PRINT: ISSN 0970-9274 ONLINE: 2456-6608
J Hum Ecol, 27(1): 27-33 (2009)
DOI: 10.31901/24566608.2009/27.01.03

Cropping Systems and Post-Cultivation Vegetation Successions: Agro-Ecosystems in Ndop, Cameroon

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KEYWORDS Cropping Intensity. Post-Cultivation. Vegetation Successions. Environmental Degradation. Agro-Ecosystem. Sustainable

ABSTRACT The sustainability of traditional farming systems in many parts of Africa is threatened by losses in the variety of species, reduction in land, forest, soil and water resources under demographic pressure. Together with foreign influences these farming system are no longer in equilibrium with local culture and ecology and are therefore disintegrating due to the lack of local capacity to adjust to these changes. This has led to environmental degradation. The paper employs a combination of qualitative and quantitative techniques to: analyse the farming systems, assess the effect of cropping intensification on the climatic climax vegetation, and to establish the post-cultivation vegetation successions in fallows. It reports four crop fallow rotations: crop 3 years with 1 year bush fallow, crop 5 years with 1-2 year bush fallow, crop 10 years with 1-3 year bush fallow and continuous cropping. The post-cultivation successions present a plagioclimax dominated by *Hyparhenia* species with scattered shrubs maintained by cycles of cultivation and burning. The paper concludes that these shifting cultivation cycles involving cropping intensification and post cultivation savannization have deprived the farming system of its ecological benefits, that is, nutrient recycling through a long and mature fallow. The inability of the vegetation to reconstitute itself requires the development of farming systems that combine trees and crops in the field because of proven micro-ecological and ecological benefits. The paper therefore identifies the scope for the development of ecologically sustainable agro-ecosystems as a development path for shifting cultivation systems.

INTRODUCTION

The sustainability of agriculture in many parts of Sub-Saharan Africa is threatened by losses in the variety of species, reduction in land, forest and water resources, soil erosion, salinization, acidification, desertification and environmental pollution (Bassey and Ndenecho 2006). Traditional farming systems which over centuries developed in constant interaction with local culture and local ecology have disintegrated because of the lack of local capacity to adjust to population growth and the influence of foreign values. The inability to mange change has led to severe environmental degradation. (Weiskel 1989; TAC/CGIAR 1988; Lawton and Wike 1979). In response to these influences there has been a tendency towards intensification characterized by short duration fallows with low external inputs (Chambers et al. 1989; OTA 1988). For most of Africa, production therefore lags behind population growth. As new technologies to intensify land use in a sustainable way have not been developed or are not known to farmers, they are often forced to exploit their land beyond its carrying capacity (Harris 1999; Sachs 1987). The over use of land under demographic pressure and the expansion of farm boundaries and small holdings to new, often marginal farming areas leads to deforestation, soil degradation and increased vulnerability to torrential rains and droughts (Reijintjes et al. 1992). Many African land use systems are therefore in the midst of such downward spiral of nutrient depletion, loss of vegetation cover, soil erosion and economic, social and cultural disintegration.

The paper seeks to analyse the farming systems in both qualitative and quantitative terms, and to assess the role of cropping intensification (shortening of fallow duration) on the climatic climax vegetation, and post-cultivation derivatives as they relate to the development of sustainable agro-systems in peasant communities.

THE STUDY AREA AND STUDY SITES

Ndop plain is an intermontane basin in the Bamenda Highlands. The average attitude is 1200 m above sea level. It has a humid tropical climate with annual rainfall in the range of 1500 to 2000 mm. The wet season lasts from mid-March to mid-November. The rest of the months are dry.

Annual average temperature is 21.3^{O}C. Large water deficits are experienced from December to February.

Three geological formations characterize the area: granites and migmatites in the north, ancient basalts in the south, and alluvial deposits in the centre and east. The main pedomorphic units are: alluvial soils on the Nun River flood plain, alluvio - colluvial deposits on the gently undulating foot-hills in the north, soils developed on basalts and trachytes in the south and fine-grained granitic soils on undulating hillocks in the plain (Kips et al. 1987) The vegetation is mainly wooded grassland with gallery forests at the head of thalwegs and *Raphia Vinifera* palm bushes in swampy areas. The natural rain forest vegetation has greatly been disturbed by man (Hawkins and Brunt 1965; SEDA 1983; Champaud 1973). The average population density is 96 inhabitants/ km^2.

Demographic pressure on land is high resulting in an average farm size of 1.54 hectares fragmented into two or three plots at different locations in the village. Shifting cultivation with short duration fallows is typical. This has resulted in the need to procure external inputs and to modernize the farming systems (Lambi 2001; Mchugh 1988; Aseh 1997). The average farm family size is 6 with 3 active farm workers. The main field sites investigated were (Fig. 1):

- Nun flood plain south of Bamuka village chief's palace: cultivation fallows and fields on silty-loams.
- Colluvial zone west of Rest House along the Bamenda-Kumbo Highway; cultivation fallows and fields on granitic colluvium.
- Colluvial unit in Babungo Agricultural station: cultivation fallows and fields on lava colluvium.
- Fine – textured granitic soils in Bambalang: forest remnant and regenerating fallows and cultivated fields.
- Coarse-grained granitic soils beyond Bamali

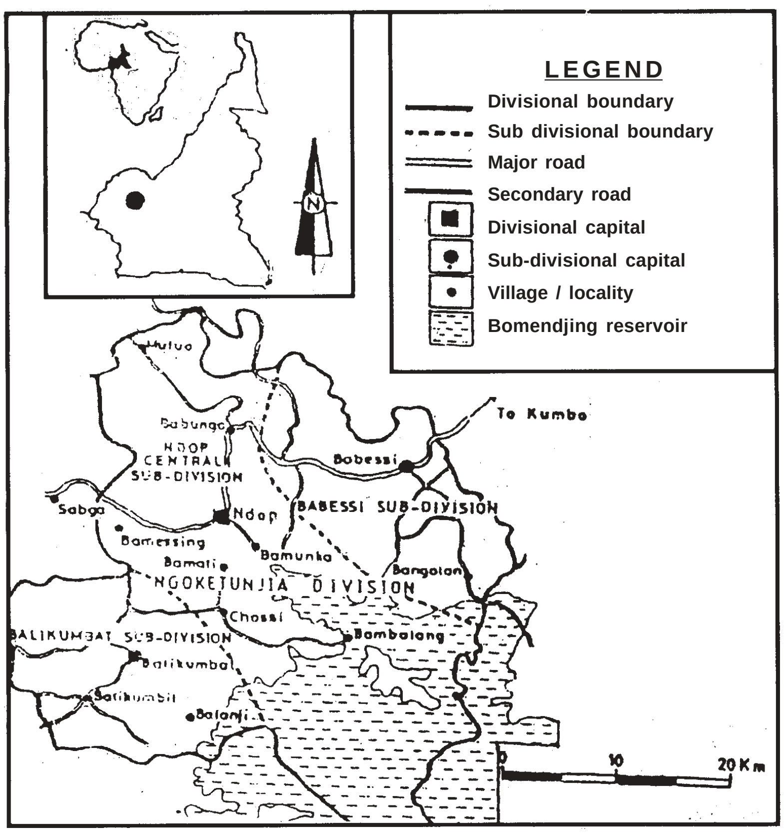

Fig. 1. Location of the study area (Ndop) and villages investigated.

village chief's palace: fallow plots and cultivated fields.

METHODS AND DATA SOURCES

In order to establish the cropping system, cropping intensity and cropping sequence pattern 130 randomly selected fields were investigated in 5 villages. The frequency of selected crops in crop associations and the distribution of crop associations on 23 randomly selected fields were the main aspects of the cropping pattern investigated with the assistance of the various village agricultural extension workers. The data collected were analysed using appropriate quantitative methods. The results were complemented by the maize – based farming system described by McHugh (1988). Each farmer was interviewed on the cropping sequence, cropping years and duration of fallows. Once the duration of fallows was established 5 post-cultivation vegetation successions per fallow year were investigated using random quadrant sampling. The distribution or the way plant species were dispersed over a quadrant was done by the inspection and identification of species present or absent from the area within each quadrant. The species so identified were then grouped under three abundance classes per fallow year: Class 1: very numerous, Class 2: numerous, Class 3: not numerous. The data obtained from the farming system analysis and quadrant sampling were used to develop a model of the shifting cultivation cycle, the process of cropping intensification and post – cultivation vegetation successions. The model assisted in the identification of the scope for the development of a sustainable agro-system under shifting cultivation systems with short duration fallows.

RESULTS AND DISCUSSIONS

The cropping systems can best be described as multiple cropping systems with mixed inter-cropping, that is, two or more crops are grown simultaneously with no distinct row arrangement and row inter-cropping, that is, growing two or more crops simultaneously with one or more planted in rows (Table 1).

Table 2 presents the main types of crop associations. Maize is represented in all associations as the main crop. The various crops presented in table 1 are associated in varying combinations of few crops. The main crop associations observed on farms include:

- Groundnut (*Arachis hypogaea*) is the most common intercrop with maize. It is present in 66% of the maize fields. Groundnuts are planted with and harvested just after the maize. They

Table 1: Observed frequency of selected crops in crop associations in Ndop plain.

Crop	*No. of fields*	*% of fields in which observed*
Maize	130	100
Colocasia	86	66.1
Macabo (*Xanthosoma*)	83	63.8
Groundnuts	82	63.0
Okra	73	56.1
Yams	72	55.3
Beans	69	53.0
Pumpkin	61	46.9
Plantain	57	43.8
Egusi melon	56	43.0
Cassava	42	32.3
Bananas	37	28.4
Sweet potatoes	20	15.3
Cowpeas	17	13.0
Huckleberry	16	12.3
Coffee	16	12.3
Raffia palm	7	5.3
Oil palm	7	5.3
Mango	7	5.3
Bambara Groundnut	4	3.0
Irish potatoes	3	2.3

Mean number of crops per field = 7.4 Standard deviation = 2.0 Range = 2-14

Table 2: Distribution of crop association on fields in Ndop Plain.

Crop association	*No. of fields*	*(%)*
Four Crop Associations:		-12%
Maize + Groundnuts + Cocoyam** + Egusi	1	-4
Maize + Groundnuts + Beans + Egusi	1	-4
Maize + Groundnuts + Okra + Egusi	1	-4
Three Crop Associations:		-12%
Maize + Groundnuts + Cocoyam	4	-17
Maize + Groundnuts + Bean	1	-4
Maize + Groundnuts + Cowpea	1	-4
Maize + Groundnuts + Okra	1	-4
Maize + Groundnuts + Cocoyam	1	-4
Maize + Groundnuts + Egusi	1	-4
Two Crop associations		-35%
Maize + Groundnuts	3	-13
Maize + Cocoyam	2	-9
Maize + Bean	1	-9
Maize + Yam	1	-4
Sole Crops		-13%
Maize*	3	-13

yield very little because of low temperatures, high humidity, reduced sunshine hours during the wet season, shading by the maize and pests (Rosette and animals).

- Beans *(Pliaseolus vulgaris)* are the most common intercrop with maize.
- Cassava (*Manihot esculeta*) is more common in some fields than others, especially in the areas with poorer soils. Cassava was present in 32% of maize fields. It is planted with the maize but, stays in the field between 1 and 3 years, with maize being planted around it each year.

The cropping pattern sequence varies considerably from farmer to farmer. Some farmers crop the land continuously, growing the same association year after year. Others plant the same association for several years, followed by one or two years of bush fallow. Still others vary the association throughout the rotation, putting crops more demanding on fertile soils. The length of the rotation fallow also differs from farm to farm apparently partly in response to soil fertility conditions and the degree of population pressure and / or the terms of land tenure. A few examples of crop fallow rotations reported are: Crop 3 years / Bush fallow (1 year), Crop 5 years / Bush fallow (1-2 years), Crop 10 years / Bush fallow (1-3 years) and continuous cropping. This certainly indicates the influence of population pressure on fallow durations (which are too short). The farmer is therefore faced with the problem of increasing crop hectarage both in time and in space. It should however be noted that a second maize crop will further lay pressure on soil resources thereby accelerating soil fertility depletion.

Hawkins and Brunt (1965) described the climax vegetation of Ndop as lowland rain forest. Based on life form they identified 46 tree species, 4 shrubs, 5 creepers and 4 grass species. The main derivatives observed in Bambalang and Bamali at 1, 260m above sea level were *Syzygium guineensis* tree savanna. *Terminalia* shrub savanna with *Hyparrhenia* grass were also observed on fine-grained granitic soils in the Bambungo area. Today, the landscape is a mosaic of tree and shrub savanna, *Terminalia glauceseens, Lophira lanceolata*, and *Annona senegalensis*. It is characterized by a dense network of gallery forest (Ndenecho 2005; Ndenecho 2006). On the fine-granitic soils is a pure carpet of *Hyparrhenia cymbaria, Hyparrhenia dissoluta* and *Hyparrhenia rufa* grassland with tufts of C*lappertonia ficifolia.* The savannization process is the result of pyrogenic and anthropogenic factors. This study focused on post-cultivation successions.

Table 3 presents the post-cultivation suc-

Table 3: Post-cultivation invasion of fallows by grasses and herbs in Ndop plain.

Abundance classes	*Class 1: Very numerous*	*Class 2: Numerous*	*Class 3: Not numerous*
1st year fallows	*Erigeron floribundus* *Ageratium conyzoides* *Anisopapus africanus* *Guizotial scabra* *Laggera alata* *Laggera pterodonta*	*Rynchelytrum repens*	*Pteridium aquilinium* (bracken fern)
2nd year fallows	*Imperata cylindrica*	*Erigeron floribundus* *Ageratium conyzoides* *Anisopapus africanus* *Guizotial scabra* *Laggera alata* *Laggera pterodonta*	*Rynchelytrum repens*
3rd year fallows	*Hyparrhenia spp.* *Digitaria spp* *Melinis minuntiflora*	*Imperata cylindrica*	*Erigeron floribundus* *Ageratium conyzoides* *Anisopapus africanus* *Guizotial scabra* *Laggera spp.*
4th year fallows	*Hyparrhenia rufa* *Hyparrhenia dissoluta* *Hyparrhenia cymbaria*	*Imperata cylindrica*	*Imperata cylindrica*
5th year fallows	*Hyparrhenia rufa* *Hyparrhenia dissoluta* *Hyparrhenia cymbaria*	*Digitaria spp.* *Melinis minuntiflora*	*Imperata cylindrica*

cessions observed in fallows. Slash-and-burn shifting cultivation with short fallow durations of 1 to 5 years provokes a savannization process. The succession of fallow grasses and weeds is as follows (Plagiosere):

- During the first year there is rank weed growth dominated by members of the compositae, that is, *Erigeron floribundus* dominates together with *Ageratium conyzoides, Anisopapus africanus, Guizotial scabra, Laggera alata* and *Laggera pterodonta.* The annual grass *Rynchelytrum repens* is often also abundant on first year fallows while *Pteridium aquilinium* (bracken fern) is rare.
- During the second year of fallow, there is invasion by *Imperata cylindrica* which may become dominant towards the end of the rainy season.
- Third year invasion is by grasses such as *Hyparrhenia* species, *Digitaria* species and *Melinis minuntiflora.*
- Fourth and fifth year fallows are rare. However, in areas where population pressure on land is low, fourth and fifth your fallows show a gradual decline in *Imperata cylindrica* and *Hyparrhenia spp*. dominance. *Imperata cylindrica* tends to persist on land which is under permanent cultivation or is being fallowed from a year to two because it is capable of growing on soils of poor fertility. It is a light demanding species and is shaded out later in the successions by the taller *Hyparrhenia* grasses.

Hawkins and Brunt (1965) report that germination rates of *Hyparrhenia spp.* are very low. This may partly account for the time it takes

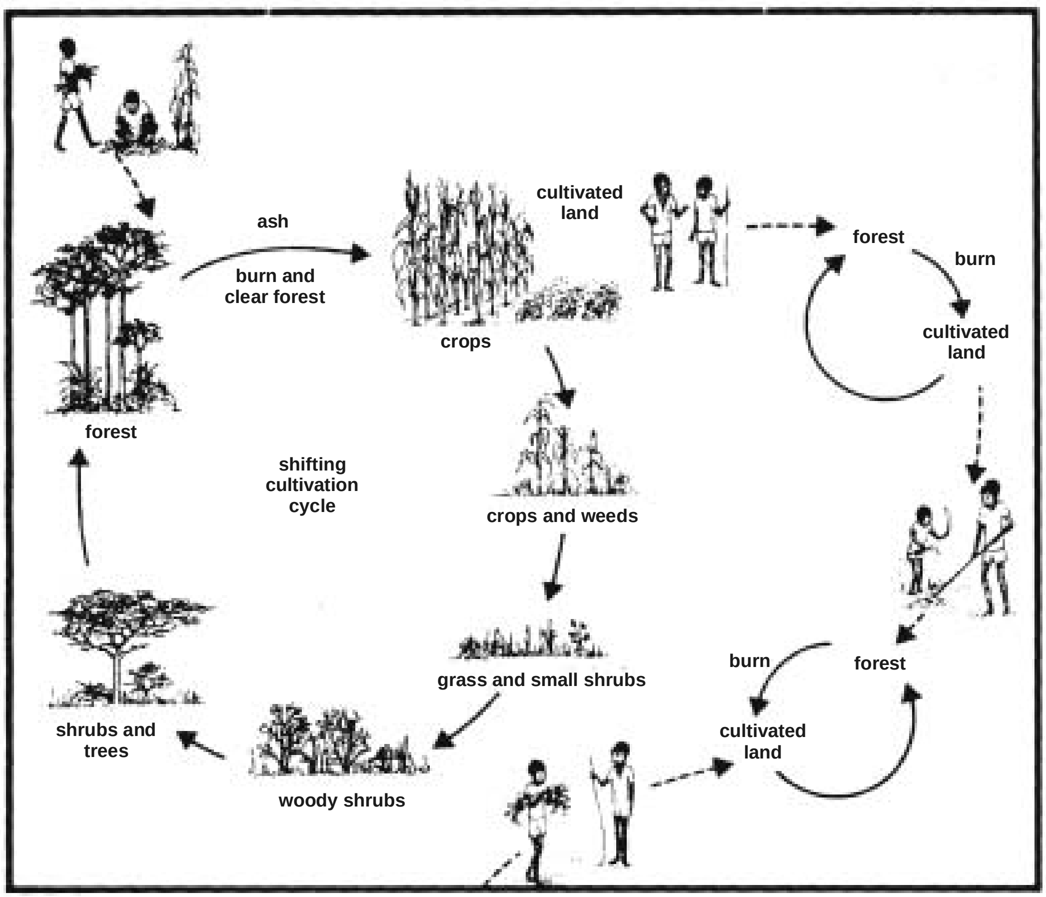

Fig. 2. Model of the shifting cultivation cycle, the process of cropping intensification and post-cultivation vegetation successions.

Table 4: Indigenous woody species feasible for integration in crop production systems of Ndop Plain (Asah 1994; Zimmermann 1996)

Woody species	*Functions / uses*
Albizia adianthifolia	Fodder, agroforestry, fuel wood, timber
Albizia gummifera	Fodder, agroforestry, fuel wood, timber
Albizia zygia	Fodder, agroforestry, fuel wood, timber
Bridelia speciosa	Fodder, agroforestry, live fence, medicinal, fuel wood, watershed protection, timber
Caesalpina sp.	Live fence, soil conservation, watershed protection
Calliandra calothynsus	Fodder, agroforestry, live fence, erosion control, fuel wood, N-fixation
Cassia siamea	Fodder, agroforestry, live fence, fuel wood
Dracaena sp.	Live fence, traditional uses, erosion control
Daniellia oliveri	Agroforestry, live fence, fuel wood
Entanda abyssinica	Live fence, fodder, agroforestry, fuel wood, erosion control, watershed protection
Erythrina sigmoides	N-fixation, live fence, medicinal, fodder
Ficus glumsa	Live fence, erosion control, fuel wood, watershed protection
Ficus vogellanum	Fodder, live fence, erosion control, fuel wood, watershed protection
Leucaena leucocephala	Fodder, reduces soil acidity medicinal, fuel wood, watershed protection, live fence, N-Fixation
Leucaena diversifera	Alley planting, green manure, N-fixation, fodder, live fence, fuel wood, watershed protection
Maesa lanceolata	Agroforestry, medicine, erosion control
Newtonia buchananii	Reforestation, soil enrichment via foliage
Piliostigma thonningii	Fodder, fuel wood
Polyscia fulva	Carving, reforestation, soil enrichment, watershed protection
Pseudospodia microcarpa	Agroforestry, fuel wood
Schefflera barteri	Live fence, medicinal
Schizolobium	Live fence, erosion control, fuel wood
Sesbania marcrantha	N-Fixation, fodder, erosion control, fuel wood, watershed protection
Spathodea	Reforestation, shade, timber, medicinal, watershed protection
Sorindeia sp.	Reforestation, shade, timber, honey, watershed protection
Terminalia sp.	Live fence, erosion control, fuel wood, shade, timber, watershed, protection
Tephrosia sp.	N-fixation, fuel wood, erosion control, medicinal
Trema orientalis	Reforestation, shade, timber, watershed protection
Vitex diversifolia	Reforestation, carving, timber, medicinal, ink, watershed protection
Vernonia sp.	Food (vegetable), live fence, erosion control

before it re-establishes itself in old farmlands. When left uncultivated for several years there is the dramatic invasion by several other grasses and herbs. For example, in a forest remnant in Bambalang village, certainly not farmed for a very long time, *Newtonia* dominant trees of 25 to 30 metres height were observed. It had an understorey of shrubs and herbs such as *Caesalpinia decapetala, Clausena anista*, and *Ouratea fleva*. The creepers included *Clerodendrum umbrellatum*, *Dalbergia spp*, and *Smilax kraussiana*; and grasses such as *Setaria caudula, Panicum maximum* and *Centotheca lappacea*. This is indicative of the fact that when fallowed for decades of years it can revert to lowland rain forest (Fig. 2).

Figure 2 conceptualizes the above successions. Farmers clear the climax vegetation by burning the trees and bush. They plant crops in the ash-fertilized soils using the clear-bury in the mounds and burn method. When the fertility declines, or when weed infestation becomes serious, they abandon to move to other locations. After the fields are abandoned, forbs quickly colonize, and gradually give way to woody shrubs and trees as the forest or bush returns. Shifting cultivation can make use of the land for a while but the ecosystem is soon re-established once the human influence ceases. With increasing population pressure on land and the shortening of fallow durations the vegetation is composed of wooded savannas and various post cultivation vegetation successions of grasses and weeds. The typical shrub savannas are *Terminalia* shrub savannas with *Hyparrhenia* grass layer derived from evergreen forest and *Syzigum* guinensis tree savanna which in Bamali has replaced the evergreen forest between Bamali and Bambalang. These shrub savannas are a plagioclimax resulting from the anthropic interruptions of successions towards the climatic climax. Fallows are therefore impoverished by each cultivation cycle as a result of no natural nutrient recycling by a mature forest.

There is the need to enrich fallows by integrating indigenous multipurpose trees in the field. Work in this direction by research has been haphazard (Asah 1994) with no comprehensive inventory list of socially, ecologically and economically accepted shrubs. Table 4 summarizes the work of Zimmermann (1996), Asah (1994) and Yamoah et al. (1994) in the medium (800 m to 1500 m above sea level) and high altitude (above 1500 m) regions of the Bamenda Highlands.

CONCLUSIONS

Population pressure in most of Sub-Saharan Africa is such that forest land is being lost to cultivation at a very fast rate; often this leads to the adoption of inappropriate farming systems such as shifting cultivation which does not allow a long enough fallow period for the land to recover. Apart from the degradation of forest by cultivation, is also the degradation of watersheds, soil and fauna. It is apparent that these are prime areas for the adoption of ecologically integrated land use systems and that agroforestry must form an element of such systems. It has the potential to increase land productivity and to decrease the instability associated with environmental deterioration. The instability is caused by the deployment of ecologically unsound practices in which system outputs exceed inputs. This study recommends the combination of trees with annual crops because of the established micro-ecological benefits (Reijntjes et al. 1992; Beets 1989):

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