-1}, ranging from 193 to 252 t C ha^{-1}. This value was compared to data for the following land-use systems (Figure 2).

1) Annual cropping phase of 2 years followed by 4 years of chromolaena fallow,
2) 2 years cropping followed by either 9 or 23 years of bush-tree fallow,
3) 2 years cropping followed by establishment of cocoa (jungle cocoa) over 25 years,
4) A 40 year rotation versus a non-rotational cocoa system established through gap and understorey plantings of cocoa,
5) one year cropping followed by establishment of an oil palm plantation with 146 trees ha^{-1} with a 7 year establishment phase and a 25 year rotation.

The maximum C stock attained in the various crop-fallow systems was 167 t C ha^{-1} for the traditional long fallow. The amount is reduced by more than half, to 76 t C ha^{-1}, if the fallow is shortened to 11 years, and further reduced to 12 t C ha^{-1} with the 4 year chromalaena fallow. The time-averaged C stocks of these crop-fallow rotations are 77, 32, and 5 t C ha^{-1}, respectively. A mature jungle cocoa stand contains about 43% of the C of the forest, ranging from 54 to 131 t C ha^{-1}, with an average of 89 t C ha^{-1}. If the jungle cocoa system is established simply by clearing the understorey and planting cocoa, then the time-averaged carbon of this non-rotational system is the same as the carbon stocks measured. If the system is established through slash-and-burn clearing and cropping, followed by planting of cocoa with a 25 year establishment phase and total rotation time of 40 years, the time-averaged carbon is 61 t C ha^{-1}. The maximum C and time-averaged C of an oil palm plantation with a 7 year establishment phase and rotation time of 25 years are about half that of the cocoa system.

The rates of C accumulation (sequestration rates) varied with age of the fallow; beginning with 2.89 t C ha^{-1} the first two years when chromolaena dominated, increasing to 8.5 t C ha^{-1} for the next 6 to 10 years. The overall accumulation rate during the traditional long shifting cultivation fallows was 7.26 t C ha^{-1}. The C accumulation rate of the rotational jungle cocoa was only half that of the natural fallow systems, whereas that of the oil palm plantation was similar at 6.03 t C ha^{-1}. The rates of C accumulation are quite high compared to most reported for the humid tropics, but they do fall within the range measured by Szott et al., (1994).

Fig. 2: **Maximum C stock (Cmax) and land use time-averaged C (LUSCta) for the different ASB land use systems.**


Accumulated carbon (t C/ha)
250
200
150
100
50
0
Forest
Crop/long fallow
Crop/cacao
Crop/oilpalm
Crop/bush fallow
Crop/chrom fallow

Greenhouse gas emission

Green house gases (N_20, $C0_2$, CH_4) were sampled in five land cover types in Cameroon (Table 2). Samples were taken only once during the rainy season in April 1997, according to the ASB protocol in use at that time. The same land use cover types were sampled in three different villages, Nkofulu, Awae and Mengomo. There were no significant differences in the gas fluxes from the different land use cover types. The sampling protocol was subsequently revised, to better account for high temporal variability and fluctuations and intensive monthly sampling has been tested in Indonesia and Peru (Palm, C. et al. 1999).

Table 2. Greenhouse gas emissions of various land cover types in Cameroon.

Land cover		Gas emission	
	$FC0_2$ ($\mu g\ m^{-2}hr^{-1}$)	FN_20 ($\mu g\ m^{-2}hr^{-1}$)	FCH_4 ($\mu g\ m^{-2}hr^{-1}$)
Secondary forest (> 15 years)	719	112.80	-5.59
Old Chromolaena fallow (> 8 years)	702	59.81	-8.32
Young Chromolaena fallow (2 - 4 years)	836	48.41	9.00
Cocoa plantation	739	136.33	-8.51
Forest food crop field	771	207.59	-9.97

N_20 → Forest food crop < plantation//Forest < Young fallow

Above-ground biodiversity

The aim of this part of the ASB research is to explore methods of rapid resource appraisal with respect to biodiversity and to provide a cost-efficient method that can be readily transferred to stakeholders concerned with integrating natural resource management.

Visits were made to field sites at Mengomo, Akok, Mbalmayo, Awae, Nkol Foulou, Nkometou, Bafia and Batoum II, over a range of about 500 km from humid forest to savanna. The scientists recorded 18 plots, focusing mainly on a range from *Imperata* grasslands and *Lophira* & *Butyrospermum* shrub savanna, through different slash-and-burn fallow sequences, to closed-canopy (mostly secondary) forest. Included were 'Jungle' Cocoa plantations and sedentary fallows dominated by *Chromolaena odorata*. To these were added three plots recorded from an earlier reconnaissance visit in 1996. Site physical and locational data are listed in Table 3, plant species, PFTs and PFT diversity indices (Gillison and Carpenter, unpubl. 1999) are listed in Table 4 and vegetation structure in Table 5. The first ten sites were co-located with Dr Cheryl Palm (TSBF), who made assessments of above-ground carbon. Listings of all species and PFTS collected for each site are contained in Annex II of the Above-Ground biodiversity working group report (Gillison, A.N. 2000). All plot data have been stored in MS ACCESS format and a copy of field sheets was left at IITA Nkolbisson together with copies in electronic media. Copies of the more recent data conversions via PFAPro have been emailed to these repositories.

Data analyses included standard regression measures and exploratory data analysis using the PATN program (Belbin, 1992). In addition to these, a single index that represented key elements of vegetation structure, total plant species, total PFTs per plot and their ratios, was extracted using multi-dimensional scaling (MDS) as described by Gillison (1999) in Box 1. This is termed a "V" index and is an exploratory attempt to seek a relative ranking of

Table 3. Site location and physical features for Cameroon above-ground biodiversity sampling

Site	Symbols	Location	Date	Observers	Lat. (N)	Long. (E)	Elev (m)	Slope (%)	Aspect (Deg)	S_Dpt (cm)	Ltr (cm)	Terrain Unit	Soil Type
CAM01	15 ○	AWAE Village	30-May-97	AG/MN/ZL/BS/Ka/NT	03-36-05	11-36-15	657	0	0	>100	4	Plain	Ultisol
CAM02	2 ●	AWAE	30-May-97	AG/MN/ZL/BS/Ka/NT	03-36-05	11-36-15	657	0	0	>100	8	Plain	Ultisol
CAM03	+	AWAE	30-May-97	AG/MN/ZL/BS/Ka/NT	03-36-05	11-36-15	657	0	0	>100	0	Plain	Ultisol
CAM04	12 ●	AWAE	30-May-97	AG/MN/ZL/BS/Ka/NT	03-36-05	11-36-15	657	0	0	>100	12	Plain	Ultisol
CAM05	5 ○	NKOL-FULU	02-Jun-97	AG/MN/ZL/BS/Ka/NT	03-55-31	11-35-49	696	6	240	>100	2	Upper slope	Ultisol
CAM06	4 ●	NKOL-FULU MEFOU & AFAMBA Dept.	02-Jun-97	AG/MN/ZL/BS/Ka/NT	03-55-31	11-35-49	696	6	240	>100	1	Upper slope	Ultisol
CAM07	+	NKOL-FULU MEFOU & AFAMBA Dept.	02-Jun-97	AG/MN/ZL/BS/Ka/NT	03-55-41	11-35-49	696	6	240	>100	0	Upper slope	Ultisol
CAM08	12 ○	MENGOMO (Ebolowa-Station)	03-Jun-97	AG/MN/ZL/BS/Ka/NT	02-34-45	07-02-05	554	7	165	>100	6	Upper slope	-
CAM09	2 ●	MENGOMO (Ebolowa-station)	03-Jun-97	AG/MN/ZL/BS/Ka/NT	02-34-37	11-01-29	576	4	340	>100	1	Upper slope	-
CAM10	J △	MENGOMO (Ebolowa-station)	03-Jun-97	AG/MN/ZL/BS/Ka/NT	02-34-37	11-01-29	576	3	275	>100	3	Plain	-
CAM11	2 ●	AKOK (Ebolowa-Station)	04-Jun-97	AG/MN/ZL/BS/Ka/NT	02-42-19	11-16-09	554	0	0	>100	2	Plain	-
CAM12	1 ●	AKOK (Ebolowa-Station)	04-Jun-97	AG/MN/ZL/BS/Ka/NT	02-42-27	11-16-30	554	5	170	>100	0	Upper slope	-
CAM13	4 ●	AKOK (Ebolowa-station)	04-Jun-97	AG/MN/ZL/BS/Ka/NT	02-43-08	11-17-05	585	5	130	>100	2	Upper slope	-
CAM14	2-8 ●	AKOK (Ebolowa-Station)	04-Jun-97	AG/MN/ZL/BS/Ka/NT	02-43-12	11-16-58	585	5	130	>100	2	Upper slope	-
CAM15	P ◇	AKOK (Ebolowa-station)	04-Jun-97	AG/MN/ZL/BS/Ka/NT	02-42-45	11-16-42	559	0	0	>100	4	Plain	-
CAM16	1S ●	BAFIA (20 km after Bafia)	05-Jun-97	AG/MN/ZL/BS/Ka/NT	04-48-58	11-10-27	560	12	50	> 50	0	Upper slope	-
CAM17	D □	MAKAM III - BATOUM II	05-Jun-97	AG/MN/ZL/BS/Ka/NT	05-02-40	10-42-04	977	35	205	>100	0	Upper slope	-
CAM18	1-25 ●	NKOMETOU II	06-Jun-97	AG/MN/ZL/BS/Ka/NT	04-04-51	11-33-17	596	8	195	>100	0	Upper slope	-
CAM19	H ■	Near BAFIA	27-Aug-96	AG/MN/ZL/BS/Ka/NT	04-48-56	11-10-25	640	25	45	>100	0	Upper slope	-
CAM20	▲	NKOLITAM	28-Aug-96	AG/MN/ZL/BS/Ka/NT	03-28-21	11-29-25	0	0	0	>100	0	Swamp	Sandy
CAM21	45 ○	AKOK 'Enuzam'	28-Aug-96	AG/ZL/ Nico-TCHA	02-42-45	11-16-45	550	7	0	>100	3	Upper slope	Sandy clay loam

AG: Andy Gillison; **MN:** Martine Ndogo; **ZL:** Zapfack Louis; **BS:** Bonaventura Sonke; **Ka:** Kanfiani; **Lat:** Latitude; **Long:** Longitude; **Elev:** Elevation; **S_Dpt:** Soil Depth; **Ltr:** Litter

Table 4. Summary data for vascular plant species, PFTs or modi and species/PFT ratio, S/W PFT index, Simpson PFT index*

No.	Site	Symbols	Total Records	Unique PFTs	Unique Species	Unique Species/PFTs	S/W PFT Index	Simpson PFT Index
1	CAM01	15 ○	103	43	103	2.40	0.0789	3.15
2	CAM02	2 ●	61	37	61	1.65	0.0422	3.41
3	CAM03	+	20	19	20	1.05	0.0550	2.93
4	CAM04	12 ●	54	35	54	1.54	0.0418	3.38
5	CAM05	5 ○	50	33	50	1.52	0.0432	3.34
6	CAM06	4 ●	30	22	30	1.36	0.0556	3.00
7	CAM07	+	14	12	14	1.17	0.0918	2.44
8	CAM08	12 ○	93	42	93	2.21	0.0517	3.36
9	CAM09	2 ●	76	47	76	1.62	0.0461	3.55
10	CAM10	J △	80	47	80	1.70	0.0372	3.59
11	CAM11	2 ●	71	50	71	1.42	0.0395	3.65
12	CAM12	1 ●	78	55	78	1.42	0.0256	3.85
13	CAM13	4 ●	100	66	100	1.52	0.0228	4.01
14	CAM14	2-8 ●	61	44	61	1.39	0.0309	3.65
15	CAM15	P ◇	63	43	63	1.47	0.0426	3.52
16	CAM16	1S ●	51	37	51	1.38	0.0358	3.49
17	CAM17	D □	47	41	47	1.15	0.0267	3.67
18	CAM18	1-25 ●	45	29	45	1.55	0.0528	3.17
19	CAM19	H ■	25	18	25	1.39	0.0656	2.81
20	CAM20	▲	57	29	57	1.97	0.0612	3.08
21	CAM21	45 ○	57	41	57	1.39	0.0360	3.55

* S/W = Shannon-Wiener diversity index for PFTs; Simpson's diversity index for PFTs (Gillison and Carpenter, unpubl.)

Table 5. **Vegetation structural data**

Site	Vegetation	M_Can	CC	CW	CNW	Wdy	Bry	Litter	M_BA	M_FI	FI CV%
CAM01	Not previously gardened; very disturbed; secondary forest. Logged 15 yrs	20.00	70	0	0	7	3	4	18.00	26.25	88.24
CAM02	2 year *Chromolaena* fallow	2.50	95	0	0	9	2	8	2.00	100.00	0.00
CAM03	New garden with groundnut, Cassava	0.40	5	0	0	2	1	0	0.50	90.50	32.31
CAM04	8-10 year *Chromolaena* fallow ex forest.	3.50	95	0	0	9	2	12	4.67	65.50	64.48
CAM05	Secondary forest heavily disturbed	12.00	95	0	0	8	3	2	7.33	45.00	64.89
CAM06	4 year *Chromolaena* fallow with Oil Palm	2.60	95	0	0	9	2	1	2.17	100.00	0.00
CAM07	New garden (Egusi melon); slashed and burned 8 months prev.	0.40	30	0	0	1	1	0	4.67	17.25	147.94
CAM08	Secondary forest - logged.	18.00	70	0	0	7	5	6	20.67	37.50	78.64
CAM09	2 year *Chromolaena* fallow - from secondary forest	2.50	95	0	0	9	1	1	0.50	100.00	0.00
CAM10	Cocoa plantation non maintained (Jungle cocoa (*T. cocoa*) > 45 years)	12.00	75	0	0	6	3	3	17.33	15.75	172.74
CAM11	2 year *Chromolaena* fallow from secondary forest.	2.30	95	0	0	9	1	2	1.50	80.00	51.30
CAM12	One year old garden fallow slash-burn ex forest	2.00	90	0	0	8	1	0	1.00	75.00	59.23
CAM13	4 year *Chromolaena* fallow ex forest	3.50	95	0	0	8	2	2	1.00	58.60	76.88
CAM14	2 year *Chromolaena* fallow (from an 8 years fallow)	2.50	95	0	0	9	2	2	1.00	79.25	51.35
CAM15	Cocoa plantation maintained < 30 years	18.00	75	0	0	3	5	4	20.00	51.00	44.49
CAM16	1 year Cassava (only) crop after major planting. Last year sedentary.	2.50	50	0	0	6	1	0	2.00	85.00	24.66
CAM17	Humid savanna (Shrub savanna dominated by *Lophira / Butyrosperma*)	3.00	70	0	0	3	1	0	2.00	86.25	26.46
CAM18	1 year *Chromolaena* fallow following 25 years mult. *Chromolaena* fallows.	1.80	98	0	0	10	1	0	0.20	95.25	22.30
CAM19	Annually fired savanna, tall grass (*Hyparrhenia*)	4.00	8	0	0	2	1	0	0.67	76.75	29.84
CAM20	Slightly disturbed, *Raffia* palm swamp.	18.00	90	0	0	8	2	0	14.00	17.00	103.83
CAM21	Old secondary forest (Old coppice slumps, upper storey & dense *Tabernaemontana* under storey ca. 1-2 m. Many ground Marantaceae.)	20.00	85	0	0	8	5	3	26.00	31.75	79.36

M_Can: Mean Canopy Height ; **CC:** Crown Cove%r; **CW:** Crown Cover% Woody plants; **CNW:** Crown Cover% Non Woody plants; **M_BA:** Mean Basal Area m^2 ha^{-1}; **Bry:** Bryophyte cover-abundance; **Wdy:** Woody Plants<1.5m tall, cover-abundance; **M_FI:** Mean vegetation that may have the potential to serve as a useful correlate for biodiversity and site productivity potential or carbon sequestration. The elements included vegetation structure, species and PFTs and V-Indices arranged according to site (Table 6) and according to the ranked "V" index itself (Table 7). Cumulative species/area, PFT/area and spp/PFT ratio/area curves were plotted for each contiguous 5x5 metre quadrat along the 40m transect, using PFAPro.

Table 6. Matrix values for above-ground plant biodiversity arranged according to site

Plot No	Mean_ht	Basal_A	PFTs	Species	Spp:PFT	V-Index
Camasb01	20	18	43	103	2.40	0.10
Camasb02	2.5	2	37	61	1.65	0.67
Camasb03	0.4	0.8	19	20	1.05	0.94
Camasb04	3.5	4.7	35	53	1.51	0.71
Camasb05	12	7.3	32	50	1.56	0.54
Camasb06	26	2.2	24	29	1.21	1.00
Camasb07	0.4	4.7	12	14	1.17	0.96
Camasb08	18	20.7	41	93	2.27	0.15
Camasb09	2.5	0.5	45	76	1.69	0.63
Camasb10	12	17.3	47	80	1.70	0.38
Camasb11	2.3	2	49	71	1.45	0.67
Camasb12	2	1.3	55	78	1.42	0.65
Camasb13	3.5	1	66	100	1.52	0.53
Camasb14	2.5	1	44	61	1.39	0.69
Camasb15	18	20	29	45	1.55	0.35
Camasb16	2.5	2	44	63	1.43	0.69
Camasb17	3	2	40	51	1.28	0.72
Camasb18	1.8	0.2	41	47	1.15	0.78
Camasb19	4	0.7	18	25	1.39	0.87
Camasb20	18	14	29	57	1.97	0.32
Camasb21	20	26	41	57	1.39	0.27

Table 7. Matrix values for above-ground plant biodiversity arranged according to Vegetation ('V') index.

Plot No	Mean_ht	Basal_A	PFT	Species	Spp:PFT	V-Index
Camasb01	20	18	43	103	2.40	0.10
Camasb08	18	20.7	41	93	2.27	0.15
Camasb21	20	26	41	57	1.39	0.27
Camasb20	18	14	29	57	1.97	0.32
Camasb15	18	20	29	45	1.55	0.35
Camasb10	12	17.3	47	80	1.70	0.38
Camasb13	3.5	1	66	100	1.52	0.53
Camasb05	12	7.3	32	50	1.56	0.54
Camasb09	2.5	0.5	45	76	1.69	0.63
Camasb12	2.0	1.3	55	78	1.42	0.65
Camasb02	2.5	2	37	61	1.65	0.67
Camasb11	2.3	2	49	71	1.45	0.67
Camasb16	2.5	2	44	63	1.43	0.69
Camasb14	2.5	1	44	61	1.39	0.69
Camasb04	3.5	4.7	35	53	1.51	0.71
Camasb17	3.0	2	40	51	1.28	0.72
Camasb18	1.8	0.2	41	47	1.15	0.78
Camasb19	4.0	0.7	18	25	1.39	0.87
Camasb03	0.4	0.8	19	20	1.05	0.94
Camasb07	0.4	4.7	12	14	1.17	0.96
Camasb06	26	2.2	24	29	1.21	1.00

Both classification and ordination (MDS) (Fig 3 and 4) reveal three readily distinguishable clusters of LUTs. The first is represented by closed canopy forest, including both 'jungle' *Cocoa* and 'Plantation' *Cocoa*. The second is characterised by the *Chromolaena* - dominated fallow systems, with sub-structure suggesting some differentiation according to time since the original forest was 'opened' by slash-and-burn. The final category consists of the savanna woodland sites including a Cassava garden, and two newly established food gardens within the Mbalmayo rain forest zone. If total species richness is regressed on total richness of PFTs, the result is a highly significant statistical correlation (Fig. 5) where plot distribution reflects land use intensity within a broad climate gradient. It is informative to note that relatively high plant biodiversity is contained in both the *Cocoa* plots. The fact that the 'plantation' *Cocoa* also figures highly is due to the presence of a number of ground-dwelling, semi-herbaceous, weedy species and close proximity to surrounding highly disturbed, secondary forest.

The 'V' index (Fig. 6) illustrates the relative position of each plot in terms of increasing structural complexity and richness in both species and PFTs. It is of interest to note that in this instance, 'Plantation' Cocoa is much lower in the sequence. When 'V' Index values are regressed against above-ground average carbon, there is a very significant statistical relationship. This is also mirrored in similarly high correlations between above-ground carbon, mean canopy height and basal area (Gillison, A.N. 2000).

All the forest types examined in this study were heavily used by the local people for hunting, fuel and medicinal resources. From this point of view, they are highly regarded as a potentially rich source of extractable non-timber forest products. The inclusion of savanna LUTs has improved the ecological and environmental context needed to assess biodiversity overall and provided an additional, spatially-referenced framework for spatial modelling of actual and potential land use impact on plant-based biodiversity. Should there be a need to consider the likely effects of climate change, then this extended gradient will be of potential use in modelling different climate change scenarios. A recent report of a biodiversity baseline study (Lawton *et al.*, 1999) found little evidence to support the use of one taxon to predict the presence of another. That study was restricted to a localised, rain forest land use mosaic in Mbalmayo and did not use plant indicators. Because most or all animal taxa depend on plants for survival and because the distribution of many taxa extend beyond the immediate bounds of closed forest, it is likely that predictive performance could have been considerably improved had plants been included and had the samples been extended to a wider array of LUTs as in the present study.

Box 1
Matrix values for Cameroon plots

The following attributes are considered to be the minimum set need to effectively describe above-ground biodiversity. All data are recorded from within a 40 x 5m plot. These are:

1. **Vegetation structure**
   Mean canopy height (m)
   Basal area (m^2 ha^{-1}) (Bitterlich estimate)
2. **Plant species**
   All vascular plant species
3. **Plant Functional Types (*Modi*)**
4. **Species : PFTs, ratio**
   (a measure of taxonomic and functional heterogeneity)

Vegetation (‘V’) Index
An index derived by seeking the single best eigenvector solution from a multi-dimensional scaling analysis using the above attributes. The index is standardised from 0.1 – 1.00, the highest values indicating lowest vegetation complexity and, by implication, plant biological diversity. This index corresponds generally with increasing land use intensity expressed as an ‘R’ (Ruthenberg) value. All values are listed in Tables 6 and 7.

Plot numbers refer to those listed in the 1997 ASB Annual Review Meeting report for Above-ground biodiversity for Cameroon and Tables 3, 4, 5 in this report.

Fig. 3: Classification of all sites according to species and PFT richness and vegetation structure

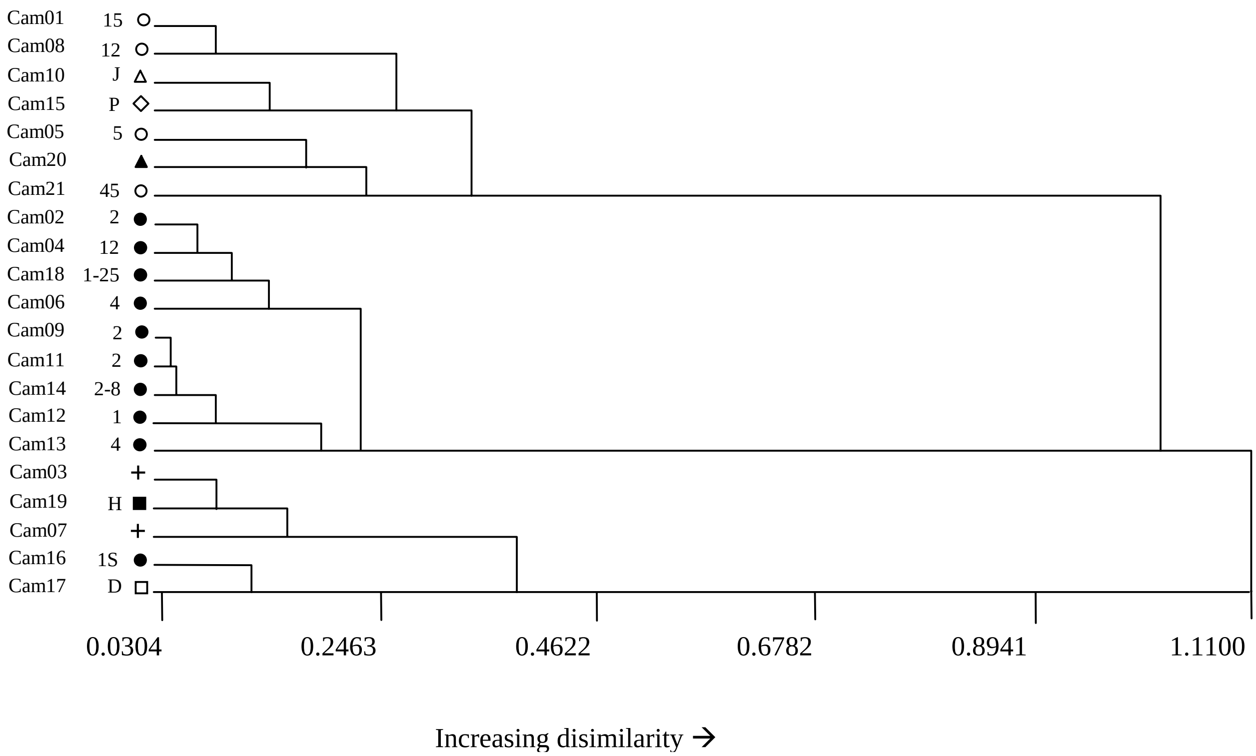


Fig. 4: Multidimensional Scaling of species and PFT richness and vegetation structure

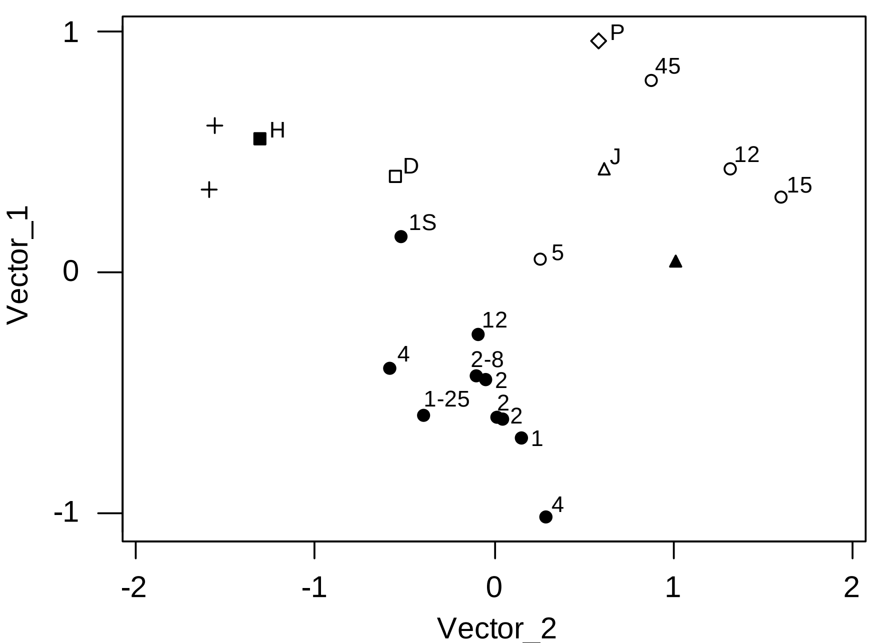


Fig. 5: Relationship between vascular plant species and PFTs along gradient of land use types in Cameroon (arrow indicates Jungle Cocoa)

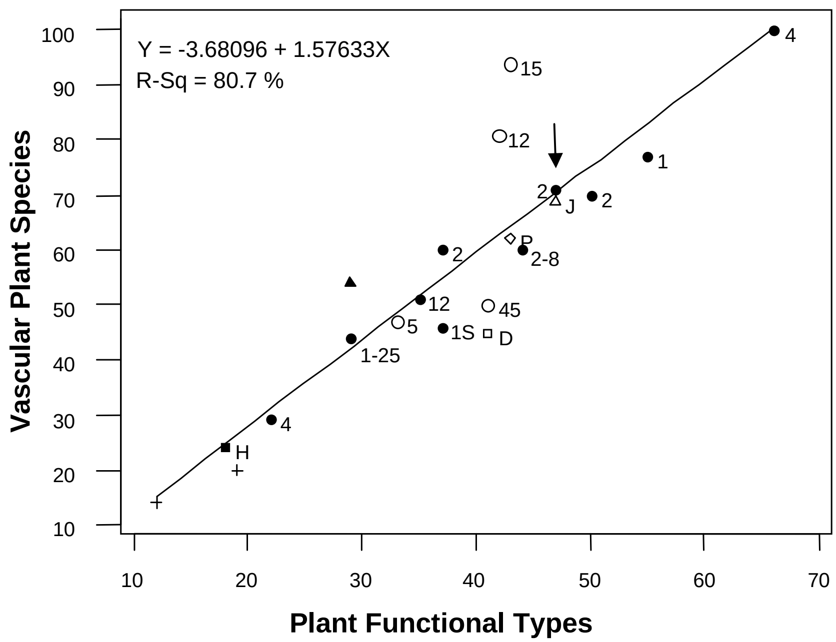
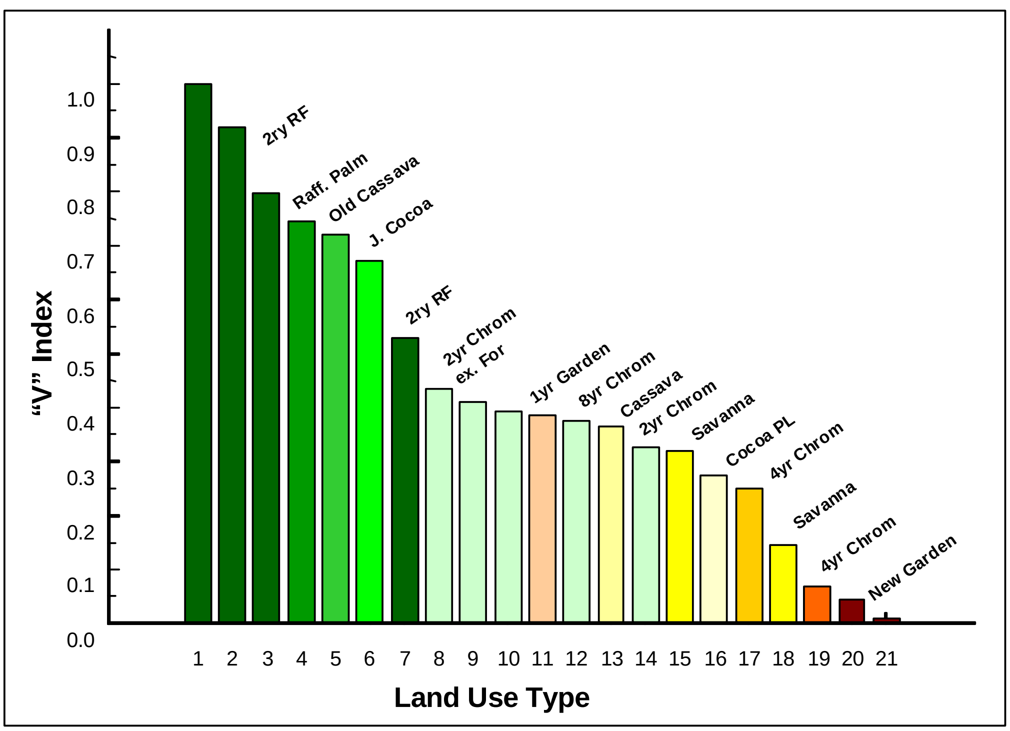


Fig. 6: Land Use Types ranked against "V" index (from: vegetation structure, species and functional types), Mbalmayo, Cameroon



Agronomic sustainability of ASB Cameroon land use systems

The Agronomic Sustainability Working Group officially started work in January 1998, following a decision made at the Bogor Global Steering Group meeting in August 1997. As researchers were making headway along the original Phase II themes of global environmental benefits and systems adoptability, it became clear that agronomic sustainability is an important interface for linking global environmental issues with local farmer concerns. Increases in productivity on already cleared land could very well directly and indirectly contribute to global environmental benefits: directly through the development and enhancement of, for example, complex agroforests and planted short fallows, and indirectly through a reduction in farmers' need to clear forest land for agriculture. However, it is key that these increases in productivity are achieved in a sustainable manner. To this end, the working group developed indicators of sustainability as a tool for the preliminary assessment of the longer-term field-level agronomic constraints in each of the land use systems.

No specific field measurements were made by the agronomic sustainability working group. The indicators are based on measurements made by the climate change, biodiversity and synthesis and linkages working groups. Some of this information was used directly, e.g. for soil compaction assessments; some data was combined with information derived from literature to create new parameters, e.g. the nutrient balance calculations; and some critical assessments were based on the field experience of relevant researchers, e.g. the crop protection constraints. Many of the indicators thus derived and assessed for Cameroon have to be further validated in the field.

The indicators employed for the Phase II evaluation fall into three main categories of measures: soil structure, nutrient balance, and crop protection. The methodological details follow.

Soil structure

Good soil structure is critical for maintaining the long-term capacity of agricultural land to produce crops. Soil compaction, carbon saturation deficit, active soil carbon, and soil exposure were used to assess the status of land use systems (hereafter referred to as land cover types).

Soil Compaction

Soil bulk density was used as an indicator for soil compaction. Although two data sets were available (Table 8 and 9), the number of fields per land cover type sampled was very limited, and the samples were confounded with inherent differences in soil properties that affect bulk density. For example, at Akok, the lower bulk density of the secondary forest was associated with greater clay content (Figure 7). In general, the values for the forest sites, which are the basis for comparisons across land cover types, were relatively high in 4 of 5 observations. Although the picture presented by these data sets is not very clear, some preliminary deductions can be made. The data appear to point to some soil compaction taking place in cocoa fields (Table 8). This is not surprising, since there is significant human traffic in this system during the different field operations and at harvest. At Akok, the comparison of cropped land, fallowed land and primary forest is possible, as these sites were on similar soil (Table 9). Cropped and fallowed land have a higher bulk density than the forest. Data not presented showed that the greatest differences in bulk density between the land cover types were in the 10-15 cm layer. The bulk density in deeper layers was similar, indicating that any impact of land use in the benchmark area appears to be limited to approximately the first 20 cm. Targeted sampling is required to get more precise information on the effect of land use on soil compaction. The present data sets would indicate there are changes taking place; however, the impact on long term sustainability still needs to be verified.

Table 8. Soil bulk density (0-15 cm) in different land cover types at three locations in the Cameroon benchmark area (the greenhouse-gas data set)

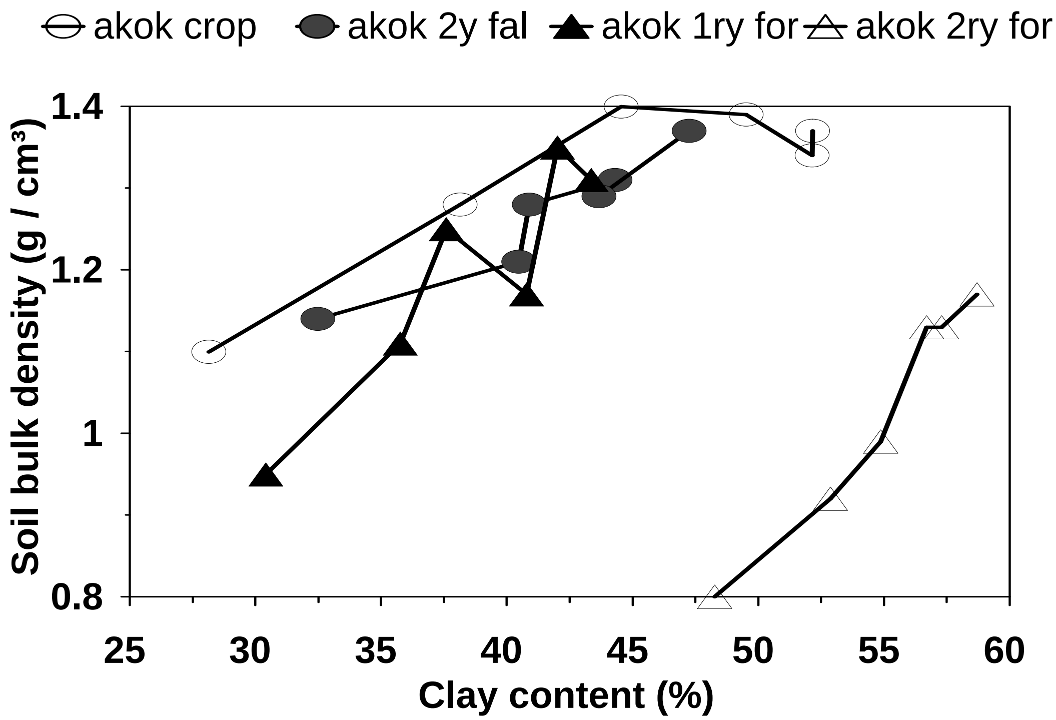
	Nkolfoulou	Awae	Mengomo	Means	Relative to Forest
Secondary Forest	1.20	1.27	1.14	1.20	1.00
Old Chromolaena	-	1.06	1.13	1.10	0.92
Young Chromolaena	1.20	1.23	1.30	1.24	1.03
Cocoa	1.34	1.39	1.18	1.29	1.08
Food Crop	1.20	1.16	1.20	1.19	0.99
Means	1.24	1.22	1.10	-	-

Note: Data provided by C. Palm and R. Njomgang. One field per land cover type and village.

Table 9. Soil bulk density in different land cover types at three locations in the Cameroon benchmark area (the below-ground biodiversity data set)

	Nkolfoulou		Awae		Akok		Means		Relative to For.	
DEPTH	10-15 cm	0-15 cm	10-15 cm	0-15 cm	10-15 cm	0-15 cm	10-15 cm	0-15 cm	10-15 cm	0-15 cm
Primary Forest	-	-	-	-	1.25	1.10	1.25	1.10	1.00	1.00
Secondary Forest	1.10	1.02	-	-	0.99	0.90	1.05	0.96	0.84	0.87
Young Tree Fallow	-	-	-	-	1.28	1.21	1.28	1.21	1.02	1.10
Young Chromolaena	1.20	1.08	-	-	-	-	1.20	1.08	0.96	0.98
Cocoa	-	-	1.31	1.15	-	-	1.31	1.15	1.05	1.05
Forest Food Crop	-	-	-	-	1.40	1.26	1.40	1.26	1.12	1.15
Annual Food Crop	-	-	1.14	1.06	-	-	1.14	1.06	0.91	0.96

Note: Data provided by T. Nyobe and S. Hauser. Based on 1 field per land cover type and village.



(below-ground biodiversity data set provided by T. Nyobe and S. Hauser)

Figure 7. Relationship between soil bulk density and soil clay content in different land cover types at one location in the Cameroon benchmark area.

Carbon Saturation Deficit

Carbon saturation deficit is a measure of the decline in soil organic matter relative to a calculated reference. The calculation is based on an equation using soil texture and pH values (0-15 cm depth) calibrated against soils in Sumatra (van Noordwijk et al., 1997):

reference carbon (refC) = exp(1.333 + 0.00994*Clay% + 0.00699*Silt% - 0.156*pH)
orgC = organic carbon in soil as measured by soil analysis;
relative carbon (relC) = (orgC / refC);
Carbon Saturation Deficit (defC) = 1 - relC;

The values of non-forested land cover types are then compared to adult forest at 100%.

These calculations of carbon saturation deficit are also based on a limited sample size. They have been derived using a formula that was only calibrated in Indonesia. The findings have to be treated with caution. The relative carbon values of different land cover types compared to that of the forest do not show any significant trend (Table 10). All the systems show higher values than the forest system. The cropping areas had only been cleared 6 months previously and a crop had just been planted. Perhaps the lack of differences are an indication of a relatively low level of land use intensity in the Cameroon benchmark area, where soil carbon stocks have not yet been depleted.

Table 10. Carbon saturation deficit (0-15 cm) in different land cover types in the Cameroon benchmark area (the greenhouse-gas data set)

	Organic C	Reference C	Relative C	Rel to Forest
Forest	1.56	2.97	0.53	1.0
Cocoa	1.47	2.62	0.57	1.09
Old Chromolaena	1.72	3.04	0.57	1.08
Young Chromolaena	1.49	4.22	0.53	1.01
Food Crop	1.62	2.81	0.58	1.10

Data provided by C. Palm. Based on 3 fields per land cover type, except "Old Chromolaena" is 2 fields.

Soil Exposure

Adequate soil cover is important to protect from the direct impact of raindrops and full sunlight. Longer periods and frequent exposure of the soil can lead to deterioration of soil structure. Several indicators were developed:

Soil Exposure = months of low soil cover / length of system cycle in months; (no units)

low soil cover = the canopy of all stratum of vegetation and any litter provide soil cover less than 75-80% . Assumptions: All crop/plant species and litter are distributed in a regular pattern across the farmer's field, and the soil surface is adequately protected with greater than 75-80% soil cover.

An indicator was developed to assess the frequency of the removal of a protective canopy cover:

Open time = number of years since the land was last cleared for land use types, or
= interval in years between land clearings for land use sequences;

The soil cover index integrates the information of both soil exposure and open time into one indicator:

Soil Cover Index = length of system cycle in months - soil exposure time in months

In short fallow-food crop systems, the soil is inadequately covered for one-fifth of the cycle, and the canopy is disrupted every 6 years (Table 11). Oil palm systems exhibit similar soil exposure values, however, this occurs only during their establishment phase in a production cycle of over 30 years. Cocoa systems have similar open times but more rapid canopy closure after establishment. Lowest soil exposure values are found in the long fallow systems, as the canopy is opened up every 16 years. The combined effect of soil exposure and open time is reflected in the soil cover index. Frequent removal of soil cover (e.g. short fallow systems) and a longer period without soil cover (e.g. the oil palm systems) are probably most detrimental to soil structure.

Table 11. Soil exposure, open time, and soil cover index in different land use systems in the Cameroon benchmark area

Land Use Systems*	**Soil Exposure** (% time)	**Open Time** (years)	**Soil Cover Index** (months)
SF – Food intercrop	19.4	6	58
LF – Food intercrop	7.3	16	178
SF – Intensive Cocoa with fruit	11.1	30	320
SF – Intensive Cocoa without fruit	11.1	30	320
FOR – Extensive Cocoa with fruit	10.8	30	321
FOR – Extensive Cocoa without fruit	10.8	30	321
SF – Oil Palm	16.7	30	300
FOR – Oil Palm	17.5	30	297
Community-based Forest	0.0	100	360

SF=Short fallow; LF= Long fallow, FOR= Forest

Nutrient balance

As nutrients are removed from a piece of land through the harvested product, it is important to assess if these are adequately replenished through internal processes and/or external inputs such as fertilizers. Internal processes making nutrients available to plants include soil organic matter mineralization, release from the soil matrix, and biological fixation of atmospheric nitrogen. At the same time, nutrients can be lost from the system through processes such as leaching, lateral flow, soil erosion, and denitrification. It is not easy to rapidly measure many of these processes. Simplified nutrient balances are, therefore, often used as a first indication of the nutrient dynamics of a system. We limited our calculations to the 3 major plant macronutrients: nitrogen (N), phosphorus (P), and potassium (K).

Nutrient Export, Balance, and Depletion

Nutrient exports are easily determined if the quantity of harvested products, including any crop residues removed from the field, and their nutrient content are known.

Nutrient Export = (nutrient content x harvest off-take) summed across all products over system cycle / length of system cycle; (kg/ha/yr)

A more precise measure is:

Simple Nutrient Balance = nutrient import - nutrient export; (kg/ha/yr)

Nutrient imports include fertilizers and N fixation through legumes in the system. Fertilizer inputs are corrected for use efficiencies, i.e. 25% of N, 20% of P, and 30% of K fertilizers are assumed to be effectively taken up by crops and thus helping to compensate for nutrient exports. Negative balances indicate greater exports than imports.

It is often desirable to calculate an NPK index that combines the 3 macronutrients to investigate trade-offs between nutrient balance and other parameters of a system (e.g. biodiversity, profitability etc.):

NPK Index = Sum of N, P, and K ranks / 3;

Where land use systems are ranked in terms of the simple nutrient balance with the highest value receiving a 1, the second receiving a 2, the third a 3 etc. The NPK Index is valid for within country comparisons only.

Nutrient exports are high in the intensively managed, high-yielding cocoa systems and in the oil palm systems (Table 12). The potassium export in oil palm systems, through harvesting of oil palm bunches, is particularly high. Farmers use fertilizer to off-set this potassium export quite successfully, as the simple nutrient balance values indicate. In contrast, little to no fertilizers are used in cocoa systems, resulting in negative nitrogen, phosphorus and potassium balances. In the extensive cocoa systems, less nutrients are exported due to the lower yield levels. Exports by annual crops from short fallow systems are only slightly lower. The long fallow food crop systems have the lowest nutrient exports together with community forests. The NPK-index closely reflects the trends in the simple nutrient balance.

The key to understanding the implications of these nutrient exports is relating them to nutrient stocks in the soil as well as in dead and living plant biomass. Since this information was not available for the sampled sites in Cameroon, the nutrient balance to carbon stock ratio acts as a proxy, assuming that there is a close correlation between carbon and nutrient stocks (Table 13). The values clearly indicate that the short fallow-food systems are in greatest danger of depletion. They are followed one level down by the intensive cocoa systems and the oil palm systems, except that the potassium in the oil palm systems is compensated for by external inputs of K fertilizer. The extensive cocoa systems fall in at the next lower level. The ratio indicates that no depletion is expected from the long fallow and community forest systems.

Table 12. Nutrient export, simple nutrient balance, and the NPK-index in different land use systems in the Cameroon benchmark area

Land use systems	Nutrient Export (kg ha^{-1} yr^{-1})			Simple Nutrient Balance (kg ha^{-1} yr^{-1})			NPK Index
	N	P	K	N	P	K	
SF – Food intercrop	8.5	1.3	4.9	- 8.5	- 1.3	- 4.9	3.7
LF – Food intercrop	1.3	0.2	1.0	- 1.3	- 0.2	- 1.0	2.0
SF - Intensive Cocoa with fruit	18.6	3.9	13.3	- 18.6	- 3.9	-13.3	8.7
SF - Intensive Cocoa without fruit	18.3	3.9	13.0	- 18.3	- 3.9	-13.0	8.0
FOR – Extensive cocoa with fruit	10.0	2.1	7.3	- 10.0	- 2.1	- 7.3	5.3
FOR – Extensive Cocoa without fruit	9.7	2.1	7.0	- 9.7	- 2.1	- 7.0	4.7
SF – Oil Palm	17.0	3.0	16.6	- 16.9	- 3.0	0.7	4.3
FOR – Oil Palm	17.2	3.0	17.6	- 17.1	- 3.0	- 0.3	5.0
Community-based Forest	(1.0)	(0.2)	(1.0)	(- 1.0)	(- 0.2)	(-1.0)	(1.7)

Note: Community-based forest values are based on estimates only.

Nutrient Replacement Value (NRV)

Fertilizers play an important role in replacing nutrients exported through harvested products. However, if the cost of the fertilizer required to balance the export is too high relative to the value of the products, farmers will hesitate applying fertilizer even if it is available. The lower the proportion of the fertilizer cost compared to the farm-gate value of the crop, the more likely the farmers will be to consider using fertilizers and thus avoiding nutrient mining (van Noordwijk et al., 1997):

Nutrient Replacement Value =
sum of cost of fertilizers required to replace all exported NPK nutrients / monetary value of all products used throughout the system cycle;

Fertilizer required is corrected for nutrient recovery, ie. only 25% of N, 20% of P, and 30% of K fertilizers are assumed to actually be recovered by the crops. Nitrogen provided through N-fixation of legumes is deducted from N export before calculating N fertilizer replacement requirements. Low NRVs indicate that the crop sequence is of high value relative to the cost of nutrient replacement through fertilizers. Generally, NRV is only calculated on a specific crop and year basis. This works well for monocrop situations.

The nutrient replacement value is highest in oil palm systems, followed closely by cocoa systems without fruit trees (Table 13). This indicates that the value of exported nutrients relative to the value of the harvested crop is high. The inclusion of fruit trees in the cocoa plantation reduces NRV, i.e., the value of the greater nutrient export is smaller than the value of the crop harvested. Medium levels of NRVs are associated with cocoa systems with fruit trees and short fallow food crop systems. This is the case even though the value of the crop exported from the cocoa systems with fruit trees is 1.5 to 2.5 times higher than the value of food crops planted in short fallow systems. NRV ratios are lowest for the long fallow system.

This NRV approach does not appear to work well for the Cameroon situation. Low NRVs generally indicate that one is dealing with a high-value crop; in which case, the farmers would be more willing to compensate the nutrient export through fertilizer imports. The long fallow system has the lowest NRV, but farmers would not consider applying fertilizers in this system since it has been established on a newly cleared long fallow where fertility levels are generally still high. On the other hand, oil palm systems have the highest NRVs, and this is exactly where farmers are applying fertilizers.

Table 13: Nutrient balance to carbon stock ration and the nutrient replacement value in different land use systems in the Cameroon benchmark area

Land use systems	Nutrient Balance to C Stock Ratio (g nutrient/yr/ton carbon) N	P	K	Nutrient Replacement Value
SF – Food intercrop	- 733	- 112	- 422	0.25
LF – Food intercrop	- 10	- 2	- 8	0.12
SF – Intensive cocoa with fruit	- 210	- 44	- 150	0.25
SF – Intensive cocoa without fruit	- 206	- 44	- 147	0.30
FOR – Extensive cocoa with fruit	- 113	- 24	- 82	0.21
FOR – Extensive cocoa without fruit	- 109	- 24	- 79	0.28
SF – Oil Palm	- 239	- 42	9	0.35
FOR – Oil Palm	- 242	- 42	- 5	0.32
Community-based Forest	(- 5)	(- 1)	(- 5)	-

Note: Community-based forest values are based on estimates only.

Crop protection

Another important agronomic constraint to sustainable production can be the development of problem weeds and specific pest and diseases. An attempt was made to identify potential crop protection problems, although no field observations were made. Based on the field experience of researchers, it was assessed whether weed problems are or could become a major constraint in different land use systems, unless this were addressed by additional labour and/or technical inputs. A similar assessment was made for pest and disease problems.

Weed Problems

As farmers move through recurrent short fallow cycles in the short fallow annual food crop system, pressure from arable weeds in general is expected to increase significantly (Table 14). There is not only a greater number of weeds, but also a shift from less problematic broadleafs to more difficult grasses. In cocoa and oil palm systems, weed problems are only anticipated during the establishment phase of the perennial crop, after the harvest of the associated annual crops. Weed pressure may be lower in perennial crops planted into newly cleared forest. No major weed problems are expected in the long fallow system.

Pest and Disease Problems

As with weeds, as farmers move through more short fallow cycles in the short fallow, annual food crop system, the general pressure from cassava, groundnut, plantain, and cocoyam pests and diseases is expected to increase significantly (Table 14). The pest and disease problems in the cocoa systems are quite serious. Cocoa varieties grown in southern Cameroon are particularly susceptible to fungal and insect attack of the pod. In contrast, the hybrid oil palms are generally quite robust. However, young palms are often attacked by rodents who eat the palm heart and grasshoppers who destroy the leaves. No major problems are encountered in the long fallow food crop system, although localized nematode and fungal problems can be encountered in plantain and insect problems in egusi melon.

Table 14. Assessment of the potential for weed, pest and disease problems in different land use systems in the Cameroon benchmark area

Land Use Systems	Weed Problems	Pest and Disease Problems
SF – Food intercrop	YES	YES
LF – Food intercrop	NO	NO
SF – Intensive Cocoa with fruit	(YES)	YES
SF – Intensive Cocoa without fruit	(YES)	YES
FOR – Extensive Cocoa with fruit	(YES)	YES
FOR – Extensive Cocoa w/o fruit	(YES)	YES
SF – Oil Palm	(YES)	(YES)
FOR – Oil Palm	(YES)	(YES)
Community-based Forest	NO	NO

Note: Parentheses indicate that assessment refers to a specific phase of the system cycle.

An overall assessment

The overall assessment of agronomic sustainability based on the information presented above is provided in Table 15.

Soil Structure: We expect significant decline in soil structure over time in intensively managed, short fallow, annual food crop systems. Alternative biomass management practices associated with planted fallows may reduce this potential problem. A deterioration of soil structure is also expected when perennial crop systems are planted into forest fields. In contrast, perennial crops planted into short fallow land would help to protect the soil better than annual cropping systems. There is greater concern about soil compaction in oil palm systems than cocoa systems because of the slower canopy closure at establishment for the former and the more regular traffic required for harvesting bunches.

Nutrient Balance : The systems that cause most concern in terms of over-exploitation of nutrients are the intensive perennial crop systems, i.e., cocoa and oil palm. The potassium lost in the oil palm systems is compensated for by fertilizer use; however, no fertilizer is applied in the intensive cocoa system. The extensive cocoa system is of somewhat less concern, since the yield levels are significantly lower. Fertilizer use can alleviate most of these concerns, and farmers are willing to use them if the institutional and financial environments are conducive. Although the nutrient exports from the short fallow/food crop system are moderate, we must assume that the nutrient stocks are already low in a system where fallows only grow for 4 years and the above-ground biomass is regularly burned and cleared. Given that short fallows are often planted to subsistence crops with little cash return, the probability of farmers using external inputs is very low. Only the association of higher value annual food and horticultural crops (e.g. tomato) with these systems would enable the use of fertilizers. Nitrogen could be supplied by the planting of nitrogen-fixing fallow species. Finally, we do not expect any nutrient problems in the long fallow and community forest systems.

Crop Protection : We expect that major weed, pest and disease complexes will develop in recurrent short fallow systems. The latter can probably only be addressed through crop breeding. Intensive weed management associated with a prior high value crop (e.g. tomato) may reduce the weed pressure in subsequent subsistence food crops. The cocoa systems also face a major challenge in terms of pest and disease problems that would require a concerted control effort at the community level with major inputs of pesticides. Weeds are a threat in the establishment of all perennial systems.

Overall Agronomic Sustainability : The most sustainable systems appear to be the long fallow and the community forest systems. The next most sustainable is the establishment of oil palm systems on land previously under short fallows. All other systems have important agronomic constraints associated with them or lead to possible deterioration of the resource base. As indicated above, there are potential solutions, but the financial and institutional environment has to be conducive.

Table 15. Assessment of soil structure, nutrient balance, and crop protection status in different land use systems in the Cameroon benchmark area

Land Use Systems	Soil Structure	Nutrient Balance	Crop Protection
SF – Food intercrop	-1	-1	-1
LF – Food intercrop	-0.5	0	0
SF – Intensive Cocoa with fruit	0	-1	-1
SF – Intensive Cocoa without fruit	0	-1	-1
FOR – Extensive Cocoa with fruit	-0.5	-0.5	-1
FOR – Extensive Cocoa without fruit	-0.5	-0.5	-1
SF – Oil Palm	0	-0.5	-0.5
FOR – Oil Palm	-1	-0.5	-0.5
Community-based Forest	0	0	0

Note: Scores (0, -0.5, -1) indicate relative severity of problem, with -1 most severe.

Adoption potential of land use systems

No matter how wonderful the parameters concerning agronomic sustainability or the environment may be for a particular land use system, small scale farmers are only likely to undertake these systems if the systems promise to improve farmer livelihoods without requiring them to assume an extraordinary amount of risk. Livelihoods in the forest margins of Cameroon are sustained by a complex set of productive and social activities conducted within the context of a risk-reducing kinship network of social relationships. A particular land use can contribute to livelihoods in numerous fashions: the two most obvious and important are through the generation of revenues and subsistence food production. Other secondary contributions include maintenance of clan patrimony and land tenure rights, medicinal products (e.g. medicinal herbs and barks which are often collected in cocoa agroforests), accommodation needs, and as a source of ancestral continuity and beliefs (e.g. certain trees are considered magical sources of ancestral essence). Additionally, the adoption of some land- use systems has high requirements in terms of institutional development and support services, which can limit uptake in institutionally underdeveloped areas. In ASB, we attempted to capture certain aspects of these dimensions for various land use systems by evaluating measures of system profitability, labor requirements, household food security and institutional requirements for the eight land-use systems discussed above. (Vosti, S. et al. 1998)

Profitability

The most important criterion for adoption in a commercialized agricultural economy is arguably the profitability to the farmer of the proposed system or system intervention. Two measures of profitability were estimated by using two sets of prices—financial and social. Financial prices are those actually paid by farmers and include any distortions from the competitive market norm (i.e., taxes, subsidies, trade quotas, misaligned exchange rates, other non-tariff barriers and market power). These are the prices most relevant for technology adoption. In contrast, social prices are a first order estimate of what prices would be in the absence of economic distortions. From a policy perspective, the divergence between financial and social prices is an important indicator of the degree of distortion in a given market and the opportunities for improving economic incentives.

Since six of the systems were perennial, with yields varying as a function of age, profitability was evaluated over a 30 year period using the discounted net present value (NPV) accounting approach and a discount rate of 10%. The opportunity cost of household labor was evaluated at a value of $1.21 per day.

When social profitability was measured on an annual, per hectare basis, the more lucrative perennial crop systems tended to strongly dominate the two slash-and-burn systems (Table 16).[7] The social NPVs per hectare were $288 and $644 for long and short fallow intercropped food systems, versus $1,755 and $1,654 for the shaded intensive cocoa/mixed fruit tree system and the hybrid oil palm system in forested land. Among the perennial crop systems, the extensive cocoa system was least profitable, at $616 ha^{-1}.

In the relatively land surplus economies characteristic of much of the Congo basin, adoption potential is more appropriately measured by the estimated financial returns to labor. On this basis, the enterprises were clustered as follows:

relatively high profit	medium profit	low profit
1) intensive cocoa w/fruit	1) extensive cocoa w/fruit	1) mixed groundnut
2) oil palm in forest fallow	2) intensive cocoa w/o fruit	2) oil palm in short fallow
		3) *Cucumeropsis/*plantain
		4) extensive cocoa w/o fruit

Differences among enterprises are compared to the official minimum wage of $2.17 per day for unskilled manual labor. The highest returns to labor were for the oil palm system planted in forested land ($2.44) and the intensive cocoa system with fruit trees ($2.36 per day) (Table 16). Earnings in intensive cocoa with no fruit and extensive cocoa with fruit were similar to the official minimum wage ($1.95 and $2.13 per day). Returns tended to lie below the official minimum wage for the mixed groundnut ($1.79 per day), *Cucumeropsis/*plantain

[7] Since per hectare profitability is measured on an annual basis and includes any non-productive fallow period, annual profitability of slash-and-burn systems is reduced significantly.

($1.70), the extensive cocoa system without fruit ($1.63 per day), and the short fallow oil palm system ($1.78). Although the absolute differences in labor returns do not seem to be very large, the relative difference between the highest and the lowest returns is 40%.

This static view of profitability masks the volatility that characterizes agricultural and world commodity markets. The recent episode of low cocoa prices (1988 to 1996) had a significant impact on the profitability of the sector. In 1997, the average price received in southern Cameroon varied from 600 to 700 FCFA, whereas in 1996, producers were receiving 350 to 400 FCFA. At a producer price of 400 FCFA for cocoa, the return to labor for the intensive cocoa system with fruit falls to $1.58 day^{-1} and the social profitability per hectare drops to $785 ha^{-1}.

Although economies of scale are not assumed for any of the above systems, they are likely to exist in oil palm systems, based on the observation that worldwide, most production tends to occur on large plantations. The converse seems true of cocoa systems, for which most large plantation schemes have failed.[8]

[8] Large cocoa plantations which were initially established around Mount Cameroon in the early 1900s had, by 1930, largely converted to oil palm and rubber. More recently, large scale cocoa plantations in Malaysia have undergone a similar conversion. Cocoa trees tend to exhibit a much greater degree of heterogeneity than hybrid oil palms, and therefore, require more individual attention on a tree-to-tree basis, thus precluding the implementation of a standard task regime which can be efficiently applied, as in the case for oil palm.

Table 16. Profitability of ASB land use systems in Cameroon

Land use system		Returns to land		Returns to labor (wage NPV=0)		Establishment costs		Years to positive cash flow
	scale (ha)	Fin.	Social	Fin.	Social	Fin.	Social	
		$ ha^{-1}		$ day^{-1}		$ ha^{-1}		years
1. SF-annual food crop	0.25	623	644	1.79	1.80	n.a.	n.a.	n.a.
2. LF-forest crop field	0.25	283	288	1.70	1.72	n.a.	n.a.	n.a.
3. SF-intensive cocoa w/ fruit	1.30	1,409	1,755	2.36	2.64	1,198	1,177	7
4. SF-intensive cocoa w/o fruit	1.30	889	1,236	1.95	2.23	1,304	1,277	8
5. FOR-extensive cocoa w/ fruit	1.30	943	1,136	2.13	2.32	1,188	1,172	7
6. FOR-extensive cocoa w/o fruit	1.30	424	616	1.63	1.82	1,247	1,227	8
7. SF-oil palm	1.00	736	982	1.81	2.01	1,264	1,257	5
8. FOR-oil palm	1	1 471	1 654	2.44	2.67	1,150	1,142	5
9. Community-based forest	5 000.00	Valuation issues still to be resolved.						

Labor requirements

In labor scarce, rural economies, or where labor markets are institutionally underdeveloped (both pertinent to southern Cameroon), labor intensity is an important determinant of the extent to which a given system will be adopted. On the basis of annual person days required for operations, the most labor-extensive systems are the *Cucumeropsis/*plantain field, and the extensive cocoa systems, at 44, 46, and 43 person days ha^{-1} yr^{-1}, respectively (Table 17). In the case of the *Cucumeropsis/*plantain field, the figure is deceptive because of the long fallow period (15 years) over which the system requires no labor input. In fact, to actually bring a hectare of *Cucumeropsis/*plantain into production requires an estimated input of 731 person days of labor, which explains its small average size in the farming systems of the region (2 ,500 m^{-2}). A similar situation confronts adoption of the mixed groundnut field system which requires an annual input of 690 person days, which, when averaged over the 6 years of the fallow-production cycle, lowers the figure to 115 person days. This is still the highest annual labor intensity of any of the systems.

Table 17. Labor requirements and food entitlements for best bet land uses

		Labor		Food entitlements during productive stage			Source of food security		Risk
	Scale	estab-lishment	operat-ing	calories	protein	micro-nutrient	during establish	during operation	
	ha	days ha^{-1} yr^{-1}		000 kcal ha^{-1} yr^{-1}	kg ha^{-1} yr^{-1}				
1. SF-food intercrop	0.25	n.a.	115	3,803	54.8	yes	--	op & cash	?
2. LF-food intercrop	0.25	n.a.	44	780	10.9	yes	--	op & cash	?
3. SF-intensive cocoa w/ fruit	1.3	148	97	1,463	19.8	yes	op	op & cash	?
4. SF-intensive cocoa w/o fruit	1.3	135	95	762	11	yes	op	op & cash	?
5. FOR-extensive cocoa w/ fruit	1.3	136	46	1,143	15	yes	op	op & cash	?
6. FOR-extensive cocoa w/o fruit	1.3	123	43	442	6.2	no	op	cash only	?
7. SF-oil palm	1	209	71	762	11	yes	op	op & cash	?
8. FOR-oil palm	1	196	73	442	6.2	yes	op	op & cash	?
9. Community-based forest	5,000								?

n.b.: op = food security from consumption of own production

Among the perennial crop systems, where comparisons are more relevant, the most labor-intensive systems were intensive cocoa with and without fruit trees, at 109 and 106 person days ha^{-1} yr^{-1}, respectively. Extrapolation domains for these relatively labor-intensive systems are those locales where labor markets function and/or where rural population densities are high. Examples of relatively intensive cocoa systems in Cameroon are to be found in the Moungo, Fako, and Meme divisions of the Southwest province and the Lekie division of the south-central portion of the state. All of these divisions have relatively high population densities. The extensive cocoa systems were the least labor demanding, at roughly two-thirds the labor requirement of the intensive systems, while the oil palm systems were intermediate between the two types of cocoa systems.

Food security

The capacity of the systems under examination to contribute to both national and household food security is a concern of both household and national decision-makers. At the household level, food production may be directly consumed, or alternatively, export crops and food production may be sold and the revenues used to ensure food security. The latter option requires the existence of secure and reliable food markets in rural areas. At the national level, the foreign exchange earned by export crops can be used to finance rice and wheat imports which are a growing component of the urban food basket. At the national level, the food surpluses generated from the mixed groundnut, oil palm, and *Cucumeropsis/*plantain systems contribute more significantly to urban food supply than do cocoa systems.

In many areas of the Congo basin, rural food markets either don't exist or, if they exist, are often periodic and access is limited. As a consequence, most households rely on their own production for the vast bulk of their food intake. Under such conditions, the contribution of a system to household food subsistence goals becomes important. In essence, the mixed food crop field is the household granary and is usually planted in the benchmark. Subsistence objectives are paramount, and commercial objectives are secondary. The same is largely true of the *Cucumeropsis*/plantain field, although in some areas this field is planted by farmers with primarily commercial objectives in mind.

Potential caloric and protein supply from each system was estimated. Again, the assumption problem of zero production during the fallow period reduces the per hectare figures significantly for the two slash-and-burn systems.[9] Nonetheless the caloric and protein output of the mixed groundnut field was the highest of all the systems (Table 17). Among the perennial crop systems, cocoa with fruit had the highest values, due largely to the significant contribution of avocados and African prunes, which have high fat contents. This system, with an estimated annual provision of 1.5 million kilocalories, would provide sufficient calories for 585 person-days at a rate of 2,500 calories consumed per day. This is more than double the caloric value of the other systems.

The production from oil palm systems plays a key role in national food security. The importance of palm oil in the typical Cameroon diet is high, a fact which is recognized by government trade policy prohibiting oil palm exports during the dry season when production declines to ensure urban supply at low prices (lowering producer price and profitability). Oil palm is also the major source of cooking oil among forest dwellers in the Congo basin, and many producers who have adopted small holdings of hybrid oil palm often cite meeting household oil demand as a factor in their adoption decision.

Institutional requirements

In conjunction with the above factors, the adoption potential of a given land use system is conditioned by the level of institutional and organizational development, as well as infrastructure. In a liberalized economy, the functioning of market institutions is a key determinant in whether a household will be able to adopt an intensive system of production. Cameroon producers are still adapting to the new economic reality of liberalized input markets that came about in the early 1990s. The intensification gradient in the Forest Margins Benchmark is also a function of the level of institutional development. In the more densely populated portions of the benchmark and the Congo basin, markets and communication infrastructure tend to be better developed. As a result, agriculture is more commercially oriented and diversified. Better functioning, more competitive markets in conjunction with better infrastructure, result in significantly lower marketing margins and consequently, higher producer prices and lower input prices. However, a major handicap for producers across the benchmark in areas of both well-developed and underdeveloped market institutions is the near

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[9] Zero production during the fallow phase is rarely the case. In areas where fallow periods have shortened considerably, significant quantities of cassava, cocoyams and plantains are harvested from so-called fallow fields. In addition, certain NTFPs such as *Gnetum africanum* are harvested from fallow fields and many fruit trees are also often located in fallow fields (Gockowski and Ndoumbe, forthcoming).

nonexistence of capital markets in rural areas. When an unexpected financial crisis arrives (e.g. illness, death, etc.), liquid assets that might have been set aside for purchasing agrochemicals are spent, and production suffers. The abandonment of tomato fields in mid season because of "*manque de moyen*" is not an uncommon occurrence.

A panel of experts familiar with rural institutions in southern Cameroon evaluated the institutional constraints facing the spread and/or improvement of specific land use systems. The panel ranked these constraints on a scale of no constraint, possible constraint under certain conditions, or clear constraint. There were a total of 10 market and non-market institutions evaluated: input supply, output, labor, and capital markets; information requirements; regulatory issues; local environmental impacts; property rights; equity biases; and social cooperation requirements.

The market institutional requirements (inputs, outputs, labor and capital) of each of the 9 land use systems were evaluated in terms of three criteria—dependence on a particular market (e.g. input-intensive systems require credit markets), the current state of market development in southern Cameroon, and the possibility of using social cooperation as a substitute for market imperfections or failures (e.g. cooperative marketing). The LUSs vary with regard to purchased input intensity and, thus, adoption domains are likely to differ according to input market development (Tables 18 and 19).

The intensive cocoa systems are the most dependent on the reliable supply of agrochemicals. Intensive cocoa systems with fruit trees also presume good access to urban fruit markets. The oil palm systems are dependent on fertilizer inputs and the multiplication and distribution of hybrid palm varieties. Oil palm production also requires further transformation. The types of post-harvest processing technology available include artisanal methods requiring almost no capital investment, small scale oil presses requiring intermediate levels of capital investment, and large scale industrial processing with high capital requirements. The development of this industry using a smallholder approach will require cost effective methods of transforming the oil.

Land tenure is still largely by customary right, although there is an evolution towards more individualistic ownership patterns and away from communal control of land, along the gradient from low to high population areas. There is a much higher incidence of official land disputes in areas of high population. There is, however, little official titling of land due, in part, to the high transaction costs of doing so (estimated at over $500 at current prices). Commercial rights to timber belong to the state, with the exception of timber cut for the landholder's own use. The minimal economic incentives faced by farmers for maintaining timber species on the landscape do not provide a competitive alternative to slash-and-burn agricultural use.[10] However, the 1994 forestry law has established a statutory framework through which a village can gain communal commercial rights to timber within "community forests" of 5,000 ha. Land tenure and property rights raise issues for systems requiring access to new forest lands for planting perennial tree crops. In certain parts of the benchmark this land has not been appropriated at the household level but instead remains within the domain of the larger family clan and requires negotiation within the clan unit. These issues do not affect the implantation of perennial systems on existing fallow lands for which customary tenure rights at the household level are relatively robust.

[10] Farmers do sell timber rights to chainsaw

Knowledge gaps and diffusion are probably most critical for the oil palm systems, as the production of commercial hybrid oil palm is just in the process of being introduced at the household level (Tables 18 and 19). There is currently a World Bank-sponsored training and visit extension program being implemented in Cameroon (as well as in many other African countries) that will hopefully reinvigorate a moribund extension service. The encouraging development of local farmer groups, farmer federations, and grassroots NGOs throughout southern Cameroon offers an additional avenue for interfacing the knowledge generated by agricultural research and rural development.

Equity biases

There are two major types of equity issues surrounding these systems which we evaluated qualitatively. The first is the issue of an increasing concentration of wealth and land holding. Among the systems evaluated, this is mainly a concern for oil palm systems, where economies of scale in both production and transformation seem to exist (Table 19). Hybrid oil palm is a crop that grows uniformly and can, therefore, benefit from specialization in time and task among work crews. There are also significant economies in processing that are beyond the reach of small farmers. In the long-run, there is a question as to whether smallholder, production, which is typically reliant on family labor, can remain competitive with large, scale plantations. To the extent that these systems are also meeting subsistence needs, the issue of economics-to-scale is less likely to be an impediment to the continued adoption of these systems.

Table 18. A checklist of market institutional issues

	Input Supply Markets			Output Markets			Labor Markets			Capital Markets		
Land Use System & Aggregate Assessment	Depend-ence	Develop-ment	social compen-sation for imperfec-tions	depend-ence	develop-ment	social compen-sation for imperfec-tions	depen-dence	develop-ment	Social compen-sation for imperfec-tions	depen-dence	develop-ment	social compen-sation for imperfec-tions
SF-food intercrop	⊕	n.a.	n.a.	⊕	n.a.	n.a.	•	♦	⊕	⊕	n.a.	n.a.
		⊕			⊕			♦			⊕	
LF-food intercrop field	⊕	n.a.	n.a.	♦	♦	♦	•	♦	⊕	⊕	n.a.	n.a.
		⊕			♦			♦			⊕	
SF-int. cocoa w/ fruit	•	•♦ (varies)	♦	•	♦	♦	•	♦	⊕	•	•	♦
		•♦			♦			♦			•	
SF-int. cocoa w/o fruit	•	•♦ (varies)	♦	•	♦	♦	•	♦	⊕	•	•	♦
		•♦			♦			♦			•	
FOR-ext. cocoa w/ fruit	♦	•♦ (varies)	♦	•	♦	♦	⊕	n.a.	n.a.	⊕♦	•	♦
		♦			♦			⊕			♦	
FOR-ext. cocoa w/o fruit	♦	•♦ (varies)	♦	•	♦	♦	⊕	n.a.	n.a.	⊕♦	•	♦
		♦			♦			⊕			♦	
SF-oil palm	•	•	♦	•	•	♦	♦	♦	⊕	•	•	♦
		•♦			•			♦			•	
FOR-oil palm	•	•	♦	•	•	♦	♦	♦	⊕	•	•	♦
		•			•			♦			•	
Community-based forest	⊕	n.a.	n.a.	•	•	♦	⊕	n.a.	n.a.	♦	•	♦
		⊕			•			⊕			♦	

⊕=no constraint ♦=possible constraint • = constraint

Table 19. Institutional capacity vis-a-vis system-specific institutional needs--A checklist for other institutional issues

	Non-Market Information			Regulatory Issues			Local Environ-mental Impact	Property Rights	Equity Biases		Social Cooperation		
Land Use System & Aggregate Assessment	depend-ency	Know-edge gap	develop-ment of extension-commun-ication	depend-ency	ability of household to deal with regulation	Ability of system to deal with regulations	importance of local environ-mental impacts beyond the farm	security of rights to access, use, and bequeath of land and investment	economy of scale	intra-household distribution of revenues	Depen-dency	develop-ment	capacity to generate & deliver
mixed groundnut field	⊕	⊕	•	⊕	⊕	⊕	♦	⊕	⊕	⊕	⊕	⊕	⊕
		⊕			⊕				⊕			⊕	
Cucumeropsis/plantain field	⊕	⊕	•	⊕	⊕	⊕	⊕	⊕	⊕	♦	⊕	⊕	⊕
		⊕			⊕				♦			⊕	
cocoa med intensity w/ fruit	•	♦	•	♦	♦	♦	♦	⊕	⊕	•	•	♦	♦
		♦			♦				♦			♦	
cocoa med intensity w/o fruit	•	♦	•	♦	♦	♦	♦	⊕	⊕	•	•	♦	♦
		♦			♦				♦			♦	
extensive cocoa w/ fruit	⊕	⊕	•	♦	♦	♦	⊕	♦	⊕	•	♦	♦	♦
		♦			♦				♦			♦	
extensive cocoa w/o fruit	⊕	⊕	•	♦	♦	♦	⊕	♦	⊕	•	♦	♦	♦
		♦			♦				♦			♦	
oil palm short fallow	•	•	•	⊕	⊕	⊕	⊕	⊕	•	•	♦	♦	♦
		•			⊕				•			♦	
oil palm long fallow	•	•	•	⊕	⊕	⊕	⊕	♦	•	•	♦	♦	♦
		•			⊕				•			♦	
community-based forest	⊕	⊕	•	•	•	•	⊕	•	⊕	⊕	•	♦	♦
		⊕			•				⊕			•	

⊕ = no constraint ♦ = possible constraint • = constraint

The other equity concern surrounds the intra-household distribution of returns. Among the systems identified above, women manage only mixed groundnut fields. There is a significant risk that women might not share equitably if an expansion of the other land use systems were to occur. For this reason, any equitable strategy to reduce deforestation due to slash-and-burn agriculture should focus attention, as well, on technology improvements for the cropping systems and crops that are traditionally grown and marketed by women. Improvements in the productivity of these systems would deflect the pressure to clear more forested land as populations grow and would increase women's revenues and social prestige. Within the perennial tree crop systems, the labor divisions need to be further studied and, if possible, innovations developed to ensure that women also benefit. Indications are that women receive a more equitable share of fruit tree revenues than is the case for the cocoa component in the fruit-cocoa agroforests found in the Yaoundé block (Dury, 1999).

To summarize, the land-use systems examined are placed in rank order below by the respective quantitative measures of adoption (Table 20).

Table 20. Ordinal ranking of land use systems by the various adoption criteria.

Social Profitability (return ha^{-1})	Financial Profitability (return to labor $ day^{-1})	Labor Intensity (lowest to highest)	Household Food Security (kcal ha^{-1})
1. Intensive cocoa w/fruit	Oil palm in forest fallow	Extensive cocoa w/o fruit	Intercropped food in short fallow rotation
2. Oil palm in forest fallow	Intensive cocoa w/fruit	Intercropped food in long fallow	Intercropped food in long fallow rotation
3. Intensive cocoa w/o fruit	Extensive cocoa w/fruit	Extensive cocoa w/fruit	Intensive cocoa w/fruit
4. Extensive cocoa w/fruit	Intensive cocoa w/o fruit	Oil palm in short fallow	Extensive cocoa w/fruit
5. Oil palm in short fallow	Oil palm in short fallow	Oil palm in long fallow	Oil palm in short fallow
6. Intercrop food field in short fallow	Intercrop food field in short fallow	Intensive cocoa w/o fruit	Intensive cocoa w/o fruit
7. Extensive cocoa w/o fruit	Intercrop food field in long fallow	Intensive cocoa w/fruit	Oil palm in long fallow
8. Intercrop food field in long fallow	Extensive cocoa w/o fruit	Intercropped food in short fallow	Extensive cocoa w/o fruit

Tradeoffs between global environmental benefits, agricultural sustainability and adoption criteria

Tradeoffs within land use systems

In order to compare tradeoffs across the various columns of the matrix, it was first necessary to come up with summary indicators for greenhouse gas emissions, above- and below-ground biodiversity, soil structure, nutrient balance, crop protection, institutional requirements, food security, and labor requirements. For each of these, several indicators were developed and are summarized in "submatrices" of the "meta-matrix" (tradeoff matrix Table 21). Only for carbon stocks and profitability were single valued measures available for comparing the socio-economic and environmental properties of these land-use systems over time (i.e. time-averaged carbon stocks per hectare and discounted net present value). Although a single value indicator of biodiversity is presented in the tradeoff matrix, it only represents the maximum biodiversity attained over the course of the land use (i.e., in the long fallow intercrop, the measure was taken in a 15-year-old bush fallow, which differed considerably from the measure during the cropping phase).

The overall net impact on Global Environmental Benefits (GEBs) is a function of the land conversion process--each system assumes some type of change in land use patterns at start up. For the intercrop-fallow rotational systems (#1 and #2), this involves an increase in the number of fallow-crop cycles (from ***n*** to ***n+1***) and, if population pressure is increasing, a decrease in the fallow period over time (i.e. an increase in the "Ruthenberg index" of cropping intensity). For intensive cocoa and oil palm systems planted in short fallows, land use is assumed to shift from a *Chromolaena odorata* short fallow intercrop to a perennial tree crop system. Extensive cocoa and oil palm systems planted in forested fallow involve conversion of either long fallow or forest land to a perennial tree crop system. The starting point of a particular land conversion process has enormous importance for whether there will be gains or losses in terms of GEBs. The rehabilitation of degraded short fallow-crop rotation systems with perennial systems is a clear objective of the ASB program.

The same starting point argument holds for the soil structure component of agricultural sustainability. The shift from a short fallow/annual crop cycle to a perennial tree crop system such as shaded cocoa can result in an improvement in soil structure. However, nutrient export levels may be increased, resulting in lowered soil fertility.

For the intercrop food field in a short fallow rotation, the major concerns are relatively low profitability, agricultural sustainability and the low levels of biodiversity and carbon stocks. There are potential concerns surrounding soil structure, nutrient export and pests and disease with this field system, especially as the number of crop-fallow cycles increases and as the soil restoration period, i.e., fallow, shortens. The nutrient export of this system was intermediate, however, soil exposure was higher than for any other system, indicating possible erosion potential. Given the central role of this cropping system in the social fabric of village life and the underdeveloped rural food markets of the Congo basin, efforts to replace this slash-and-burn system are likely to fail in the near and mid-term. Efforts to improve the productivity of this system should focus on the introduction of improved varieties of groundnuts, cassava and maize, in combination with integrated soil fertility management. Fertility management should combine the improvement of the soil restorative component of the fallow period with the strategic use of fertilizers (particularly in areas with developed input markets and good rural roads).

The major tradeoffs surrounding the intercrop food field in a long fallow rotation are the low profitability of the system and the decrease in carbon stocks and biodiversity. This system, the principal components of which are *Cucumeropsis mannii*, plantain banana and cocoyams (*Xanthosoma sagitiifolium*), assumes a relatively land-abundant household, which limits its extent in areas where population pressures are high. However, in areas where land is still abundant and populations are low, market infrastructure and institutional development can also be limiting factors. The starting point for land-use change in this system is the forest; thus, there are also concerns over a decline in global environmental benefits if this extensive system increases in area. Low profitability (returns to labor = $1.70 per person day) and the negative environmental effects associated with this extensive system would be ameliorated by an increase in agricultural research targeting the three principal crops—*Cucumeropsis manni*, cocoyam (*Xanthosoma sagitiifolium*) and plantain—which have been largely neglected by agricultural research to date. The relatively fertile, high biomass, and subsequent high input of ash fertilization following the burn of a long fallow warrants the development of nutrient efficient varieties and crop management interventions to exploit the relatively fertile environment. Developing nutrient efficient varieties, along with their multiplication and distribution to farmers, presents a major institutional challenge for research and development in the Congo basin. There is the "Pandora's box" issue of whether or not an increase in land and labor productivity would lead to an expansion in this land use type and further deforestation. This valid concern would be assuaged by broad-based productivity increases in land-use systems. To achieve this difficult task will require a balanced agenda involving multi-institutional collaboration on the research and development of the major components of the Congo basin farming systems. The Pandora's box issue will also be a function of the size of output markets and the elasticity of demand. If, as is likely, they are small, then an increase in productivity of these systems would most likely deflect pressure to further clear new forest. Both of the crop-fallow rotational systems are likely to remain important across the Congo basin and should be the focus of land-saving and labor-neutral or labor-saving interventions. Abating the environmental loss associated with extensive slash-and-burn systems will require both alternative perennial systems capable of sustaining rural livelihoods and more productive slash-and-burn systems. The latter would permit farmers to convert land currently in these crop-fallow systems to what are arguably more agronomically sustainable perennial tree crop systems.

The intensive cocoa system with fruit trees planted to short fallow is among the most profitable of the systems examined (returns to labor = $2.36 per person-day). Both biodiversity and carbon sequestration (time-averaged, above-ground carbon stock values increase from 4.5 to 61 tons ha^{-1} yr^{-1}) would increase following a shift from a short crop/fallow land use to a perennial tree crop system. However, there are concerns about the agronomic sustainability associated with the high incidence of pest attack (capsid insects, *Phytoptera palmivora* and *Phytoptera megakarya*), which can result in losses of up to 80 percent. Both intensive cocoa systems receive cautionary scores on soil structure, as the higher level of management and human traffic may lead to the higher bulk density noted in cocoa plantations relative to other land covers. The elevated productivity of this system is a function of an increase in labor and pesticide input. Institutional constraints in many areas of the Congo basin, such as the unavailability of inputs and scarce labor availability, are likely to limit the extent of this particular land-use system. The fruit tree component contributes significantly to the profitability of this system, but because of the relatively low value to weight ratio of fruit, it results in increasing transportation costs with distance to market. The underdeveloped road infrastructure of the Congo basin will also be a constraint to the development of this multi-strata complex agroforestry system. The most extensive extrapolation domains for this particular system are likely to lie in the more densely populated, humid forest areas of West Africa (Ghana, Cote d'Ivoire, Nigeria, and Togo), where cocoa production is already a significant cash crop activity and market institutions are more robust. The intensive cocoa system without fruit trees planted to short fallow is subject to the same set of tradeoffs as above, with the exception of the need for urban market access. Pesticide and labor constraints correspond exactly.

Extensive cocoa systems with fruit trees planted in forest land are moderately profitable (returns to labor = $2.03 per person-day) but entail a significant decline in global environmental benefits (declines in carbon stocks from 210 to 65 tons ha^{-1} yr^{-1}). If instead of forest land, these systems are targeted to be planted in long fallow-crop rotations, there would be negligible environmental change. The issue of agronomic sustainability for extensive cocoa is mainly a question of pest management. In these extensive systems the lack of capsid control, which can destroy the productive potential of the tree stock, is a great concern. Institutional and labor constraints attached to cocoa production are less than the intensive cocoa systems. Urban market access will, however, limit the extent of this system. The extensive cocoa system without fruit trees is the least profitable of any system considered (returns to labor = $1.63 per person-day). The agronomic sustainability of this system is also subject to the problems associated with capsid control. The nutrient cycling and relatively low yields in these shade canopy systems result in a favorable nutrient balance score.

The oil palm system planted on forest land is the most profitable of all land use systems considered, with an estimated return to labor of $2.44 per person-day. Profitability is increased substantially by food intercropping during the first two years, in particular by the possibility of producing 10 tons of plantains in the second year. Global environmental tradeoffs are the most pressing. Time-averaged carbon stocks decline from 211 to 61 ha^{-1} yr^{-1} and, although biodiversity measures were not taken, there is little doubt about the lack of plant and faunal diversity in these monoculture systems. When planted in short fallow fields, yields at maturity are 6% lower than the same system planted on forest land, due to differences in soil fertility, and the returns from plantain production during the establishment intercrop are much lower. As a result, profitability declines to $ 1.81 per person-day. Institutional and organizational constraints are significant for these oil palm systems. Post-harvest processing must normally occur within 48 hours of harvest. There are also likely to be scale economies in both time and space, which will warrant some type of collective action in the processing phase. There is also the organizational issue surrounding the multiplication and distribution of improved "Tenera" hybrid material. Currently there are only two suppliers--the national research institute and a parastatal industrial oil palm plantation charging 200 to 250 FCFA per germinated seed and wielding significant market power. The ready supply and distribution of these highly productive hybrids is likely to be a major constraint to the development of small scale oil palm production systems throughout the Congo basin and, to a lesser degree, West Africa.

Communal management of forest lands for commercial timber production and other purposes received positive scores on all environmental and sustainability accounts, although the sustainable commercial harvest of tropical timbers has proven to be an elusive goal for many timber companies. The financial incentives attached to the commercial harvest of timber could be a deterrent to the practice of slash-and-burn agriculture. However, there are numerous institutional and regulatory issues that a community has to resolve before it can obtain legal community tenure to timber. As currently written, the state-imposed regulatory framework requires more than 20 procedures in order to obtain community tenure. There are also many collective action problems associated with distribution of benefits, sanctions, and free-ridership. Overcoming these obstacles is a necessary condition if slash-and-burn farming communities are to limit their agricultural activities to areas outside the community forest.

Table 21. Analysis of tradeoffs

Land Use System	Global Environmental Benefits						Indicators of Agricultural Sustainability			Adoption Criteria			
	carbon stock		Green-house gas	above ground biodiversity		Below ground biodiver-sity	Soil structure	nutrient K balance	plant protec-tion	profit-ability	average labor req.	food security	institutional req.
	tons ha^{-1}			species/modi				kg ha^{-1}		\$ ha^{-1}	days yr^{-1}		
1. SF-food intercrop	♦	4	(⊕)	♦	1.45	⊕ L	•	-4.9	•	644	115	⊕	⊕
2. LF-food intercrop	♦	63	(⊕)	(♦)	1.51	-	♦	-1.0	⊕	288	44	⊕	⊕
3. SF-int. cocoa w/ fruit	⊕	61	(⊕)	⊕	1.66	♦ M	⊕	-13.3	•	1,755	109	♦	♦
4. SF-int. cocoa w/o fruit	⊕	61	(⊕)	⊕	1.66	♦ M	⊕	-13.0	•	1,236	106	♦	♦
5. FOR-ext. cocoa w/ fruit	•	61	(⊕)	♦	1.66	• M	♦	-7.3	•	1,136	67	♦	♦
6. FOR-ext. cocoa w/o fruit	•	61	(⊕)	♦	1.66	• M	♦	-7.0	•	616	64	♦	♦
7. SF-oil palm	•	61	(⊕)	•	1.18	-	(⊕)	0.7	♦	982	94	♦	♦
8. FOR-oil palm	⊕	61	(⊕)	•	1.18	-	(•)	-0.3	♦	1,654	93	♦	♦
9. Community-based forest	⊕	211	(⊕)	⊕	1.97	⊕ M	⊕	(-1.0)	⊕	?			♦

Key 1-- global environmental benefit (GEB) and agricultural sustainability (AS)

⊕ = improvement/maintenance of status quo in GEB or AS

♦ = possible deterioration in GEB or AS

• = expected deterioration in GEB or AS

L = relatively low level of carbon stock/biodiversity

M = relatively medium level of carbon stock/biodiversity

H = relatively high level of carbon stock/biodiversity

Key 2 -- adoption criteria

⊕ = favorable to adoption

♦ = possible constraint to adoption

• = expected constraint to adoption

() indicates tentative finding with further verification required - indicates no data collected

Tradeoffs across land use systems

Comparing biodiversity and social profitability across systems, the two intensive cocoa and the extensive cocoa system with fruit trees offer both relatively high profitability while maintaining a satisfactory level of biodiversity (Figure 8). In contrast, the crop/fallow rotational systems and the short fallow/oil palm system perform rather inadequately on both accounts. For both these systems and the monocrop oil palm system planted in forest land, biodiversity will be sacrificed for increased profitability, as the possibility of augmenting the biodiversity in these systems is low (unlike the potential for increasing their productivity and profitability). Although information was not collected on social profitability on a per hectare basis for the community forest, its value is probably low (although the returns to labor may be high). For illustrative purposes we have included it, assuming a value of $25 per ha for the collection of non-timber forest products (higher than that measured in Indonesia). The successful implementation of the institutional reform on community tenure of timber rights would increase the social profitability of this land use system and serve as a deterrent to deforestation by slash-and-burn agricultural communities at the forest margin. The impact on biodiversity of sustainable logging practices remains a question.

The ecological relationships among biodiversity, management practices and productivity are an area for future research, especially in the relatively species-rich cocoa agroforests. Specifically, interactions between entomopathogenic fungi, plant functional attributes, ant and termite mosaics, applications of copper fungicides and the population dynamics of *Phytoptera spp.* are important for strategic research.

In terms of tradeoffs between carbon stocks and biodiversity, there is, in general (with the exception of the oil palm monoculture systems), a direct and positive correlation between the time-averaged carbon stock in a system and plant biodiversity.

Both carbon stocks and social profitability are high for the intensive cocoa, extensive cocoa with fruit and the hybrid oil palm in forest land systems (Figure 9). The tradeoff between profitability and carbon stocks is less significant for oil palm systems than that of biodiversity. The short fallow-intercrop rotation performs the worst in the carbon profitability tradeoff. The long-fallow intercrop rotation is comparable to the perennial tree crop systems in terms of time-averaged carbon, however, the social profitability of this land-use system is low. Long fallow systems, though relatively sustainable in the long run, are found only under conditions of low population density. This is, however, a widespread domain in the Congo basin.

Unlike biodiversity, the carbon stocks in these systems are amenable to change and system performance can be improved. For instance, typical existing short fallow-intercrop rotations were estimated to have a time-averaged value of carbon equal to 4.53 tons and a carbon accumulation rate of 2.90 tons ha^{-1} during the fallow period. However, on-station work with improved fallow interventions has shown an average accumulation of up to 10 tons of carbon using leguminous tree species such as *Calliandra spp.* A short fallow-intercrop rotation with Calliandra, accumulating carbon at 5 tons ha^{-1} would increase the time-averaged carbon stock value of this system to 6 tons ha^{-1} (an increase of 25 %). All of the cocoa systems modeled incorporate a shade canopy, which is a major source of carbon in these systems. Increasing the density of the shade canopy will result in a higher level of carbon stock. Shade management has important implications for pest populations, yields and agronomic sustainability. The maintenance of these systems in some cases for over 60 years with virtually no fertilizer applications is a testimony to the tight nutrient cycles of these systems.

The relationship between social profitability and the farmer's return to his or her labor is shown in Figure 9. The relatively linear relationship between these two sets of indicators implies that there are not large distortions between social prices and farmer (i.e. financial) prices. In other words, the most socially profitable land use systems also tend to be the most profitable for farmers.

At current prices, the oil palm planted in forested land and the intensive cocoa system with fruit are roughly equivalent in terms of both social profitability and the financial returns to labor. In terms of effective rates of protection, the intensive cocoa system with fruit trees had a slightly lower ratio (0.90) than did the oil palm system (0.92), indicating a relatively higher rate of taxation in the cocoa sector.[11] Taxation in the cocoa sector (mainly consisting of import tariffs on pesticides and a 10 % excise tax on production) is significantly lower today than when the national marketing board was operating and official producer prices were set by presidential decree. While cocoa farmers are now under a less taxing price regime, there is also more price uncertainty.

Figure 10 also illustrates the impact that an overvalued FCFA can have on farmer returns. We assumed for the case of intensive cocoa with fruit that the FCFA was overvalued by 50%. Under this scenario the producer's return to labor ($1.36) would be lower for than the slash – and-burn systems. Farmers facing this type of incentive structure would be expected to shift labor out of cocoa and into the production of annual food crops, despite the much higher social profitability of producing cocoa. Prior to the devaluation in 1994, the overvalued FCFA was a source of heavy implicit taxation for producers of tradeable commodities such as oil palm and cocoa, and there was a noticeable impact felt in the Yaounde food market. In contrast to export crops, an overvalued exchange rate has little impact on farmer incentives for commercial food production because of the nontradeable nature of the most important food crops in the humid forest zone (i.e. plantains, cocoyams and cassava). Overall, the effect of the overvalued FCFA was to favor food production systems over export crops such as coffee, cocoa and oil palm.

[11] The effective rate of protection is here defined as the ratio of discounted total revenues less the discounted costs of tradeable inputs evaluated at social prices and discounted total revenues less the discounted costs of tradeable inputs evaluated at financial prices.

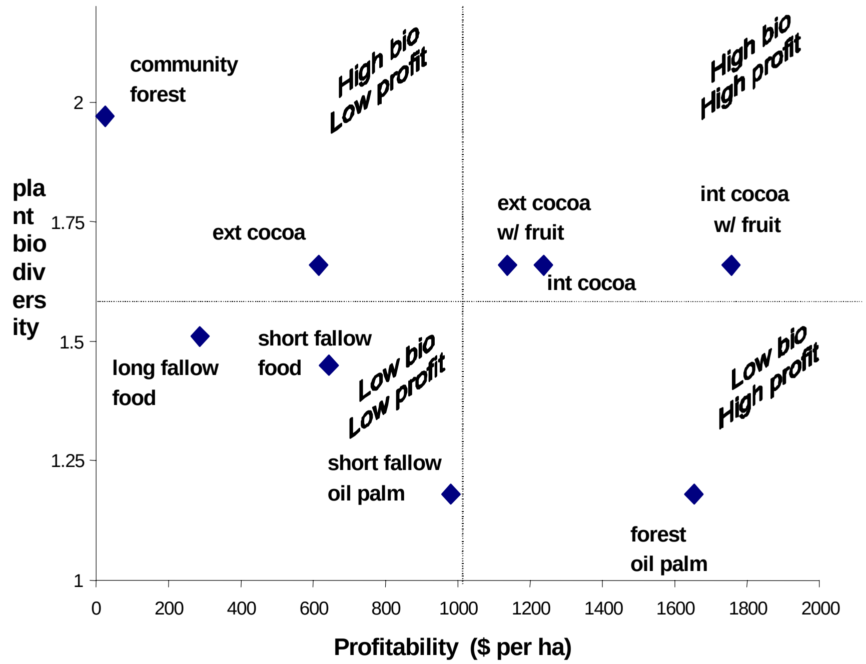


Figure 8: Biodiversity and social profitability of humid forest land use systems in Cameroon

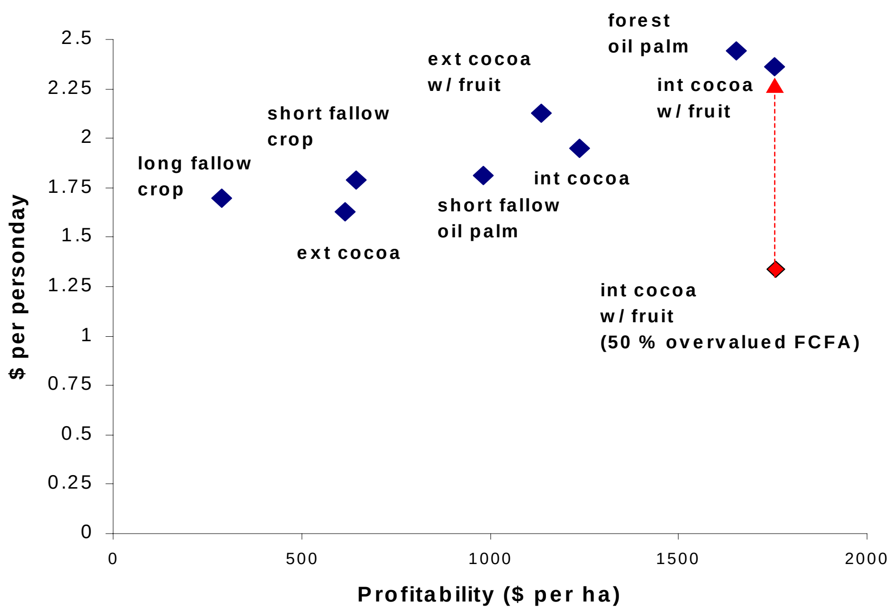


Fig. 9: Social profitability versus farmer returns to labor, for land use systems in Cameroon.

Trends in land-use patterns and impacts

Additional land use systems besides those in the matrix were included in this analysis, namely horticultural cropping systems, robusta coffee and inland valley land uses.

Cocoa systems

In southern Cameroon several of the land-use systems are already widespread. These include both the intensive and extensive cocoa production systems, which nationally account for approximately 300,000-400,000 hectares, depending on whose estimates are used. Intensive systems are mainly found in the Meme and Fako divisions of the Southwest Province, the Moungo division of the Littoral Province and the Lekie and Mbam divisions of the Center Province. The more extensive production systems are characteristic of the South and East Provinces. From 1990 through 1996, the area in cocoa has probably declined, as some farmers have abandoned production in the face of low world and national prices. Most of these plantations were old and had low productivity. Labor was reduced in both extensive and intensive cocoa systems and was largely reallocated to long fallow-intercrop rotations focused on the production of *Cucumeropsis* + plantain + cocoyams. There was a negative environmental impact (loss of biodiversity and carbon stocks) as this annual cropping system replaced secondary forest. The decline in cocoa profitability and the reduced foreign exchange earnings during this period had major repercussions on economic growth and probably led to a higher incidence of poverty in the HFZ. Despite the decline, cocoa still remains the dominant land use system in the HFZ of Cameroon and the major source of household revenues.

Given current and expected supply and demand conditions in world cocoa markets, it is likely that cocoa prices will remain robust in the foreseeable future, which should ease the negative trend seen in recent years. The higher prices of 1997 and 1998 (550-650 FCFA versus 350 FCFA in 1996) have increased farmer incentives and, subsequently, input use in cocoa systems. Input markets, which have been liberalized since 1992, are better developed today than they were 5 years ago. This will reinforce the trend towards more intensive cocoa systems. A high proportion of this increase will likely come from a shift from extensive to intensive production systems. Whether there will be significant new land conversion to either extensive or intensive cocoa production is difficult to predict. Estimates of small-holder new planting elasticities in the Cameroon robusta coffee sector (3.0) and in the cocoa sector of Cote D'Ivoire (1.6) indicate that farmers' investment behavior is responsive to price incentives (Akiyami 1988, Gockowski 1994). If a similar result holds for the Cameroon cocoa sector, then there is likely to be some expansion in new planting area. To the extent that new planting could be directed to areas under short fallow land uses, net environmental gains could be expected. If, however, the new planting occurs at the expense of secondary and primary forest, environmental losses will result.

Currently, cocoa is not widely produced in the Congo basin. Cocoa expansion into the basin is a possibility but requires attention by research and extension to the problems posed by *Phytoptera megakarya*, a particularly virulent fungal agent of blackpod disease, as well as a possible acid soil constraint. Expansion of the systems with fruit in Cameroon is dependent on improvements in the local food marketing systems. This could entail building more and better roads, importing more economical transport vehicles (reducing the high import tariff on commercial vehicles is a policy option to consider) and reducing fruit assembly costs through the cooperative bulking of products at strategic assembly points.

The impact on the environment of an increase in new plantings will depend on whether or not these systems are targeted to degraded short fallow land or forested land. Given the choice, the producer will normally choose the latter in an effort to capture the forest rent (Ruf 1998). Policy incentives should be targeted towards the creation of perennial crop systems in degraded lands. This strategy should be accompanied by an increase in the productivity of food cropping systems, in order to compensate for a reduction in the area of the food crop fallow system. To encourage the intensification of cocoa production, policies to promote the agricultural input supply sector should be considered. One possible avenue would be to work through the various farmer organizations that are springing up across the landscape as a result of the provision of production credits, etc. One of the major problems in the Cameroon cocoa sector is the low level of plant resistance to cocoa blackpod disease caused by *Phytophthora* spp. The efforts underway at IRAD to evaluate, test and diffuse resistant varieties, working with the increasingly vital grassroots farmer organizations, need to be strongly supported.

Coffee systems

Although not included in the analysis, robusta coffee is an important cash crop in the Congo basin and is, indeed, more important than cocoa. The Democratic Republic of the Congo, Cameroon, and the Central African Republic are all large producers (there is an estimated 240,000 hectares of robusta coffee in central Congo around the river port of Mbandaka). Robusta coffee, which is indigenous to the forests of the region, is a lower story tree in its natural environment, like cocoa. When grown commercially under shade, the two systems are similar in their environmental parameters.

Policy and price trends in the robusta coffee sector in Cameroon mirror the cocoa sector. A market calamity similar to that afflicting cocoa producers in the late 1980s also struck coffee producers. The combination of depressed cocoa and coffee markets led to the liberalization of the National Produce Marketing Board, which was bankrupt by 1992. With foreign exchange earnings historically similar to cocoa, the impact of this decline on economic growth and poverty was severe. The environmental consequences of depressed producer prices of coffee were similar to those in the cocoa sector.

In recent years, a structural shift in preferences among coffee consumers towards higher quality mild arabicas has resulted in a widening gap in the price of robusta and arabicas. New production on world markets from Vietnam has also somewhat depressed the robusta market. Gockowski (1994), in a study of robusta coffee planting in western Cameroon, found producers were quite price elastic in their price behavior (in the face of declining prices). Assuming asymmetries in planting response do not exist, a rise in real expected prices should engender a significant planting response.

Oil palm

Palm oil has always been the most consumed edible oil in Cameroon. In rural areas of the humid forest zone, most households are self sufficient, relying on production from the semi-domesticated Dura variety of oil palm. The bulk of production for the urban market comes from large-scale parastatal plantations (CDC, Palmol, and SOCAPALM) producing the *tenera* hybrid (a cross between the Dura and Piscifera varieties). However, as urban populations have increased, small-scale producers have also adopted industrial-type plantation monoculture of the hybrid tenera variety in recent years. Whether or not this small producer movement, which has been fairly robust in recent years, continues will depend on several critical institutional issues. First of all, the distribution system of the hybrid plants is not well developed and the market is controlled by the oil palm research unit of the IRAD at Dimbamba and by PALMOL, a parastatal producer. If smallholder systems are to expand significantly, further improvements in the distribution and supply of these hybrid plants will be required. However, there are long biological lags in the production of hybrid seed due to the perennial nature of the crop. Second, post-harvest processing is required. The ability of small producers to compete with large scale producers in the face of economies of scale in production and processing is questionable in the long-run. Economies of scale could outweigh the advantage of the lower opportunity cost of family labor, driving producer prices and profits too low. Third, export restrictions on palm oil during the dry season period drive down producer prices. This policy creates an artificial price below the equilibrium value. Mitigating in favor of the expansion of the smallholder sector is the perception by producers that unlike cocoa, palm oil and its multiple products (oil, wine and building materials) can also be used to meet direct household needs in consumption.

As for cocoa and coffee, the net environmental impact of an expansion of oil palm systems will depend on whether they are planted in short fallow or forest land. The most likely candidate is for farmers to choose the latter, again because of the fertility rent they capture. When planted to forested land, these systems tend to decrease the total carbon stock in the landscape. However, if planted to *Chromolaena odorata* fallow, the total carbon stock would increase over time. In terms of biodiversity, these monoculture systems would cause a net loss, regardless of where they were planted. The overall contribution to the rural economy of smallholder oil palm production from 1986 to 1990 was still relatively minor, with the exception of the area around Edea-Eseka-Makak in the western-most portion of the benchmark. Oil palm trailed cocoa, coffee, plantains, cassava, cocoyams, and dessert bananas, as measured by total producer revenues (MINAGRI, unpublished survey data). Thus, the overall economic impact of an increase in this sector will be felt slowly at first, as the production base is built. At the household level, the profitability of the enterprise when targeted to forestlands indicates a significant positive impact on revenue.

One policy instrument that the Cameroon government could consider is to target new planting subsidies of both cocoa and oil palm systems to degraded short fallow crop rotational systems. Under these conditions, carbon would be sequestered and, at least in the case of shaded cocoa, biodiversity in the landscape would increase. Following the Kyoto conference on global warming, discussion of carbon emissions trading among nations has focused some attention on perennial tree crop systems in the tropics as a possible sink for carbon sequestration. The idea of new planting subsidies paid by nations in the north in exchange for carbon credits is currently being explored in Costa Rica for shaded coffee systems.

Long fallow-intercrop rotational systems

According to household surveys conducted throughout the HFZ in the 1980s by MINAGRI, plantain is the most important commercial food crop in the zone. Plantains, grown predominantly in long fallow/intercrop systems with *Cucumeropsis mannii* and cocoyams, were the recipient of much of the labor that shifted out of cocoa when incentives in that sector declined in the late 1980s. The increase in production in the plantain market resulted in a glut in urban markets which, in combination with the declining per capita revenues, resulted in a subsequent decline in the price of plantains.[12] The environmental impact of this increase in

[12] In 1988 the average annual price of plantain in the Yaounde market was 129 FCFA kg^{-1}; in 1989 the price fell to 85 FCFA kg^{-1} and continued to descend to 60 FCFA kg^{-1} in 1993.

slash-and-burn annual cropping has been serious, significantly lowering overall carbon stocks and biodiversity. The exact extent of the loss depends on the acreage and type of land converted to this system. If additional lands already in this type of long fallow-crop rotation were brought into production, then fallow periods would have to shorten and, subsequently, less carbon would be sequestered during the fallow period. If the lands converted were in secondary forest, then there would be a one time decrease in the carbon stock, assuming that the system remained in the long fallow crop rotation cycle. The impact on biodiversity is difficult to determine. In the studies of plant biodiversity, older bush fallow fields were relatively rich in species and functional attributes, while the *Cucumeropsis/*plantain field was relatively deficient. Given the patchwork of fallow fields on the landscape required to support the long rotation, biodiversity is probably not greatly threatened by this system.

Rural poverty, which increased with the decline of the cocoa sector, was probably reduced by the smallholder expansion of this field system. However, as plantain prices declined over time, the positive effect on total revenues tended to decline as well. An even more significant positive impact on the poor probably occurred on the consumption side, where the decline in retail price allowed the urban poor to continue purchasing plantains.

This system will likely continue to increase in area as long as population grows and urban tastes for plantains remain important. Given approximately 2.9% current population growth, this system is likely to continue to expand in importance. A possible mediating factor could be a change in tastes towards other starch products, such as rice and wheat flour, by urban populations as incomes rise.

Short fallow-intercrop rotational systems

Among the slash-and-burn annual cropping systems in the benchmark, the short fallow-intercrop rotation is the most prevalent. This system is likely to increase in area, in rough proportion to the increase in rural and urban population (unless of course technical change increases its productivity). Locally, with good market access, opportunities for commercial surplus production would be expected to lead to proportionally greater expansion than in areas with poor market access.

The environmental impacts of an increase in this cropping system are similar to those of the *Cucumeropsis spp.*/plantain field. If expansion occurs by bringing more short fallow land into production, then fallow cycles will shorten and time-averaged carbon and biodiversity will decline. If long fallow lands are converted into this short fallow rotational system, there will be a step down in carbon stocks and, most likely, biodiversity as well. From the standpoint of poverty alleviation and food security, this system is crucial to the HFZ of Cameroon and most of the Congo basin. A significant proportion of the marketed production in the urban markets of the region comes from this field system and generates, for the women farmers who manage it, an important portion of their revenues. The major crops marketed from this field type are cassava, cocoyams, leafy green vegetables (including cassava leaves) and, to a lesser degree, groundnuts and plantains. More importantly, in rural areas this food system feeds the household. Given the underdeveloped state of food markets in the region, most households cannot rely on rural food markets for the majority of their needs and will, therefore, continue to rely on this system to meet their consumption needs. Given this fact, agricultural research targeting the productivity and sustainability of this system is vital to the strategy of taking pressure off the forest margin.

Horticultural cropping systems

One of the most rapidly growing cropping systems in the more densely populated portion of the benchmark is the intensive cultivation of horticultural crops. These systems have been integrated into the short fallow-intercrop system through an extension of the cropping period (i.e. an increase in the "Ruthenberg" index of cropping intensity). Typically a tomato or okra monocrop (with inorganic fertilizer often applied) is followed by the traditional groundnut-based intercrop. This phenomenon is a relatively recent event, with the introduction of intensive horticultural techniques occurring only in the last 20 to 25 years. These systems are vastly more dependent on chemical inputs than any other cropping system in the forest margins benchmark. This is largely because of the difficulties posed by the humid and warm climate that tends to augment pest pressures. The profitability of these systems can be very high, with gross revenues surpassing \$2,000 ha^{-1} in one season. However, they are also very risky and require a significant management input not only in production and pest management, but for marketing as well. Their heavy use of inputs also limits their extent to those areas in which input supply markets are well developed. A similar diversification of agriculture in the humid zone has occurred in Cote d'Ivoire and Ghana, especially in areas with regular and reliable market access. In the Lekie administrative division in the northern portion of the forest margins benchmark, approximately 11,000 ha are now planted to these intensive systems. In terms of economic growth, these systems generate significant forward and backward linkages and have a relatively large regional multiplier effect.

Inland valley land use systems

The dominant focus of this analysis has been on upland land use systems. Another important land type in the region is the inland valley. This land type in the Congo basin is characterized by several natural vegetation types, including hardwood swamp forests, raffia palm swamp forest and papyrus reed marsh. The first two vegetation types present major problems for clearing and land preparation for agricultural purposes. In certain areas of the Congo basin, inland valleys have been profitably used for the aquaculture of *Oreochromis nilotica* (in particular Bandundu Province of the Democratic Republic of Congo).

Within the forest margins benchmark, the agricultural use of inland valleys for paddy rice production was at one time required by the colonial regime, a practice that was widely resented by many farmers. With the exception of the area near the Gabon-Equatorial Guinea border, rice cultivation in these valleys no longer takes place in southern Cameroon.

Their major agricultural use within the benchmark is for dry season production of green maize, and in the urban perimeter of Yaounde for the intensive production of lettuce, leafy vegetables and other horticultural crops. They are also used to a lesser degree for aquaculture of *Oreochromis* spp.

Land use shifts, land use mosaics and policy

A core issue in sustainable agricultural development in a rain forest environment, today, is that of mitigating the potential environmental and social costs of economic growth. At the same time that alternatives are being sought to increase the overall performance of agricultural systems, protect the environment and alleviate poverty, appropriate attention has to be given to the potential contradiction among these three sets of objectives. By the same token, the development of alternatives to hundreds-of-years-old slash-and-burn systems in the Central African rain forest has to be based on a field-grounded knowledge of the dynamics and resilience of those systems. This will facilitate the understanding of the realistic range of possibilities and tradeoffs related to land use change and expected land use shifts at a broad scale.

Land uses and the notion of best bets

To understand Cameroon's research approach to the notion of "best bets", one has to keep in mind the structural composition of households' food, cash and social basket (Figure 10) and the basic structure of the landscape in the humid forest margin (Figure 11). Households' subsistence and food security needs in the HFZ benchmark are typically met through the integration of multiple crops and tree-based systems, complemented by an array of activities that include monocropping options, fish farming, hunting, fishing, and the gathering of non-timber forest products.

This multi-level system of land use is built upon a kin-based system of nested property and access regimes. So far, the latter has been able to guarantee intergenerational access to natural resources, despite a patrilineal bias concerning women's access to capital inheritance and evolving conditions of demographic pressure. The biophysical (carbon, GHG, biodiversity) and institutional (property rights) studies carried out in Cameroon have targeted the basic structure of interfaces between different segments of this landscape and human interventions. The economic study has simulated the cost-benefit analysis of environmental, economic, and social conditions pertaining to a selected set of agricultural interventions (Figure 12). The issue of agricultural sustainability, as well as the collective action component of the research on local institutions, have also focused, by their very nature, on agricultural development conditions in the study area. The analysis of impacts and research and policy orientations elaborated by Cameroon's country meeting have both benefited from, and been limited by, this configuration of biophysical and socioeconomic research at different scales. The policy and action research recommendations following this evaluation of the anticipated impacts of land use shifts are thus based on expert judgement and best-of-knowledge assessment, and not on specific policy research. It is believed, however, that the exceptional scientific mix forming the basis of these evaluations and recommendations is both robust and credible.

The systems identified and submitted to an economic evaluation are *improved cropping systems*, which are likely to yield differing environmental and social benefits. As such, they are but one component of *a mosaic* of systems and activities which, together, make up the actual pattern of land use in the humid forest margins. This relationship is described by (Figure 11). The notion of "best bets", which has been instrumental in the research design of Phase II, needs to be clarified in that respect. In the research framework developed by the Cameroon team, the "best bets" are not conceived as brand new technologies that are going to be developed from scratch, in order to replace current land uses. Rather, they are based on existing systems, of which we know the economic, environmental, and social potential and limitations, and which can, therefore, be the target of specific interventions that could increase the overall performance of the system.

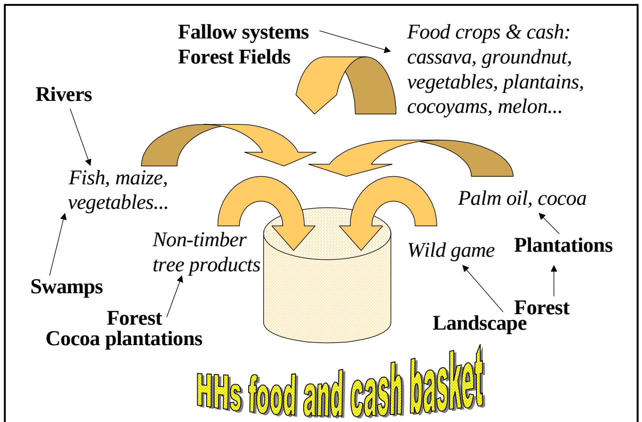


Figure 10. Food, cash and social basket of the household

It is the anticipation of probable trends in land use changes over time that has provided the basis of the Cameroon team's approach to the question of "best bets".

Land use history and present configuration in the HFZ clearly demonstrate intercropping and cash production strategies dominated by small-scale farms and household needs in the general framework of a collective and common property system of land and natural resource allocation. This strategy is shaped by household structure (family labor and gender relations, in particular) and preferences, land and natural resource configurations, and the institutional make-up of property and access rights in the rural landscape. It is very unlikely that any policy or technological innovation, however radical, would drastically alter those patterns and trends in the near future. The changes that are most likely to produce lasting impact are those that take place within that mosaic of multiple use and complementary production systems. They are themselves developing parts of the system and, as such, they can modify its evolutionary path. It is within that realm that technological innovation and improvements-- "best bet" systems for which environmental, economic and social implications are predictable -- can be targeted for research, development and policy efforts.

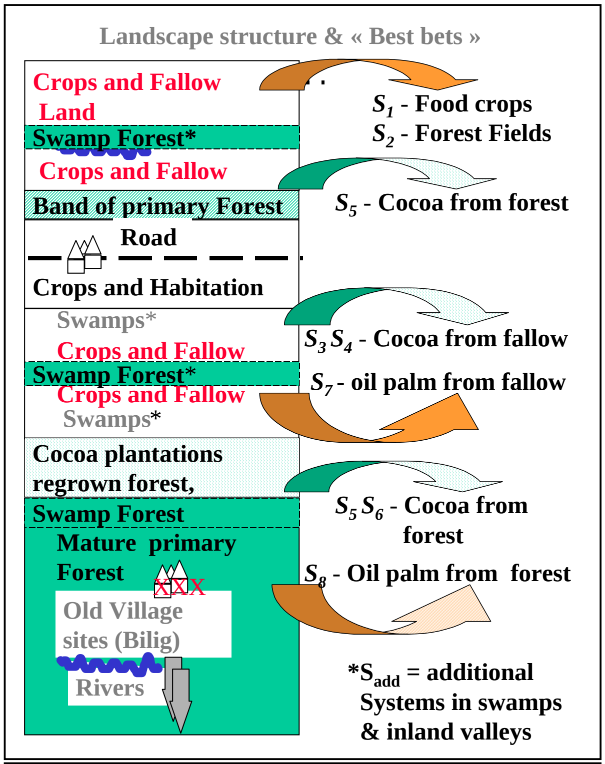


Figure 11. Structure of the landscape in the humid forest zone

Evaluation of problems associated with anticipated shifts

A key criterion for making research and policy choices is the balance of social benefits and costs that can be expected from the development of alternatives.

- Who is likely to benefit or suffer from the development of oil palm plantations or the implementation of community forests? What do the history of cocoa expansion in Cameroon and the initial phase of development of plantation systems tell us in that regard? How do those systems compare with improved food crop fields on short fallow rotation and forest *cucumeropsis* fields with regard to their beneficiaries and potential social biases? What are the other promising land use or cropping systems, which, for various reasons, are not the most likely to emerge as dominant in the landscape? What could be their impact and what can be done to integrate their positive features into alternative strategies?

- What are other negative implications of expected land use shifts with regard to environmental, social and economic variables? What are the various scenarios and options and how can their social impact be anticipated?

The very nature of the research approach taken –"best bets" as an improvement of smallholder plantations and actual land use systems in village communities -- points broadly at small farm households and communities as potential beneficiaries of those options.

Communities, however, are not homogenous, while various social interests, outside of the communities, are also at stake. Social options also need to be weighed against other types of benefits within and across systems.

In addition, the different constraints and problem areas identified with regard to each of the selected production and resource management options indicate trends that depend, to a different extent, on the way institutions, markets and policies will actually behave in the near future. Another essential factor to consider is the relative heterogeneity of the humid forest margin itself, with its gradient of environmental conditions, agricultural intensification and human pressure on the resource base.

Stakeholder analysis of potential benefits and "Losses" from the anticipated shifts in land uses

Schematic presentations for the stakeholders who are most likely to be affected by "best bets" development follow. The presentations summarize the basic context or assumptions related to the land uses considered and indicate the expected patterns of benefits, risks and losses. In the case of community forestry, where the direction of change is most sensitive to conditions external to the control of communities and small farmers, two alternative scenarios are provided. In that case, the contextual differences would notably affect not only stakeholder groups but also the development -- expansion or contraction -- of the system itself.

A. Oil-palm systems		
Context/Assumptions: (1) Strong spread of oil palm systems in the benchmark; (2) Dominant smallholder monocrop system based on the industrial 'SOCAPALM' model (Oil palm associated with food crops in the first three years, followed by monocroping).		
Beneficiaries	**Benefits**	**Risks/Losses**
▪ Farm households ▪ Social elite ▪ Palm oil industry ▪ Government ▪ Urban consumer ▪ Regional consumer	▪ Increased revenues from sales (men mainly) and artisanal processing (women included) ▪ Increased revenues, prestige and money ▪ Greater profits (privatization of process), steady supply at favorable prices ▪ Increased tax revenues ▪ Mitigate the monocrop Soca model ▪ Better supply of oil palm products and by-products/ 'Urban bias' through seasonal quotas on exports (hidden tax)	▪ Reduce women's influence on HH decisions ▪ Loss of common property forest lands ▪ Concentration risk against capital-poor households. ▪ Producers' dependency on the industry (tied loans for inputs) ▪ Rural producers' loss of market advantages and revenues during low-season ▪ Some loss in environmental benefits
Options: Develop and promote improved varieties. Mitigate environmental, concentration and gender biases through "mosaic" management strategy. Develop small-scale processing. Maintain seasonal quotas for resource preservation (?)		

B. Cocoa systems		
Context/Assumptions Likely to remain stable in present conditions, following structural adjustment programs that cut subsidies and state services. Recent increase in world and producer market prices for cocoa might result in a renewal of the activity but not in a dramatic expansion of the system throughout the landscape. Considerable increase in the quantity and quality of cocoa production could result from appropriate policies and the availability of affordable technologies to control pests, particularly, black pod fungal disease.		
Beneficiaries	**Gains**	**Risks/Losses**
▪ Farm households ▪ Farmer organizations ▪ Government ▪ International cocoa sector and chocolate industry ▪ Global consumers	▪ Increased revenues ▪ New occupational niche in marketing sector ▪ Fiscal benefits and rents ▪ Biggest profit from the sector's growth	▪ With no control on world prices, the producer is mainly a price-taker; ▪ Intensification might induce bias against poor farmers ▪ Information and position in regulatory bodies still weak ▪ Lower benefits than desirable under present international terms of trade

Further conditions: Fair international share of the cost of environmental conservation. Internal policies supporting plantation renewal and the strengthening of farmer organizations. Increased representation of farmers in regulatory bodies.

C. Community Forestry (CF)--Scenario 1:

- No change in present policy orientations
- Weak implication of traditional tenure institutions

Context: *1994 Forestry Reform* – Includes provisions for granting 'community forest' concessions to communities represented by 'legal entities' taken from a pool of farmer organizations, which acquired legal status through the 1990, 1992 and 1993 laws on associations, common interest groups and economic interest groups. These organizations can play a strong proactive role in conservation and development. They do not, however, have the community mandates required in matters of tenure and devolution. Anthropological institutions, which are not considered by the reform, such as lineages, clans and village councils, retain these functions.

Beneficiaries	**Position/Power**	**Benefits**	**Potential Risks/Losses**
Communities	**Medium:** *little information*, can participate but only through legal entities	Small tax & logging-related revenues	Loss of forest & forest-related revenues; risks of social restructuring
Local elite	**Strong:** main beneficiary of Information asymetries	Rent capture of logging-related revenues & taxes	Conflicts harmful to influence in community
Farmer organizations (GICs)	**Intermediate**: can be recognized as legal entity; low information & legal limits to economic benefits		GICs a potential vehicle of vested interests
Farm Households & lineages	**Weak:** family institutions not recognized as legitimate stakeholders		Low returns from forest exploitation, loss of agricultural lands, weakening of traditional authority
National and international logging interests	**Strong**: bargaining position; have the technical & financial capacity to fulfill inventory & logging requirements in CFs	Quick-profit Low-cost logging in community forests	Unsustainable logging, small size of CFs (5000 ha) Loss of environmental & economic benefits
National public interests	**Intermediate:** limited influence through NGOs & other private & public bodies		
Government	**Strong:** Retain main decision-making power for recognition, design & monitoring of CFs		Loss of long-run fiscal revenues, negotiation failure
Global consumers			Loss of global environment benefits, non-sustainable consumer benefits

- **C. Community Forestry—Scenario 2:** Adoption of reform at implementation stage
  - Empowerment of customary tenure institutions;
  - Flexible adaptation of criteria related to size of Community Forests (CF);
  - Adaptive management plan that takes into account the relation between forest and agricultural cycles.

Beneficiaries	**Position/Power**	**Benefits**	**Potential Risks/Losses**
Communities	**Strong**, can participate through all institutions and organizations	Balanced revenues from agriculture, small-scale logging, gathering and domestication of NTFPs, use of other natural resources; tax revenues from logging	
Local elite	**Intermediate**: Benefit from information but not institutional asymetries.		
Farmer organizations	**Strong**: can participate & play a proactive role	Reinforced collective action for poverty alleviation and forest-related alternatives	
Farm households and lineages	**Strong**: family institutions recognized as stakeholders	Increased household's welfare	
National and international logging interests	**Intermediate**: have the technical & financial capacity to invest CFs, but this influence is subordinated to larger community interests	More local accountability & economic discipline of logging; sustainable logging based on genuine stakeholder negotiation	Higher short-term transaction costs
National public interests	**Intermediate**: some influence thru NGOs and other civil interests	Forest conservation & increased availability of forest-related products	
Government	**Strong,** Main supervision power in recognition, design & monitoring of CFs	Long-term economic & environmental benefits & fiscal revenues.	Loss of short-term tax revenues
Global consumers	**Intermediate:** through donors & international agencies	Gain of global environment benefits at sustainable consumer prices	

<table>
<tr><th colspan="3">D. Improved Food Crop and Long Fallow/Forest Fields</th></tr>
<tr><td colspan="3">Context/Assumptions:
1. Significant labor constraints restrict the possibility of a large portfolio of food crops and forest fields per household. Under present technological conditions, a large-scale spread of these systems is likely to happen only with the multiplication of farm households, as a consequence of demographic growth.
2. These two types of fields are complementary within households' agricultural cycles
▪ Their improvement is dependent upon research and technological innovation (short fallow & multi- trata systems, IPM, plant health management, etc.)</td></tr>
<tr><td>Beneficiaries</td><td>Gains</td><td>Risks/Losses</td></tr>
<tr><td>Women for food crops
Men for forest fields
Farm households in general
National and regional consumers</td><td>▪ Increased revenues from increase in marketed surplus
▪ Increase in farm household food security
▪ Increased food supplies and improved regional food security</td><td>▪ Lack of marketing infrastructure and difficult market access limit farmer incentives to intensify.
▪ Small market size and inelastic demand leads to decrease in farm prices and fall in farm revenues.
▪ Increased profitability of extensive long fallow systems leads to an increase in resources allocated to this land use system , increasing its relative extent and depleting forest resources.
▪ Enhanced rural technologies and increased profitability of slash-and-burn farming along forest margins leads to influx of rural migrants.
▪ Marketing infrastructure remains underdeveloped.</td></tr>
</table>

Other important areas for mosaic strategic options

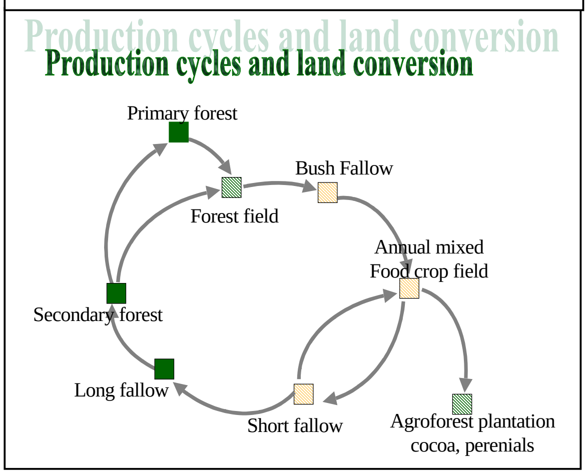
- Dry -season inland valley systems (*asan*)
- Fish/horticulture farms under Integrated Resource Management (crop-livestock-fish)
- NTFPs domestication in cocoa plantations
- Small-scale processing in home gardens and off-farm enterprises
- Rationale: occupy all the natural resource and man-made niches across the landscape.
- Emphasize system-driving, revenue-generating enterprises, associated with land-saving technologies and sustainable natural resource management systems.
- Integrate with strategic policy choices

Mitigation of problems associated with anticipated shifts

To improve the performance of expanding land uses and lift the obstacles to the development of other promising systems, our best option is to mimic farmers' integrative strategies, while improving individual components of the system. *Our main bet is thus to develop an improved mosaic within a strategy of Integrated Landscape Management* (ILM). Technological development and natural resource management in socially integrated African farming and resource use systems can, in no way, be a zero sum game. The model of land use specialization inherited from the European tradition of agricultural development may not be best suited for the development of agricultural and natural resource systems of the type found in the HFZ. This was partially recognized by farming systems research two decades ago.

The mosaic approach to integrated landscape management recognizes the positive features of this research tradition and goes beyond it. Particularly adapted to the configuration of multiple use, nested rights and multiple eco-niches on which production systems have been socially built in the African rain forest, this approach reconciles agricultural development objectives with environmental and social concerns, and individual benefits with community needs, as well as anchors technological and management innovations in a traditional substratum. The ILM approach goes further, and integrates key factors both upstream and downstream of the production process. For primary production alternatives to develop their full potential and to create positive spin-offs onto the overall development-conservation nexus in the forest, a host of interconnected initiatives will have to be taken *simultaneously, or, at worse, in a close sequence*. Research conducted in the HFZ (Ndoye, 1998) indicates that revenue increase in conditions of expanding markets for non-timber forest products will not allow for resource preservation, unless the pace of species domestication is accelerated and information is adequately disseminated to farmers. Cocoa plantations, which our research has targeted for best-bet improvement, are presently the main domesticated reserve for NTFPs in the HFZ. Research and development work on cocoa plantations would thus fit naturally with on-going endeavors related to the marketing and domestication of NTFPs. The development of post-harvest systems and peri-urban enterprises, which are a focus of the new Ecoregional Program for the Humid and sub-humid Tropics of Africa (EPHTA), are also necessary to reduce post-harvest losses, and to benefit from the added-value of small-scale rural businesses and the proximity of expanding urban markets. Such enterprises could generate rural wealth while *deflecting* some of the anthropic pressure on land and forest. Oil palm systems are a "natural" candidate for these post-harvest enterprises, as small-scale palm oil processing technology can be readily made available to farmers at a large scale. The *deflection* feature of these "off-farm" alternatives cannot be neglected as we aim at mitigating the negative environmental impacts of any single technological option. This holds, at the landscape level, for the mix of integrated systems, which all have their pluses and minuses. In order to achieve the objectives defined above, appropriate policies would have to be designed and institutional

Figure 12. Land conversion processes



constraints to the availability of research results, the development of infrastructures and market access, lifted.

It will also be necessary to build upon the long-term cycles of land use systems. These cycles, that once permitted the complete reconstitution of a mature primary forest after generations of use (Figures 12 and 13), have been disturbed by several factors. Most salient among those are the relatively high demographic and land pressure on forest areas in the northern part of the benchmark and the forced settlement of villages along major roads and trails under successive colonial regimes during the first quarter of the century. This second factor applies to the entire research area. It is probably responsible for the pattern of land use sedimentation across lateral bands of forest, agroforests, agricultural and swamp lands which, as participatory maps done in the region indicate, run parallel to the transportation channels across which villages have settled. This means that in "forest rich" areas, the complete reconstitution of the long term cycle that enabled primary forest reconstitution in abandoned village sites (*bilig*) would imply a return move of habitation into the deep forest (totally improbable) or the abandonment of present agricultural land coupled with the construction of major trails linking habitations to new fields and plantations in the forest (very unlikely).

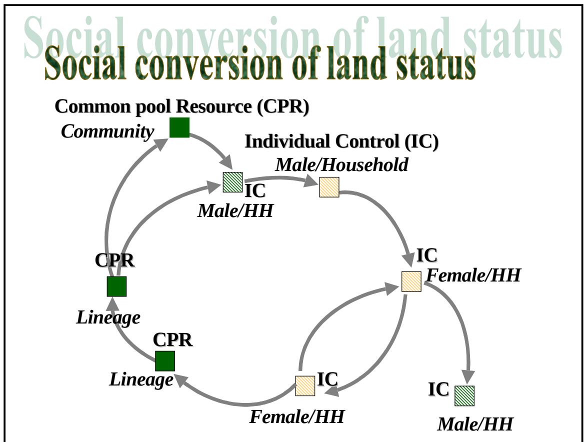


Figure 13. Control of property rights

The present configuration of land use is thus likely to remain, with a probable intensification of anthropic pressures on farm land, agroforests and swamps. If not checked by appropriate policies linking research, development and conservation strategies, these pressures will necessarily, in the long run, coalesce into a frontier front that will ultimately touch and transform communities' main forest reserves. The latter are presently used as a granary of non-timber tree products and as hunting and fishing grounds. As indicated by Figure 1, they are often located at one end of community landscapes, opposing residential areas.

Research options, policy and collective action

The first question to raise, with regard to the means of influencing policy changes, is that of the limited usefulness of 'country action plans'. Not only is most research not timed to fit a protocol leading to the design of such plans, but an influence at the planning level gives little guarantee as to actual implementation. As shown by a recent study of the 1994 forestry law in Cameroon (Ekoko, 1997), the level of policy implementation is critical, as it might result in a significant alteration of principles and orientations carefully designed at an earlier stage. The sociology of the political and civil environments in Cameroon requires that appropriate attention be given to direct linkages with policy-makers and that research results be brought to their attention in an appropriate fashion. In Cameroon, it is expected that this could be effectively done though policy briefs, targeted workshops and individual contacts with high and medium level decision-makers.

It is also foreseen that the particular institutional configuration set up by the decentralization reforms of the early 1990's have created a favorable environment for community-based collective action. Following the 1990, 1992 and 1993 laws on associations, common interest groups and common economic groups, thousands of grassroots organizations have acquired legal status and have formed large federations and confederations of farmers. These organizations have taken numerous initiatives on their own and are also seeking active collaboration with research institutions and NGOs. In collaboration with the CGIAR NGO committee, IITA, IRAD, ICRAF and CIFOR have initiated talks with two dozen NGOs and farmer federations about a platform of action on common research and development priorities. Such a platform of action could be a powerful vehicle for participatory research and concerted development action, in order to tackle local policy challenges through strategic institutional linkages. This, in turn, could significantly influence higher levels of decision-making. The EPHTA ecoregional program is another forum where a broad group of conventional and non-conventional stakeholder organizations (national and international) have gotten together with the view of linking research with development and extension. Overall, changes in the institutional makeup of the research, development and conservation sectors in Cameroon and Central Africa offer a great opportunity for the emergence of a broad-based alliance of research with a diversity of organizational interests in the region. This alliance could help shape the orientation of land use systems in a manner coherent with ASB's objectives and results and develop an influence at both the community and state levels of decision-making. Given the global environmental services that would result from the adoption of 'best bets', it must be stressed that the level of policy action or lobbying required goes beyond national states, to include the contribution of global interests to the environmental, economic and social alternatives inherent to the ASB program. This also will require appropriate intervention at the appropriate level.

Summary and Conclusions

Cameroon's forest resources, one of the country's greatest riches, have played and continue to play a significant role in its economic growth and development. In the 1950s, 1960s and 1970s, conversion of approximately 500,000 ha of moist forests to smallholder coffee and cocoa agroforests resulted in relatively equitable economic growth, averaging 3 to 4 %. In more recent years, timber exploitation has overtaken coffee and cocoa production as the most important economic activity in the moist forests. Cameroon is now the leading African exporter of tropical timbers, with over $270 million in annual export sales. By and large a poor nation, Cameroon has little choice but to develop its forest resources. From the standpoint of government policy, the critical question is whether Cameroon's tropical forests will be turned into sustainable agricultural and forestry production systems or "mined" into a state of degraded vegetation.

Agricultural intensification is inevitable for Central Africa. Given the rapid population growth of the region, the question is not whether intensification will proceed, but rather— Where? When? What type? And with what impact on the environment and rural development? The above analysis has shown that in the Forest Margins Benchmark of southern Cameroon, substantial environmental costs are associated with endogenous population-driven intensification, characterized by declining fallow periods and nutrient depletion of soils. In the process, carbon stocks decline significantly and biodiversity is lost. Across land-use systems, the importance from both environmental and rural development perspectives of maintaining perennial tree crop systems on the landscape is clearly indicated. Mature cocoa agroforests (> 25 yr) maintain approximately 60% of the carbon stock of primary forest, are important genetic reserves for indigenous fruit trees, and preserve important habitat for avian populations of threatened species such as African gray parrots and hornbills. The cocoa and oil palm perennial crop systems are also the most profitable production systems examined, now that major policy distortions such as overvalued exchange rates and fixed price marketing regimes are no longer factors.

In Cameroon, smallholder slash-and-burn agriculture is the major source of deforestation, and, therefore, any proposed approach for addressing deforestation must start with agriculture. We argue for a proactive, policy-led effort to intensify both perennial and food crop systems in order to deflect further advance of the forest margin at the household level, in combination with migration and industrial macro policies to limit access of migrants to closed canopy forests. We also suggest that perennial crop agroforests are more sustainable agronomically and can provide some portion of the environmental services of tropical forests, as compared to fallow-based food crop systems. At the same time, given the current state of underdeveloped rural food markets, food crop systems managed by women will remain an integral component of farming systems for the foreseeable future and, therefore, must be subject to policy-led intensification as well.

Any technology or policy innovation that increases the productivity of farming in the humid forest region runs the risk that additional land and labor resources will be allocated to that particular activity, increasing deforestation. Therefore, at the regional and national level, policies should strive to limit rural migration to the forest frontier. So far, in the Forest Margins Benchmark of Cameroon, customary tenure institutions have been sufficiently robust so as to prevent large-scale in-migration (Diaw 1997). Such has not, however, been universally the case in Cameroon. A case in point is the large-scale rural-to-rural migration to the forested lowlands of the Littoral and Southwest Province from the densely populated western highlands (Dongmo 1981). More research is needed to understand the social, institutional and infrastructural factors affecting migration so that better informed policies can be devised.

The necessary elements for policy-led intensification are grouped around the provision of improved price incentives and the strengthening of both local and national institutions. A viable and dynamic research and extension system capable of responding to farmers' demands and generating appropriate solutions is one of the main requirements. In the typical circumstances of the Congo basin, where the farmer's scarcest resource is labor, traditional technology systems typically economize on labor and, therefore, viable solutions, must ensure that the farmer's return to labor is increased. The differentiated labor roles of men and women in these systems and variation in time allocation over the agricultural calendar have direct bearing on technology adoption and labor productivity. Land and labor productivity are sometimes increased simultaneously by a given innovation. A case in point are the fertilizer-seed systems of the green revolution, which increased both land and labor productivity and are credited with having deflected vast areas from agricultural conversion (Hayami and Ruttan 1985). Labor productivity measured in economic returns can be also increased through appropriate subsidies and taxes, to correct for production externalities that are not reflected in market prices. Fertilizer subsidies in the Congo basin take on a new perspective when one considers the potential economic costs in a carbon market of a smallholder burning her fallow field and releasing 100 to 135 tons of CO_2 annually into the atmosphere.

Market mechanisms such as ECO-OK labeling and the fair trade movement are attempting "market" corrections for coffee and cocoa produced in an environmentally benign fashion, albeit on a small scale and largely without the support of large donors. These efforts should be expanded.

For rehabilitating areas that are already significantly degraded, institutional mechanisms for transferring carbon credits to smallholders should be explored as a means of providing new planting incentives for reforestation through agroforests. Supportive rural institutions such as credit markets and input markets, and the multiplication and distribution of improved planting material must also be strengthened.

Intensifying production in the forest zone is not a new idea. As early as the 1930s the French were searching for ways to intensify cocoa production in Cameroon. Most of these efforts did not achieve their goals. What is different today, however, is the much improved economic environment for intensification. Producers are now showing renewed interest in their perennial crop systems, following the removal of implicit producer taxation administered by the now defunct export marketing board. The infusion of new competition into export crop marketing has also reduced marketing margins and increased producer incentives. These incentives need to be further augmented with improved technologies and strengthened institutions to more efficiently exploit Cameroon's natural comparative advantage. This will require capacity building in the public sector and the exploration of new institutional arrangements for the provision of services and inputs by the private sector, NGOs, and farmer organizations.

Policy change has been described as a pillar of the strategy for agricultural development in sub-Saharan Africa (Cleaver 1993). In southern Cameroon, most of the price distortions which characterized export markets have been eliminated, as evidenced by only slight disparities between social and farmer profitability, although perennial tree crop producers remain more heavily taxed than annual food crop producers. Historically, this disparity has been much wider. A strong economic argument for subsidizing production from agroforests can be made on the basis of the range of outputs which are not valued by markets (biodiversity, carbon sequestration, and watershed functions). There is, of course, a major caveat: perennial tree crop systems generate net environmental benefits only when replacing degraded short fallow lands. If they are established in primary or secondary forest, then there would be a net loss to the environment (although conversion to multi-strata agroforestry systems retains more environmental services than any other type of agricultural land conversion).

From both an agronomic and an economic perspective, perennial crops are well adapted to the conditions of the Congo basin. However, with the exception of cocoa and robusta coffee in southern Cameroon and robusta coffee in the Democratic Republic of the Congo, smallholder perennial tree crop systems are not widespread (Manyong *et al.1996*). Encouraging the establishment of perennial tree crop systems in the Congo basin should be a development priority. Encouraging their establishment in already deforested fallow land offers a win-win situation for both development and the environment. However, farmers will normally choose to establish their plantations in long bush and forest fallows when this type of land is disposable, in order to capture the fertility rent (Ruf 1998). To counter this rational economic behavior, new planting subsidies could be targeted for planting in degraded short fallow situations, perhaps as part of a still-to-be-developed carbon emissions/sinks trading scheme.

Such a strategy presumes either increased productivity of the remaining short fallow lands or the substitution of market food purchases for previously produced on farm production.

In much of Central Africa, rural markets are not well developed in comparison to West Africa. Without their institutional development, households have no choice but to rely on their own production for the bulk of their food consumption. In the short and medium term, while awaiting better infrastructure and rural food market institutions, heavy emphasis must be placed on the intensification of food cropping systems. Improving the overall productivity of farming systems and generating sustainable livelihoods will require a *land-use mosaic* approach at the household and community levels, focused on increasing productivity, environmental services, and sustainability of the overall agricultural landscape. Essential elements include an empowering participatory research and development approach, the intensification of subsistence-oriented food production systems, the conversion of short fallow lands with intensified agroforests, the intensification of existing agroforests, and the improved management of common property resources, including community forestry.

Intensifying annual crop systems will require that attention be paid to institutions, infrastructure, and factor endowments. In areas such as the Yaounde block of the benchmark, where fallows are short but market access for outputs and inputs is high, 'green revolution' seed-fertilizer technology systems have a role to play in the intensification process. Where medium and long fallows are still the norm for annual food crop systems and where infrastructure and market institutions are less developed, new varieties and cropping techniques are called for. Crop breeding should focus on increasing varietal tolerance to pests and diseases as well as the many mineral deficiencies that characterize the soils of the basin. At the same time, cropping systems and land husbandry techniques that are more efficient at capturing the high flush of nutrients following the burn are needed. Most of the staple crops of the region--cassava, plantain, yams, taro and cocoyams--are vegetatively propagated (VP). This is both a blessing and a curse for achieving impact from plant breeding efforts. It is a blessing in that once farmers have new VP varieties they do not need to continue to repeatedly purchase the same variety, as is the case with hybrid maize and horticultural crops. On the other hand, it means that the private sector is unlikely to play a role in research and multiplication. This places the onus on national research, extension, NGOs and farmer organizations to find, develop, adapt, and distribute these varieties. Multiplication of VP material is generally more time consuming than seed multiplication and often results in the transmission of pests and disease. Tissue culture speeds up the process and can control pest and disease problems. This capacity needs to be built up in the region. Perhaps the most promising vehicle for diffusing improved VP materials are farmer groups and farmer federations. These organizations are proving to be an important means for the diffusion of varieties using rapid multiplication techniques on the shelf for plantain, cassava, yams and cocoyams.

The allocation of political resources is relatively inefficient in Central Africa, and the capacity for implementing and enforcing policy in the agricultural sector is weak. The overall capacity of the public sector in Cameroon was significantly weakened by the across the board salary reduction that the government implemented as part of its structural adjustment program, which greatly diminished public sector efficiency and output. While the civil service has slowly been decreased in size through hiring freezes and forced early retirements, the problem of a low paid, inefficient civil service still remains a major obstacle to the strengthening of institutions required for the sustainable development of forestry and agricultural resources. Without support for institutional development, the significant gains achieved in environmental and forestry policies since the mid 1990s will remain little more than paper policies.

The restrictions placed on political organization have limited political development in rural areas and biased the allocation of state resources in favor of the urban-based political elite (Bates 1981). The institutionalization of public sector capacity to provide a continuous stream of technology consistent with resource endowments has generally been most effective when the political environment has encouraged the development of farmer organizations (Binswanger and Ruttan 1978). The impetus given to farmer organizations in southern Cameroon with the reform of the cooperative law in 1992 is a step in the right direction, but much more needs to be accomplished in this regard in Central Africa. These grassroot initiatives are a potentially important vehicle for accomplishing the bottom-up institutional change so desperately needed to effect agricultural intensification in the Congo basin.

At the national level, policy makers are concerned about food security issues and maintaining adequate food supplies in urban areas. Interregional trade liberalization should be encouraged, particularly across agro-ecological zones, to address these concerns. All countries in the Congo basin have significant land areas of moist savanna. The productive potential of annual food crop production in this ecological zone can be even higher than in the humid forest zone due to increased insolation, and the environmental costs of production in savanna zones are considerably lower. However, a large portion of the population of the Congo basin lives in urban centers with extremely poor linkages to these potentially productive savanna areas. Developing transport corridors would significantly reduce the von Thünen intensification pressures around urban centers in the humid forest zone and enhance urban food supply.

It is also important to consider the impact that rapid urbanization in West and Central Africa is having on consumption patterns. Urban household consumption of imported rice and wheat flour is many times higher than that in rural areas. According to the last Cameroonian census, 52% of the population residing in the humid forest zone of Cameroon was urban-based in 1987. Countries across West and Central Africa are experiencing similar demographic trends, with many predicted to be predominantly urban-based within a short time. These factors lead to questions about the strategic comparative advantage for the humid forest zone of West and Central Africa. Would the countries of West and Central Africa be better off concentrating food production in savanna areas, while promoting diversified perennial tree crop systems to generate foreign exchange in the humid forest zone? The areas in the world agronomically able to successfully produce cocoa, coffee, rubber, oil palm and other tree crops are limited compared to the areas that can grow maize, wheat, rice, and other staple grains.

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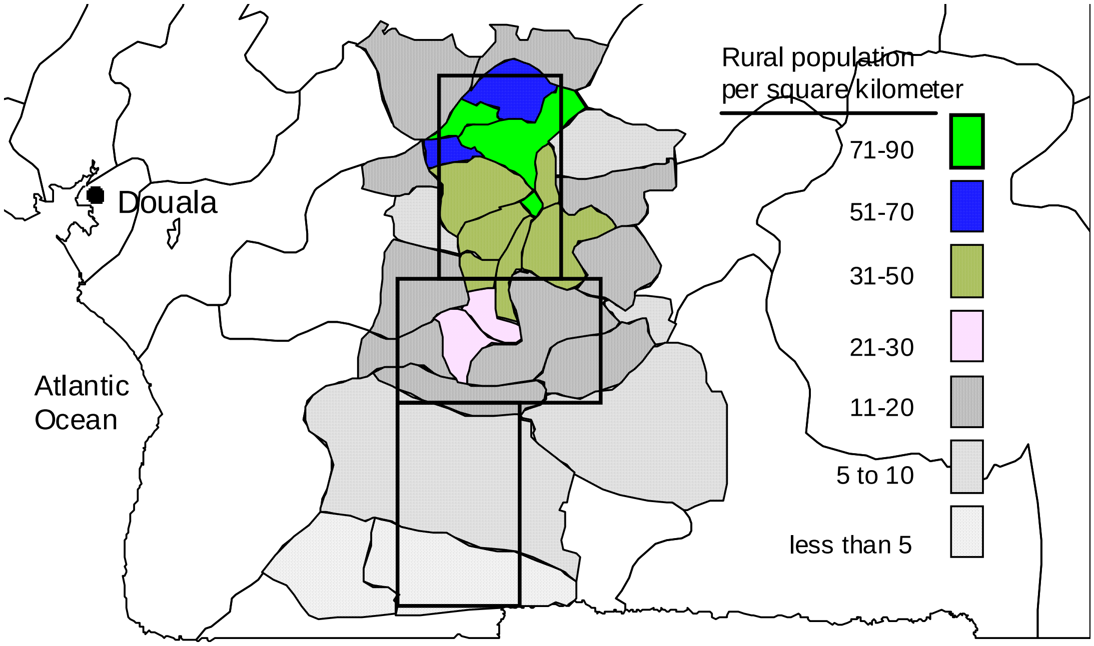

Source: Densities from 1987 population census

Annex Figure 1. Population gradient across the Forest Margins Benchmark.