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Historical land use evolution in a tropical acid upland agroecosystem

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Abstract

Understanding the historical evolution of land use in humid tropical agroecosystems may assist in developing more appropriate farming systems better able to sustain dense human populations, alleviate deforestation and regenerate degraded land resources. We analyzed land use change over a 40 year period for a key acid upland farming systems research site (8 km × 10 km) undergoing rapid transformation in Claveria, Mindanao, Philippines. The landscape is dominated by small-scale cereal cropping on gently to steeply rolling volcanic Oxisols. The six slope classes identified (ranging from 0–3% to more than 60%) each occupied between 9 and 19% of the study area. Aerial photographs (1:15000) taken in 1949 and 1967, and a ground survey in 1988, were used to map land use patterns at three points in time. Settlement by in-migration began early in the twentieth century. By 1949 9% of the land was cultivated, but grassland (59%) and forest (14%) were the dominant land uses. From 1949 to 1967 the cultivated area doubled to 20%, and the proportion of grassland decreased to less than 50% of the land. The forested area remained unchanged. Subsequently, settlement by small-scale farmers accelerated. Between 1967 and 1988 the area cropped annually doubled again to 41%. Forest land declined drastically during this period to 1%, while perennial cropland (mainly coffee) increased to 30%. Land use on the steeply sloping lands (more than 15%) was particularly affected during the 21 year period: 27% was converted to field crop production, and 43% to perennial crops. More than 33% of the food crop area is now on steep slopes. The analysis of the historical evolution of land use may guide research priorities for developing sustainable technologies on sloping land based on agroforestry.

Keywords: Agroforestry; Deforestation; Farming systems; Oxisols; Philippines; Sustainability

1. Introduction

The uplands of southeast Asia are dominated by strongly acidic soils and hillslope topography. The geographic extent of the region's strongly acid upland soils is estimated at 188 million ha, or 39% of the region's total land area (IRRI, 1986). More than 50% of this area is dominated by soils of pH less than 5.0. The acid uplands vary from 33% of total land area in Indonesia and the Philippines, to as high as 66% in Laos (IRRI, 1986).

Until recently the acid uplands were not subjected to serious human settlement pressure.

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Currently, however, these ecosystems are undergoing major transformation in all countries in the region due to a greatly accelerated inmigration, and rapid natural population increase. Settlement is dominated by small-scale farm families that produce cereal crops, mainly upland rice and maize, to meet subsistence food needs. The soils typically exhibit rolling to steep topography with high erosion potential, and chemical properties typified by severe P deficiency, Al toxicity, and low cation exchange capacity (IRRI, 1986). As large areas of these lands are converted to short-fallow rotation systems, or to permanent food crop cultivation, the pace of ecosystem degradation has accelerated (Garrity and Sajise, 1992).

A research location in Claveria, Misamis Oriental, northern Mindanao, Philippines was selected as representative of the general problem complex of acid upland environments in the region (Magbanua and Garrity, 1990). It has been the site of intensive work on sustainable upland farming systems for strongly acidic soils since 1984 (IRRI, 1990). An interdisciplinary on-farm research framework (Zandstra et al., 1981; Conway, 1986) was employed to address major technical constraints to more productive upland rice-based farming systems.

A major challenge to research and development is the complex pattern of cultivation on hilly landscapes. The use of steeply sloping land for annual cereal cropping without soil conservation practices was increasing rapidly. Erosion rates are known to be excessive (Garrity et al., 1993) and farmers are concerned about the consequences (Fujisaka and Garrity, 1989). It was evident that research and development must provide specific technical options relevant to the range of slopes and farmer circumstances. To focus research, greater understanding was needed of the historical evolution of the current land use patterns, and their relation to the land type, particularly slope. This information would indicate rates of change in the ways that different types of land were managed, and reveal insights as to future trends. We aimed to document these relationships to interpret land use change, and the prospective evolution in future land use that may be anticipated.

This paper presents a spatial and quantitative analysis of the changes in land use over a 40 year period in Claveria. The general objective of the study was to test the utility of historical land use analysis as a tool in farming systems research. The specific objectives were to conduct a detailed analysis of the land use in Claveria at three specific dates, and relate changing land use patterns to slope type.

2. The research setting

The farming systems research site lies within the southwestern portion of the municipality of Claveria in Misamis Oriental Province, northern Mindanao, Philippines (Fig. 1), covering the major agricultural zone of the municipality. The landscape is derived from pyroclastic parent materials deposited by two volcanoes, Mt. Balatocan and Mt. Mogabon, which are positioned 15–20 km north and southeast of the town center, respectively (Bureau of Mines, 1963).

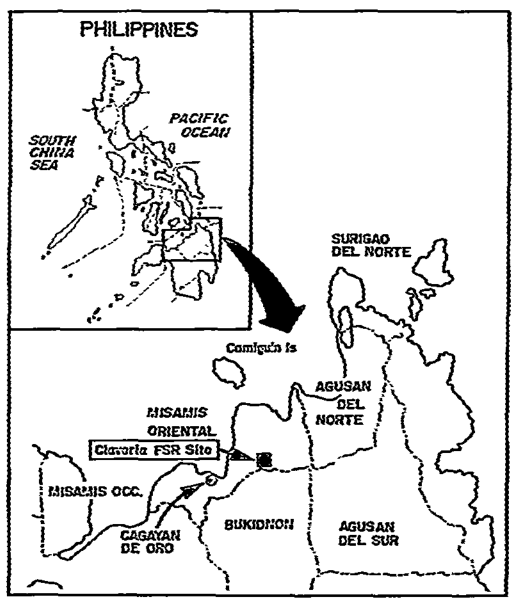

Fig. 1. The location of the Claveria research site.

The site is a volcanic plateau ascending abruptly from sea level on the west to about 500 m elevation in the east. Local topography is complex, ranging from flat to steeply hilly, and from broad smooth terrain to extremely dissected landscapes (Bureau of Soils, 1985).

The soils are deep (more than 1 m) fine, mixed, isohyperthermic Ultic Haplorthox. Rainfall is approximately 2000 mm $year^{-1}$ in the study area, with a 7 month rainy season from June to December (Magbanua and Garrity, 1990). On average rainfall exceeds 200 mm $month^{-1}$ for 5–6 months per year. A serious midseason drought in August is common. Annual rainfall and length of the rainy season tend to increase significantly with elevation.

Kenmore and Flinn (1987) gave a historical account of the development of Claveria based on anthropological research in the communities. Edgerton (1982) discussed frontier society on the Bukidnon plateau between 1870–1941. Dupasala (1986) analyzed the development of the agricultural system from an ecological perspective. Mandac et al. (1986) surveyed the current socio-economic profile of the farming population. And an agroecosystems analysis of the area was given in Magbanua and Garrity (1990).

The agroecosystems of Claveria were primarily under dense tropical dipterocarp forest until the early twentieth century. Swidden agriculture was practised on a very limited portion of the land surface by the native Higa-onon people. In a process that characterized most of the upland ecosystems in the Philippine archipelago, loggers harvested substantial portions of the old growth timber in the early decades of the twentieth century. Small-scale farmers, mainly from the Visayan islands, followed the logging operations into the area. Logging roads facilitated permanent settlements linked to the national economy. The displaced Higa-onon populations were forced to retreat upward onto the more remote slopes of the mountains, massifs, settling at elevations greater than 700–1000 m.

Swidden farming, and the regular occurrence of extensive dry season fires, converted large areas into grassland. Cattle ranchers gained control of extensive areas through leases distributed by the Bureau of Lands. The ranchers completed the permanent transformation of much of the forest area into extensive fire climax grasslands dominated by *Imperata cylindrica*.

The small-scale settlers cultivated upland rice and maize in a grass fallow rotation system on the limited areas of level or very gently sloping lands, avoiding the steep slopes. Coffee, coconuts, and perennial fruit trees were planted on small areas during the 1950–1970 period. Settlement accelerated greatly from the 1960s, increasing the density of both farms and land use. During the 1970s market tomatoes became an important component of the agricultural economy, shipped directly to urban centers (particularly Manila). Cassava also became an important commercial crop on the more acidic, infertile lands.

Maize is presently the dominant crop, cultivated twice annually without crop rotation. Upland rice is commonly planted on the more strongly acidic soils where maize is not well-adapted. Until very recently use of inorganic fertilizers was insignificant.

Farm sizes presently range from 0.25 ha to 19.5 ha, averaging 3.0 ha (Mandac et al., 1986). Ownership is common among larger farmers (more than 3.2 ha). Tenancy or leasehold is common among small farmers. There is intense pressure for land. Clean cultivated fields, tilled with animal power extend to the steepest slopes. The amount of fallow land has been rapidly decreasing. Fallow rotation has yielded to permanent field farming. Claveria is linked via two roads to the main coastal highway, and to the major entrepot of Cagayan de Oro City. One of these roads is now paved.

3. Methods

3.1. Slope analysis

Conventional aerial photographs (scale 1:15 000), dated March–April 1967, were used to map the slope classes of the study area. The segregation of standard slope classes was facilitated by stereoscopic viewing (binocular vision) using photogrammetric techniques (American Society of Photogrammetry, 1975a,b). Estimation of the slope between two points on the airphotos was determined as the ratio of the vertical (or elevation) difference between the two points, and the horizontal distance between the points, as measured directly on the airphoto. A stereometer was used in conjunction with a mirror stereoscope to determine the parallax (image displacement) between the two points, using standard methods (American Society of Photogrammetry, 1975a).

A detailed slope interpretation was performed on the photographs. The area of coverage was limited to the barangays (villages) and sitios (small villages) in which on-farm research activity was located. From the interpretations, a slope map was constructed by manually plotting the effective area of each photograph to minimize radial distortion effects. The resulting slope map, an 8 km × 10 km block, gave the distribution of six slope classes. The slope map was digitized using the PC ARC/INFO Geographic Information System (GIS), and the area in each slope class was calculated. There were limited areas in the study block for which aerial photos were unavailable. These accounted for the land areas labelled as 'unclassified' in the tables.

3.2. Land use mapping

Aerial photos were obtained for the study area from the years 1949 and 1967. The images were visually analyzed to discriminate major categories of land use: Forest, annual crops, perennial crops, and grassland. This information was mapped at a scale of 1:45 000. Aerial photos of the area were not available for recent years. Therefore, in 1988 a detailed ground survey was conducted to map the current land use. The survey team used the land use and slope maps that had been previously developed for 1967 as base maps.

The three land use maps were digitized using PC ARC/INFO, and the areas in each class determined. Map overlay analysis was used to quantify the change in land use between dates. The land use map for 1949 covered an area 23% smaller area than that in the 1967 and 1988 maps. Consequently, the land use changes from 1949 to the later years were slightly biased, because of any difference that might have been present in the land use mix of the area excluded in 1949 compared to the whole coverage area.

4. Results and discussion

4.1. Distribution of slope classes

The complex nature of the land distribution by slope class is evident in Fig. 1. Lands in all slope classes were commonly observed at all elevations. Table 1 presents a breakdown of the hectarage in each of the six slope classes. Of the 8569 ha analyzed, 9% (797 ha) was nearly level land (0–3% slope). The level lands occurred only in small plots, dispersed across the study area at elevations ranging from 400 m to more than 900 m (Fig. 2). They were not strongly associated with any particular elevation band, but were low in occurrence at the lower elevations (400–500 m). The diffuseness of level land was due to the presence of abundant dissections in the landscape, such as creeks. Prime agricultural lands with a low threat of soil erosion were a very limited resource.

The other five slope classes, each occupied between 14 and 19% of the total area (Table 1). The area of moderately steep (30–60%) slopes was the most extensive (19%). Very steep areas

Table 1
Land area distribution in different slope classes. Claveria, Misamis Oriental, Philippines

Topographic description	Slope range (%)	Area (ha)	Percent
Flat to very sloping	0–3	797	9
Gently sloping	3–8	1262	15
Sloping	8–15	1175	14
Moderately steep	15–30	1538	18
Steep	30–60	1647	19
Very steep	Above 60	1119	13
Unclassified	No data	1031	12
Total		8569	100

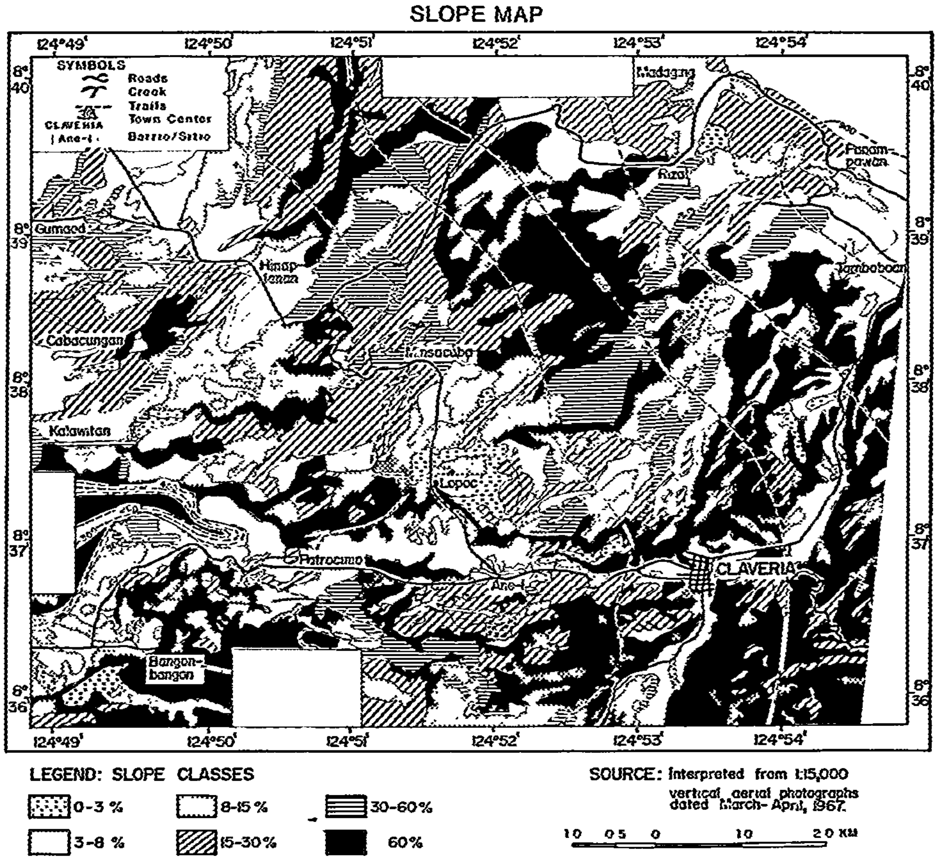

Fig. 2. The distribution of land by slope class in the study area, Claveria, Misamis Oriental, Philippines.

(over 60% slopes), which included the numerous escarpments along deeply incised ephemeral creeks, accounted for 14%. These were most common in the 600–800 m elevation band, but were observed at all elevations. Although in general the land tended to become steeper with elevation, above 800 m there was a major area of gently sloping land in the vicinity of the village of Rizal (Fig. 2).

4.2. Land use changes

4.2.1. The agroecosystem in 1949

The 1949 photo analysis pictured the Claveria agroecosystems as they emerged from the first major period of settler influx, from the 1920s to the end of the Second World War. Claveria was then dominated by grassland (Fig. 3). Forests still occupied 14% of the land area, mostly at elevations above 600 masl, predominantly on the steep land units with least accessibility and greatest protection from fire.

Ranching was a major enterprise at the time. Grass vegetation occupied 85% of the non-forested land. The sward was natural range land dominated by *Imperata cylindrica*, which currently still dominates the grassland community.

Cultivated land occupied one-tenth of the area in 1949. It was concentrated in contiguous patches in sites that subsequently developed into the major villages of Hinaplanan, Plaridel, and Patrocinio. On these lands, slopes were predominantly less than 8%. Proximity to roads was an obvious determinant of settlement pattern (Fig.

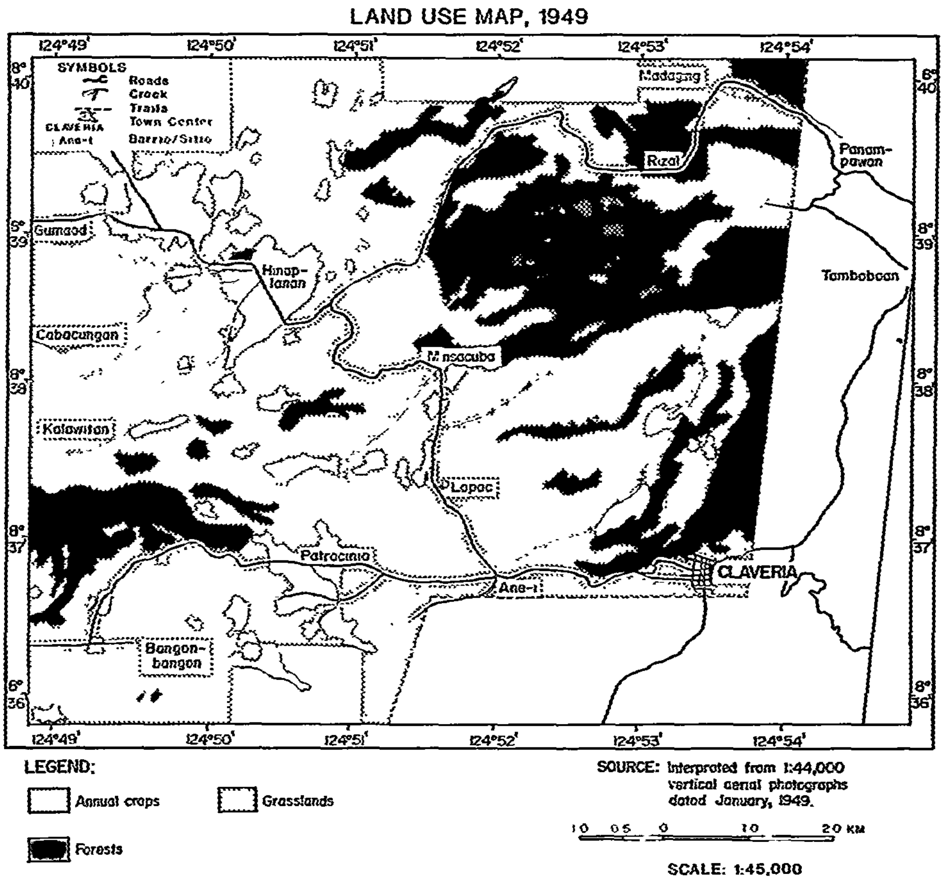

Fig. 3. The distribution of land by land use class in 1949, Claveria, Misamis Oriental, Philippines.

3). Consequently, cultivated areas tended to be located in grassland areas rather than forested areas. This distribution suggests that swidden cultivation was nearly absent within the forested areas at the time, and did not contribute to further forest reduction.

Perennial crops, if present, were difficult to detect and delineate in the 1949 aerial photos due to scale limitations (1:44 000). Consequently, perennials were not mapped separately in the interpretation. The only known area of perennial culture during that time (detected from interviews with older residents) was 50 ha of abaca (*Musa* sp.) in the Rizal–Panampawan vicinity. This area was treated as an inclusion in the forest mapping unit in Fig. 3.

4.2.2. The agroecosystems in 1967

The 18 year period between 1949 and 1967 was marked by a steady influx of new settlers. The immigration was spontaneous but government-encouraged. Commercial logging of primary and secondary forest ended in Claveria in the early 1960s (Kenmore and Flinn, 1987). There was no substantial change in the forest cover between 1949 and 1967, as shown in Fig. 4. Timber harvesting shifted to the higher elevations in the east, outside the study area, near the villages of Luna, Lanise, Mat-i. These areas had abundant virgin forest resources at the time.

Between 1949 and 1967 the cultivated area doubled from 767 ha to 1693 ha (Tables 2 and 3). Many new areas were opened for annual crop production, particularly in the vicinity of the

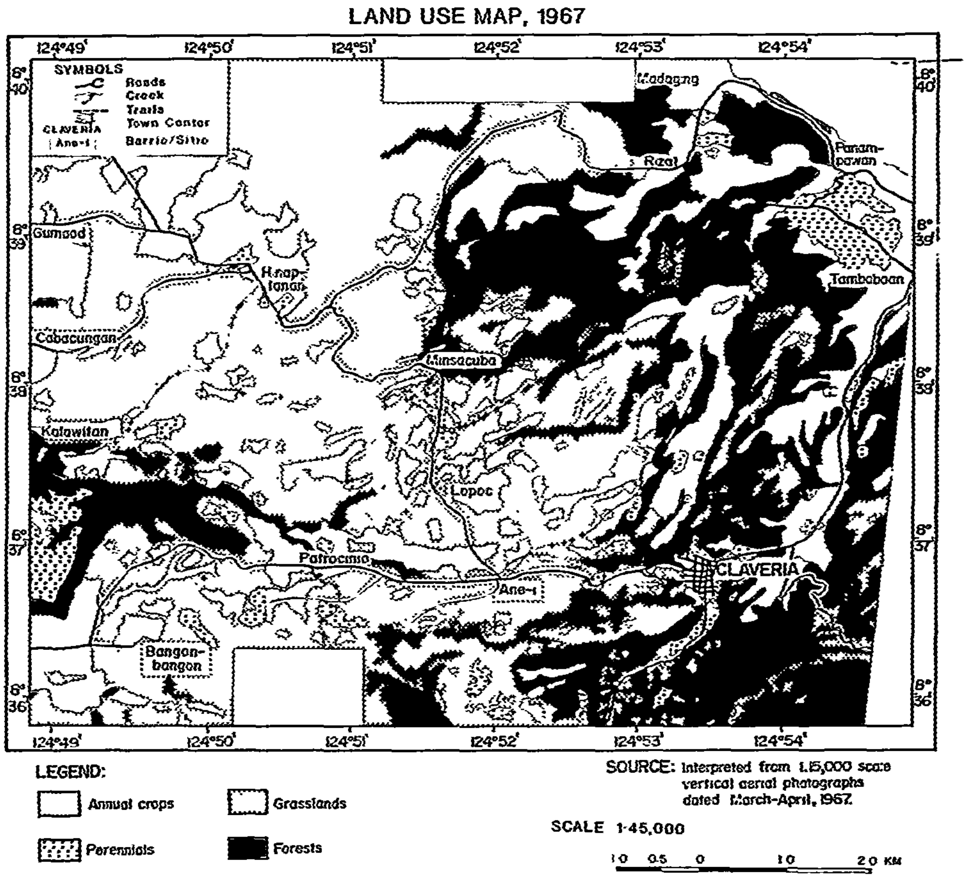

Fig. 4. The distribution of land by land use class in 1967, Claveria, Misamis Oriental, Philippines.

Claveria urban area, and the village of Rizal (Fig. 4). By 1967 over 20% of the study area was cultivated. However, some cultivated areas in 1949 had reverted to grassland in the 1967 photographs. Shifting cultivation was still practised, with substantial cultivated land having been either abandoned or left fallow to regenerate soil fertility. In general, there was a major expansion of small clearings at the expense of both grassland and forest.

There was a 20% decrease in the grassland area from 1949 to 1967. Most of the converted grassland was now in annual crop cultivation, but some had reverted back to forest (Table 4). The most significant change from grassland to cropland occurred around the villages of Madaging, Rizal, Panampawan, and Banban in the upper elevations, and Patrocinio, Ane-i, Bangonbangon, Kalingagan and Gumaod in the lower elevation areas (Fig. 4).

Perennial cropping had become a significant land use by 1967, covering 4% of the land surface (Table 3). Small coffee groves were observed in numerous locations, the species having been introduced some 15 years previously (Kenmore and Flinn, 1987). The plantations appeared as neatly spaced tree crops in fields adjacent to cultivated lands, occurring in most villages and hamlets.

4.2.3. *The agroecosystems in 1988*

Change in the land use systems of Claveria accelerated dramatically during the period 1967–1988 (Fig. 5). Nearly all remnants of intact for-

Table 2
The area distribution of major land uses in different slope classes. Claveria, Misamis Oriental, Philippines, 1949[a]

Slope class (% range)	Land use								Total	
	Cultivated		Grasslands		Forests		Unclassified		ha	%
	ha	%[b]	ha	%	ha	%	ha	%		
0–3	146	(18)	464	(58)	65	(8)	122	(15)	797	(100)
3–8	188	(15)	720	(57)	195	(15)	159	(13)	1262	(100)
8–15	102	(9)	800	(68)	109	(9)	164	(14)	1175	(100)
15–30	122	(8)	1135	(74)	102	(7)	179	(12)	1538	(100)
30–60	96	(6)	871	(53)	317	(19)	363	(22)	1647	(100)
>60	64	(6)	482	(43)	273	(24)	300	(27)	1119	(100)
Unclassified	49	(6)	619	(60)	119	(12)	244	(24)	1031	(100)
Total	767		5091		1180		1531		8569	
Percent	(9)		(59)		(14)		(18)		(100)	

[a] The 1949 land use map coverage was 23% less than that of the 1967 and 1988 area analyzed (see Fig. 3).
[b] Percentages of area within a slope class. Percentages sum to 100 within each slope class (read horizontally).

Table 3
The area distribution of major land uses in different slope classes. Claveria, Misamis Oriental, Philippines, 1967

Slope class (% range)	Land use										Total	
	Cultivated		Perennials		Grasslands		Forests		Unclassified		ha	%
	ha	%	ha	%	ha	%	ha	%	ha	%		
0–3	401	(50)	80	(10)	253	(32)	58	(7)	5	(1)	797	(100)
3–8	565	(45)	99	(8)	435	(34)	110	(9)	53	(4)	1262	(100)
8–15	333	(28)	51	(4)	682	(58)	86	(7)	23	(2)	1175	(100)
15–30	154	(10)	12	(1)	1247	(81)	118	(8)	7	(0)	1538	(100)
30–60	154	(9)	30	(2)	828	(50)	618	(38)	17	(1)	1647	(100)
>60	85	(8)	15	(1)	557	(50)	444	(40)	18	(2)	1119	(100)
Unclassified	1	(0)	52	(5)	167	(16)	34	(3)	777	(75)	1031	(100)
Total	1693		339		4169		1468		900		8569	
Percent	(20)		(4)		(49)		(17)		(11)		(100)	

Table 4
The area in each land use class in 1949 that was observed in the same or alternative land use class in 1967. Claveria, Misamis Oriental, Philippines

1967	1949					Total (ha)
	Cultivated (ha)	Perennials[a] (ha)	Grassland (ha)	Forest (ha)	Unclassified (ha)	
Cultivated annual crops	219[b]	–	1015	231	228	1693
Perennial crops	51	–	142	61	85	339
Grasslands	400	–	2699	228	842	4169
Forests	60	–	694	583	131	1468
Unclassified	37	–	541	77	245	900
Total	767	–	5091	1180	1531	8569

[a] No land classified as perennial in 1949.
[b] Area of cultivated annual crop land in 1949 that remained in annual crops in 1967.

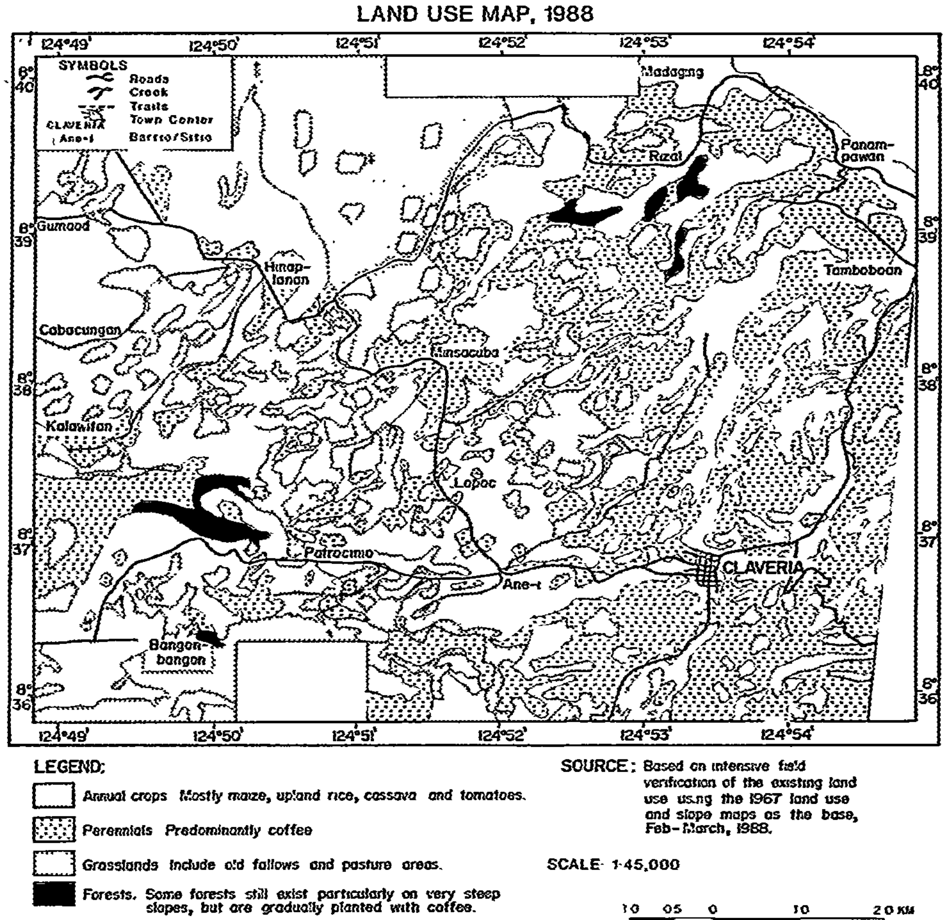

Fig. 5. Distribution of land by land use class in 1988, Claveria, Misamis Oriental, Philippines.

est had disappeared by 1988, a 93% decrease from the 1468 ha of forest in 1967 (Table 5). Only 1% of the study area remained forested. This included a steep, narrow escarpment in Patrocinio in the southwest, and a few sites in the highly dissected upper streamheads near Rizal in the northeast (Fig. 5).

The area of annual cropland doubled between 1967 and 1988, reaching 41% of the total land surface (Fig. 6). The scattered cultivated areas of 1967 had coalesced into extensive contiguous zones of tilled land. During the 40 year period (1949–1988) the area under field crop cultivation had increased five-fold. This was predominantly at the expense of grassland (Table 6). Annual crops now grown in Claveria include maize, upland rice, cassava and tomatoes. A few hectares of lowland rice are produced on wetland soils in the narrow drainageways between slopes.

Perennial crops, especially coffee, became an important component of the agroecosystem during the 1967–1988 period. Their area increased from 4 to 30% of the land surface (Fig. 6). Other fruit-bearing trees, in addition to coffee, were coconuts, cashew, marang, jackfruit, and bananas.

There was a marked increase in the area devoted to coffee in the upper elevations, replacing large areas of forest and grassland on the steeper slopes. The variety Excelsa, which produces berries throughout the year, become commonly intercropped in cultivated fields, planted at a much

Table 5
The area distribution of major land uses in different slope classes. Claveria, Misamis Oriental, 1988

Slope class (% range)	Land use										Total	
	Cultivated		Perennials		Grasslands		Forests		Unclassified		ha	%
	ha	%	ha	%	ha	%	ha	%	ha	%		
0–3	575	(72)	197	(25)	21	(3)	2	(0)	2	(0)	797	(100)
3–8	940	(74)	256	(20)	58	(5)	8	(1)	–	–	1262	(100)
8–15	799	(68)	167	(14)	207	(18)	2	(0)	–	–	1175	(100)
15–30	645	(42)	334	(22)	556	(36)	3	(0)	–	–	1538	(100)
30–60	338	(21)	890	(54)	385	(23)	32	(2)	2	(0)	1647	(100)
>60	198	(18)	631	(56)	238	(21)	51	(5)	1	(0)	1119	(100)
Unclassified	6	(1)	72	(7)	80	(8)	–	(0)	8783	(85)	1031	(100)
Total	3501		2547		1545		98		878		8569	
Percent	(41)		(30)		(18)		(1)		(10)		(100)	

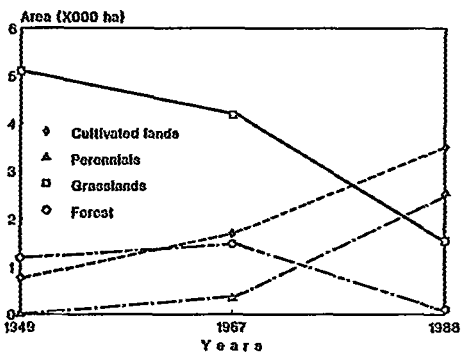

Fig. 6. Comparative changes in the hectarage of the major land uses analyzed at three different dates over 40 years. Claveria, Misamis Oriental, Philippines.

wider spacing than when managed as a pure stand.

The area of grassland in Claveria continued to decline sharply during the 21 year period as the proportion of cultivated land increased (Fig. 6). It was now reduced to 18% in 1988. The last substantial area of contiguous grassland lies to the northeast of the barangay of Hinaplanan, where ranching had long been dominant.

During the early 1980s this zone was under the influence of insurgents of the communist New People's Army. Subsequent to the 'People Power Revolution' (in 1986) the area became relatively secure. Pending enactment of national land reform legislation (in 1988) there was rapid settlement, prompted by confidence among the migrants that the land would eventually be designated as alienable, and distributed to homesteaders. At the time of the survey, a large portion of these rolling to steeply hilly grasslands were being opened to small-scale farms of upland rice, maize, and cassava.

Land frontier is now virtually closed. The only significant areas that have not been densely settled are on steeply sloping landscapes. Interviews with recent migrants indicated that many of the families that have recently settled on farms in Claveria had moved several times prior to reaching this location (Fujisaka, 1989b; Fujisaka and Garrity, 1989). They indicated that they had left their previous farms due to lack of land or declining yields.

4.3. Land use changes by slope class

Trends in land use changes by slope class are evident in comparisons among Tables 2, 3 and 4. The level land (0–3% slope) was generally of the highest soil fertility, as indicated by numerous on-farm experiments. In 1949 most of this level land was in grass (Table 2). By 1967 the majority of the level land was cultivated (Table 3), and by

Table 6
The area in each land use class in 1949 that remained in the same or alternative land use classes in 1988. Claveria, Misamis Oriental, Philippines

1988	1949					Total (ha)
	Cultivated (ha)	Perennials[a] (ha)	Grasslands (ha)	Forests (ha)	Unclassified (ha)	
Cultivated annual crops	381[b]	–	2208	414	498	3501
Perennial crops	211	–	1108	496	732	2547
Grasslands	122	–	1229	130	64	1545
Forests	5	–	21	72	–	98
Unclassified	48	–	525	68	237	878
Total	767	–	5091	1180	1531	8569

[a]No land classified as perennial in 1949.
[b]Area of cultivated annual crop land in 1949 that remained in annual crops in 1988.

1988 the proportion of cropland on 0–3% slopes was 72% (Table 4). Nearly all the remainder was in perennial crops.

On the steeply sloping lands, which include the categories of 15–30%, 30–60%, and >60%, there was little change in the land use pattern between 1949 and 1967 (Tables 2 and 3). Significant changes in land use between these dates occurred on the more level lands, as cultivation intensified, and as perennials entered the system.

The land use pattern on the steeper lands was altered dramatically between 1967 and 1988. Twenty-seven percent of the steeper lands were converted to annual cropping, and 43% was under perennial crops. The use of steep lands for permanent cropping of field crops indicated a serious scarcity of good quality land.

The population of the Municipality of Claveria (National Census and Statistics Office, 1980) increased from 14 282 in 1960 to 29 088 in 1980. The increased demand for farmland is evident in that more than 33% of the area currently cultivated to food crops is now located on slopes greater than 15%. Slopes in this range are highly susceptible to accelerated soil erosion (Garrity et al., 1993; Carson, 1989). Seven percent of the cultivated land is on slopes greater than 60%.

5. Implications

5.1. Agroecosystem sustainability

Farming systems evolve along alternative trajectories, depending on the interaction of physical, biological, social, and economic conditions (Ruthenburg, 1980). Predicting the utility of a new agricultural technology in an agroecosystem depends on accurate evaluation of future land use trends. Much research and development is wasted promoting inappropriate technical changes in tropical small-scale farming due to unrealistic judgements of these trends. Pingali et al. (1987) demonstrated this in the case of agricultural mechanization research and development in Africa.

Immense change has taken place in Claveria in the short span of 20 years from 1967 to 1988. The trends indicate that in future the amount of open grassland and fallow area will be further reduced, perhaps eliminated, following the pattern of disappearance of the forested area during this period. Farm size is decreasing, forcing most smallholders without cash sources to continually intensify food cropping on slopes. However, the historical analysis suggested a transition toward perennial-based systems, as perennial crop hectarage increased strongly during the previous two decades. There was much debate in the research team as to whether the serious degradation in land quality would be contained or reversed in time to prevent much of Claveria's farmland to be ruined beyond productive use.

Direct observation over a short time frame (1985–1990) challenged the premise of a perennial-crop transition: New planting of coffee had stopped, and many older coffee gardens were removed. There were indications that perennial crop hectarage was now on a decline, in response to historically low commodity prices.

Counteracting this situation is the emergence of a new perennial opportunity: Small-holder timber production with short-cycle tree species, particularly *Gmelina arborea* (Garrity and Mercado, 1994). This agroforestry system has become popular due to rapidly rising timber prices induced by the collapse of natural forest logging in the late 1980s.

Nevertheless, many small-scale farmers with inadequate land and capital to invest in agroforestry or perennial crop production will be forced to retain their limited land area in food crops. They may be increasingly marginalized due to soil erosion and declining yields. Research must be accelerated to develop sustainable technologies for food crop production on acid, sloping lands through contour hedgerow farming systems (Garrity et al., 1993).

5.2. Research methodology

Farming systems research methodology (Harrington et al., 1989; Zandstra et al., 1981) conventionally includes a phase involving characterization of the system and the diagnosis of the critical limiting factors amenable to research solutions. Agroecosystem Analysis (Conway, 1986) evolved as a conceptual framework and toolkit to identify key directions for positive intervention in complex systems. However, the development of tools to effectively capture the relevant evolutionary trends in farming systems have been neglected.

Aerial photographs have been extensively employed as a foundation for land surface mapping by most branches of the earth and agricultural sciences since the 1930s (American Society of Photogrammetry, 1975a,b). Fox (1990) discussed how aerial photos may be useful in facilitating interviews with farmers about land use changes. Carson (1985 cited in Carson (1989)) used them in village level planning in Nepal. We found them useful for both static analysis of slope classes in relation to land use at a single point in time, as well as for the analysis of change across historical periods.

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References

American Society of Photogrammetry, 1975a. Manual of remote sensing. Vol I: Theory, Instruments and Techniques. Falls Church, VA, 867 pp.

American Society of Photogrammetry, 1975b. Manual of remote sensing. Vol II. Interpretation and Applications. Falls Church, VA.

Bureau of Mines, 1963. Geological map series. 1st edition. (Sheet NC-51).BM-BTSM, Philippines.

Bureau of Soils (Philippines), 1985. Detailed reconnaissance soil survey suitability classification: Claveria Complementation Project, Claveria, Misamis Oriental. Bureau of Soils, Manila.

Carson, B., 1989. Soil conservation strategies for upland areas of Indonesia. East-West Environment and Policy Institute Occasional Paper No. 9. East-West Center, Honolulu, Hawaii, 120 pp.

Conway, G.R., 1986. Agroecosystems analysis for research and development. Winrock International, Bangkok 111 pp.

Dupasala, I.R., 1986. The influence of agricultural activity on the terrestrial community of Claveria, Misamis Oriental. Ph.D. Dissertation, University of the Philippines, Diliman (unpublished).

Edgerton, R.K., 1982. Frontier society on the Bukidnon plateau. In: A.W. McCoy and E.C. de Jesus (Editors), Philippine Social History: Global trade and local transformations. Ateneo de Manila University Press, Quezon City, Philippines, pp. 361–389.

Fox, J., 1990. Diagnostic tools for social forestry. In: M. Poffenburger (Editor), Keepers of the Forest: Land Management Alternatives in Southeast Asia. Ateneo de Manila University Press, Quezon City, Philippines, pp. 119–132.

Fujisaka, S., 1989b. A method for farmer participatory research and technology transfer:upland soil conservation in the Philippines. Expl. Agric., 25:423–433.

Fujisaka, S. and Garrity, D.P., 1989. Developing sustainable food crop farming systems for the sloping acid uplands: A farmer-participatory approach. Proceedings of the SUAN IV Regional Symposium on Agroecosystem Research. Khon Kaen University, Khon Kaen, Thailand, pp. 182–193.

Garrity, D.P. and Mercado, A., 1994. Agroforestation: Market driven smallholder timber production on the frontier. In: J. Raintree and H. Francisco (Editors), Marketing Multipurpose Trees in Asia. Winrock Int., Bangkok.

Garrity, Dennis P., Kummer, David M. and Guiang, Ernesto S., 1993. The Philippines. In: Sustainable Agriculture in the Humid Tropics. National Research Council, Washington, D.C. pp. 549–624.

Garrity, D.P. and Sajise, P.E., 1992. Sustainable land use systems research in southeast Asia: A regional assessment. In: Sustainable Land Use Systems Research and Development. Rodale Press, Emmaus, PA, pp. 59–76.

Harrington, L., Read, M.D., Garrity, D.P., Woolley, J. and Tripp, R., 1989. Approaches to on-farm client-oriented research: Similarities, differences, and future directions. Paper presented at the International Workshop on Developments and Procedures for FSR/OFR. Bogor, Indonesia, 13–17 March, 26 pp.

IRRI, 1986. Area and distribution of acid upland soils in Southeast Asia. In: IRRI Annual Report for 1985. The International Rice Research Institute. Los Baños, Philippines, pp. 214–215.

IRRI, 1990. Proceedings of the 1988 Acid Upland Design Workshop. International Rice Research Institute, Los Baños, Philippines, 174 pp.

Kenmore, Z. and Flinn, J.C., 1987. An ethnohistory of an upland area: Claveria Misamis Oriental. IRRI Saturday Seminar 24 January 1987. Agricultural Economics Department Paper 87–02.

Magbanua, R.D. and Garrity, D.P., 1990. Agroecosystems analysis of a key upland farming systems research site. Proceedings of the 1988 Acid Upland Design Workshop. International Rice Research Institute, Los Baños, Philippines.

Mandac, A.M., Flinn, J.C. and Genesilda, M.P., 1986. Developing technology for upland farms in Northern Mindanao, Philippines. Phil. J. Crop Sci., 11(2): 69–79.

National Census and Statistics Office, 1980. Final report. Manila.

Pingali, P.L., Bigot, Y. and Binswanger, H.P., 1987. Agricultural mechanization and the evolution of farming systems in sub-saharan Africa. Johns Hopkins, Baltimore, MD, 216 pp.

Ruthenburg, H., 1980. Farming Systems in the Tropics. Clarendon Press, Oxford, 371 pp.

Zandstra, H.G., Price, E.C., Litsinger, J.A. and Morris, R.A., 1981. A methodology for on-farm cropping systems research. International Rice Research Institute, Los Baños, Philippines, 149 pp.