Land use change and land degradation in West Malombe, Mangochi District, Malawi: a geographical study

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Abstract

This paper reveals that there has been a major land use change through smallholder agriculture intrusion in West Malombe Catchment, Mangochi District in Malawi. This change has also been associated with much gullying of the catchment, culminating in significant sedimentation of the Lake Malombe littoral plain. This calls for remedial action by emphasising the long-term benefits of soil and water conservation technologies by land husbandry specialists in the area. This paper is based on the analysis of aerial photographs taken between 1957 and 1995 and topographical maps with limited groundtruth observations.

Introduction

Agriculture is the dominant sector in the economy, which for the past ten years, has accounted on average for 34% of real GDP, with small-scale agriculture having a 25% share of the GDP (Malawi Government, Ministry of Economic Planning and Development, 1995). In small-scale agriculture, maize is a major component, contributing about 60% of output. Agriculture contributes about 90% of export earnings and 85% of employment. Given the central importance of agriculture, any deterioration in land resources has serious consequences for Malawi's sustainable economic development and growth.

Sustainable development does not necessarily mean complete conservation of the resource base. Indeed, a certain level of environmental degradation is an inevitable by-product of economic activity. The critical issue, however, is to ensure that the level of

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resource use remains consistent with society's development objectives. To achieve this in Malawi, where soil erosion and deforestation are widespread, there is need for a clear understanding of the forces that influence smallholder agricultural productivity and result in land degradation. With an understanding of land use, management and land degradation, it is possible to have an approach to sustainable development. An analysis of the spatial patterns of existing practices, their productivity and of the distribution of land degradation is required, as is that of the economic, social and temporal factors that affect the attitudes and perceptions and decision-making processes of smallholders.

Land degradation can be defined as a reduction of the physical, chemical or biological status of the land which restrict its productive capacity. Research on land degradation has long focused on the physical or chemical or economic, which led to technical prescriptions and remedies for halting land degradation (Hudson, 1971; Blaikie, 1985; Olsson, 1993). Scott, Stonehouse, Blackburn and Hilts (1992), presenting a review of models of soil conservation practices, also state that research efforts in the past that attempted to find solutions to land degradation had tended to be sectoral or discipline oriented. Instead they recommend a multidisciplinary approach to provide an integrated perspective with which to conceptualise and explore possible solutions. The complexity and interrelated nature of the causes of land degradation has lately been highlighted in a number of studies (e.g. Blaikie and Brookfield, 1987). Similarly, in Malawi, the policy document, the *National Environmental Action Plan* (NEAP), underlines the multidimensional causal approach and multi-pronged management strategies and policy proposals (Department of Research and Environmental Affairs, 1994).

This paper presents some results of a broad study that aimed at exploring the degree of land use, management and land degradation. It assesses spatial and temporal change of land use and the spatial extent of degradation.

Methodology

Black and white panchromatic aerial photographs and topographical maps for the area were analysed by using mirror stereoscopes and visual appraisal respectively. The technique has successfully and reliably been used in several other studies (Keech, 1969; Stromquist et al., 1985; Marker, 1988; Ntsaba, 1989; Rowntree et al., 1991; Galg and Harrison, 1992; Whitlow, 1994; Rowntree and Dollar, 1995, 1996; and Watson, 1995, 1996). Topographical maps of scale 1:50,000 Numbers 1435 C1 and C3 for 1962 and 1976, and aerial photographs of 1:25,000 scale for years 1957 and 1982 were used to determine spatial and temporal changes of land use patterns in West Malombe Catchment (WMC). From the topographical maps, there was already delineation of the various land use categories and detail was extracted. The results are presented in Figures 4 and 5.

In the case of the 1957 and 1982 aerial photography, the area had to be mapped, involving the use of 20 and 18 exposures respectively. The extra two for 1957 include those that covered the waters of Lake Malombe. The results are shown in Figures 3 and 6. The categories used for the classification have been kept simple and include cultivation area, settlement, major relief features and road networks, but the results give a clear picture of the main changes that have taken place in land use and vegetation cover between 1957 and 1982.

Stereoscopic interpretation was carried out using ST4 photo-interpretation instrument and hand lens. This facilitated rapid stereo-viewing and provided a magnification which ranged from three to 15.5 times. Examination of each stereo-pair was carried out at a magnification of three times and sometimes much higher. At the six times magnification, crop ridges not covered by dry season weed growth could be clearly seen.

The spatial extent of land use problems was analysed through the same topographical maps and aerial photographs interpretations. While topographical maps at the scale of 1:50,000 could be too general to pinpoint change and characterise land use pattern, particularly of smallholders, they are still useful in showing broad land use. Most features of erosion were visible in direct stereoscopic viewing and were identifiable by their form, shape and size, and their association with other features. To a lesser extent, tone, texture, shadow and pattern were also used.

Tone refers to the reflectance of the land cover features. A dark tone indicates green vegetation and a grey one, dry season vegetation. Texture represents variation in greyness in relation to tone. Rough texture shows that vegetation is sparse, while smooth texture indicates dense and green vegetation. Pattern reveals the relationship of cover type with its adjacent attribute; thus, a regular pattern with light tone and smooth texture shows a cultivated and dry area. Notes on the erosion, sedimentation and other relevant features seen on each stereo overlap and a judgement of the severity of the erosion was made. As far as possible this was related to the physical environment of the area.

Visual observation was also used during field work and this was useful in the validation of the observations made during the photo interpretation. However, it is worth noting that groundtruth observations are not a true reflection of the degradation on the dates the aerial photographs were taken. As a result, it becomes difficult to detect and quantify morphologically inconspicuous erosion forms. Such erosion forms are easily concealed on aerial photographs by, for instance, woody vegetation. To help overcome this, the views of land husbandry staff on land resource use and mismanagement were obtained during the field visits.

A review of previous work on spatial and temporal changes of land use patterns and the erosion assessment at national level forms the background to the results here. Two recent studies have provided data, namely *Land Utilization Study: Customary Land Sector* (1996) commissioned by Government of Malawi, and the International Centre for Research in Agro-Forestry's (ICRAF) *Study of Land Use and Cover for all the ADDs in Malawi* (1996). The latter, which made use of aerial photographs from 1995, was particularly useful for TA Chimwala, which was one of the enumeration areas, yielding some interesting results on land use and the nature of land degradation. These photographs at a scale of 1:25,000 taken between June and September 1995, were used in the erosion assessment.

While the interpretation of aerial photographs is one valuable technique of evaluating environmental change, it is also crucial to note its weaknesses (Rowntree, 1988). For example, very old photographs are of low resolution and groundtruthing is impossible. Scale differences between one set of aerial photographs and another, as well as scale distortion on individual photographs particularly in rugged terrains, make comparison difficult. In addition, it is difficult to interpret environmental change from photographs taken over a period of years, and which were taken at different times of the year (i. e. in different seasons).

The study area: WMC

Choice of study area

One basic and pragmatic factor for choosing this area is its closeness to Chancellor College. Secondly, the study area has experienced some of the worst ecological disasters through floods and displays visibly severe symptoms of land degradation in form of soil erosion and deforestation. Consultation with the Programme Manager and Land Husbandry staff of Machinga Agricultural Development Division (ADD) allowed the research to focus on WMC as a critical site. The area is most appropriate as 'field school' laboratory for geographers interested in sustainable land resource management.

Location, boundaries and administrative structures

WMC forms part of Mangochi district, headed by a District Commissioner. However, from a provision of agricultural services point of view, WMC is in the Machinga ADD, formerly known as Liwonde. The ADD borders on Mozambique in the east, on Blantyre ADD and Salima ADD in the south, and south-west and west respectively (see Figure 1). An ADD is headed by a Programme Manager. It is administratively broken down into Rural Development Projects (RDP), headed by a Project Officer, which in turn are split into Extension Planning Areas (EPA), under Development Officers.

Mangochi RDP (see Figure 2) is situated in the northern part of the ADD and has an area of 345,000ha (Venema, 1991). The RDP has five EPAs: MNG 1 in the north-west, MNG 3 in the south-west, MNG 4 in the south-east, MNG 8 in the east, and MNG 9 in the north. The Project offices are at Mangochi. WMC thus lies within MNG 3.

Topography, precipitation and agro-ecological zones

Knowledge of topography, precipitation patterns and agro-ecological zones is important for understanding agricultural activity and environmental change in general.

From the land resources appraisal by Venema (1991), MNG 3 falls in the natural region of Phirilongwe Hills (PH) at an altitudinal range of 500-1,000m above sea level (asl), underlying a gneiss bedrock. The PH is an upland area, consisting of two agro-ecological zones which have different lengths of growing periods (LGP), namely North, East and South Phirilongwe Hills (PH1) and West and Central Phirilongwe Hills (PH2).

PH1 is made up of two sections: rolling hills and plains in the northeast and a ridge in the south. The zone is underlain by basement complex rocks which mainly consist of gneisses. Slopes vary within the range of 2-25%. Soils on the hills and ridges are mostly moderately deep, well drained and medium textured and classified as Eutric Cambisols and Haplic Phaeozems (rudic phase). Deep soils, classified as Haplic Luvisols and Luvic Phaeozems, are found on the gently sloping footslopes. Mean annual rainfall is 800-1,200mm and LGP around 135 days on the plains and around 150 days in the hills. Mean monthly temperature is 22.5-25°C during the growing period. The area is mostly covered by mixed low altitude savanna and Brachystegia woodland. Cultivation is sparse, with maize, pulses, groundnuts, cotton and cassava as the main crops.

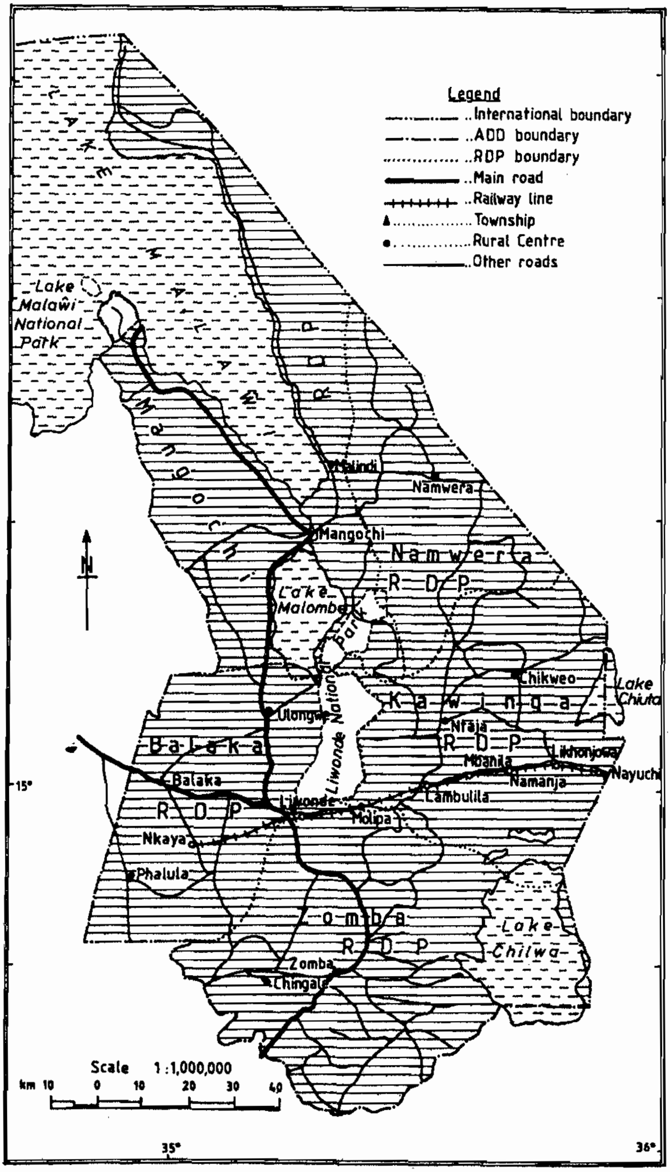

Figure 1. Machinga Agricultural Development Division spatial system

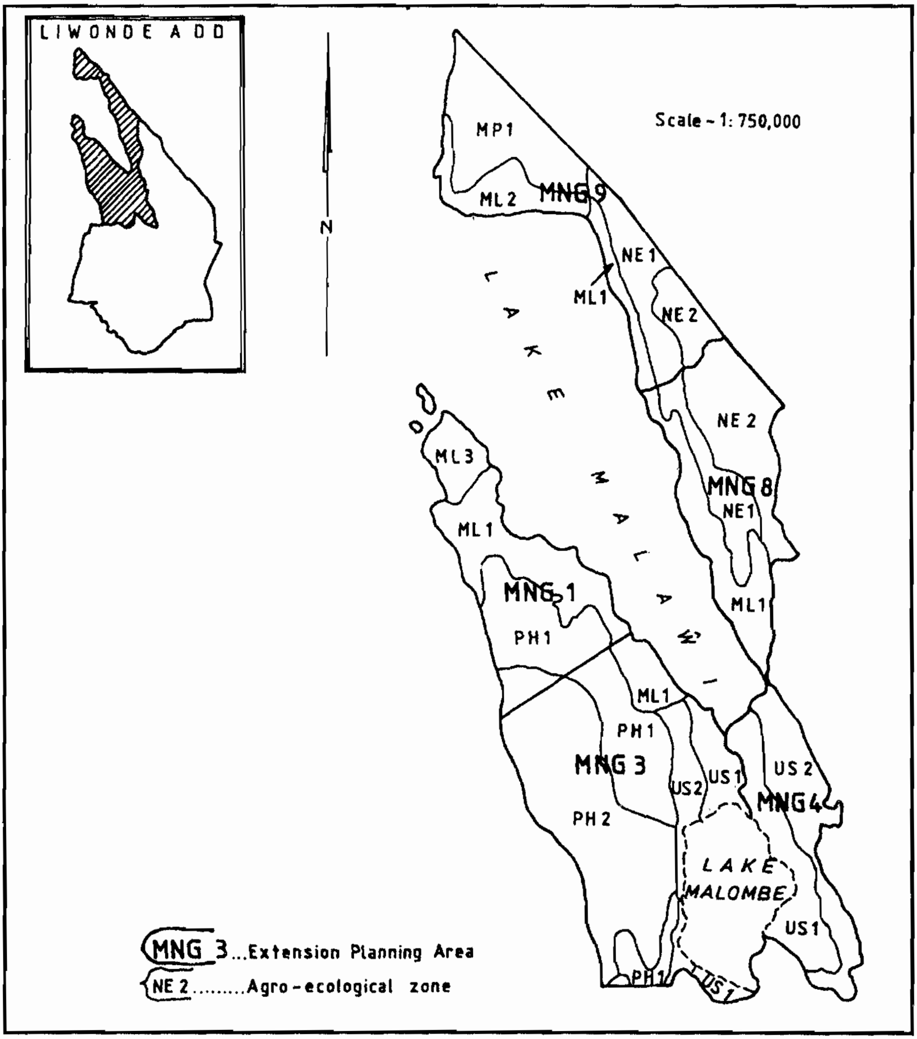

Figure 2. EPAs and agro-ecological zones, Mangochi RDP

PH2 contains the Phirilongwe Hills proper and surrounding uplands. The hills are moderately steep with dominant slopes of 13-25% and have moderately deep, well-drained, coarse-to-medium textured, gravelly soils which have been classified as Eutric Cambisols and Haplic Phaeozems (rudic phase). The uplands around the hills have gentle slopes (2-6%) and have deep, well-drained, medium-to-fine textured soils, classified as Chromic and Haplic Luvisols. Mean annual rainfall range is the same as that of the PH1 area, while the LGP ranges between 150-80 days. Vegetation and land use is similar to that of PH1.

In general the Phirilongwe Hills (PH1 and 2) have areas with steep slopes which are not suitable for cultivation, but they also have areas with gentle to moderate slopes and deep soils which are moderately suitable for various crops. In terms of forestry, PH1 and 2 are moderately suitable for *Azadirachta indica*, *Callitris hugellis*, *Cassia siamea*, *Cordyla africana*, *Eucalyptus camaldulensis*, *Eucalyptus tereticornis* and *Melia azedarach*.

Population, economy and political environment

Table 1 reveals that at district level, Mangochi represented about 5.8%, 5.4% and 6.2% of the national population in 1966, 1977 and 1987 respectively. The intercensal annual growth rate between 1966-77 and 1977-87 for the district stood at 2.4% and 5.0%, representing the population increase of 29.9% and 64.2% respectively. The district growth rate was slightly below the national average of 2.9% in the period 1966-77, but well above the 3.7% for the period 1977-87. The proportion of males to females has been below the national average in the three censuses, probably due to migration out of the area of the male population for wage employment to urban areas in the country as well as to the mines in southern Africa.

Population density for the district in the period 1977-87 showed a dramatic rise, probably reflecting the rapid intercensal annual growth rate. Even more useful insights can be gained from analysing net migration, i.e. the difference between persons who moved into the area and those who moved out. Such movement can be either lifetime (those moved since birth) or period (those moved 12 months before census). By using the 1987 context, rates of internal migration can be worked out. Thus the lifetime net-migration rate for the district stood at +2.3, while the period net-migration rate was +1.0 (Mwafongo, 1993). The district was a net gainer of population. In the Malawian context, migration linkages have been associated with a tremendous structural change in the economy that occurred in the 1970s (Kydd and Christiansen, 1982; Christiansen,

Table 1: Mangochi District population and TA Chimwala: % totals, growth rates, sex and tribe, 1966-87

Population variable	**1966**	**1977**	**1987**
Totals	232,692	302,341	496,576
% population of national total	5.8	5.4	6.2
% population increase	(na)	29.9	64.2
Intercensal annual growth rate (%)	(na)	2.4	5.0
(Malawi Average)	(na)	(2.9)	(3.7)
Density	37	48	79
Sex ratio	80	84	90
TA Chimwala	**1966**	**1977**	**1987**
Totals	23,078	36,752	73,321
Intercensal annual growth rate (%)	(na)	4.9	8.2
Density	24	48	95

Source: National Statistics Office (NSO), 1980; 1993

1984; Mkandawire, Jaaffe and Bartoli, 1990; Kalipeni, 1992). In particular, the examination of net migration of predominantly rural districts, Mangochi district included, reveal that there has been a rapid expansion of the agricultural estate sector, which has created job opportunities for smallholders as tenants.

In the specific case of TA Chimwala which makes up WMC, increasing population densities in the two intercensal periods were associated with the government order to the TA and subordinates that they were to receive and allocate land to any immigrant from other districts looking for land to settle; this included those from Mozambique as they were fleeing the war of independence and later the civil war. The then President of the Malawi Republic publicly declared that those who were fleeing from Mozambique were their brothers and sisters, hence the need to welcome them and provide them with the land necessary for their survival. For fear of the government, settlements have been established even in marginally suitable terrain (Personal communication, TA Chimwala).

The other school of thought is that before those from either Mozambique or other districts were given portions of land to settle in WMC, the indigenous communities used to have isolated gardens. The main problem with such gardens was that monkeys and wild pigs would devastate crops. The solution was for those who had gardens to spend most of the rainy season in the fields guarding and tending their crops. However, it is important to note that people did not want to do this (Paseli, 1984). Thus, for those who came to TA Chimwala wanting to settle, it was easy for the authority to allocate them land in this area to increase the population and reduce the effect of crop-marauding animals.

Economic infrastructural investment in the area includes a tarmac road running through the study area (see Figure 1). Subsistence agriculture forms the main source of livelihood, with communities situated along Lake Malombe being heavily engaged in fishing. Malawi has just emerged from a single party rule of three decades to pluralistic politics. The study area is a stronghold of the ruling United Democratic Front (UDF) party.

Results and discussion

Changes in land use patterns

On a general note, the results of the 1988-90 land use inventory (Land Resources Evaluation Project (LREP) 1991-2) and those of a 1965-7 study by Stobb and Jeffers (1985) indicate significant changes in land use patterns in Malawi. In 1965-7, 3,532,000ha (or 37.5%) of the total land area of Malawi was under cultivation and fallow. In the 1988-90, the figure rose to 4,641,350ha (or 40.2%). At national level, it means that agriculture grew by 1,108,550ha (or 31.4%). This gives an average rate of expansion of land for rainfed cropping of about 1.4% per annum over the past 23 years. At a regional level, agriculture grew by 326,900ha (or 56.6%), 734,250ha (or 49.7%), and 47,400 (3.2%) in the North, Central and South respectively. These expansions represent 2.5%, 2.2% and 0.14% average growth rates over the past 23 years. Eschweiler (1993) notes that because areas recently fallow are included in the figures above, the growth in cultivated land must be the result clearing forest and woodland. Thus these figures might also reflect the average annual deforestation rates for the nation.

A recent study of all ADDs in the country by ICRAF indicated that significant changes have taken place in the area under cultivation. Thus in 1972, around 32% of all selected ADD land was cultivated while in 1995, the figure rose to about 50% (see Table 2). All ADDs have experienced rapid growth of land under cultivation. One of the selected enumeration areas in Machinga ADD under the ICRAF study was TA Chimwala, under which WMC falls. Land use and vegetation cover is presented in Table 3 and Figure 3.

Table 2. Changes in area under cultivation in selected ADDs

ADD	1972 (ha)	1972 (%)	1995 (ha)	1995 (%)
Mzuzu	5,734.0	14.8	10,624.0	27.4
Kasungu	7,641.0	46.1	13,963.0	84.2
Salima	763.0	34.5	1,660.0	74.9
Lilongwe	5,823.0	75.0	6,497.0	83.7
Machinga	2,556.0	34.9	3,126.0	42.7
Blantyre	1,967.0	54.1	2,185.0	60.1
All ADDs	**24,484.0**	**32.1**	**38,055.0**	**49.9**

Note: Cultivated land includes land use codes A-t1 to A-t5, B, C, and D (see Appendix I).
Source: ICRAF, 1996.

Table 3: Land use and cover in TA Chimwala, Machinga ADD

Land use code	Area (ha)		Area (%)		Change	
	1971	1995	1971	1995	ha	%
A-t1	103.0	80.0	11.1	8.7	(23.0)	(2.4)
A-t2	85.0	12.0	9.2	1.3	(73.0)	(7.9)
A-t3	12.0	0.0	1.3	0.0	(12.0)	(1.3)
EF	364.0	697.0	39.4	75.4	333.0	36.0
GW-t1	49.0	0.0	5.3	0.0	(49.0)	(5.3)
GW-t2	148.0	62.0	16.1	6.7	(86.0)	(9.4)
GW-t3	32.0	8.0	3.5	0.9	(24.0)	(2.6)
GW-t4	28.0	6.0	3.0	0.7	(22.0)	(2.3)
GR-t1	30.0	0.0	3.2	0.	(30.0	(3.2)
GR-t2	2.0	0.0	0.2	0.0	(2.0)	(0.2)
M	72.0	20.0	7.8	2.2	(52.0)	(5.6)
Z	0.0	40.0	0.0	4.3	40.0	4.3
TOTAL	**925.0**	**925.0**	**100.1**	**100.0**	**0.0**	**0.1**

Note: The () symbol represents a loss in land area under that use.
Source: ICRAF, 1996.

The most noticeable feature in Table 3 is that there has been tremendous increase in seasonally wet grassland of floodplains and lake margins, marshes as well as in built-up area. The area of seasonally wet grassland of floodplains and Lake Malombe margins increased from about 39% in 1971 to about 75% in 1995. This has added to the excessive erosion in WMC, which has led to significant siltation/sedimentation of the littoral plain. The total amount of rainfed cultivation with less than 2-10% tree canopy cover declined from about 22% in 1971 to around 10% in 1995.

This decline in area under cultivation could partly be explained in terms of the loss to seasonally wet grassland area. It is worrying to observe though that this cultivation occurs in almost bare land, with less than 5% tree canopy cover. Such conditions result in excessive soil loss to the lakeshore. Furthermore, in all crown cover categories of the woodlands and tree savannas there has been a decline between 1971 and 1995. This could suggest that the woodlands have undergone some deforestation. In other words, the loss in land area under natural forests and woodlands could be a clear testimony of the opening up of the areas to cultivation and fuelwood collection. The booming traditional fishing industry along Lake Malombe could be contributing to deforestation, because of the use of firewood in preserving fish and the over-reliance on dug-out canoes. With the increase in population density in WMC, the built-up environment has increased in area by about 4% between 1971 and 1995.

Figure 3 represents land use patterns for the northern part of WMC from the 1957 aerial photographs. No aerial photos for the same year could be found for the rest of WMC. The map area covered ı the photography was about 44.7km^2, of which about 28.2km^2 (63%) was under cultivation and around 2.7km^2 (6%) under settlement. The cultivation took much of the floodplain area, drained largely by Nasenga River and several rivulets. The settlements were established along the main road but close to Lake Malombe. The marsh land was used for cultivation. This lakeshore area is subjected to severe flooding almost every year.

Figures 4 and 5 show land use patterns from the 1963 and 1976 topographical mapsheets of the central and southern part WMC. The 1963 map coverage was around 27.6km^2, of which about 9.2km^2 (33%) was under cultivation and about 2.6km^2 (9%) was under settlement. Much of human activity in terms of farming and built-up area was concentrated in the flat area, with some isolated pockets in the hilly area. The settlements were along the main road. The 1976 map is much wider in coverage and includes more settlements than the 1963 map. The conspicuous feature on this map is that smallholder plots and settlements have extended into much of the hilly area. The map coverage was 235.3km^2 of which about 20.3km^2 (8%) was under smallholder cultivation and about 30km^2 (about 13%) was occupied by human settlements. Figure 6 outlines land use patterns for the same central and southern part of WMC from the 1982 aerial photographs. The area extent of about 114.3km^2 was covered in the photography, with approximately 6.9km^2 (6%) and 4.1km^2 (4%) coverage for smallholder agriculture and settlements respectively. The photography reveals much of cultivation taking place in the hilly area and settlements being centred along the main road in the flat area. About 90% of the remaining land is part of the scattered settlement area.

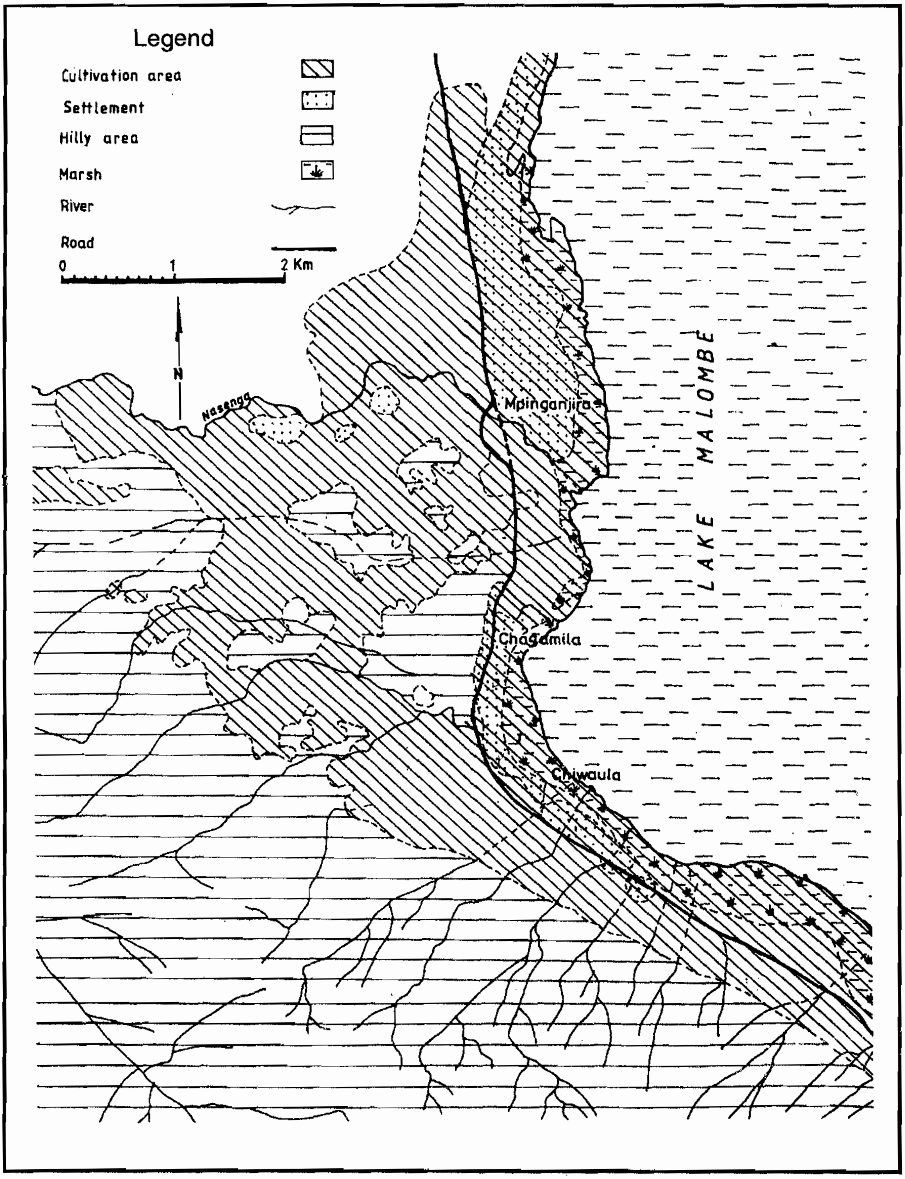

Figure 3. West Malombe Catchment: land use pattern, 1957

The process and spatial extent of soil erosion

Soil erosion is a major issue in Malawi. In the context of land degradation, soil loss poses the greatest threat to sustainable agricultural production and contributes to contamination of water resources. However, knowledge about the extent and significance of soil erosion is essentially qualitative. Indeed, contradictions between the scientific evidence of erosion, the selective use and misuse of results, orthodox 'knee-jerk' responses to visual evidence of erosion and policy responses have amply been exposed (Stocking, 1996).

The results of various attempts at obtaining information on the level of soil loss on different land classes and under different uses, have been reviewed in Saka, Green and Ng'ong'ola (1995). For example, results from spot trials of soil erosion under various cover and farming practices have shown that soil loss in Malawi ranges from 0-50t/ha/yr (Amphlett, 1986; Kasambala, 1984; Machira, 1984). The data obtained from a more recent study of four small catchments at Bvumbwe (Vitsitsi, 1991) are also often equally cited. The results from this work are remarkable in that the catchment with the worst management only recorded an average annual soil loss of 8.8t/ha over an eight year period, and the other three negligible results. The sediment yield from the worst catchment would be considered well within the soil loss tolerance for this area and one which only the most intensive conservation system might hope to achieve. The figures are at variance with those from other countries with a somewhat similar environment (Stocking, 1986). However, it was noted in the report that the sampling of late rain storms did not take place if all the sampling bottles had been used. Similarly, when rain storms were frequent, power failure often occurred.

The World Bank (1992) estimated aggregate soil loss in Malawi from cultivated land at 20t/ha/yr. It was partly based on erosion hazard maps prepared by the Land Resources and Conservation Branch (Khonje and Machira, 1987). Erosion rates were found to vary significantly throughout the country. However, it is important to emphasise that quantitative data on different aspects of soil erosion, including that for predicting the potential of soil loss and for determining critical land use management alternatives, is not readily available (Chimphamba, 1993).

The most obvious features in WMC from the available photos were the general standard of cultivation, rills, gullies and stream bank erosion and areas where soil tones indicated exposure of the subsoil. Areas of soil deposition were also clear.

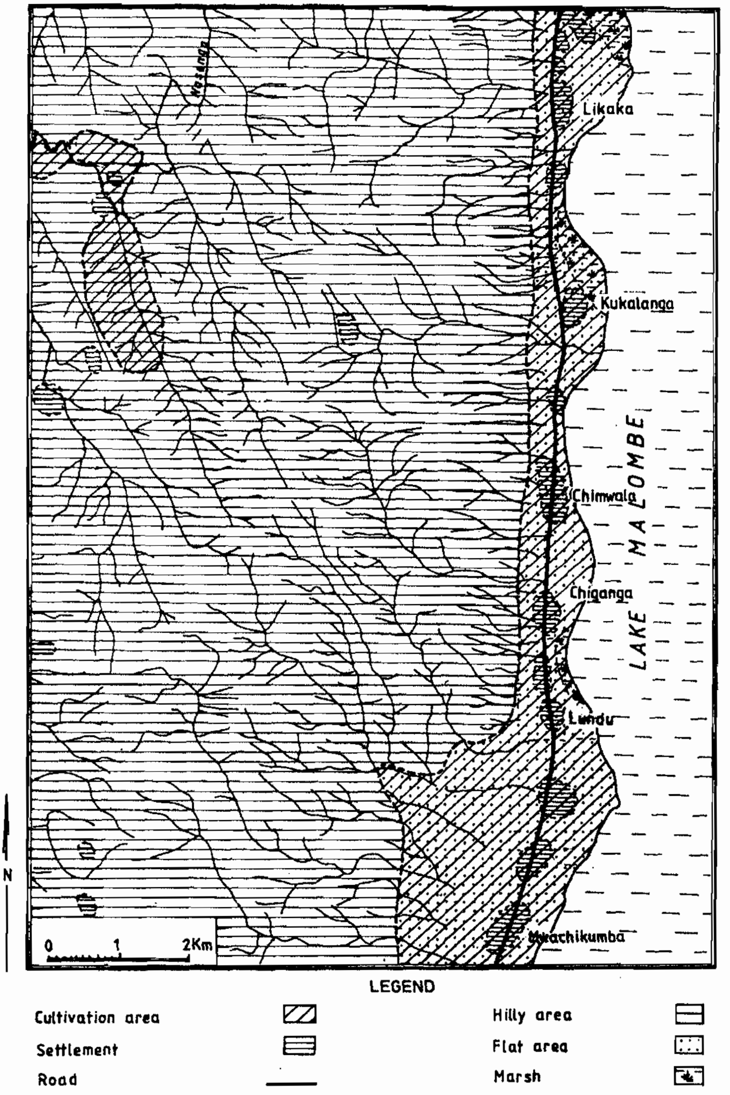

Figure 4. West Malombe Catchment land use pattern, 1963

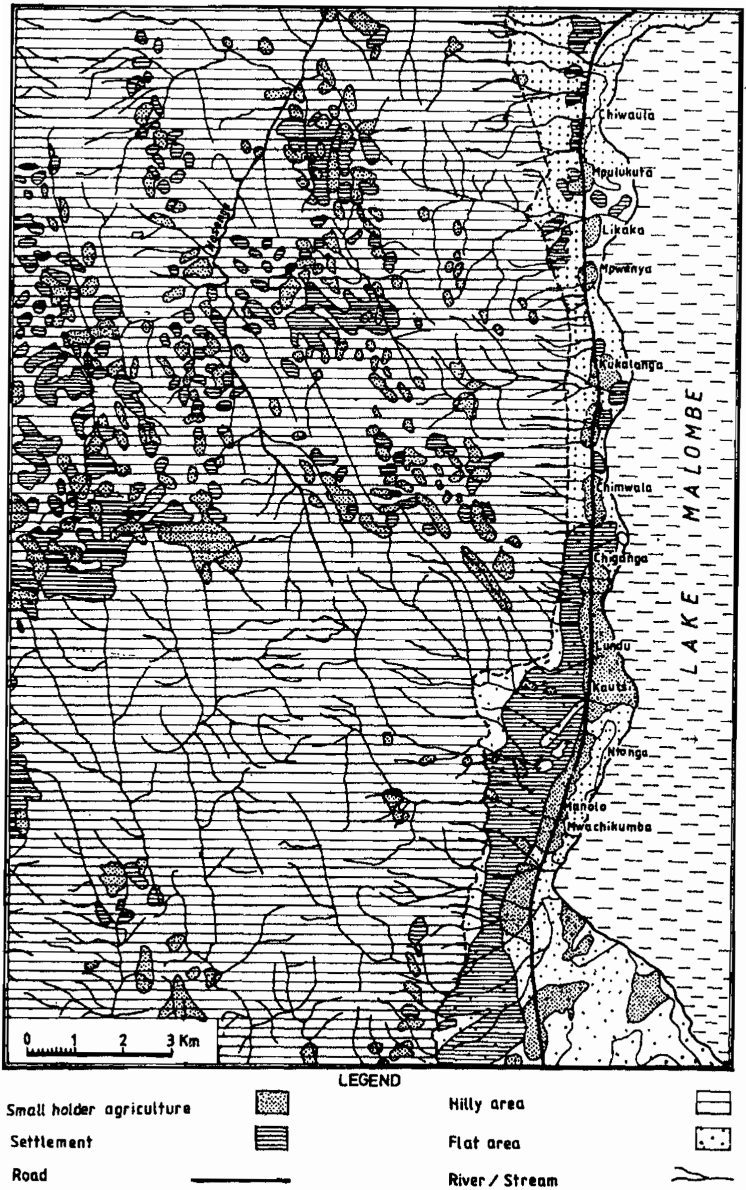

Figure 5. West Malombe Catchment land use pattern, 1976

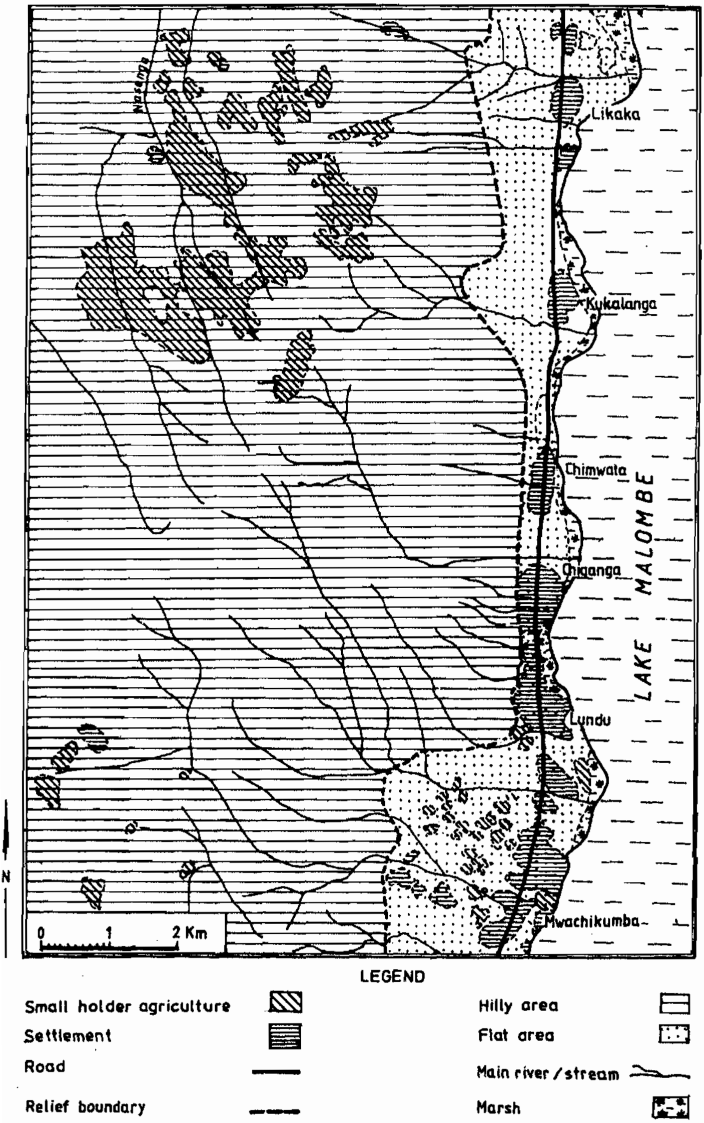

Figure 6. West Malombe Catchment land use pattern, 1982

Erosion is influenced by rainfall intensity and amount, topography and type of soil, but above all by land use (Morgan, 1995). It is not so much what the land is used for as the standard of management that is important. For example, maize grown with a high standard of management following the recommended practices is fairly quick to give good ground cover, and with correct ridging, erosion can be kept to an acceptable level, provided the land on which it is being grown is suitable.

In WMC, erosion on cultivated land from raindrop impact, rills and gullies is widespread. The results of erosion by raindrop impact were widely observed in the field in the form of erosion pedestals and pavements, sand mulching and sediment deposits. Gullies were clearly seen and most commonly occurred under the following circumstances: paths representing garden boundaries, often running up and down slope; where cultivation had taken place across natural drainage lines; where runoff from above the cultivated area had concentrated and discharged through the cultivated land, carrying away mainly the clay fraction of the soil in suspension. It is a fact that a gradual deterioration in organic matter, soil structure, water-holding capacity and the availability of nutrients increases the susceptibility of the soil to detachment and transport. It also makes the soil less suitable for plant growth, resulting in reduced crop productivity.

Significant gullies were found mainly in natural drainage lines through which cultivation had taken place as well as in those parts of the catchment which had been degraded leading to high runoff which destabilised the waterways. Many of these gullies had reached the heads of their catchments. Furthermore, the streams from the catchment appeared to be unstable due to their rapid down cutting as part of the rejuvenation process, giving rise to deeply incised stream beds. The resulting vertical banks were also unstable and liable to slumping.

Conservation measures through correctly aligned crop ridges, box-ridging and making of bunds were fairly common on cultivated land. However, areas of the catchment which were more recently opened for cultivation showed signs of more rapid deterioration than those which had been in use for a long period. The latter had some conservation structures on them, e.g. survival of correct crop ridge alignment. It would appear that farmers opening up new land in the catchment area did not have any guidance on layout. Erosion due to livestock overgrazing and trampling was also limited.

Conclusions and recommendations

The analysis shows that there is considerable land use change in WMC. Much of the hilly area is now the scene of smallholder cultivation. The prominence of gullying, rill formation and sedimentation along the Lake Malombe shore is indicative of excessive soil erosion. It is important that conventional land or soil and water conservation measures should vigorously be sustained by land husbandry specialists. Constructing marker ridges for guiding ridge alignments in the fields, box ridging, use of cover crops and vetiver grass on contours could be low cost, effective measures in the reduction of soil loss. However, farmers with medium or high resource endowment could be encouraged to establish buffer strips above contour marker ridges or construct narrow contour bunds in their fields which could be vegetated with nappier grass or hedgerows of woody leguminous plants. These farmers could also construct and maintain graded bunds and stormwater drains in their fields. Furthermore, there is need for more elaborate research on the quantitative analysis of environmental change to be able to recommend appropriate location specific technologies, for management of land resources.

Appendix 1

Present land use and vegetation cover codes

Cultivated land (including recent fallow)

A — rainfed (dryland) cultivation

- A-t1 — rainfed cultivation with less than 2% tree canopy cover
- A-t2 — rainfed cultivation with 2 to 5% tree canopy cover
- A-t3 — rainfed cultivation with 5 to 10% tree canopy cover
- A-t4 — rainfed cultivation with 10 to 20% tree canopy cover
- A-t5 — rainfed cultivation with 20 to 40% tree canopy cover

B — wetland cultivation: rice grown under naturally flooded conditions

C — dimba cultivation

D — irrigated cultivation: land being cropped within a controlled irrigation scheme

Grassland

EM — high or low montane grassland

EG — dry grassland/scrub (usually secondary, having been cleared from woodland or previously cultivated)

EF — seasonally wet grassland of floodplains and lake margins

ED — seasonally wet grasslands associated with upland drainage systems (dambos)

Plantation forests
F — forest plantations of mainly exotic species

Natural forests and woodland
GE — evergreen forest
GE-t1 — normally stocked
GE-t2 — depleted (less than 60%)
GW — woodlands, woodland and tree savannas (average height >4m)
GW-t1 — open: 2-20% crown cover
GW-t2 —medium: 20-40% crown cover
GW-t3 — dense: 40-60% crown cover
GW-t4 — very dense: over 60% crown cover
GR — recent regrowth of woody vegetation: thickets (average height <4m)
GR-t1 — open: 2-20% cover
GR-t2 — medium: 20-40% cover
GR-t3 — dense: 40-60% crown cover
GR-t4 — very dense: over 60% crown cover

Marshes
M — marshes (reed and sedge communities)

Rock
R — bare or sparsely vegetated rock outcrops

Water
W — open water (lakes, ponds, dams and rivers)

Built-up areas
Z — towns, villages and other significant buildings

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