From Integrated Toposequence Analysis to Land Resource Mapping at the Confluence Zone of the River Ebonyi Headwater Catchment, South Eastern Nigeria

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1. Abstract

A methodology is presented to derive land resource maps through Integrated Toposequence Analysis (ITA), Participatory and Rapid Rural Appraisals (P/RRA) and aerial photographic interpretation (1:6,000) processed in a GIS (Arc/Info) environment. A two level P/RRA is carried out in order to distinguish different land use strategies at both field and village decision making levels. At field scale, ITA combines components from soil science/land evaluation and P/RRA; couples indigenous knowledge with scientific information; and sets a framework for generating land resource maps that can be used in land use planning. Special attention is paid to the relationships between physiographic position, soil characteristics, land cover, land use, cropping systems and indigenous classification schemes. Two toposequences forming one continuum and traversing fluvial and interfluvial zones are surveyed in detail, including soil physical and chemical measurements at five pedons, and farmer interviews. At village scale, additional verification transects conducted by soil augering and interviews, are used to assist aerial photographic interpretation. Soil landscape and land use/cover maps are produced by relating the toposequences and verification transects to their surroundings, delineating homogeneous soil landscape and land use/cover zones. A topological overlay of land use/cover patterns with soil landscapes is compared to geo-referenced socio-economic factors and land use dynamics from a farmers' perspective obtained through P/RRAs at village scale. Results indicate the limited scope for further development on the interfluvial upland areas with the present farming system practices, and the increasing pressure to exploit the fluvial wetlands.

key words: Integrated Toposequence Analysis, Participatory Rural Appraisal, land resources, land use, cropping system, GIS, south eastern Nigeria

2. Introduction

The term Inland Valley (IV) represents the fluvial and interfluvial zones of a lower order river system characterized by minor alluvial sedimentation processes (Andriesse *et al.*, 1994). The fluvial zones, in particular, constitute a considerable potential to improve food production, for mainly local markets, through sustainable intensification and/or expansion of the present land use systems (Thenkabail and Nolte, 1996). Therefore, the development of a standardized methodology to build up a spatial database is a crucial step in identifying priorities and opportunities for improved land resources management. Most research in

West Africa has concentrated on describing IVs underlain by the Basement Complex lithology. South east Nigeria, however, is dominated by sedimentary deposits of Upper Cretaceous age.

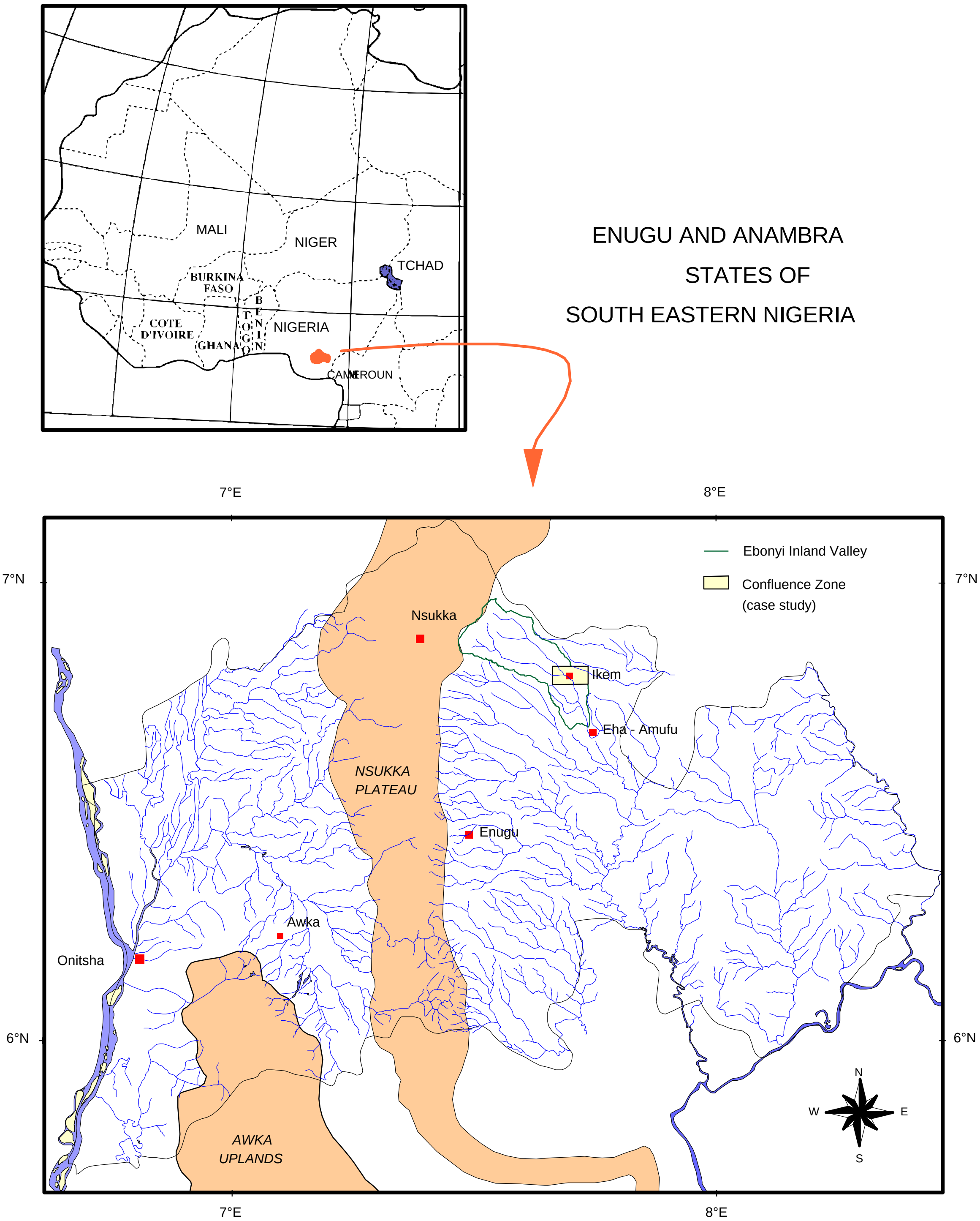


Figure 1: Location of the confluence zone at Ikem (case study area) in the River Ebonyi Headwater Catchment, south eastern Nigeria.

The growing trend of incorporating Rapid and Participatory Rural Appraisals (P/RRA) into natural resources research is reported by Farrington (1996). The socio-economic and cultural information obtained through these techniques help identify non-bio-physical factors in land use and establish the context for formulating sustainable solutions at different decision making levels.

The 40 km² case study focuses on land resources management at the confluence zone of two perennial rivers of the River Ebonyi Headwater Catchment or Inland Valley, south east Nigeria (Figure 1). The highly erosive nature of the sandstone escarpment at the source of the two major river systems provides a heavy coarse textured sediment load deposited on the Enugu Shale, a shale and mudstone formation.

3. Methodology

Figure 2 presents a schematic diagram of a methodology which combines Participatory and Rapid Rural Appraisal techniques with conventional land resource surveying and mapping methodologies to obtain both socio-economic and bio-physical data at two decision making levels and corresponding geographic scales: 1. field and 2. village.

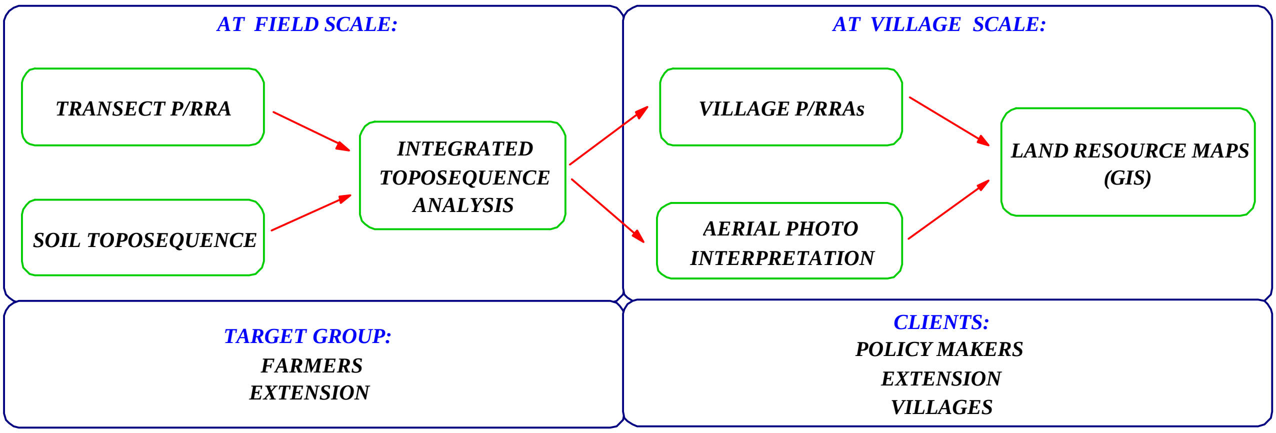


Figure 2. Schematic diagram of the methodology adopted.

3.1 Participatory and Rapid Rural Appraisals

The overall methodology adopted for the Participatory and Rapid Rural Appraisals was adapted from McCracken *et al.* (1988) and realised with the aid of two interpreters and local village guides. An initial group interview with the village elders provided information on the history and development of the area, its social structure and organisations and helped develop a strategy for further interviewing and mapping. Mapping out the village external/internal boundaries, physical features and public utilities onto an existing topographic map and drawing the transect of features across the area, gave an immediate orientation to the proceeding interviews in relation to accessibility of different hamlets to roads, markets and facilities and the layout and location of the different farming areas and activities. Individual interviews across the existing social classes and analytical games with social groups provided more insight in household and group land management strategies. Where appropriate, the male interviewer talked with the men and the female interviewer talked with the women in different locations using semi-structured interviewing techniques and topic headings.

3.2 Integrated Toposequence Analysis

Integrated Toposequence Analysis is the combination of toposequence description as classically employed by soil science/land evaluation and transect walks as propagated by Participatory/Rapid Rural Appraisal (P/RRA) (Figure 2). Two representative toposequences were selected traversing the different physiographic units of the fluvial and interfluvial areas of the confluence zone. In total, five soil profile pits were described according to the guidelines provided by the FAO (1990). Soil samples taken by horizon were chemically and physically analysed in order to, *inter alia*, classify the soils according to the FAO/Unesco Legend (1994). The toposequences were measured by dumpy level, clinometer, altimeter and geo-referenced using a GPS-Trimble Navigation Basic. The natural vegetation class was derived mainly through observation and local tree names. At this level, the owners of the land, land users and villagers were interviewed in both formal and informal ways based on P/RRA techniques (Mettrick, 1990). An indigenous soil classification scheme was derived and a reconstruction was made of the various cropping systems including cropping calendars, fallow periods, crop rotations and soil management aspects. Additional verification transects were conducted by soil augering and interviews.

3.3 Aerial Photograph Interpretation

Sixty pairs of aerial photographs (1:6,000) of 1982 from the Ministry of Land Resources were interpreted by stereoscope and selected photographs were scanned. The toposequences and verification transects were related to their surroundings and similar landscape units were delineated using key features such as slope shape and distance from the river. Subsequently, homogeneous land use/cover zones were identified based mainly on vegetation and field plot characteristics. Aerial photographic interpretation enabled geo-referencing of some socio-economic factors such as infrastructure, settlement patterns and location of market squares. Digitizing and geometric correction in a GIS environment resulted in soil landscape and land use/cover maps.

Field sizes and number of mature trees and shrubs were recorded for 200 plots on different classes of land use intensity and soil landscape. Tree density as derived by stereoscopic analysis was crosschecked with the scans and subsequent graphic analysis of selected key photos.

3.4 Geographic Overlay of Thematic Maps

Further geographic analysis was carried out in Arc/Info (ESRI, 1996) to examine the relationship between the digitized soil landscape and land use/cover maps. Using the overlay technique (Identity command), it was possible to intersect the polygon units of both map coverages and list the area size matching. These pairing areas provided information on the hectareage of each cross-tabulated land use/cover - soil landscape unit.

4. Results and Discussion

4.1 Brief Description of the Farming System

The traditional farming system concentrates on cropping with small livestock kept in the vicinity of the homestead. Different cropping systems in the area can be recognized in function of the socio-economic environment, soil landscape, gender and objectives of the farmer. The adopted cropping system is strongly linked to the settlement pattern and physiographic position in the landscape. Flooded areas occurring mainly along the perennial rivers and streams are referred to as ‘lowland’, whereas the other areas not seasonally inundated by flooding from rivers or run-on accumulation are termed ‘upland’ by local farmers.

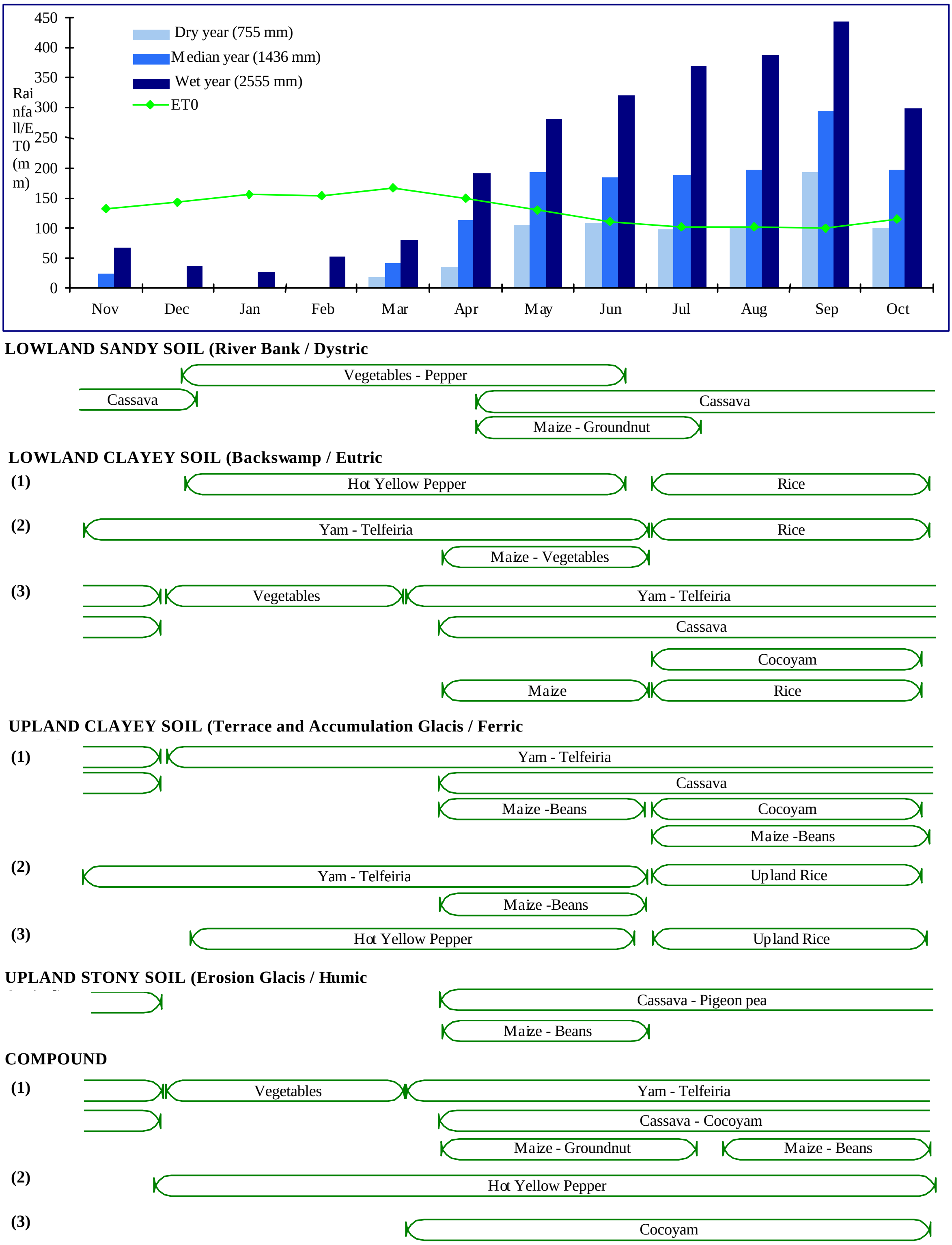


Figure 3. Cropping calendars for different soil-landscapes related to climate based on a monthly rainfall frequency analysis of 27 years at Nsukka.

This clear distinction between lowland and upland areas is reflected in the cropping calendars for the farming areas (Figure 3). Crops are grown predominantly for home consumption and then for sale at local markets as a means of generating income. Recent increases in the cultivation of cash crops such as rice and hot yellow pepper have altered the traditional cropping systems and intensified cultivation.

Fields located in **low-lying, often swampy areas** close to the rivers and perennial streams are cultivated annually in both the rainy and dry seasons. The lowland sandy soils, i.e. river banks, are cropped with a mixture of cassava, maize and groundnut in the rainy season and dry season vegetables such as hot yellow pepper, *Amaranthus*, garden egg, *Telfeiria* and tomatoes. Traditionally, the lowland clayey soils, i.e. backswamps, are cultivated with a rich mixture of crops, dominated by yam, on huge mounds to protect the crops against flooding. The specific arrangement of crops on a mound depends on several factors such as the growing season, tolerance to waterlogging and competition or importance of the crop in the farming system: cassava and yam are grown on top; maize, sweet potato and vegetables on the sides and cocoyam at the bottom. Monocropping of the shade and water tolerant cocoyam is occurring on recently cleared lands with still some forest trees left. This system has experienced substantial changes under influence of the increasing popularity of rice and a shift is observed towards monocropping during the last decade. At first, rice was mainly interplanted between the mounds. At later stages, rice occurred as a monoculture from July to October thereby shifting the yam intercrop towards the dry season. In the latter case, yam and telfeiria are grown on residual soil moisture and at the onset of the rains, other crops are interplanted. Since the 90's, farmers have embarked on cultivating the lucrative hot yellow pepper during the dry season and rice during the wet season. Families owning land close to the rivers and perennial streams are often leasing their land for cash or kind. However, a lot of land close to the rivers is still under lush riparian forest vegetation as traditional beliefs in water related spirits prohibit tree logging in the vicinity of springs, streams and rivers, and interest in cultivation is limited due to the presence of water associated diseases such as malaria. Here, forest use is predominantly confined to non-timber products such as food or medicine often rendering indispensable sources of cash income. Once cleared, plots are under continuous cultivation or kept under cassava fallow for one year.

The **upland area**, not prone to flooding, is characterised by settlement areas, and farmlands where mainly rainfed agriculture is practised. Slash and burn is the common method of land clearing in the upland farming areas followed by hoeing and mounding. Two distinct planting seasons can be identified: an early season at the onset of the rains around March/April and a late season beginning in July/August after the first crops are harvested. Farmers distinguish between stony soils and clayey soils in the upland, and consequently plant different crop mixtures. The low fertility of the 'upland stony soils' is reflected in cassava dominant cropping systems such as cassava/maize/pigeon pea. On the 'upland clayey soil', cassava, yam and cocoyam predominate in the fields and are intercropped with maize, sweet potatoes and different vegetables in various mixtures (Figure 3). Since 1994, the local extension service is promoting upland rice cultivation on the 'upland clayey soils'. For farming areas fairly close to the settlements, fallow periods on the upland are around 2 to 3 years including one year of cassava fallow, a longer period being applied to the 'upland stony soils'.

Oilpalm trees occur either as scattered or in groves usually in the vicinity of **settlement areas**. These multipurpose trees play an important role in the prevailing farming system and particularly the wine and oil provide a good revenue for men and women respectively. Other fruit trees such as mango, kolanut, cashew, citrus and plantain are planted near the settlement areas where they appear in conjunction with remnant forest tree species and oil palm. Fields of mainly cocoyam occur in the shade of the trees. The compound farm near or within the premises of the homestead is providing mainly for home consumption and is continuously cropped. Goats and poultry are raised within the compound and their droppings together with additional household refuse provide excellent manure to the compound plots. During the dry season, many women are maintaining small vegetable gardens on these plots. Recent trends are towards hot yellow pepper cultivation on (a portion of) the compound farm and many men are also engaging in this traditionally woman's crop.

4.2 Integrated Toposequence Analysis

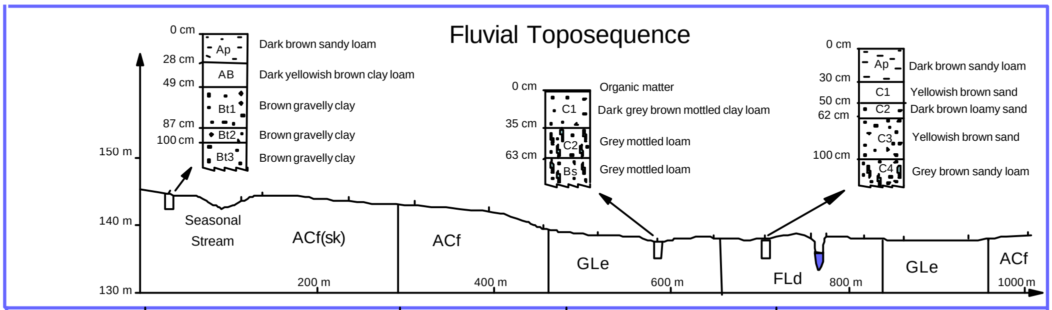
Four geomorphologic units were identified along the two toposequences: river floodplain corresponding to 'lowland'; river terrace, accumulation glacis and erosion glacis corresponding to 'upland'. Concerning the cropping systems, two distinct phenomena were observed along the toposequences: the degree of land use intensity in terms of fallow period, crop rotation and dry season agriculture; and the particular choice of crops.

Figure 4 presents the results of an Integrated Toposequence Analysis for the fluvial and interfluvial toposequences which are in fact part of one continuum.

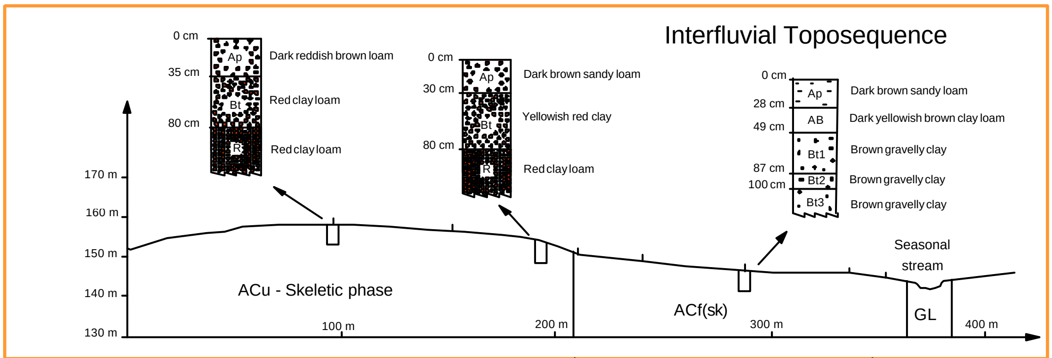
The sandy sediments transported by the river systems result in river banks characterised by Fluvisols with a low base saturation (Dystric), named 'lowland sandy soils' by farmers. The backswamps with numerous streams receive finer particles and are flooded during the wet season by the river and run-on from the adjacent uplands. Clear mottling at shallow depth indicates the presence of oxido-reduction processes due to fluctuating groundwater and surface water. The soil was classified as a Eutric Gleysol or 'lowland clayey soil' by the local farmers. Figures 3 and 4 clearly indicates that they adapt their cropping systems accordingly. The natural vegetation fringing the river is the Guinea-Congolian, wetter type rainforest (White, 1992) with raffia palm, bamboo and flood tolerant trees.

The river terrace, by the farmers referred to as 'upland clayey soil', is bordering the floodplain and probably represents the old floodplain. The fluctuating groundwater table does not occur within profile depth and characteristic are the ferric properties in a clayey subsoil (Ferric Acrisol) suggesting lateral substratum flow. The vegetation is moist evergreen to semi-deciduous forest with mighty trees such as *Lophira alata, Parinari polyandra, Triplochiton scleroxylon, Khaya ivorensis* and *Terminalia superba*.

The upper landforms are accumulation glacis and erosion glacis based on the processes of parent material disintegration and transport. The term glacis was used in favour of pediment as the former refers to development on sedimentary rocks and a planation surface formed by scarp retreat and pedimentation (van Zuidam and ITC, 1985). The erosion glacis displays ferricrete gravel at the surface and throughout the profile depth (Humic Acrisol in skeletic phase), whereas on the accumulation glacis ironstone nodules occur at greater depth usually in association with ferric properties (Ferric Acrisol, skeletic phase at depth). Edaphic factors play an important role in determining the vegetation type (Hopkins, 1979) within the glacis. The drier soils of the erosion glacis are colonised by mainly Guinea savannah woodland tree species such as *Lophira lanceolata, Parkia biglobosa, Afzelia spp., Burkea africana* and *Entada abyssinica*. Much of the natural vegetation has gone due to expansion of cultivated land, and has turned into bush savanna consisting of trees and tufts of tall grasses with or without shrubs depending on the fallow period.



PHYSIOGRAPHY SLOPE	Accumulation Glacis with stream 2%	River Terr ace 2%	Floodplain: backswamp 2%	Floodplain: river banks and channel 1% - 2%
LOCAL CLASS	Upland clayey soil	Upland clayey soil	Lowl and clayey soil	Lowl and sandy soil
GEOLOGY SOIL(Depth) PROPERTIES DRAINAGE GROUNDWATER	Enugu Shale Ferric Acrisol (110 cm) Ferric and skeletic from 50 cm Well drained None	Enugu Shale/Alluvium Ferric Acrisol Ferric from 35 cm Fairly well drained More than 150 cm	Alluvium Eutric Gl eysol (100 cm) Gleyic from 35 cm Very poorly drained 35 cm to 100 cm	Alluvium Dystric Fluvisol (160 cm) Gleyic from 100 cm Moderately well drained 100 cm to 170 cm
RAINY SEASON FALLOW DRY SEASON	Yam/cassava/maize/beans Upland rice/cassava 2 years incl. 1 year cassava fallow Early planting of seed yam Irrigated vegetables	Yam/cocoyam Upland rice/cassava 1 year cassava fallow Early cropping Irrigated vegetables	Yam/cocoyam/cassava Rice/cassava 1 year cassava fallow Residual moisture cropping Irrigated vegetables	Cassava/maize/groudnut/beans None Irrigated vegetables/pepper
VEGETATION LAND USE OTHER USES	Moist for est Grass fallow farmland/settlement Upland Rice	Moist for est Continuous cropping Tree products	Riparian forest Continuous cropping Tree products	Riparian forest Continuous cropping Tree products



PHYSIOGRAPHY SLOPE	Erosion Gl acis and convex slope 3% - 4%	Accumulation Glacis 2%	Stream overflow ar ea 2%
LOCAL CLASS	Upland stony soil	Upland clayey soil	Stream side clay
GEOLOGY SOIL (Depth) WEATHERING	Enugu Shale Humic Acrisol - skeletic phase (80 cm) Ferricrete throughout profile	Enugu Shale Ferric Acrisol (110 cm) Ferric and skeletic from 50 cm	Enugu Shale Gleysol/Ferric Acrisol Gleyic properties
RAINFED CROPS FALLOW DRY SEASON	Cassava/Maize/pigeon pea 3 years No cr opping	Yam/cassava/maize/beans 2 years incl. 1 year cassava fallow Early seed yam / irrigated vegetables	Yam/cocoyam/cassava (1 year) No cr opping
VEGETATION LAND USE OTHER USES	Grass savanna Grass fallow farmland Grass for thatching	Moist for est Grass fallow farmland / settlement Upland rice	Moist for est Bush fallow farmland Rice

Figure 4: Results of an Integrated Toposequence Analysis on two toposequences at Ikem, south eastern Nigeria (auger holes are indicated with ı).

4.3 Spatial Distribution of Land Resources and Mapping

Transects consisting of soil augering and interviews with villagers in the area verified the previous classifications and a framework was set for stereoscopic interpretation of 1:6,000 aerial photographs through identification of features typical for the land use or soil landscape.

4.3.1 Soil Landscape Map

The soil landscape map (Figure 5) combines soil group and geomorphology as both are closely linked to topography. The farmers' soil classification for the confluence area mainly reflects soil texture of the arable layer and topographic position in the landscape which corresponds to the research findings of Kanté and Defoer in Mali (1994). The indigenous taxonomy does not include any reference to subsoil properties which might become critical in future land management. However, the local soil taxonomy provides a common ground for discussing land use strategies and a better insight in local land use decision making. Therefore, it was incorporated while demarcating the different soil landscape units. Experienced farmers usually posses fields in different soil landscapes and take indicator plants or colour of grass into account to assess fertility and determine crop rotation and land capability. Contrary to these findings, Habarurem and Steiner (1995) found this knowledge present only among older farmers in Rwanda. This type of knowledge was not considered common at this stage and was therefore not included.

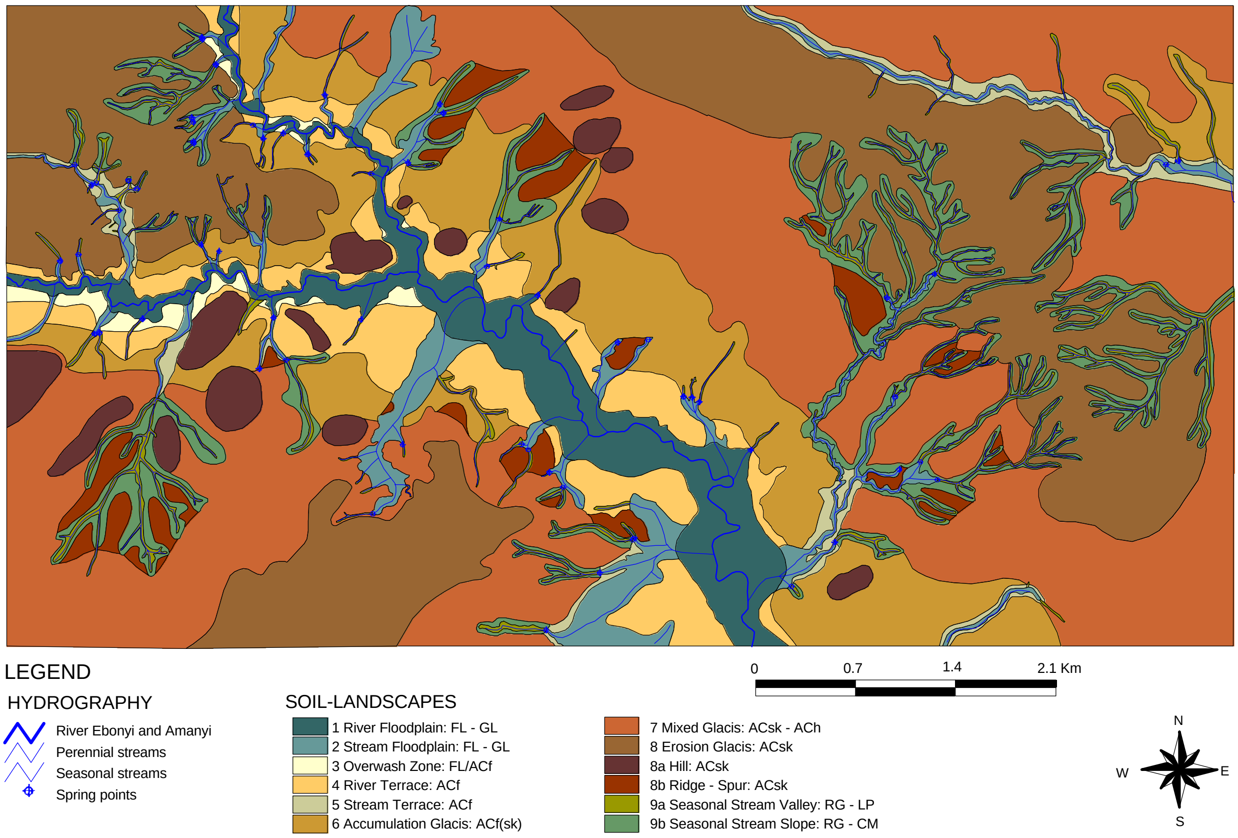


Figure 5. Soil-landscape map of the confluence zone at Ikem, south eastern Nigeria.

The river floodplain including the river channel, riverbanks and backswamp is presented as one unit mainly occupied by riparian forest on the 1982 aerial photographs. Likewise, stream floodplains or stream overflow valleys are demarcated and, where possible, spring points are indicated. The persistently wet areas can be recognized by the occurrence of bamboo trees. Associated river and stream terraces are characterized by linear slopes, at times displaying a pronounced scarp towards the river or stream suggesting vertical erosion of the channel. Before the confluence, the river floodplain is limited in area and first order terraces that are still influenced by river deposits can be distinguished. Where the floodplain widens, downstream of the confluence, backswamp lakes are found, which are usually fed by small tributaries.

The regional joint trellis drainage pattern (Howard, 1967), better seen on a larger scale map, results in streams flowing orthogonal into the main rivers. These perennial streams are headed by springs, which occur where the underlying Enugu Shale is exposed at the surface. The block-like form of the perennial drainage system reflects the tectonic activity that has taken place in this region resulting in rectangular joint lines, which encourage preferential flow and downcutting. On the other hand, the seasonal streams and gullies, which have been carved into the upland areas above the spring points, have a more dendritic type of pattern and are more influenced by surface denudation processes.

The interfluvial transects indicate the existence of an undulating zone consisting of repeated patterns of erosion and accumulation glacis over a short distance. These perturbations are difficult to differentiate on a map using aerial photographs and are classed mixed glacis. Convex slopes, at times vegetated by small savanna trees, shrubs and grasses are good indicators for the denudated areas dominated by ferricrete gravel (erosion glacis). Flatter land with linear slopes and usually taller tree vegetation are less eroded and typical for the accumulation glacis. Special features for the glacis landscape are pronounced ridges and hills.

4.3.2 Land Use / Cover Map

The land use/cover map integrates vegetation, settlement patterns and farmland characteristics (Figure 6). Areas under natural vegetation are divided into riparian forest, savanna and semi-deciduous forest. Dense luxuriant forest occurring along rivers and perennial streams is termed gallery to stress the fringing nature of the forest vegetation. Not uncommon are advancing savanna patches as cultivation along the rivers is increasing, as well as relict rainforest patches mainly confined to the terraces bordering the floodplain. Seasonal streams are often bordered by a line of forest trees, representing a tree corridor through the landscape. Natural vegetation confined to the upland areas is classified as grass, shrub or savanna woodland depending on the amount of tree vegetation in relation to undergrowth. Woodland savanna and semi-deciduous forest patches are in the same class as they are not very abundant. Oil palm groves and palm dominated forest, often named oil palm bush (Hopkins, 1979) occur in the vicinity of settlement areas, where the lighter coloured patches present the compound farms. Local farmers categorize their farmlands according to the vicinity to the homestead and the corresponding fallow period or return period for cultivation respected in the particular area.

As the fallow period corresponds to the land cover, farmland areas are categorized as follows: continuous cultivation with a fallow period of less than 1 year; grass fallow cultivation divided into two classes of 1 to 3 and 3 to 5 fallow years; and, bush fallow cultivation with return periods of 5 years or more. The term 'bush' is applied to a dense woody vegetation without trunk consisting largely of tree seedlings. Marginal land is confined to very steep slopes adjacent to seasonal streams, erosion gully spheres and cleared land for development purposes such as roads and government housing areas.

A major constraint of land use/cover mapping is that land use changes are often governed by socio-economic aspects which are difficult to map apart from infrastructural features such as settlement areas, markets, roads and paths that are location specific and feature in the map presented in Figure 6. Other socio-economic factors related to credit facilities such as rotational saving groups or market unions are driving forces for prosperity in the region but can not be geo-referenced.

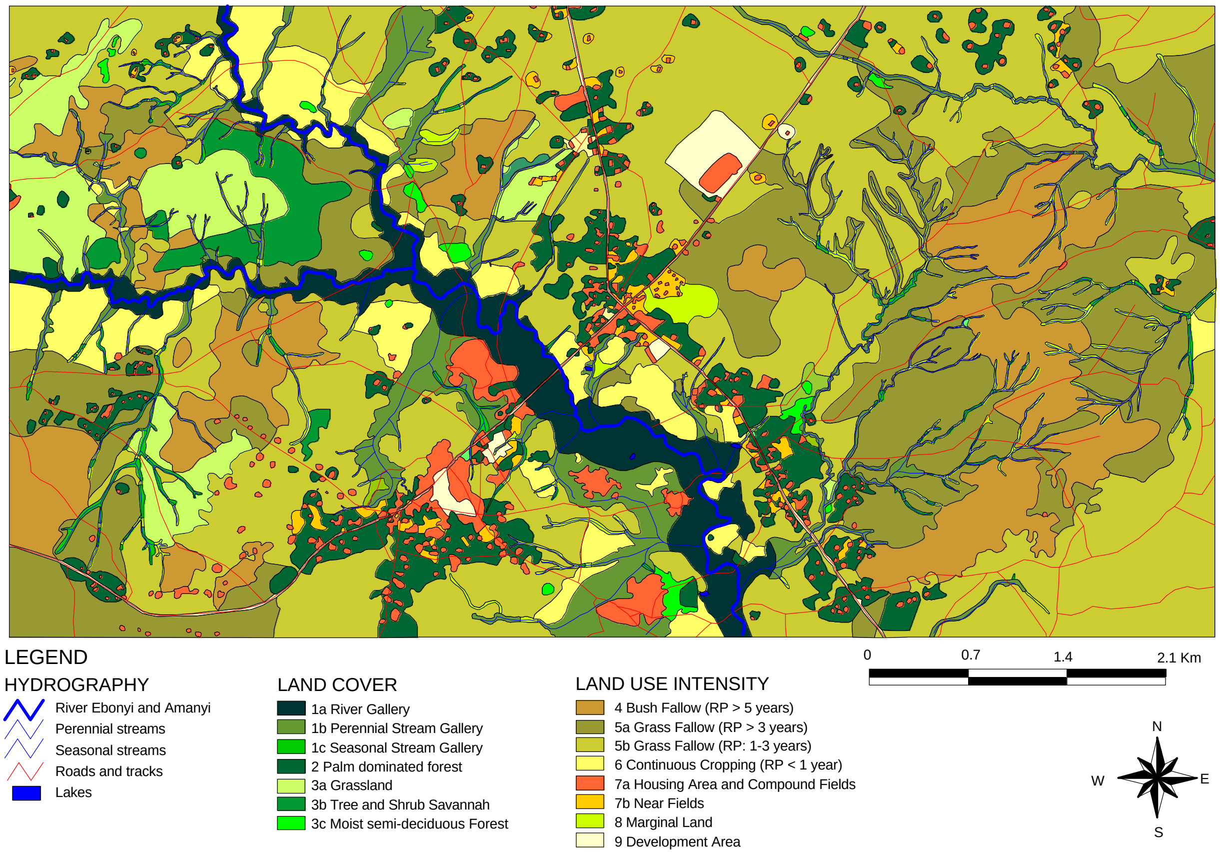


Figure 6 Land cover and land use intensity map of the confluence zone at Ikem, south eastern Nigeria.

4.4 Land Use Patterns

A spatial differentiation exists in land use and follows a somewhat concentric pattern around the settlements influenced by the population pressure and the land tenure system. The traditional land tenure system involves both private and communal land ownership. Land within the settlement and near farmland areas is privately or family owned in a patrilinear system of inheritance, whereas distant farmland is communal and the allocation is decided upon by the Village Chief assisted by the Community Council (family heads). The customary law regards tree products from communal lands as collective property and therefore economic important trees are planted on individual or family land where the products belong to the owner. Likewise, long-term land improvements and higher inputs/care are devoted to individually owned land such as the compound farm. A clear tendency to individual ownership exists with increasing population pressures. The land use decree of 1978 has replaced the Chiefs with the State Governor who holds the State's land in trust for the common benefit of its citizens. Ambiguity surrounding the decree emanates from the right of occupancy, which may be altered only by approval of the Governor with the consent of the assisting Land Allocation Advisory Committees in each Local Government Area (Ajomale, 1981). Villagers are often confronted with land use decisions made at government level.

The oldest settlement areas are located in the ‘upland’ centred around the market place from where expansion took place along the major roads in a direction away from the river. The establishment of Local Government offices at Ikem, have further ensured the permanence of the settlement. Markets, schools and improved road access have influenced the settlement patterns and the demand for land. The local classification for the farmlands is based on distance from the housing area and river and field plots in these different land use zones vary significantly in field area and amount and size of trees or shrubs. Table 1 provides the results of a statistical analysis of the field size and number of mature trees and shrubs for 200 field plots grouped by land use intensity and landform. The *F* tests for land use and soil landscape effect proved statistically significant at the 5% (or less) level for all dependent variables but mature trees by soil landscape class. Pair comparison and subsequent grouping was performed by heteroscedastic *t* tests on the mean differences. Close to the settlement areas, named 'near farmlands' by the local farmers, small sized fields (370 m²) occur sometimes under oil palm or other important trees. The tree density is around 19 mature trees per ha whereas the number of shrubs and small trees averages at 40 per ha. Correspondingly, 'distant farmlands' are characterized by larger sized fields (1805 to 2750 m²), longer fallow periods and tree densities (11 mature trees and 35 to 54 smaller trees per ha), generally increasing with distance away from the settlement areas. A clear exception are the farmlands located on the terrace and accumulation glacis, i.e. upland clayey soils, towards the river that are perceived as fertile upland areas and are continuously cultivated with rich crop mixtures. They were the first lands to be cleared and as a result of continuous cultivation and fragmentation, less than 8 mature trees per ha (95% confidence) occur. A recent tendency of settling in the distant farmlands where people formerly only possessed temporary houses has distorted the clear pattern described above. Examples are provided by the settlement area along the main road next to the river, which was not present on larger scale aerial photos of 1962, and the smaller housing areas nearer springs and along rural tracks.

Table 1. Field plot analysis per land use and soil landscape class at Ikem, south eastern Nigeria

Land use[1]	*n*	Field size (m²)			Mature trees per 0.1 ha			Shrubs per 0.1 ha		
		X	SE	Group[3]	X	SE	Group[2]	X	SE	Group[3]
GBF	50	2750.1	119.8	a	1.1	0.2	ab	5.4	0.5	a
GF	50	1804.7	92.1	b	1.1	0.2	a	3.5	0.3	b
CC	50	694.4	54.7	c	0.6	0.1	b	1.3	0.3	c
NCF	50	369.1	16.3	d	1.9	0.5	c	4.0	0.7	b
Soil landscape[1]	***n***	**Field size (m²)**			**Mature trees per 0.1 ha**			**Shrubs per 0.1 ha**		
		X	SE	Group[2]	X	SE	Group[2]	X	SE	Group[2]
EG	36	2442.6	171.9	a	1.1	0.2	ab	5.0	0.5	a
MG	63	2125.1	110.0	a	1.1	0.2	a	4.2	0.4	ab
T	29	727.9	75.3	b	0.6	0.2	b	1.2	0.4	c
AG	72	527.7	48.6	c	1.5	0.4	a	3.3	0.5	b

Where: *X*= mean, *SE*= standard error, *Group*= grouping by heteroscedastic t-test on the mean differences

1 : GBF= Grass and Bush Fallow (return period: more than 3 years); GF= Grass Fallow (return period: 1 to 3 years); CC= Continuous Cultivation (return period: less than 1 year); NCF= Near and Compound Fields; EG= Erosion Glacis; MG= Mixed Glacis; T= Terrace; AG= Accumulation Glacis.

2 : discernible at the 5% significance level

3 : discernible at the 1% significance level

4.5 Land Use Opportunities

A summary of the intersection between the different soil landscapes and land use/cover classes is presented in Table 2. An increasing trend exists towards shortening fallow periods and is reflected in the percentage of total area devoted to it. Grass Fallow with return periods of less than 3 years is the most common type of cultivation (35% of the total area), followed by Grass Fallow with return periods of more than 3 years (18% of the total area) and then Bush Fallow (11% of the total area). Moreover, the first year of fallow usually consists of the staple-food cassava. Regeneration of soil fertility is certainly reduced with shorter fallow periods and cassava dominant cropping systems become more widespread particularly on the less fertile erosion and mixed Glacis. Fresco (1993) states that cassava hinders agricultural intensification, as it is tolerant to low soil fertility, poor soil structure and even drought. However, the vicinity of the market and infrastructure as well as the degree of land ownership have modified the traditional fallow farming system particularly near the settlement areas. At Ikem, the proximity of two State roads linking the area to other towns offers good market opportunities, and agricultural intensification regardless of the soil can be observed close to the settlement areas on the near-and-compound fields (e.g. tree crops, the hot yellow pepper cash-crop). Well-established near-and-compound fields and larger sized palm dominated forests are strongly associated with the older settlements near the two main roads. Continuous cultivation on the 1982 aerial photographs is confined to the more fertile terraces and accumulation glacis (5 to 6 % of the total area).

Possibilities for agricultural expansion are limited to the savanna vegetation (6% of the total area) mainly located on the less fertile erosion glacis and riparian forest of the flood plain (10% of the total area). A combination of agricultural expansion and intensification is taking place on the latter with cash crop farming of rice and yellow hot pepper. Land tenure insecurity and limited access to credit facilities and agricultural inputs such as organic manure remain constraining factors.

Table 2. Summary matrix of the land use / soil landscape overlay at Ikem

Land Use	Code	Landform						
		FP	T	AG	MG	EG	SSV	Total
		'1,2'	'3,4,5'	'6'	'7'	'8(a,b)'	'9a,b'	(Ha)
Riparian forest	*'1a,b'*	341.4	20.9	7.4	1.7	1.3	11.4	384.1
Stream Gallery	*'1c'*	4.8	0.0	0.1	0.0	0.4	26.0	31.3
Palm Forest	*'2'*	0.9	8.6	84.9	66.7	77.4	2.7	241.2
Savannah	*'3a,b,c'*	0.5	10.6	31.5	12.9	151.0	27.3	233.8
BF (>5 years)	*'4'*	0.0	18.6	41.8	134.0	179.1	43.8	417.3
GF (>3 years)	*'5b'*	0.0	21.3	60.6	302.0	196.2	110.6	690.7
GF (1-3 years)	*'5a'*	13.5	92.7	150.7	606.9	403.9	62.0	1329.8
CC	*'6'*	12.2	111.9	44.7	16.9	10.0	4.9	200.6
NCF	*'7b'*	0.0	0.8	14.2	8.4	11.3	0.1	34.8
Housing Area	*'7a'*	0.9	31.3	17.7	26.2	29.6	0.3	106.0
Dev. Area	*'9'*	0.7	0.9	8.1	26.3	15.6	0.4	52.0
Marginal	*'8'*	3.8	0.1	7.4	3.8	1.4	75.5	92.0
Lake	*'lake'*	0.5	0.1	0.0	0.0	0.0	0.0	0.6
TOTAL	***(Ha)***	**379.2**	**317.8**	**469.1**	**1205.8**	**1077.2**	**365.0**	**3814.2**

BF= Bush Fallow (return period: more than 5 years); GF= Grass Fallow (return period: more than 3 years); GF= Grass Fallow (return period: 1 to 3 years); CC= Continuous Cultivation (return period: less than 1 year); NCF= Near and Compound Fields; FP= Flood Plain; T= Terrace; AG= Accumulation Glacis; MG= Mixed Glacis; EG= Erosion Glacis; SSV= Seasonal Stream Valley.

5. Conclusions

A two level P/RRA is proposed: a detailed field level appraisal along toposequences, i.e. Integrated Toposequence Analysis, and a more general village level appraisal (Figure 2). This enables one to relate field scale features along transects to spatial patterns at village scale in order to understand land use dynamics and strategies within a socio-economic framework. A combination of local and scientific classification schemes is used in mapping land resources. These maps in conjunction with the results of P/RRAs make it possible to define farming trends in terms of expansion and intensification. Dry season cultivation encompasses a lucrative and therefore important aspect of the local farming system, and the maps could be further refined into opportunity maps by incorporating the results of soil physical and fertility measurements, and including ease of access to perennial rivers and streams for utilization in dry season agriculture.

Scopes for agricultural expansion are limited on the mixed and erosion glacis due to their poor physical and chemical features, whereas the floodplains and terraces are under increasing pressure for cultivation. However, developments of the floodplain should take into consideration the stabilizing effect of river gallery forest on the riverbanks in protecting them against erosional flash floods. Danger of overcultivation on the accumulation glacis could result in denudation exposing the gravely and generally less fertile subsoil. As has been noted, agricultural intensification is strongly related to land tenure and is predominantly confined to the settlement areas and near fields. This clearly indicates farmers' reluctance to invest in farmlands not recognized to belong to them. The land tenure system will therefore need further clarification and guarantees before farmers will sustainably develop 'potential' areas to increase production.

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