A SURVEY OF LAND USE CHANGES IN ARABLE SOILS IN THE SOUTH-WESTERN CORNER OF UGANDA

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Abstract
The majority of the population in Uganda depend on agriculture for their livelihood, yet agricultural production is being very strongly affected by land degradation. There is, therefore, an urgent need for sustainable management of the land resources. Sustainable management depends on effective decision-making and a requirement for this is up-to-date information on the extent and severity of degradation. This study, carried out in Bubale sub county, Kabale District in the southwestern corner of Uganda, was aimed at assessing the extent and severity of land degradation in the district, information of which would be used in decision-making for natural resource management and land use planning in the district. Soil degradation was investigated using remote sensing and GIS techniques. Aerial photographs of the years 1954 and 1990 were interpreted for three parishes in the sub county, namely, Kashenyi, Nangara and Nyamiyaga and a land cover change analysis was made. Features of soil degradation were examined on four hill slopes: Kitumbeezi-Rwenkunguru, Kafunjo, Kabindi and Rwamate, representing the East, West, South and North respectively. The features examined were soil chemical characteristics and erosion features. The interpretation of the aerial photographs revealed only the different classes of land cover and not the features of erosion. Erosion features in Bubale sub county are not very extensive and could only be observed on the ground. From the land cover change analysis it was observed that the cultivated area and that under grassland decreased appreciably between 1954 and 1990 while that of settled area and woodlots increased. The cultivated area was turned to settlements due to increased population and to woodlots because it could yield no more. The grasslands, which were actually marginal land, were converted to cultivated area due to the demand for more arable land. Land degradation was observed to be responsible for declining yields, which was reported to be about half to two thirds of what they were during the 1970s. Erosion features were in form of rills, alternating scours and sediment fans, pedestals, collapsed terrace bunds and gullies.

Keywords: Land degradation, erosion, grassland, cultivation, bunds, gullies.

Introduction

Land degradation is a serious problem of worldwide concern today. In Africa in particular, the combination of widespread land degradation and rapid population growth is reducing food production per person in Africa thus fuelling the region's mounting external debt and leaving millions of Africans hungry and physically weakened (Brown *et. al.* 1990). In Uganda, 80% of the employed household population work in the agricultural sector (Population Census 1991). However, the current agricultural practices present some serious land use problems such as land fragmentation, overgrazing, deforestation and inappropriate farming systems all of which have led to acidification of soils, soil compaction, soil erosion and mass movements, sedimentation, siltation of water bodies, reduced productivity and loss of biological diversity (National Environment Information Centre (NEIC) 1994). Land degradation is hereby broadly defined as a decline in the utility of land for various purposes but in particular, agriculture.

Recent studies in Kabale district confirm that the high population density in the district has created intense pressure on the land and has resulted in soil and vegetation degradation. Bagoora, (1993) carried out an assessment of some causes and effects of soil erosion and concluded that the soils of the highland, most of which are already degraded, are very prone to erosion. Bagoora also found that one of the major causes of accelerated erosion was poor soil management. The effects of soil erosion were decline in land productivity, food shortage and general decline in the quality of the human environment. The work of Tukahirwa, (1996) included rainfall intensity as one of the factors, which may make Kabale District prone to severe erosion. Runoff and soil loss were found to be significantly influenced by surface cover, rainfall intensity and slope steepness but the effect of cover was more pronounced than that of slope. On the causes of accelerated soil erosion in the study area, Tukahirwa concluded that biophysical, socio-economic and institutional factors forced the land users to promote accelerated soil erosion. Siriri, (1996) investigated sorghum biomass and grain yields within a field and concluded that there is a multi-constraint to crop production on bench terraces. The upper parts of fields have mostly physical soil limitations, notably saturated hydraulic conductivity, soil depth, clay percentage coupled with a nitrogen nutritional constraint and a low organic carbon content. Kakuru, (1993) criticized tree planting as an ineffective means of erosion control because the trees reduce vegetation cover by the undergrowth. He recommended the use of contour hedgerows for soil erosion control in the highlands because his investigation revealed that hedgerows substantially reduced water and soil losses as the sediments were deposited on the upper side of the hedgerows.

Uganda's population in general and, in particular, that of Kabale District is growing at a fast rate (2.50% and 2.17% respectively, according to the 1991 Census) with increasing pressure on the land. This rapidly increasing population has led to intensive cultivation in a number of areas particularly the southwest, one of the country's most agriculturally productive areas. Deforestation, shortening of fallow periods and cultivation on unprotected slopes and on contour bunds have led to depletion of soil resources and to accelerated erosion (Overseas Development Administration (ODA) 1992). These and other detrimental effects are further compounding the long standing socio-economic problems of the country (NEIC 1994). It is unlikely that the pressure on the land will lessen. There is, therefore, a need to assess and monitor the state of land resources for the purpose of planning their management for sustainability. Sustainable management depends on effective decision-making, which requires accurate and up-to-date information among others on the extent and severity of degradation. Data on land degradation in the country are hard to come by. Therefore the present study attempts to provide some information on this critical issue. This goal pursued through the development of land use indicators of land degradation can be used to identify areas of concern for environmental management. The overall objective of the study was to contribute to the assessment of the land degradation problem in Kabale District for natural resource management and land use planning in the district.

The study area

Kabale district lies in the southwestern corner of Uganda bordering Rwanda. It lies between latitudes 1°00'S and 1°30'S and longitudes 29°30'E and 30°15'E. It covers an area of 1,827 sq. km of which 92.8% is arable land and the rest covered by forests, grassland, open water and swamps (National Environmental Action Plan (NEAP) 1994). The rock system is of the pre-Cambrian era and it is characterized by argillites, phyllites, shales, schists, slates, quarzites, sandstones and conglomerates. Folding in a northwesterly direction gave rise to the prominent topographical ridges of the district. The pattern of rainfall is bimodal with the long rains beginning in March and ending in mid-May and the short rains beginning in October and ending in December. The total annual rainfall ranges between 720 mm and 1390 mm. There are also frequent mists. The mean annual minimum and maximum temperatures are 10.9°C and 24.4°C, respectively.

Kabale is a highland area with altitudes ranging from 1219 m to 2347 m above sea level. It is a dissected plateau consisting of long smooth nearly flat ridges, 3-6km apart, the flanks of which are dissected by many minor streams a few hundred metres apart. The mid-slopes are straight and steep with convex upper margins and concave lower ones gently sloping to valley bottoms, which are seldom very wide. There are some broad flat-bottomed valleys, which are swampy. Very little land is on gentle slopes. The central and western part of the district is dominated by *Haplohumults* and *Kandiudults* according to USDA Soil Taxonomy (Yost *et al.* 1990). These are fine textured ultisols with thermic temperature and udic moisture regimes. The eastern part of the district is dominated by the *Kandiudults*, *Sombrihumults* and *Lithic Dystrochrepts*, which are medium and fine textured with isohyperthermic temperature and udic moisture regimes. The soils typically form a catena.

According to Langdale-Brown *et al.*, (1964), the vegetation of Kabale District then consisted of forest/savannah mosaic, which was a mixture of forest remnants, incoming savannah trees and a grass layer dominated by *Pennisetum purpureum*. However, today, except for a few vegetation patches surviving under protection, the vegetation is largely human induced (Bagoora 1993). There is papyrus and *Miscanthidium* sp. in the swamps.

According to the 1991 Population Census, the total population of the district is 417,218 persons and the average density 246.1 per sq. km. The average for the whole country Uganda is 85 per sq. km. Only 7% of the people live in the main town, Kabale. Of the 93% living in the rural area, 88.5% depend for their livelihood on subsistence farming.

Land Use, Tenure and Management

The highlands of Kabale District are in principle suitable for agriculture due to good climate, fertile soils, low incidence of diseases and good drainage. This suitability for agriculture has brought about rapid population growth and increasing pressure on the land. The crops grown are mainly annual and include sorghum, sweet potatoes, beans, peas, maize, vegetables, millet and wheat. The few perennial crops grown are bananas, tobacco and pyrethrum. The cash crops are Irish potatoes, sorghum, wheat, tobacco, vegetables and pyrethrum. Due to land shortage in the district, continuous cultivation and/or rotational cultivation is practiced. Apart from some big commercial dairy farmers occupying the reclaimed swamps several households own livestock such as goats, cattle, pigs, poultry and rabbits on a small scale. The animals are grazed on communal marginal areas, on fallow plots and along roadsides. Bee keeping is also practiced. Apart from the four forest reserves managed by the Forest Department there are several small privately owned woodlots scattered over the area. Land tenure is such that most of the land, 75%, is not registered but is held under customary private ownership whereby the owner by birth has a right to own the land.

Due to intense population pressure, the land is over-utilised resulting in serious degradation of the soil and consequently a decline in soil productivity. Conservation programmes in the Kabale highlands were started by the colonial government in 1941 and by 1949 the programmes reached an advanced stage, unsurpassed anywhere else in Africa at the time. The foci of the programmes were forestation of steep slopes and contour cultivation of strips of about 11.0 to 14.5 m wide, separated by bunds or strips. These conservation measures were enforced through legislation and the people were not educated about their role. However, after independence in 1962, the conservation measures were abandoned while population pressure on the land continued to build up (Bagoora 1993).

Bubale Sub County

Administratively, Kabale District consists of four counties: Rubanda, Ndorwa, Rukiga and Kabale municipality. There are 19 sub counties of which Bubale in Rubanda is one. Bubale sub county was chosen for this study because it is well covered by recent aerial photography. In terms of representativeness, it has similar geology, relief, soils, climate, vegetation, population and land use and management characteristics as the greater part of the district. Fig. 1 shows the location of the sub county in the district and that of the district in the country.

Methodology

Collection of background information and secondary data

Background information were collected through an archival survey by studying existing literature and research reports and holding discussions with people knowledgeable about the study area and topic under study. In addition to this, topographic and thematic maps of the district as well as the aerial photographs covering the study area were acquired.

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Fig. 1. Study area

Interpretation of remotely sensed data
Aerial photographs were interpreted for an overview of the land cover and use of the area and any signs of degradation. The photographs were covered with transparent sheets on which the boundaries of the main units were traced. Two sets of panchromatic aerial photographs, of June 1954 (scale 1:50,000) and of January 1991 (scale 1:25,000) were interpreted stereoscopically. The two sets were interpreted for the purpose of comparing their delineated features in order to find out any changes in land cover, which could indicate degradation of the land. For a more detailed study, the aerial photograph interpretation was carried out for 3 of the 7 parishes, Nyamiyaga, Kashenyi and Nangara which were found to be representative for the sub county as a whole in terms of population, land use and cover, soils and slopes.

Preparation of a slope steepness map
A slope steepness map for use together with the aerial photographs during the field survey, was made by digitising the contours of the sub county from the topographic maps using the ILWIS software. A digital elevation model was then constructed by interpolating the rasterized contours and then slope steepness was calculated using the standard function slope in the Map Calculation program (International Institute for Aerospace Survey and Earth Sciences (ITC) 1992).

Preparation of Data Sheet and Checklist
A Data Sheet was designed and a checklist to be used as a guideline during discussions with the residents of the area was made.

Field survey

The field survey was conducted in two phases: an orientation and a sampling phase.

Orientation phase
A reconnaissance trip around the sub county was undertaken with the purpose of checking the accuracy of the interpretation of the aerial photographs, of selecting the hill slopes for sampling, and identifying erosion features and remnants of natural vegetation types. The delineated boundaries on the aerial photograph interpretation were checked on the ground.

Four hill slopes in the study area were selected as samples sites. These were an East, West, South and North-facing slope, respectively (Appendix 1). After deciding that aspect would be a first stratification in sample site selection, several hills were randomly picked from the topographic maps and the appropriate aspect chosen. Only those hill slopes, however, which were accessible were finally selected for sampling. A brief description of the characteristic features of the four hill slopes is as follows:

1. Kitumbeezi – Rwenkunguru hill slope; East-facing transect; a short hill. Kitumbeezi ends in a saddle onto which a much longer hill, Rwenkunguru rises.

Each hill was considered separately because the two are very different. The saddle was taken as the valley bottom of Rwenkunguru hill. Kitumbeezi is a steep cultivated hill with poor sandy clay loam soils, a typically degraded marginal slope. Rwenkunguru is a gentler slope with deep red clayey soils, intensively cultivated but exhausted.

2. Kafunjo hill slope, West-facing; a steep hill with deep red clayey soils, not erodible and fairly productive.
3. Kabindi hill slope, North-facing; a long gentle hill slope with both good and poor soils, which are also intensively cultivated.
4. Rwamate hill slope, South-facing; has both good and poor soils, which are intensively cultivated.

Sampling phase

For each of the hill slopes, a transect was followed starting from the drainage line in the valley and going up slope to the hillcrest (Morgan 1986; Bagoora 1990). The hill slope was divided into sampling areas according to slope elements. Each slope form (element) was considered as a sampling area. The sampling area was within 25 m from each side of the transect. Viewing the hill slope from an opposite one aided in identifying the different slope elements. These were the valley, the lower slope, middle slope (concave, uniform or straight), convex upper slope and the hillcrest. A summary of all the records taken in each sampling area is as follows:

1. Measurement of slope angle: This was done using a clinometer every 10 m in each sampling area and the average taken.
2. Soil profile description: This was done according to the FAO guidelines (1977). Soil samples were collected from each horizon, air dried and taken to the laboratory for further analysis.
3. Erosion features inventory: Erosion features were identified and for the rills and gullies their width and depth measured. The percentage of the area affected was estimated in 10 quadrats of 2 x 10 m for sheet and rill erosion. Other features of erosion such as exposed subsoil and bedrock were noted too.
4. Vegetation cover estimation: The aerial vegetation cover of the ground in percentage was estimated in 10 quadrats of 1 sq m distributed randomly within the sampling area. A 1 sq m wooden frame was used since the vegetation in the area is predominantly herbaceous. A visual estimation of the percent vegetation cover was made, assisted by a reference chart (derived from a chart in the Munsell Soil Colour Charts for estimating proportions of mottles and fragments (Anonymous 1962). The appearance or status of the vegetation was also recorded in terms of leaf colour and vigour using a system of classification made from the field observations. Plants that were considered by the residents of the area to be indicator species for the soil’s fertility status were identified. The species that could not be identified were collected, dried in plant presses and taken to the Herbarium of Makerere University Botany Department for identification.
5. Description of land use: The main land use activity in the sampling areas was directly observed and described.
6. Description of representative field plots: One representative field plot (terrace plot) in the sampling area was selected and divided into 2 or 3 sections according

to the appearance of the crop on it whether good, fair or poor. These sections were often the lower, middle and upper terrace, respectively. Augering was done in each section to find out the depth of the topsoil. The differences in appearance of the crops in each section were described and the local people asked how the crop looked like 30 or more years ago.

7. Assessment of conservation activities: Any soil and water conservation measures being undertaken in the sampling area were described and assessed according to their effectiveness.

Discussions with local farmers
Structured open-ended discussions with a checklist were informally held with any owners of fields who happened to be present at the sampling sites. Five key informants were also interviewed. These were a chairman of the National Farmers Association of the district, the Chief Town Planner, an elderly woman and two elderly men who had lived all their life in the study area. Discussions were also held with a local women's group and two groups of seven and ten men each. The major topics of discussion were on the history of the land use of the area, the level of land management and other relevant issues, which could not be observed directly.

Laboratory soil analysis
Physical and chemical characteristics of the soil samples were analysed at the Department of Soil Science, Makerere University. The analytical procedures used were according to Okalebo *et al.*, (1993). The parameters analysed were: texture by the hydrometer method; pH (1:2.5) in a soil-water suspension; organic carbon using a sulphuric acid and aqueous potassium dichromate mixture; exchangeable bases using ammonium acetate; phosphorus using Bray 1 and total nitrogen using Kjeldahl's method.

Aerial photograph interpretation
A systematic interpretation of the aerial photographs was carried out, based on the final mapping units identified during the field survey. The aerial photograph interpretations were then geometrically corrected by a monoplotting procedure available in ILWIS software. Two land cover base maps were then made based on the 1954 and 1990 aerial photographs. These maps were overlaid using ILWIS and the extent and distribution of the different land cover categories were compared in a land cover change analysis.

Annual Reports of the District Agricultural Office
Annual reports of up to three decades ago were compared with current reports to find out any changes in land use and yields of crops.

RESULTS AND DISCISSION

Land cover and land use survey
Apart from several scattered woodlots, a few common grazing areas and settled areas, the whole land area in Bubale sub county is cultivated. There has been swamp reclamation and an increase in land use intensity for more than thirty years.

Aerial photograph interpretation

Six classes of land cover were obtained from the interpretation of the 1954 photographs and eight from the 1990 photographs for the three parishes of Kashenyi, Nangara and Nyamiyaga. The seventh and eight classes of land cover from the 1990 photographs result from the reclamation of part of the swamp shown on the 1954 photographs. During the interpretation of the old aerial photos the topographic map was used as additional information. Table 1 below shows the different final land cover classes and their areas for the two periods. Figs. 2 and 3 are maps of land cover for the two periods, namely 1954 and 1990. Although the two groups of photographs were of different scales it was imperative to apply the same classification to them for a change analysis to be possible. But even then, the classes obtained were the only ones that could be distinguished.

Table 1. Land cover classes for 1954 and 1990 from aerial photograph interpretation.

Land cover Class	Field observations according to 1990 photographs	1954		1990	
		Area (ha)	% of Total area	Area (ha)	% of Total area
Cultivated area	Fields with hardly any trees or homesteads, on crests and gentle slopes	2280	63.2	1557	43.3
Grassland	Permanent grazing areas and fields under fallow for several years due to soil exhaustion, on uniform and upper slopes	301	8.3	115	3.2
Bush land	Heavily felled woodlots abandoned to bush, on whole slopes with poor soils	20	0.6	40	1.1
Settled area	Scattered homesteads surrounded by fields and tiny woodlots, on valley and middle slopes	583	16.2	1285	35.7
Swamp-unreclaimed	Papyrus swamp in broad valleys	337	9.3	88	2.5
Woodlot	Scattered small clumps of trees of *Eucalyptus* and Black wattle on steep slopes	88	2.4	297	8.3
Managed pasture	Extensive dairy farms	0	0.0	69	1.9
Swamp cultivation	Cultivated fields in reclaimed swamp	0	0.0	147	4.1

From Table 1, it can be observed that the greatest decrease among the classes of land cover between 1954 and 1990 was for the grasslands, which was a decrease of 61.79%. According to the people, over the years most of the grasslands have been turned to cultivated land and the rest to woodlots. These are the lands, which were originally left uncultivated because they were not considered productive. The other significant decrease was that of cultivated area, which decreased by 31.7% between 1954 and 1990. This reduction of the area under cultivation is against expectation but since by 1954 all the land in the study area had been put to cultivation already, the decrease in cultivated area

Fig. 2. Land cover of Kashenyi, Nangara and Nyamiyaga in 1954

Fig. 3. Land cover of Kashenyi, Nangara and Nyamiyaga in 1990

Fig. 4. Land cover change for Kashenyi, Nangara and Nyamiyaga 1954-1990.

was because the settled areas and woodlots increased at its expense. Considering the decrease in cultivated area, however, the settled area, which simultaneously increased, also includes cultivated area and, therefore, it is not certain that the cultivated area actually significantly decreased. An investigation into the change in acreage per landholding would give a better indication of any decrease in cultivated area. Between 1954 and 1990 the settled area increased by 120.4% and the woodlots by 237.5%. The cultivated land was turned to settlements, woodlots or grassland. When cultivated area is turned into grassland in a densely settled area such as Kabale, it is an indicator of degradation, mainly in the form of soil exhaustion. The land which was planted with woodlots could no longer generate returns with the same value as the original trees could. The total area of cultivated and settled land for 1954 is more than that for 1990 by 21 ha which is resulting from a change of cultivated area to grasslands or woodlots implying that its productivity had declined. While the cultivated land on the hill slopes was decreasing, swamp reclamation was making available 147 ha of cultivable land. The area under bush land increased by 100% because more land had by 1990 been abandoned to bush as it was no longer good enough for cultivation.

Fig. 4 is the land cover map resulting from the overlay of the 1954 and 1990 land cover maps. Almost half of the total area of the three parishes showed no changes, mainly in the cultivated areas, followed by settled areas. The major changes in land cover were as follows:

- from cultivated to settled areas, due to the increasing population;
- from cultivated areas to woodlots, due to a decline in the soil's productivity;
- from grassland to cultivation, the grasslands originally considered not suitable enough for crop production were now cultivated due to a need for more arable land;

– swamp reclamation for cultivation but because of high acidity later turned to dairy farms.

The aerial photographs gave a useful overview of the land cover and use of the study area. However, for an area such as Bubale sub county which is predominantly under indigenous subsistence farming, the degraded plots could not be distinguished on the aerial photographs because they are scattered within the area among other fields which may not be degraded.

Current land use practices

As aforesaid, the inhabitants settled mainly on the lower valley slopes and cultivated mainly the incised valleys and lower slopes. Grazing took place on the hillcrests before 1920. Thereafter, the population started increasing rapidly mainly due to better control of diseases and an influx of immigrants from neighbouring Rwanda. Soil erosion control measures were devised, introduced and enforced by the colonial government. Due to shortage of cultivable land, the Government started resettling people in the neighbouring districts of Rukungiri, Bushenyi and Kabarole. By the 1960s, government had instituted swamp reclamation for cultivation. This was short-lived as soil conservation was abandoned due to lack of will on part of the new administrators to continue overseeing the practice of the soil conservation measures. This led to continuous cultivation on the hill slopes and swamp reclamation in the valleys.

Cultivation in the swamps and V-shaped valleys: All the accessible wetlands have been drained for agricultural use. The wetlands as well as the V-shaped valleys are highly productive and are continuously replenished by depositions from upslope. The valleys, however, are occasionally centres of gully erosion and deposition, which is quite destructive to the gardens.

Cultivation on the hills: Because of shortage of land, crops are planted continuously in rotation with fallow for one season only when the land is completely exhausted. Only those with plenty of land can afford to fallow land periodically.

Settlements: These are generally concentrated on the lower slopes of the steep hills and upslope on the gently sloping hills. Recently people are shifting from the more productive lower slopes to settle on the up slopes so as to utilise the lower slopes for agriculture.

Woodlots: Black wattle trees were planted originally along the contour stripes on the uncultivated hillsides. This practice appeared more suitable for soil conservation than block planting on the steep slopes. The inhabitants were encouraged to plant trees by free distribution of seed and plants. The wattle was a source of revenue. Today, the woodlots are usually planted on the uniform slopes, which have lost fertility because of topsoil loss and consist mainly of *Eucalyptus*, which matures earlier than other trees although its wood is of inferior quality. *Eucalyptus* flourishes on degraded soils and is a source of revenue in form of wood fuel and timber. However, when mature, unlike other tree types, there is no undergrowth so that runoff through the woodlots damages fields down slope from them. It also removes a lot of moisture from the soil so that there is not enough left for any crop growing in its vicinity.

Grazing: It is traditional and on a small scale due to shortage of grazing lands as a result of conversion to cultivation. These grazing lands, however, are heavily grazed leaving the grass 1-3 cm in height and with scanty stunted herbs.

Decline in crop yields

According to the residents of the area, crop yields have declined by a half to two thirds of what they were during the 1970s. Estimates of yields in tonnes per hectare recorded in the district's Annual Reports obtained from the Department of Agriculture in Kabale District, however, do not reflect a similar decline in yields. They actually show increasing yields. This is contrary to peoples' information. This could either be due to misinformation from the farmers or improper collection of data for the latter years. The latter seems most likely because unlike the situation several decades ago when the chiefs moved through the villages to estimate acreages and yields painstakingly, in recent times, data collection is the responsibility of poorly remunerated extension workers who, make rough and inadequate estimates.

According to the Annual Reports, poor agricultural production has previously mainly been caused by heavy rainfall, in some periods causing floods (Annual Report, 1962), and fungal diseases (Annual Report 1978). The main problem, according to the most recent Annual Report, (1994), is perceived to be a degeneration of soil fertility, which is likely to affect agricultural productivity in the coming years. In many different ways, the residents of the area gave indications of the decline in crop yields. Table 2 gives a few of the expressions of the extent of the decline.

Table 2. Selected expressions of decline in crop yields.

Place	Condition in the 1970s	Condition in the 1990s	Rate of decline
Kabindi hill slope	a) 1 mound (1.5x0.75m) would yield 1 basket of sweet potatoes	Same mound yields 1/3 of same basket	1/3
	b) I plot would yield 5 sacks of sorghum	Same plot yields only 1 sack	1/5
Bubale hill slopes	a) 1 mounds' yield of sweet potatoes	2 such mounds required to produce the same yield	1/2
	b) 1 plot would yield on average 150kg of sorghum	Same plot yields 50 kg	1/3
	c) Size of sorghum heads	1/2 to 1/3 of same size of heads	1/2 - 1/3
Rwamate hill slope	1 plot 15 x 20m would yield 3 baskets of peas	Same plot yields only one basket	1/3

The present situation is that luxuriant and high yielding crop plants are found in the valleys and lower slopes as expected. On the hill slopes, these crop plants are found only on the first 2 to 6 m upslope of the terrace just next to the bund.

The primary cause of decline in yields, according to the people, is soil exhaustion as a result of continuous cultivation without fallow. The secondary cause is loss of nutrients through soil erosion. The respondents admitted that the soils of the area are inherently fertile and a fallow of 3 to 5 years would be sufficient to restore the fertility to what it was 30 to 40 years ago. However, with the prevailing agricultural practices after such a fallow period, the yields are usually higher for the first few seasons only. Fallowing for long periods is also not usually done because the uncultivated plots would be overgrazed leading to soil erosion, compaction and terrace bund collapsing. One parish, Bwindi, in the sub county was found to have highly productive soils compared to the other parishes. According to the people, this parish is not overpopulated, there is still plenty of land for the residents and therefore fields are put under fallow more frequently.

Slopes and soil survey

Slope map and classification

The map of slope steepness made is shown as Fig. 5. The preliminary classification of the slopes was according to the FAO (1993) classification, which is geared towards agricultural use. Fig. 6 shows the percentage areas covered by the different slope classes as obtained from the map of slope steepness. From this figure it can be seen that half of the area in Bubale sub county is on slopes 22% and above. This indicates that the soils of the area are highly fragile and susceptible to degradation when opened up in the absence of proper conservation measures.

Fig. 5. Slope steepness in Bubale sub county

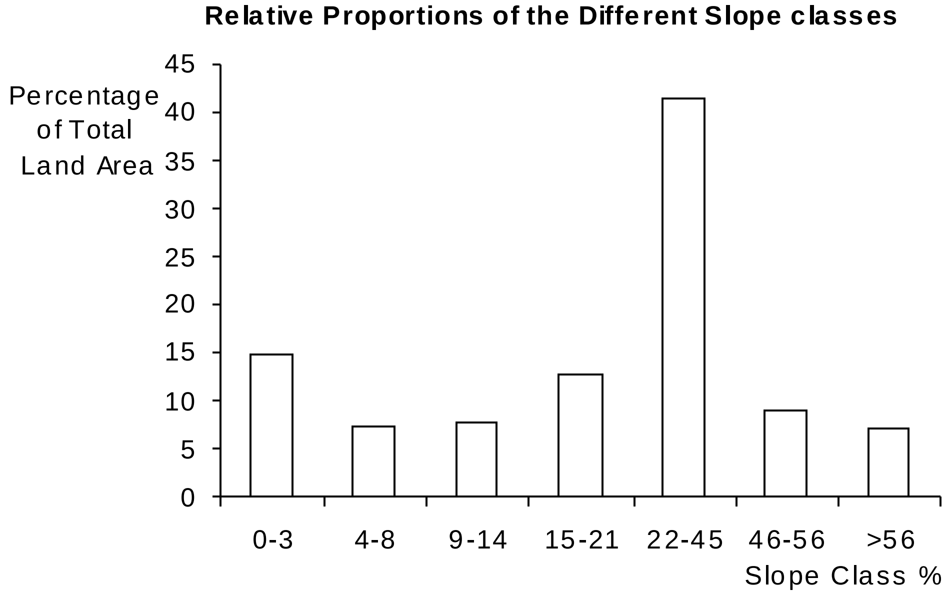

Fig. 6. Relative Proportions of the different slope classes

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Soil profile investigation and soil analysis

Weathering state: Most of the profiles had soils mixed with murram gravels for the 4 hill slopes except the pediment slopes where they were mixed with chalk-like soft sedimentary rocks. The soils are still in the process of weathering. According to Booker, (1991), the presence of weatherable minerals within 200 cm deep is a condition favouring high soil fertility. There are also several murram rock outcrops on the upper slopes of Kabindi and Rwenkunguru hill slopes.

Texture: Table 3 below shows a summary of the general textural characteristics of the hill slopes surveyed. According to Evans (cited in Morgan 1986), soils with a restricted clay fraction are most susceptible to erosion. According to Morgan (1986), the least resistant particles are silts and fine sands so that soils with a high silt content are erodible. Based on the above, it can be concluded that the soils on Kitumbeezi hill slope would be erodible due to the high silt content with the erodibility increasing down slope, considering the decrease in clay content down slope. However, the decrease in clay content down slope could be due to selective erosion of the sand particles from up to down slope, leaving the clay particles behind. Kitumbeezi hill slope exhibited the most severe form of rilling and sheetwash especially on the uniform and lower valley slopes.

Table 3. General Textural Characteristics of the Hillslopes Surveyed

Hill slope	Dominant Textural Class	Textural Changes along the Hill slope
Kitumbeezi	Sandy clay loams	High silt content. Clay content decreases significantly down slope, from 30% to 10%
Rwenkunguru	Sandy clay to clay	High clay content, up to 43%. Almost no difference in the composition of the fractions along the slope
Kafunjo	Loamy clay	Clay content increases significantly down slope, from 10% to 42%
Kabindi	Sandy loams	Clay content increases slightly down slope, on average 25%, sand fraction 50%.
Rwamate	Sandy loams	

The sandy clay loam on these slopes is erodible and the slope steepness facilitates their erosion.

The soils of Kafunjo, on the other hand, are expected to have a decrease in erodibility downslope, which would be expected from the corresponding increase in clay content. On the ground, these soils did not show any signs of severe erosion, and, according to the people, these soils have a very high infiltration capacity, which reduces the severity of erosion. These soils are red in colour, indicating a significant quantity of iron oxide minerals, which improves their stability. The loamy clay texture of these soils makes them resistant to erosion even on the steep uniform slopes and they are still yielding fairly well. Rwenkunguru hill slope, however, also with deep red clayey soils, with the clay increasing down the profile to depths greater than 150 cm exhibited severe sheetwash. The sheetwash was represented by gravels protruding up to 3 cm in height above the soil surface. These soils, as observed from their vegetation cover are exhausted and this probably explains their lack of resistance to erosion. The soils of Kabindi and Rwamate hill slopes were found to contain less clay and more sand. These soils showed signs of sheetwash erosion coupled with exhaustion.

pH: The soils of the studied slopes vary in their pH values, ranging from moderately to strongly acid. The soils in the reclaimed swamps were acidic (up to pH 4.2) but this did not affect their productivity. On the hill slopes the soils with low pH values happened to be the exhausted soils of the study area. The low pH probably restricts the availability of nutrients such as phosphorus to the plants. On the other hand, the relatively high yielding soils of the lower (pediment) slopes had higher pH values between 5.2 and 5.8 but this could be due to the fact that these are sites of deposition. The grazing lands were also found to have high pH values as well as the other fertile areas such as Bwindi parish mentioned earlier as the area still highly productive. However pH is only one of other factors, which influence the productivity of the soils.

Organic matter content of the topsoil: Organic matter content was found to be highest in the valleys for all the hill slopes exepct Rwamate. The high contents of organic matter explain the high productivity of the valleys. Rwamate valley would probably have exhibited a similar phenomenon hadn't it been for the fact that a gully from upslope had just washed the topsoils away. It was also found out that generally the uniform slopes had relatively low organic matter contents as well as those areas, which had been under continuous cultivation without fallow. Both these areas are sites of sheetwash erosion, which is enhanced by, soil nutrient exhaustion and the erosion further compounds the loss of the nutrients. The steep uniform slope of Kafunjo hill slope with the fairly stable clay loam soils also showed a relatively high organic matter content. The grazed lands as well as the plots being fertilised by plant and animal manure also showed high contents of organic matter, this was expected.

Nitrogen content: Despite the generally low organic matter content in the cultivated soils of Bubale sub county the percent nitrogen content obtained from the soil laboratory analysis was generally moderate to high according to standards by Okalebo and Gathua, (1993). The fact that the yields are generally low may be due to other factors such as low pH and low organic matter content. However, just like with organic matter content, nitrogen contents were relatively higher in the valleys and in the grazing lands and low on the steep slopes and the cultivated areas, which showed signs of exhaustion and erosion.

Phosphorus and Exchangeable bases: The amounts of phosphorus and exchangeable bases were generally highest in the valleys. Phosphorus levels were low on the pediments and uniform slopes but high on the convex upper slopes and crests. The high amounts on these upper areas were because of grazing and different management practices such as manuring. The levels of the exchangeable bases were found to be generally higher in the valleys and on the lower slopes than on the upper slopes and crests.

Generally, it was observed that there are major differences between the soil characteristics of the productive and of the poorly yielding (degraded) sites. Notable characteristics were pH, available phosphorus, organic matter, nitrogen and total bases, whose levels were generally higher for the productive soils than for the degraded soils. The grazed lands as well as those under fallow exhibited similar soil characteristics as those for the soils on the productive sites.

Soil Erosion

The different forms of erosion occurring in Bubale sub county are rill, sheetwash, gully erosion and landslides.

Rill erosion (Plate 1): Rills are small channels or rivulets in the fields in which the water concentrates after eroding the soil. Rill erosion is important not only because of the material eroded from the rill itself, but also because 80 to 85% of the interill (area between the rills) sediments are transported to rills before leaving a plot or field (Kooiman 1987). Rill is one of the main ways through which soil is lost in Bubale sub county. It occurs during the rainy season, at a time when the plots are recently ploughed, sowed and vegetation cover is at its lowest (Bagoora 1990). However, a few weeks later, during weeding, the rills are obliterated as the soil is levelled out and all evidence of this form of soil erosion is lost. Fig. 6 shows the severity of rilling on the surveyed hill slopes as observed during the field study. The severity of rilling is represented by codes for a classification made after the field survey using the field observations and is shown in Table 4 below:

Table 4. Coding for severity of Rill Erosion

Code	Class name	Observations in a (2x10) m quadrat	% of area affected
1	Not apparent	no evidence of rill	
2	Slight rill	micro rills average width 6 cm, average depth 2 cm	< 20
3	Moderate	micro rills width up to 20 cm, depth up to 10 cm	20 – 60
4	Severe	micro rills width up to 60 cm, depth up to 20 cm	60 – 80
5	Very severe	macro rills width > 60 cm, depth > 20 cm	> 80

The occurrence for rill was observed to be greater on the pediment and uniform slopes than on the convex upper slopes (Fig. 6). This is expected because, according to Morgan, (1986), rills are initiated at a critical distance downslope where overland flow becomes channelled.

Rwenkunguru and Kafunjo hill slopes were generally moderately rilled (Code 3) while Kitumbeezi and Rwamate hill slopes were very severely rilled (Code 5). The former hill slopes have, as previously mentioned mainly clayey soils, which could probably not be as prone to rill as the sandy clay loams of the latter two hill slopes. The most severely rilled slope was Kitumbeezi, East-facing, whose pediments, uniform and convex upper were classified as 5, 5 and 3, respectively. The macro rills in some of the field plots could not be easily obliterated by cultivation. Kabindi hill slope, South-facing, exhibited no rill at all. This could not be explained.

The last two classes of slope angles, namely 46-56% and >56% contained only the hill slopes shown in the figure, namely Kitumbeezi, Kafunjo and Rwamate for the former class and Kafunjo and Rwamate for the latter. For Kitumbeezi and Rwamate hill slopes rill was observed on the steepest slopes as would be expected. The runoff through the rills deposits its sediment on the lower ends of the field plots and where terrace bunds have collapsed, the runoff continues downslope and even gains momentum. In many cases the terrace bunds have been cultivated up to their edges and the runoff and sediment seeps through to the fields below. In cases of severe rill such terrace bunds as well as the collapsed areas become centres of water collection, which forms gullies. The use of small mounds for planting sweet potato vines instead of long continuous ridges across the field encourages a lot of rill as the volume of runoff increases between the mounds.

Sheet erosion (sheetwash) (Plate 2): This is the washing of surface soil by overland flow from arable land without concentration in rills/gullies. Because of the shallow water depths and obstacles in form of vegetation and stones, the surface of a hillside after a rainstorm displays sheet erosion as a pattern of alternating scours and sediment fans (Morgan 1986). Sheetwash is another important way by which soil is lost in Bubale county. In the study area, the alternating scours and sediment fans were observed and the percentage area affected was estimated and recorded. Table 5 below describes the codes used to indicate severity classes. The classification was made after the fieldwork using the field observations.

Table 5. Coding for severity of Sheet Erosion

Code	Class name	Observations in a (2x10)m quadrat	% of area affected
1	Not apparent	No evidence of sheetwash	
2	Slight	alternating scours and sediment fans in a few places and < 1 cm deep	< 20
3	Moderate	alternating scours and sediment fans affect a significant area, < 2 cm deep	20 – 60
4	Severe	alternating scours and sediment fans up to 3 cm deep	> 60
5	Very severe	Plant materials lying down facing downslope; bathed stones	100

Gully erosion (Plates 3 & 4): According to Hudson (1981) a gully is a steep-sided eroding watercourse, which is subject to intermittent flash floods. A gully is relatively permanent and experiences ephemeral flows during rainstorms (Morgan 1986) and is not ploughable. Gullies were found to be a common feature and several of them were quite extensive in the study area. They are caused mainly by rainwater accumulating in the subsurface of soils of the cultivated upper slopes, which are devoid of tree and shrub vegetation. The starting point is usually a collapsed terrace bund. The water accumulates beyond the water holding capacity of the subsoil and is then released suddenly and gushes downslope destroying gardens in its path. Many gullies are brought about by road culverts and rainwater accumulating on the roads escapes through the culverts in quantities forceful enough to form gullies. Such gullies are more extensive than those originating from cultivated upper slopes, two of these measured (depth x width) 4.6 m x 11.9 m (largest part) and 3.3 m x 0.7 m (smallest part) for one from Kagarama road at Kitagernda and 3.0 m x 2.0 m (on average) for the other gully on the same road but at Muhambo, Kagarama parish. Two of those originating from the cultivated upper slopes were on Kitumbeezi hill slope (Bubale parish), measuring 1.7 m x 2.3 m (largest part) and 0.7 m x 0.4 m (smallest part), and the other on Kafunjo hill slope measuring 0.8 m x 0.3 m. Apart from roads, cattle tracks may also be centres for water collection that forms gullies. Most of the gullies are found in the sloping incised depressions between hill spurs (upslope valleys) and almost every upslope valley has a gully. The gullies are more in number and extent in Nangara and Bwindi parishes than in other parishes because these two parishes have very steep slopes up to 75% and the upper slopes and crests from which the gullies originate are cultivated. Because of the destruction caused by the floodwater during rainstorms the people have now constructed permanent trenches in the upslope valleys for soil and water conservation.

In many gullies, rainwater flows only during extreme rainstorm events and during such storms the gullies are enlarged or even new ones created. Such storm events are said by the people to occur once in every 4-5 years. 1995 was one such year in which several extensive and highly destructive gullies were created. One such gully completely washed away a field plot leaving only the subsoil while another carried away a cow, 2 goats and 3 field plots, with sorghum ready for harvest (measuring a total of 539 sq m). Apart from destroying vegetation and gardens along their paths, gullies deposit colluvium, rocks, boulders and sediment downstream and the areas of heavy deposition are destroyed as well, especially gardens. In the valleys the sediment – loaded gully waters spread around and deposit an even layer of the lighter silt. Such valleys are, therefore rather enriched. But even though the impact of gullies is high where they occur, the area affected is small and it is not yet a major problem. Proper drainage channels constructed for runoff on the roads would reduce the formation of the more extensive gullies.

Landslides: A landslide is a form of mass movement whereby a soil mass slides downslope suddenly. Very few landslides have occurred so far in Bubale sub county; only 2 were identified, one in Nangara parish, on an area planted with *Eucalyptus*, and a more recent one on Mushunga hill slope in Bwindi parish, measuring approximately 3 m wide by 30 m downslope. These landslides were not very extensive, covering an area of only about 600 sq m. These two parishes, Nangara and Bwindi, are characterized by very steep slopes, steeper than most of the rest of the sub county. In other parts of the district such as Rukiga county land sliding is more common because the slopes are generally very steep (Bagoora *pers. comm*.).

Depositions (Plate 4): All the valleys, pediments and concave lower slopes are sites where deposition takes place. In the reclaimed valleys, the residents of the area claimed that the brown layer of topsoil is all deposition from upslope, while the black peaty sub soils were the original topsoils of the wetlands. The sediments in the valleys varied from 15 to 32 cm in depth.

Terrace observations (Plate 5): Apart from the crests and broad valleys, the cultivated area in the study area is in form of terraces which have evolved as a result of soil accumulating on the upper part of the terrace bund. The soil has accumulated because it is moved downslope during land preparation. Traditionally cultivation by hoe is done with the person facing uphill and this has caused the soil slumping. The soils accumulate just behind the grass bund leaving skeletal topsoils and exposed sub soils on the upper part of the terrace or field plot (Farley 1996). As a result, the morphology of the typical terrace is characterised by 3 distinct sections, the lower part just next to the bund (lower terrace); the middle part (mid terrace) and the upper part (upper terrace) next to the bund of the adjacent terrace upslope. These three distinct sections have different soil depths and the crop growing on each section is different in vigour and percent ground cover from that of the others.

Lower terrace: Has deep soils resulting from soil slumping. Luxuriant crops but not as in the valleys. It is on average between 1.5 and 3.5 m in length upslope compared to that of the whole terrace, which is between 8.0 and 16.0 m. No difference in these dimensions between slopes of different angles was observed.

Mid terrace: Characterised by shallow soils not highly productive. The vegetation not as good as that at the lower terrace but contributes significantly to the yield. Most of the rilling and sheetwash occurs in this portion of the terrace. It is on average between 5.0 and 10.5 m in length upslope.

Upper terrace: The uppermost 1.5 – 2.0 m of the terrace characterised by poor, yellowish, sparse and stunted crop one-third to half of the height of that on the lower and mid terraces, respectively. The topsoil is scanty or non-existent, cultivators mix decaying plant debris with the sub soils in order to support a crop on it.

Collapsing terrace bunds (Plate 6): The terrace bunds collapse repeatedly during the rainy season. Almost every terrace bund showed evidence of repeated collapsing. The terrace bunds collapse because they are not strengthened by strongly rooted vegetation that would prevent them collapsing under the weight of the accumulating subsurface waters. Before independence, elephant grass, *Pennisetum purpureum* was planted on the bunds, but later the farmers complained that mole rats and birds inhabited the grass and ate the sweet potato and bean crop, respectively. In the study area the only bunds that did not show evidence of collapsing were those that had remnants of elephant grass and other woody shrubs such as *Erythrina abyssinica* growing on them. These, however, were few and covered only about 8 – 10% of all the bunds on a typical hill slope. The bunds today are colonised mainly by *Digitaria scalarum* and other herbs such as *Bidens granti*. With each collapsed bund a lot of good topsoil is shifted to the garden below and during severe rainstorms the soil is washed a long distance downslope since there is nothing to hold it back. The poor yields from the upper and mid terrace coupled with accumulation of the topsoils on the bund at the lower terrace induce cultivation on the bunds as well. This is to utilize the good soils and as a result the bunds are being greatly reduced in width even up to 0.5 m from the crops to the edge. Others are being destroyed completely especially if the two adjacent plots have the same owner. The yields on destroyed bund spots are reasonably high for several seasons until erosion reduces the soils. However, there are a few individuals with plenty of land. Their terraces as well as those belonging to institutions such as the church and schools are well maintained and as a result are better yielding than those owned by the not-so-well-off people.

Conclusion

The major factors militating against the achievement of sustainability in the soils of Bubale sub county, Kabale district include the following:

1. Continuous cultivation without fallow brought about by land shortage due to population growth. This has resulted into the soils becoming exhausted in terms of nutrients
2. Soil erosion resulting from cultivation of steep slopes without proper measures to prevent soil erosion
3. Deliberate destruction of terrace bunds so as to utilise the good soils on them
4. Lack of will/incentive on part of the people cultivating the land to invest in soil conservation measures such as terrace bund construction
5. Lack of will on part of the government to encourage/enforce soil conservation practices

Improved sustainability of the arable soils of Bubale sub county can be achieved through improving the protection of the soil from erosion by vegetation. Vegetation protects the soil by holding the soil particles together with the roots, thus increasing the particles' resistance to detachment (Omwega 1989), and by increasing surface organic matter, thereby reducing the erodibility of the soil (Stocking *et al*. 1988). Groundcover, the cumulative percentage cover of litter or mulch, stoniness, basal cover and exposed roots, reduces erosion by removing the direct impact of raindrops on the soil surface, reducing and slowing down runoff and thus its eroding capacity, and by trapping detached particles (Kooiman 1987). In areas such as Bubale sub county, where indigenous arable farming is the dominant activity, the role of vegetation in protecting the soil against degradation is especially apparent during periods of intensive rainfall because the fields are freshly ploughed and vegetation is non-existent. This is when serious erosion always occurs (Bagoora 1990). Due to land fragmentation and consequently land shortage the vegetation to be incorporated into the cultivated plots should be able to not only help prevent soil erosion but improve soil fertility as well as provide other benefits by being multipurpose. This can only be achieved through agroforestry under which sustainability of the soils is maintained under continuous low-input agriculture (Badejo 2002). Presently, in the sub county as well as in the whole district, an NGO, AFRENA under ICRAF (International Centre for Research in Agroforestry) with the mission for soil conservation through agroforestry has introduced multipurpose trees and shrubs such as *Calliandra* to be planted on the bunds as well as among the crop plants. Where the system has been adopted results have been very encouraging in terms of improved yields. These shrubs and trees not only contribute to holding the soil particles together, they are also used to improve soil fertility through the addition of their plant residues to the soil and also through their root nodules in case of the leguminous types. They act as fodder and as sources of fuelwood. Their adoption is quite successful, as a significant number of farmers have taken to planting these multipurpose shrubs and trees. However, the majority of the population still need to be encouraged to plant these multipurpose trees and shrubs and this also calls for the intervention of the policy makers.

Other ways by which improved sustainability of the arable soils of Bubale sub county can be achieved include enforcement by government agencies, of soil conservation programmes such as adoption of agroforestry strategies and construction of soil erosion control structures so as to provide a much needed boost to the already existing efforts of the NGOs which mainly use education and demonstration to achieve their aims. So also, provision of alternative income generating activities to reduce dependence on arable farming for sustenance of families can go a long way in ensuring sustainability.

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