LUCID's Land Use Change Analysis as an Approach
for Investigating Biodiversity Loss and Land Degradation Project

Patterns and Root Causes of Land Cover/Use Change in Uganda: An Account of the Past 100 Years

LUCID Working Paper Series Number: 14

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The Land Use Change, Impacts and Dynamics Project
Working Paper Number: 14

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

A. ABSTRACT

The study was aimed at identifying root causes of land cover/use changes in Uganda over the past 100 years. Using a combination of both qualitative and spatially explicit data, it has been possible to demonstrate that land cover/use changes are triggered by specific events and then accelerated by a tandem of many biophysical-socio-economic factors in Uganda. The current land use patterns in Uganda may be attributed to many forces including droughts, presence or absence of disease, civil strife, cultural impacts and government policies that operated before 1950's. The study concludes that knowledge of the root causes of land cover/use changes in a given ecosystem provides valuable insights into other key environmental and socio-economic processes such as biodiversity loss, land degradation, societal conflicts and food insecurity. Understanding the linkages between land cover/use change and key biophysical-socio-economic processes is also beneficial to the formulation of policies for sustainable use of Uganda's natural resources base.

B. INTRODUCTION

B.1. Uganda: An Introduction

About 500 BC, Bantu-speaking peoples settled in much of present day Uganda. By the 14th Century, three kingdoms were well established: Buganda, Bunyoro and Ankole. Uganda was first explored by Europeans as well as Arab traders in 1844 (Nyeko and Compiler, 1996). An Anglo-German agreement of 1890 declared it to be in the British sphere of influence and the Imperial British East Africa Company was chartered to develop the area. The Company did not prosper financially and in 1894, Uganda was proclaimed a British protectorate. Few Europeans permanently settled in Uganda, but it attracted Christian missionaries, Indians, Pakistanis and Goans who became important players in Uganda's socio-economic development (Nyeko and Compiler, 1996).

Uganda is believed to be endowed with a rich natural resources base including reliable rainfall regimes, fertile soils and water resources. The largest proportion of the country (43%) is covered by natural or secondly woodland, bushland and grassland. Small-scale (subsistence) farming accounts for 34.7%, while 2.5% is under the cover of tropical high forests. The rest of the country, about 20%, is covered by water bodies and wetlands (NEMA, 1996). According to the National Environmental Management Authority (1996), the backbone of Uganda's economy rests on its natural resources. Over 90% of Uganda's population is rural and depends directly on natural resources for their livelihoods. The country's current level of socio-economic development and its prospects for sustainable development are dependent on its natural resource endowment. About 40% of Uganda's economy depends on subsistence production. An estimated 54% of the country's Gross Domestic Product (GDP) comes from agriculture (Grant and Weitz, 1991)

Uganda's population has been increasing since records began. For example, national population censuses have revealed that there were 2,500,000 Ugandans in 1911; 2,850,000 in 1921; 3,5400,000 in 1931; 4,958,000 in 1948; 6,500,000 in 1959; 9,500,000 in 1969; 12,600,000 in 1980; 16,600,000 in 1991 and 24,600,000 in 2002 (The New Vision, Vol. 17, No. 239, 2002). It is estimated that Ugandans will be 32,500,000 by the year 2015 (Population Secretariat, 1992). Given such ever increasing human population in a country that has a low technological base, it is logical to conclude that pressure on finite natural resources has been increasing with increasing populations over the last 100 years. In this paper, findings of land cover/use change analysis and their likely causes are discussed. Elsewhere (see Uganda LUCID Working Papers 3, 4, and 5), the linkages between land cover/use changes and biodiversity loss; and land degradation in Uganda are discussed.

B.2. Land Cover/Use Change: An Overview

As Lambin and Geist (2002) point out, the scientific community needs quantitative, spatially explicit data on the human impact on land cover/use in order to understand the changes that will occur over the next 50-100 years. A core of such spatially explicit data is land cover/use information. As NASA (2002) points out, spatially explicit data generated from remotely sensed data provides the only effective way of measuring global, regional and local land cover/use change. Hence, this study used remotely sensed data to measure land cover/use changes over the past 4.5 decades in Uganda (1955 to 2000). The period was selected for quantitative land cover/use change analysis because it coincides with the availability of remotely sensed data in Uganda.

Modeling land cover/use changes has been done elsewhere in Sub-Saharan Africa. For example, Zhang *et al.* (2001) used a simulation model to predict that there will be a loss of more than 90% of tropical forest cover in central Africa to subsistence farming by 2050 unless alternative farming methods are adopted. Serneels *et al.* (2001) have also studied land cover changes around Mara (Kenya) Ecosystem. Serneels and co-authors' techniques used were particularly important for this study because it makes important conclusions about the nature of land cover/use changes detectable from satellite imagery of different spatial resolutions. For example, the authors state that coarse-resolution imagery (NOAA/AVHRR) are suitable for seasonal vegetation indices due to annual weather variations, while TM imagery is suitable for detecting land cover changes due to land use extensification in the east African region.

A prerequisite for modeling future land cover/use is a better understanding of the past driving forces that lead to land cover/use changes in a given socio-ecosystem However, Lambin and Geist (2002) point out that land cover/use changes are not simple processes, but are often initiated by a cascade of changes along the system after a trigger by a shock event. Thus this study sought to identify factors that may have triggered land cover/use changes in Uganda over the past 100 years. To understand the root causes of land cover/use change in Uganda over the past 100 years meant that not only quantitative but also qualitative land cover/use data were used. Qualitative land cover/use data were obtained from historical archives published by the British explorers and scientists who traversed Uganda between 1880's and 1940's. Analysis of pre-1955 qualitative data was essential in light of the fact that some variables, such as population growth, poverty, and infrastructure, do not fully explain the driving forces of land cover/use changes over a few decades, according to Lambin and Geist (2002). As mentioned earlier, quantitative, spatially and explicit land cover/use information was only available for the period starting from 1955.

In the next sections the aims, background, techniques, findings and discussion of the findings are presented. In Section B.3, the aims of the study are outlined. A review of relevant literature follows in Section B.4. The study areas are described in Section B.5. Methods used during the study are presented in Section C. The findings and discussion are presented in Section D. Finally, conclusions and recommendations are presented in Section E.

B.3. Aims of the Study

The overall aims of the study was to estimate quantitative land cover/use changes in four selected sites of Uganda using data acquired by remote sensing; and identify the triggers/root causes of land cover/use changes in Uganda over the past 100 years.

B.4. Background Information

B.4.a. Definitions of Terms

A review of existing publications (see for example, Anderson, *et al.,* 1976; FAO, 2000; Lambin and Geist, 2002) leaves no ambiguity that *land cover* refers to conspicuous natural, semi-natural or man-made features while *land-use* is a function of land cover. According to Rushton (1992), ecological change in land cover/use can be classified as either *type* (i.e.

complete conversion from one type to another) or *intensity* (subtle changes in the ecology or species composition). Change in land cover/use 'type' is also referred to as *extensification* and 'intensity' as *intensification* (Lambin and Geist, 2002). In this paper, extensification and intensification were adopted but carry the same meanings as defined by Rushton (1993).

B.4.b. Land Cover/Use Change: Driving Forces

Human activities may be regarded as the single most important causes of land cover/use change over many centuries in many countries, if dramatic changes in climate and biogeochemistry are excluded from the period spanning recorded human history. In Uganda, pollen analysis in the southwestern part of the country has shown that tropical forest cover was more widespread 6,800 years ago (Hamilton *et al.,* 1986) than a handful of forest relics that remain as protected areas today. While Lambin and Geist (2002) agree that there may be links between human activities and environmental change over longer time scales, the authors point out that there is inconclusive evidence to link demographic and socio-economic variables (population growth, poverty, infrastructure) to land cover/use change over a few decades. Instead, Lambin and Geist argue that rather than demographic variables inducing land cover/use change, it is individual and societies' responses to economic opportunities and constraints (local or global) that may be the driving forces behind land cover/use change, with extreme biophysical events triggering further change. Lambin and Geist's hypothesis was tested against observed land cover/use changes that have occurred in Uganda over the past 100 years.

B.4.c. Quantitative Estimates of Land Cover/Use Change

As pointed out by Lambin and Geist (2001) and NASA (2002), quantitative techniques are the most appropriate ways of modelling past and future land cover/use changes. A practical technique of carrying out quantitative land cover/use change analysis, undoubtedly, is the use of remotely sensed data. Hence, remotely sensed data was used during this study to carry out land cover/use changes that have occurred in Uganda since 1955. Pal *et al.* (2001) state that the aim of analysing remotely sensed data is often the extraction of relevant *homogeneous* features in a process called *mapping*. Homogeneous features are defined based on relevant local, national, regional or global *classification systems*.

Given affordable satellite imagery and relevant classification systems, care must be taken in order to generate *consistent* and *accurate* spatial land cover/use information for use in land cover/use change models. There are two major limitations of characteristic of remotely sensed data: a) spectral overlap between some land cover/classes and b) limited resolution of affordable satellite imagery. Spectral overlap, according to Price (1994), is caused by leaves of healthy plants interacting with electromagnetic energy in a similar manner. The net effect of spectral overlap is low overall classification accuracies of spatial information generated from remotely sensed data. Secondly, and as has been observed by Serneels *et al.* (2001), coarse-resolution imagery does not allow the detection of land cover/use changes of extensification type. Shugart (2002) also recognize the fact that *sub-grid surface heterogeneity* may not represent the same kind of varied surface, savannah and farmed landscapes in case of land cover/use mapping in Uganda.

The limitations imposed by medium- to coarse-resolution imagery render standard spatial image software unsuitable for generating consistent and accurate land cover/use information for accurate change analysis. A mapping scale of 1:100,000 was chosen for generating land cover/use information for Ugandan study areas during this study. The chosen scale, according to Anderson et al. (1976) and Murtha *et al.* (1997), should be appropriate for use when generating land cover/use information from TM/ETM+. Yet, recent research conducted in Uganda (Mugisha and Huising, 2002) indicates that wood/grass mixtures of different densities (characteristic of savannah landscapes) are often confused with small-scale farming during image interpretation/classification even Landsat TM/ETM+. In conclusion, there are indications that even with TM/ETM+ imagery; standard automated image classification may not allow the generation of consistent and affordable land cover/use information from TM/ETM imagery for Uganda's landscapes. Yet, the demand for consistent, accurate and affordable spatial land cover/use information for modelling key environmental processes (for example, UNEP-LUCID[1] and EU-PAES[2]) is high.

Hence a suitable framework to allow us generate consistent, accurate and affordable land cover information for mapping Uganda's landscapes using TM/ETM+ imagery is required. Such a land cover/use mapping framework was developed during this study and is the subject of Uganda LUCID Working Paper Number 1.

In addition to a practical mapping technique required for the generation of periodic, consistent and affordable spatial land cover/use information, a *standardized classification system* is needed. This is particularly so given the fact that land cover/use change analysis may be taken for extensive regions, regional or global. National classification systems that may have been developed for individual countries in the region may not be appropriate when applied across many countries. Peterborough (1993) points out the need for a standardized classification system: first, as a prerequisite for understanding and structuring human knowledge of the natural world and secondly, as a technique for communicating the generated information. Gross *et al.* (1998) point out a third but important benefit of a standardized classification system: a prerequisite for *integrating* spatial information (during land cover modelling) generated by different projects/programs at different temporal and spatial scales.

While the need for standardized classification systems has been recognized over many decades, a few countries are just in the process, or have just designed, standardized classification systems. For example, while there is a standard land cover/use classification system for the USA (Anderson, *et al.,* 1976); Grossman *et al.* (1998) consent that there was no acceptable standardized plant community classification system in the USA until recently. Outside the USA, the European states are currently developing a common habitat classification system (EUNIS, 2002) after realizing that a number of national classifications systems developed over time are of limited use for the whole of Europe. The Canadians are too developing their own ecological community classification system (Ponomarenko and Alvo (2001). On the other hand, FAO Africover Project (FAO, 2000) has developed a Land Cover Classification System (LCCS) primarily for the African content. LCCS offers an opportunity (especially for countries that lack resources to develop their own national classification systems) to generate consistent land cover/use spatial information. Unfortunately, no decision was reached by the concerned scientists on the use of a common land cover/use classification system for the UNEP-LUCID East African Project. A decision not to use FAO-LCCS for the UNEP-LUCID Project was taken because the strengths and weaknesses of LCCS have not been independently evaluated for its wider applicability.

In summary, generating spatially explicit land cover/use information requires grouping geographic phenomena using four conventional *abstraction*[3] techniques (Nyerges, 1991). Because visual image rather than standard interpretation/classification software has the ability to use all the abstraction techniques (*classification*, *generalization*, *aggregation*, and *association*), a semi-automated framework for generating periodic, consistent and affordable spatial land cover/use information for Uganda's landscapes was developed for this study as described later.

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[1] 'Root causes of Land Use Change and its Linkages to Biodiversity Loss and Land Degradation in East Africa'
[2] 'Integrating Environmental Concerns in Managing Societal Conflict in East Africa'
[3] conventional abstraction techniques (classification, generalization, aggregation, and association) are commonly used by human photo-interpreters.

B.4.d. Qualitative Estimates of Land Cover/Use Change

Lambin and Geist (2002) are of the view that linking household-level information to remote sensing data increases our understanding of land use dynamics. This assertion is supported by the fact that decisions on how to use land resources are often made at household-level in agrarian communities. While household-level information may be quantitative, it may not have been collected in a spatially explicit manner in the past. In addition, most historical records regarding the status of land cover/use in Uganda are qualitative in nature. Nevertheless, qualitative data may also increase our understanding of land cover/use dynamics — such as the root causes that drive the changes. Hence, there must be a deliberate effort to use both spatial and non-spatial data during land cover/use change modelling. As pointed out by Zurayk *et al.* (2001), participatory studies that generate qualitative data offer the possibility of complementing quantitative land use studies by tapping into the *indigenous* and *local knowledge*. However, integration of spatial quantitative and qualitative spatial data using current spatial software is not a trivial matter. According to Skelsey (1997), standard spatial software falls short of integrating quantitative and qualitative data for land cover/use change analysis and modelling. Skelsey further states that an ideal spatial software designed for integrating quantitative and qualitative data during analysis should be based on evidence *pooling* rather than *fusion*. Evidence pooling is ideal for integrating and analysing quantitative and qualitative data because it allows 'human-like heuristic reasoning' during data analysis. A prototype of an automated system for monitoring land cover/use has been developed by Skelsey (1997) and was evaluated for the East African region by the author as discussed in Uganda-LUCID Working Paper Number 1.

B.5. Study Areas

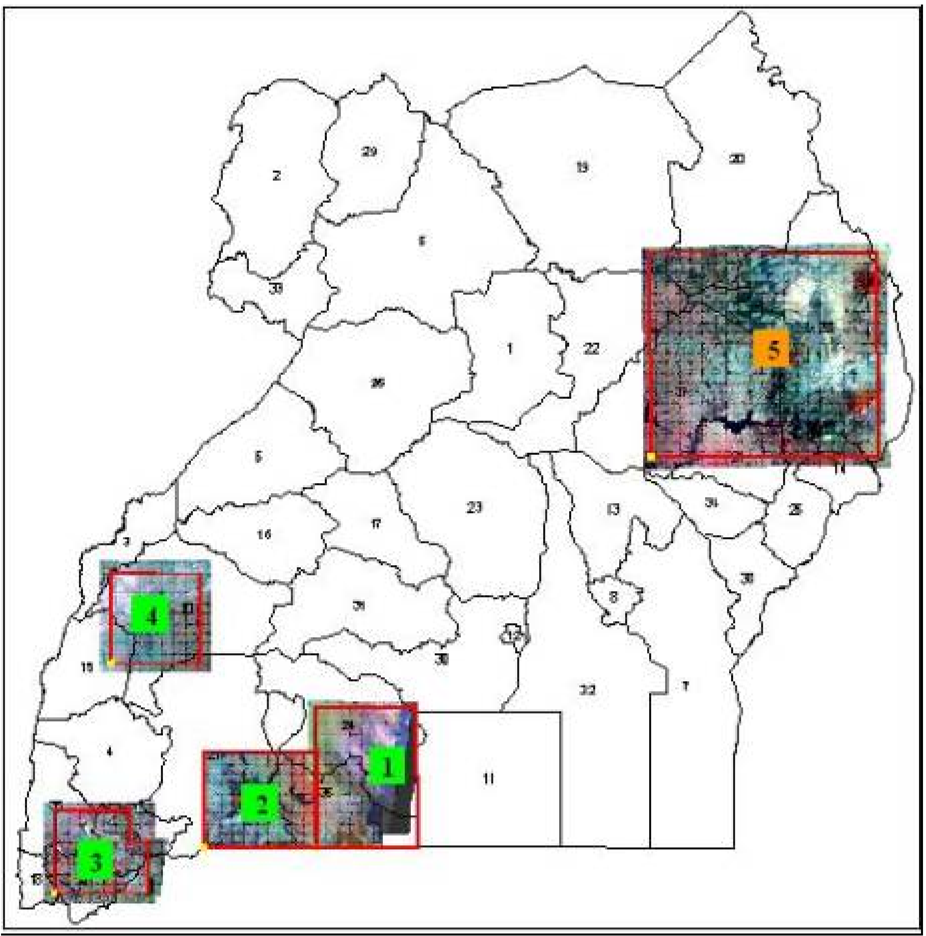
Study areas were selected based on the existence of substantial data generated overtime by past projects. Data-rich study areas were selected because the overall intention of the UNEP-LUCID Project was to analyse existing data as much as possible. Figure 1 shows the location of the five study areas: (1) Sango Bay, (2) areas adjacent to Lake Mburo National Park, (3) Kabale/Ntungamo border, (4) areas adjacent to Kibale National Park and, (5) Katakwi/Karamoja border where land cover/use change analysis has been undertaken by LUCID/UNEP-GEF and other projects. In each of the four sites, key environmental and socio-economic variables including land cover/use, soil degradation, habitat loss and fragmentation, food insecurity and environmental-induced conflicts have been studied by different projects and organizations in the past. Land cover/use change analysis results for Katakwi/Karamoja border site are excluded in this paper.

Sango Bay area borders the eastern part of Lake Victoria. The area Sango Bay is an important biodiversity area because of its rich and diverse forests and wetlands. Subsistence farming is the main economic activity and it employs over 80% of the population. Livestock rearing is the second most important economic activity in the area. Most of the cattle are owned by seasonal and permanent immigrant pastoralists from Mbarara and Ntungamo Districts. The pastoralists have been attracted to Sango Bay area due to the large expanses of grassland and availability of water during the dry seasons.

Lake Mburo National Park (LMNP) and adjacent areas are located in Mbarara District, southwestern Uganda. The area is well known for its high numbers of livestock, mainly cattle. However, mixed agriculture has been encouraged by the government and cultivation of crops is now common.

Kabale/Ntungamo border is located in southwestern Uganda. The landscape is interrupted by one major swamp system of Lake Nyabihoko. Forests constitute a minor cover while subsistence farming and grass/scrub cover significant areas. Except for the plains in the region around Rubale, the area is generally steep and mountainous.

Figure 1. Map of Uganda Showing the Five Study Areas.



Kibale National Park (KNP) and adjacent areas are located in Kabarole District, western Uganda. The area is covered by medium altitude evergreen forest, medium altitude moist semi-deciduous forests, savannas and swamps. NEMA (1996) points out that about 95% of the population in Kabarole District derive its livelihood from agricultural activities. Movement of people from other areas into the district has been evident over many decades and this is largely due to immigration from Kabale and Kisoro Districts (Nabuguzi and Edmunds, 1993).
In the next section, the methods employed to carry out land cover/use analysis for each of the four study sites are described.

C. METHODS

Quantitative information on the status of land cover/use for each site was generated from remotely sensed data acquired in 1955, 1985 and 2000 for Sango Bay and LMNP/adjacent areas. For the rest of the sites, the status of land cover/use information was generated from remotely sensed data acquired in 1955, 1973 and 2000. The dates were selected because they are associated with availability of remotely sensed data used i.e. panchromatic aerial photographs (1955), Landsat MSS (1973), Landsat TM5 (1985) and Landsat ETM+ (1999/2000).

A number of automated techniques are available for land cover/use change analysis using digital satellite imagery. Depending on the parameter monitored, different techniques have been developed to for land cover/use change analysis. For example, seasonal and annual changes of vegetation cover are often analysed using vegetation indices (see for example, Serneels *et al.* 2001; Lambin and Ehrlich, 1997; Eastman and Fulk, and 1993). However, detection of land cover change from one type to another requires a technique described by Miller *et al.* (1998). The technique described by Miller's technique is commonly known as 'post-classification comparison'. This is because it requires comparing land cover maps derived from remotely sensed data acquired at different dates.

As mentioned earlier, most techniques used for land cover/use change analysis have one common drawback: their dependence on analysis of spectral signals alone and hence yielding outputs that may not represent the actual land cover surfaces due to spectral overlap. A more serious limitation of comparing at least two data sets generated using automated classification techniques is the lack of consistency of the data sets. Consequently, a technique developed by Mugisha and Huising (2002) for generating consistent and affordable spatial land cover information for Uganda's landscapes was adopted during this study. The salient features of the technique are described below.

C.1. Generation Of Quantitative Land Cover/Use Information for the Base Years

Spatial land cover/use information for each study site was generated from imagery depicted in Table 1. Due to persistent cloud cover, there was a gap in the Landsat MSS imagery (1973) for Sango Bay and areas adjacent to Lake Mburo National Park. Hence 1984 Landsat TM imagery was substituted for 1973 Landsat MSS imagery for both Sango Bay and areas adjacent to Lake Mburo National Park.

Study area	**Year**			
	1955	***1973***	***1985***	***1999/2000***
Sango Bay	Panchromatic photographs	-	Landsat TM	Landsat ETM+
LMNP	Panchromatic photographs	-	Landsat TM	Landsat ETM+
Kabale/Ntungamo border	Panchromatic photographs	MSS	-	Landsat ETM+
KNP	Panchromatic photographs	MSS	-	Landsat ETM+
Karamoja/Katakwi border	Panchromatic photographs	MSS	-	Landsat ETM+

Table 1. Imagery used in generating spatial land cover/use data for each study site.

C.1.a. Materials used:

- Global Positing System (Germin 12 XL)
- Scanned topographic maps (1:50,000) derived from 1955 panchromatic aerial photographs (Ugandan Government map series Y732)
- Imagery shown in Table 1
- Existing spatial data sets of the study area (soils and land cover/use/vegetation)
- TNTmips version 6.5
- ArcView GIS (ver. 3.1)
- Personal computer

C.1.b. Image Processing

All imagery was processed using standard image classification procedures (Mather, 1987). This included *georeferencing* whereby existing digital topographic features (mainly road junctions and sharp features of rivers) were the source of ground control points (geographic coordinates). The georeferenced imagery was *rectified* using *Piecewise Affine* transformation algorithm and *Cubic Convolution* as the method of resampling. *MicroImages* TNTmips version 6.5 was used for all the image processing. All the imagery and existing spatial data were co-registered to UTM map Projection (UTM 36).

C.1.c. Generation of 1955 Land Cover/Use Map

Topographic maps, 1:50,000, derived from 1955 aerial photographs of each study area were scanned and geo-registered to UTM map. Polygons of different land cover/use categories were extracted from the scanned (and geo-registered) topographic maps by screen digitising. Figure 2 depicts polygon boundaries (purple lines) of sample land cover types overlaid on a scanned topographic map of part of Sango Bay. Sample land cover codes depict tropical forest (101), seasonal swamp/thicket (106), grass/thicket (105) and papyrus (202).

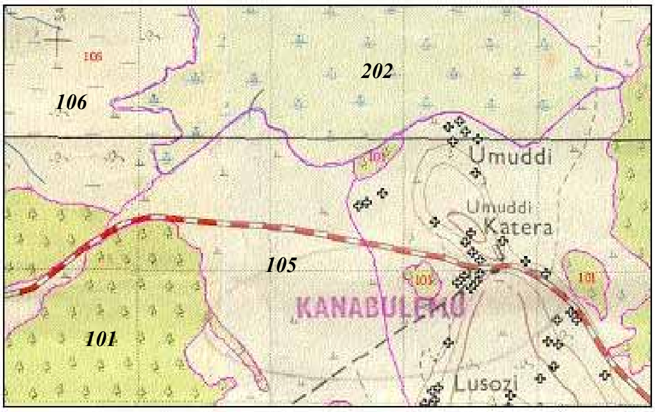


Figure 2. Scanned topographic maps were a source of 1955 land cover/use data sets. The cross-hairs indicate the digitised homesteads.

Apart from cultivated areas (small-scale farming), all the major land cover categories were directly digitised from the scanned topographic maps. Table 2 depicts the different land cover categories derived from scanned topographic maps (by screen-digitising) for all the study areas.

Land use/cover category	Meta database code
1. Tropical rain forests	101
2. Woodland	103
3. Thickets	104
4. Scrub/grass	105
5. Scrub/seasonal swamp	106
6. Scrub/woodland	107
7. Woodland/seasonal swamp	108
8. Seasonal swamp	201
9. Papyrus	202
10. Tall grass	301
11. Short grass/bare ground	402
12. Cultivation (small scale)	901
13. Cultivation (large scale —mostly tea)	902
14. Water	1201

Table 2. 1955 Land Cover/Use Categories Derived from Topographic Maps for the Study Sites

Polygons representing small-scale farming were indirectly derived from the distribution of homesteads also screen-digitised for each study area. This was possible because, in case of Uganda, it is valid to assume that homesteads, cropped areas, fallow land, and small relics of natural vegetated areas when aggregated constitute *small-scale farming*.

The files representing screen digitised and fitted polygons were merged in a GIS to create a single file. The resultant file was manually edited to correct improper boundaries generated by the fitting algorithm. Lastly, a land cover/use code was used to label each polygon.

C.1.d. Generating Land Cover/Use Spatial Information for 1975/1985 and 2000

The fundamental requirement of the mapping technique described in Uganda-LUCID Working Paper Number 1 is the establishment of a **Co**nspicuous **La**nd **Co**ver **D**ata**base** (COLACO-Dbase) (Mugisha, 2002) for 1955 from maps derived from panchromatic aerial photographs. The generated COLACO-Dbase was then used as an input for updating land cover/use information of each study area for 1975/1985 and 2000 using affordable satellite imagery. The mapping framework based on COLACO-Dbase assumes that Landsat TM/ETM (30m) has sufficient information to allow an image analyst to update land cover/use polygons by updating existing polygons in Uganda's landscapes. According to Mugisha (2002), this assumption holds even for land cover polygons defined based on different wood/grass mixtures of different densities (Figure 3) However, the assumption does not hold when using Landsat MSS data, probably due to a lower resolution (57.5m x 80m). While Landsat MSS allows identification of dense wood, grass and water covers, it did not allow differentiation between savannah and small-scale farmed patches. Therefore, it was not possible to detect the areas converted from savannah to small-scale farmed areas using MSS data. Consequently, Landsat MSS was excluded from land cover/use change analysis.

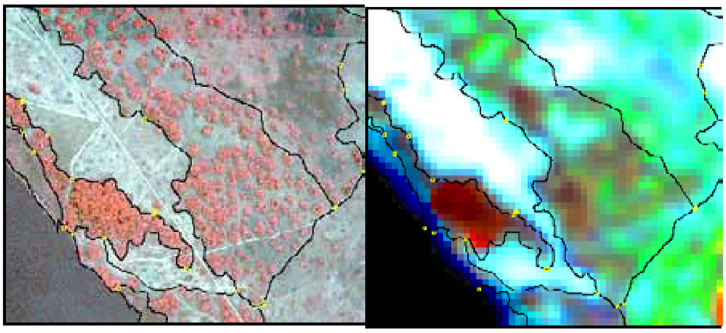


Figure 3. The technique assumes that if the 'spatial history' of individual map units is known, Landsat TM/ETM provides sufficient spectral information to allow the updating of individual polygons

Figure 4(a) illustrates how polygons (yellow lines) of the base map (1955) overlaid on 2000 ETM+ imagery. The arrangement makes it possible to update individual polygons through visual image interpretation and screen-digitising. The boundaries between classes are visible on the ETM+ imagery, but the lower resolution does not permit identification of the classes, which were determined using secondary sources and field ground truthing. The steps used to update the 1955 to 1985 and then 1985 to 2000 land cover/use spatial information were as follows:

a) The 1955 vector map was laid over the 1985 Landsat TM data using MicroImages TNTmips.
b) TM image characteristics bound by a given polygon of the COLACO-Dbase map (1955) were inspected to verify whether the land cover within the polygon had changed or not. This was possible because spectral characteristics of most land cover/use categories depicted in Table 2 are distinguishable on TM/ETM imagery.
c) If a complete change (CC) were affirmed, a given polygon would be deleted (see arrow depicting location of CC in Figure 4).
d) If partial change (PC) was evident, the boundaries of the polygon were modified accordingly (see PC in Figure 4). Secondly, the attributes (land cover/use classes) of the affected polygons were updated.
e) If there was no change (NC), the polygon was maintained (see NC in Figure 4) with all its attributes (boundaries and class characteristics).
f) The steps outlined in (a) – (e) were repeated for all the polygons, study areas and for both years (1985 and 2000).

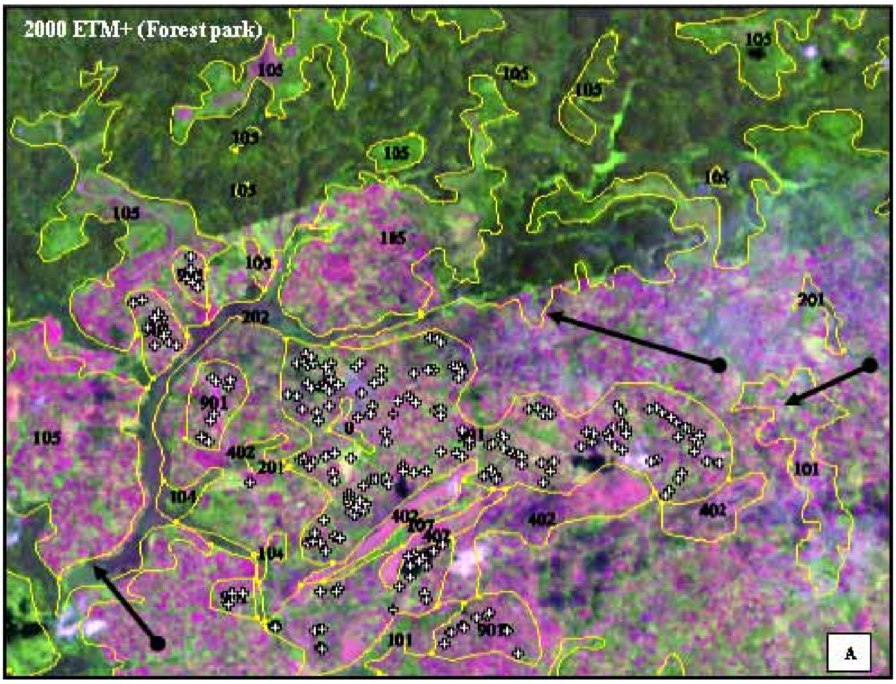


Figure 4(a). 1955 land cover-use boundaries (yellow lines) overlaid on ETM+ (2000). Distribution of individual homesteads (1955) are indicated by cross hairs.

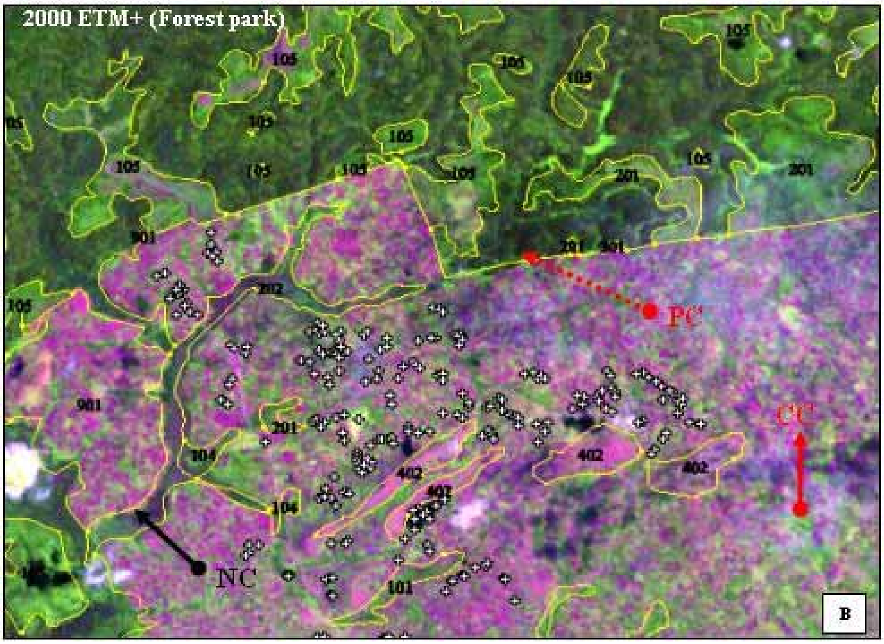


Figure 4(b). Updated (2000) land cover/use boundaries (yellow lines) overlaid on ETM+ (2000). By 2000, cultivation had consumed most of the non-protected natural vegetation.

The procedure described above has a number of limitations though. First, it is slow because screen-digitising is semi-automatic. Secondly, errors associated with COLACO-Dbase are propagated to the updated maps if insufficient ground truth is carried out. However, the advantages of the procedure outweigh its limitations. For example, the procedure allows better interpretation and classification of imagery based on well-established abstraction techniques (classification*, generalization, aggregation and association*) employed during visual image interpretation. Given the limitations of automated image classification, Comber *et al.*(2002) concedes that visual image interpretation has many advantages such as 'pooling varied evidence' about image objects. Lastly, the procedure described above allows the generation of consistent land cover information from imagery acquired by different sensors at different dates.

C.1.e. Land Cover/Use Change Analysis

Change analysis was carried out as follows:

a) All polygons belonging to the same land cover/use category were selected using ArcView's query function. In a situation where aggregation of some land cover categories was needed (such as different wood-grass mixtures belonging to savannah category), a composite query was created.
b) The total area (in km^2) for the selected polygons was determined.
c) Steps (a) and (b) were repeated for polygons belonging to other different land cover/use categories, for each year (1955, 1985 and 2000) and for all the five study areas.

Land cover/use changes between 1955 to 1985 and then 1955 to 2000 were calculated. The results of land cover/use change analysis are presented in Section D.1.

C.2. Qualitative Land Cover/Use Change

C.2.a. *Use of Local Knowledge*

Qualitative information about land cover/use change was obtained from each of the study areas using a method proposed by Dregne (1989). While the method was initially developed for assessing soil erosion, it was adapted in this case for assessing land cover/use change in each study area. The data was collected as follows:

a) A survey of randomly selected locally knowledgeable persons in a given locality was conducted by asking them questions regarding the relative land cover/use change in their locality in the period pre-dating 1970, 1970-1990 and 1990-2001. The interviewees' assessments were qualitative and provided estimates of either significant, moderate- or insignificant land cover/use change.
b) Probing techniques were used to ascertain whether any change (or lack of it) in land cover/use could be attributed to any factor other than agricultural expansion. This permitted inferences to be drawn pertaining to the relative changes of the land cover/use as either significant, moderate, or insignificant.
c) Lastly, a multi-disciplinary research team conducted focus group discussions with about 30 local people in each study area to assess any environmental change perceived by the local people.

C.2.b. *Land cover/use status: a historical perspective (1880's to 1940's)*

As described in Section D.1, quantitative land cover/use information could not be generated for all study areas prior 1955. To get information on the status of land cover/use in periods predating 1955, it was necessary to review historical archives. Useful accounts of land cover/use status (1880's – 1940's) were obtained from archives kept by many government departments in Uganda. Most accounts of the status of land cover/use prior 1955 were available in the form of diaries written by British explorers and colonial administrators. The data collected was qualitative in nature but gives a true picture of the status of land cover/use along the routes traversed at the beginning of the 20th century. In a few cases, the status of land cover/use was captured on black and white photographs.

D. RESULTS

D.1. Quantitative Spatial Results

Results of land cover/use change in Uganda (1955 to 2000) for four out of the five study areas are presented in Tables 3-6. Results of the fifth study area, Karamoja/Katakwi border are not presented in this paper. Results (maps) for each study area are presented in appendix 1.

D.1.a. Sango Bay

Results of land cover/use change analysis for Sango Bay are presented in Table 3. The results show an insignificant change in land cover/use in the area for the period under investigation (1955-2000). Between 1955 and 1985 only 33 km^2 (1.3%) of the total terrain was converted to subsistence farming in Sango Bay area. Secondly, between 1955 and 2000, 48 km^2 (2.0%) of the total terrain had been converted to subsistence farming. Only 15km^2 (0.6%) of the total terrain was converted to subsistence farming between 1985 and 2000.

Land Cover/use category	**Land cover extent (km^2)**			**Change (km^2)**		**Change (%)**	
	1955	***1985***	***2000***	***1955-1985***	***1955-2000***	***1955-1985***	***1955-2000***
Tropical rain forests	268.3	264.6	263.0	-3.7	-5.3	-1.4	-2.0
Savannah	673.1	646.8	636.8	-26.3	-36.3	-4.0	-5.4
Wetlands	321.3	317.8	316.2	-3.5	-5.1	-1.1	-1.6
Short grass/bare	67.7	67.7	66.1	0.0	-1.6	0.0	-2.4
Subsistence farming	1110.6	1143.6	1158.7	33	48.1	3.0	4.3
Large scale farming	0.4	0.4	0.4	0.0	0.0	0.0	0.0
Water	9.3	9.3	9.3	0.0	0.0	0.0	0.0
Total cover	2450.7	2450.2	2450.5				

Table 3. Sango Bay: Land cover/use changes between 1955 and 1985, and 1955 and 2000.

Hence, it may be concluded that there was insignificant land use extensification in Sango Bay between 1955 and 2000. However, based on socio-economic surveys, it appears that there is significant land use intensification, especially grazing. However, it was not possible to capture land use intensification from TM/ETM+ imagery and hence it was not quantified. However, the socio-economic surveys conducted by LUCID researchers support the proposition of increased land use intensification especially as regards extensive grazing of the grasslands by immigrant pastoralists. Secondly, during socio-economic surveys, 60% of respondents in Sango Bay reported scarcity of arable land, an indication of reduced fallow land and hence land use intensification. In conclusion, insignificant land use extensification but significant intensification occurred in Sango Bay areas over the period of investigation.

D.1.b. Lake Mburo National Park And Adjacent Areas

Results of land cover/use change analysis for Lake Mburo National Park and adjacent areas (LMNP) are depicted in Table. Unlike the Sango Bay area, the LMNP area results show a significant land cover change from natural vegetation to small-scale farming. Between 1955 and 1985, 40.7% of the total LMNP terrain (approximately 580km^2) was converted to subsistence farming. Between 1955 and 2000, the area converted to subsistence farming increased to 50% (about 715km^2) of the total terrain area. In the same period, savannah ecosystems decreased by about 700km^2 and wetlands by 12km^2. In other words agricultural expansion is reflected in the loss of two major land cover types namely savannah and wetlands in the LMNP area.

The magnitude of land use change around LMNP is high in spite the fact that the area has frequent prolonged droughts. LMNP/adjacent areas are located in the so-called cattle corridor that is characterized by prolonged droughts. The significant land use extensification in areas surrounding LMNP is in contrast to Sango Bay over the same period of time despite the fact that the latter has a better rainfall regime than the former. The contrast between land cover/use change around LMNP and in Sango Bay area may be due to the interaction of many factors such as the nature of soils, land tenure, accessibility to markets and nature/magnitude of migration. Indeed, socio-economic survey results reveal that there has been significant human migration (mostly crop farmers) from other parts of southwestern Uganda to areas adjacent to LMNP over the last 12 years (MUIENR, 2002). The significant land use extensification around LMNP may be attributed to new immigrants who open up natural vegetated land for new farms.

Land use/cover category	Land cover extent (km^2)			Change (km^2)	Change (km^2)	Change (%)	Change (%)
	1955	*1985*	*2000*	*1955-85*	*1985-2000*	*1955-1985*	*1985-2000*
Tropical rain forests	16.3	16.3	15.6	0.0	-0.7	0.0	-4.3
Savanna	2256.8	1675.1	1554.7	-581.7	-702.1	-25.8	-31.1
Wetlands	454.0	452.8	441.9	-1.2	-12.1	-0.3	-2.6
Subsistence farming	1429.1	2010.8	2144.0	581.7	714.9	40.7	50.0
Water	149.0	149.0	149.0	0.0	0.0	0.0	0.0
TOTAL	4305.2	4304	4304.3				

Table 4. LMNP and adjacent areas: Land cover/use changes between 1955 and 1985 ,and 1955 and 2000.

D.1.c. Kabale/Ntungamo Border

Land cover/use changes along the Kabale/Ntungamo District border (Table 5) for the period under consideration (1955 – 2000), like Sango Bay, shows insignificant expansion of subsistence farming. Due to the limited spatial resolution of Landsat MSS, it was not possible to differentiate between savannah from small-scale farmed land. Hence, the 1975 Landsat MSS acquired for Kabale/Ntungamo, Karamoja/Katakwi borders and areas adjacent to Kibale National Park that could not be used. Therefore, land cover/use change analysis was carried between 1955 and 2000 for the three study areas mentioned above. Along Kabale/Ntungamo border (see Appendix 3), subsistence farming increased by a mere 3.0% (about 44km^2). However, unlike Sango Bay (but like areas adjacent to Lake Mburo National Park), the Kabale/Ntungamo border is characterized by an unfavourable rainfall regime and is largely a pastoral area.

Land use/cover category	Land cover extent ((km^2		Change (km^2)	Change (%)
	1955	*2000*	*1955-2000*	*1955-2000*
Tropical rain forests	3.4	2.0	-1.4	-41.2
Savanna	10.2	10.2	0.0	0.0
Seasonal swamp	43.8	30.7	-13.1	-29.9
Papyrus	36.5	31.5	-5.0	-13.7
Grass	336.3	311.5	-24.8	-7.4
Subsistence farming	1436.2	1480.5	44.3	3.1
Water	3.5	3.5	0.0	0.0
Total	**1869.9**	**1869.9**		

Table 5. Kabale/Ntungamo border: Land cover/use changes between 1955 and 2000.

D.1.d. Areas adjacent to Kibale National Park

Like the areas adjacent to LMNP, overall land cover/use change around Kibale National Park (KNP) was significant between 1955 and 2000 (Table 6). The Kibale area is characterized by good rainfall regimes and the soils, derived from volcanic ash, are fertile (Harrop, 1960). Of all the five studied areas, areas adjacent to KNP show the largest expansion of subsistence farming, i.e. about 137% between 1955 and 2000. Even though the largest chunk of the protected rain forest (national park) is still intact, a significant proportion of relic forest patches have been converted to subsistence farming since 1955. Again, a significant increase in the size of cultivated land is reciprocated by the loss of natural vegetated areas, mostly savannah, forest relics and wetlands.

Land cover/use category	Land cover extent		Change (km^2)	Change (%)
	1955	***2000***	***55-2000***	***1955-2000***
Tropical rain forests	600.4	542.1	-58.3	-19.7
Savanna	1489.7	295.1	-1194.6	-80.2
Wetlands	206.3	166.5	-39.8	-19.3
Short grass	62.1	56.8	-5.3	-8.5
Subsistence farming	953.3	2255.4	1302.1	136.6
Large-scale farming (tea)	1888.0	1766.3	-121.7	-6.4
Water	5.6	5.6	0.0	0.0
Total cover	5205.4	5205.4		

Table 6. Kibale National Park and adjacent areas: Land cover/use changes between 1955 and 2000.

While the percentage of recent immigrants to areas adjacent to Kibale National Park is not high (Table 7), it is a historical fact that migration of Bakiga from former Kigezi District to the areas in question adjacent was significant between 1955 and 1968 (Nabuguzi and Edmunds, 1993). The significant expansion of subsistence farming, once again, is associated with immigration to areas adjacent to Kibale National as was for Lake Mburo National Park. In summary, while most communities in all study sites depend on agricultural activities, (Lake Mburo National Park = 92.4%; Sango Bay = 76.7%; Kabale/Ntungamo border = 81.4%; areas around Kibale National Park = 79.2%) as depicted in Table 7, the rate of land cover/use change (extensification) was only significant for the Lake Mburo and Kibale areas. However, in Sango Bay and Kabale/Ntungamo borders, the average rate of agricultural expansion was insignificant.

D.2. Historical accounts of land cover/use status

Useful information on the status of land cover/use (1880's to 1940's) was obtained from archives kept by various government departments. Most of the historical accounts of the status of land cover/use were recorded by the British explorers and administrators. A summary of land cover/use status between 1880's to 1940's was compiled from MacDonald (1887), Bell (1889), Thomas and Scot (1935), Tothhill (1940) and Purseglove (1950). Relevant excerpts of historical land cover/use status for three of the five study areas are summarised below.

D.2.a. Sango Bay and Koki (1987 – 1950)

- Extensive marches (wetlands)
- Extensive low-lying forests
- Luxuriant swampy grass supported a lot of game
- Large expanses of elephant grass
- Rampant tsetse flies were killing a score of people every day in the Lake Victoria shore region. Tsetse Islands in Lake Victoria were depopulated by tsetse flies of its 20,000 inhabitants between 1902 to 1909. In 1930's resettlement was permitted again in Tsetse Islands, present day Kalangala District.
- Koki was full of hills and most of the terrain traversed was wild, uncultivated land, with hills beautifully clothed with small timber and shrubs, valleys had abundant grass suitable for cattle
- There was good grazing grass on the Koki hills
- Around the Koki lake and in valleys were large areas of excellent cultivation (Figure 5)

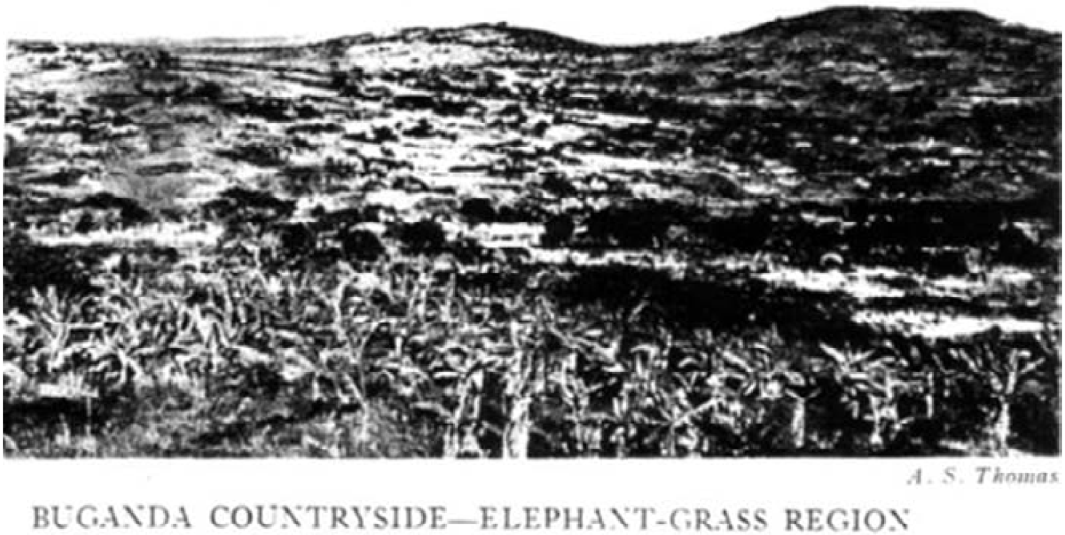


Figure 5. Elephant grass (background) and banana plantations (foreground) in former Budu District (currently Masaka and Rakai Districts) of which Sango Bay and Koki are part *[Source: Agriculture in Uganda, 1940].*

- The Koki people were partially pastoral, formerly they were entirely so
- The introduction of agricultural pursuits in Koki was thought to have been due to intermarriages with members of agricultural tribes
- At the time of the exploration in Koki, some of the better class women and princesses had begun to imitate the Baganda women in tillage, especially cultivation of bananas.
- Koki hills were full of ironstones that were smelted and turned into small bars for export to the rest of Uganda
- Koki was troubled with mosquitoes even biting during the day.

D.2.b. The Lake Mburo area (1987 – 1950)

- The country was characterized by low rainfall (30-45 in.)
- Both hills and valleys were covered with short succulent grass (suitable for cattle grazing), studded with acacia, scrubby trees were dotted around, there were a few swamps and rivers**,** presence of jungle in the area was conspicuous (Figure 6).
- The country was entirely for pastoral purposes, though at intervals of 20 miles, there were small settlements with cultivation. It appears that the whole of Ankole was devoted to raising cattle and the herds were immense. The few small settlements (at 20 mile interval) were entirely occupied by Mohammedan Baganda who settled in these places when they were forced to flee their own country (Buganda) during the unsuccessful uprising they had instigated.
- Formally, this area was more agricultural in character, the original Bantu tribe cultivating sorghum, beans and sweet potatoes in the less arid areas.
- Land between Ankole and Budu District borders was plenty, but very scantly inhabited.
- Surface water supply was deficient and acted as a limiting factor to increasing the population of men and cattle.
- Prevalence of sleeping sickness was killing scores of people every day.
- Significant numbers of people were removed from the fatal tsetse-fly belt (about 1000 sq. miles) and resettled in healthy areas.

Figure 6. Short grass, acacia, scrub in former Ankole District of which Lake Mburo and surrounding areas are part. [***Source: Agriculture in Uganda, 1940].***

D.2.c. Kabale/Ntungamo border (1987 – 1950)

- The plains of Rubale (part of Ntungamo District) were extensively covered by short succulent cattle grass.
- The broken mountains, rivers, lakes, Bwindi impenetrable rain forests were salient features of Kigezi District (present day Kabale, Kisoro and Rukungiri Districts).
- The average acreage was just under 0.5 of an acre per resident.
- While government departments were aware that much of Kabale was overpopulated, the matter came to a head in the 1943 and 1944 droughts (Figure 7).
- The prerequisites for resettlement schemes of the Bakiga were that there should be enough land that had few or no inhabitants, reasonable soil fertility, an adequate water supply, sufficient rainfall, have poles for building and that they should be near other inhabited areas.
- The land had to be reasonably healthy as the Bakiga have little natural immunity to malaria.
- The Bakiga were a conservative people, suspicious that it was the government's intention to resettle them in a hotter, less fertile, and less healthy country.
- The scheme to resettle the Bakiga started in April 1946.

Photo: R. Ward, Department of Public Relations, Uganda. Copyright reserved.

Figure 7. Over-cultivated hill near Kabale town before 1940. Note contour cultivation and planted eucalyptus trees *[Source: Agriculture in Uganda, 1940].*

Socio-economic variable	Study area			
	Sango Bay (%)	*LMNP area (%)*	*Kabale/Ntungamo border (%)*	*Kibale area (%)*
1) Economic base:				
a) Agriculture	76.7	92.4	81.4	79.2
b) Petty trading	0.8	0.8	2.5	4.2
c) Civil servant	3.2	0.0	8.0	4.2
2) Scarcity of land for:				
a) Cultivation	60.0	84.4	83.8	80.9
b) Pasture	63.2	89.5	75.6	82.2
3) Source of energy (firewood):				
a) Own land	3.3.0	29.4	24.6	35.0
b) Communal land	24.2	34.5	36.4	21.7
c) Forest reserve	60.8	9.2	3.4	1.7
d) Others (e.g. purchasing)	39.2	26.9	35.6	41.6
4) Immigration (since the 1991 national census)	11.7	52.9	11.9	11.7
5) Cattle keepers who:				
a) move in search of water and pasture	55.3	84.2	43.9	20.0
b) graze on communal land	50.0	21.9	16.7	17.8

Table 7. Key socio-economic variables collected from each study area using a structured questionnaire *[Source: primary data collected by Uganda PAES[1] socio-economic team in 2001/2002].*

D.3. Environmental Status and Change: Local Knowledge and Perception

Summary results depicting the level of knowledge held by local communities about indicators and causes of environmental change (including land cover/use) are presented in Appendix 5. While there is some variation in the responses given by local communities, overall, the answers show a consistent picture for all the study areas. Local people perceive changes in environment, they associate environment change with some indicators, and more importantly, they are aware of causes of environmental changes. Both historical and local knowledge data, while qualitative, were used to supplement quantitative land cover/use change results presented in Section D.1.

D.4. Discussion

Results presented in Tables 3-6 show that significant land cover/use changes (extensification) has taken place in the Lake Mburo and Kibale National Park and adjacent areas between 1955 and 2000. In contrast, insignificant land cover/use changes have taken place in Sango Bay and Kabale/Ntungamo border areas over the same period. Secondly, data obtained from historical archives and local knowledge, though qualitative, appear to offer important explanations to the root causes of land cover/use changes in Uganda over the past 100 years.

Table 7 shows a summary of key socio-economic variables obtained using a structured questionnaire administered by the socio-economic research team for each study area. The socio-economic statistics show that the study areas are inhabited by largely agrarian societies who depend on the natural resources for their livelihoods. The main economic activity of each of study area is agricultural production, accounting for at least 79.0% of the economic base. The dependence of the economy, in each study area, on agriculture is close to the national average of 80% NEMA (2001).

From Table 7, scarcity of arable and pasture land is also high in each study area, regardless of whether significant land cover/use changes have occurred or not (1955-2000). It appears that Lambin and Geist's (2002) observation that variables such as population growth, poverty and infrastructure do not offer meaningful explanations of land cover/use changes over a few decades for the four study sites whose results are presented in Tables 3-6. However, when asked why there is environmental change, including land cover/use, the local people in the study sites believe that population growth is a major driving force that leads to land use change in Uganda (Appendix 5). Lambin and Geist's (2002) observation may be true because the socio-economic variables depicted in Table 7 do not offer an explanation why there have been significant land cover/use changes in areas around LMNP and KNP but almost none in Sango Bay and Kabale/Ntungamo border (Tables 3-6). Based on Figure 8, it is evident that since 1911 to 2002, Uganda's population has increased tremendously.

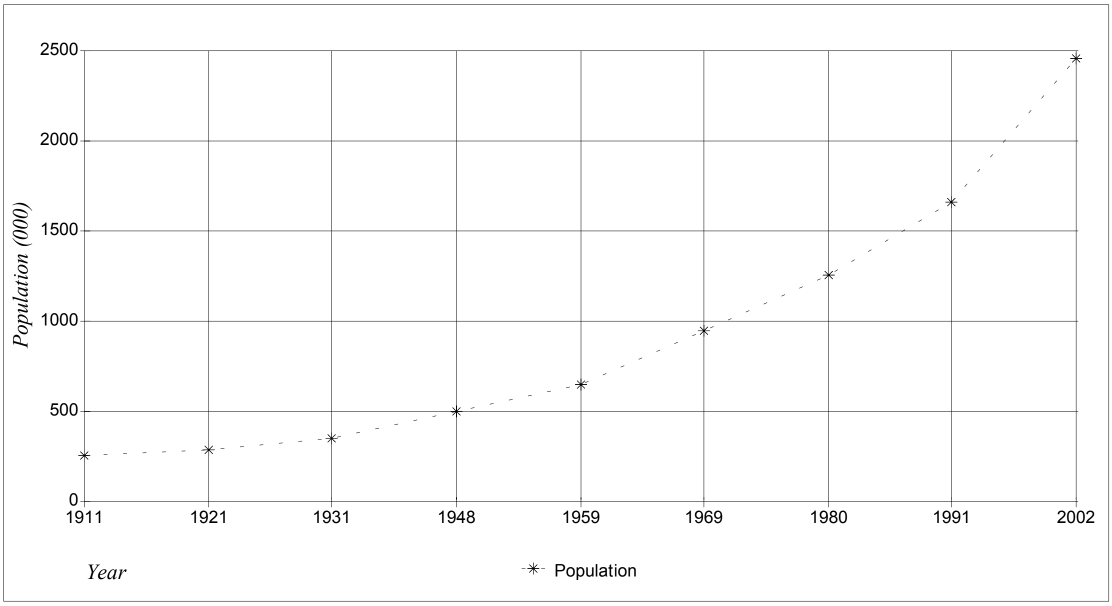


Figure 8. Population change (x000) in Uganda between 1911 and 2002 *[Source: The New Vision, Vol 17, No. 239, 2002).*

Table 8 shows the 10 most pressing problems ranked by the local people in each study area. The problem ranking was conducted by focus group discussions during socio-economic surveys (MUIENR, 2002). While the severity of problems faced by the local people varies from a study area to another, it is clear that the problems are the same. Of particular importance are poverty, overpopulation, land scarcity, soil fertility loss, limited water resources, diseases, unpredictable weather conditions and lack of markets. However, the perceived increase in population in each study area (see also Figure 8), poverty and environmental scarcity/degradation does not offer an explanation why there was significant land cover/use changes in areas adjacent to Lake Mburo and Kibale National Parks but insignificant changes in the rest of the study areas between 1955 and 2000.

Problem rank #	STUDY AREA			
	Sango Bay	*Lake Mburo area*	*Kabale/Ntungamo border*	*Kibale area*
1	Over population	Land shortage	Poverty	Poverty
2	Poverty	Poverty	Human/animal diseases	Plant diseases
3	Lack of family planning	Weather	Land shortage	Streams/rivers drying
4	Early marriages	Water scarcity	Weather changes	Land shortage
5	Loss of soil fertility	Over population	Food insecurity	Loss of soil fertility
6	Polygamy	Cattle diseases	Unemployment	Food insecurity
7	Limited markets	Deforestation	Over population	Over population
8	Plant diseases	Land disputes	Limited markets	Weather changes
9	Pollution by agricultural chemicals	Soil fertility loss	Soil fertility loss	Deforestation
10	Corruption	Poor quality of livelihoods	Poor road network	Declining big game

Table 8. Problems ranked by local communities in each study area *[Source: primary data collected by Uganda LUCID socio-economic team in 2001/2002].*

On the contrary, the historical accounts presented in Section D.2. and the local knowledge data presented in Tables 7 and 8 offer credible explanations of the root causes/trigger of land cover/use changes in Uganda over the past 100 years. Based on both quantitative and qualitative results presented above (Sections 3.1, 3.2 and 3.3), it may be concluded that:

shock events; external factors; government policies; presence or absence of disease; and the pursuit of basic livelihood opportunities by Ugandan societies may have operated in tandem to cause land cover/use changes observed over the past 100 years.

This study agrees with Lambin and Geist's (2002) observation that a cascade of changes along the system initiates significant land cover/use changes after being triggered by a shock event. For example, the 1934-1944 droughts triggered a massive migration of the Bakiga people to other districts of Uganda in search of arable land. As Purseglove (1950) points out, the Kabale area was already overpopulated by the turn of the 19th Century. Despite a mere 0.5 acres per person in Kabale area, it was not until the onset of 1943-44 droughts that a government resettlement policy was initiated in April 1946. Hence the 1943-1944 droughts (shock event) in areas around Kabale town were a trigger of a government resettlement *policy* that led to the resettlements of the Bakiga in present day Kanungu District (Purseglove, 1950).

What started as a government policy to persuade a reluctant Bakiga to resettle in less populated areas in 1940's by the British Colonial Government later resulted in voluntary *migration* to other areas of Uganda including Ankole, Tooro and Bunyoro regions. Figure 9 shows major sources and destinations of migrants based on 1991 national population census for Uganda. From the Figure, it is evident that the Bakiga have voluntarily migrated to other areas of Uganda, even though the initial (1946) resettlement scheme was on the basis of government persuasion. Migration of the Bakiga to areas adjacent to Kibale National Park appears to be linked to the significant land cover/use changes that have occurred between 1955 and 2000.

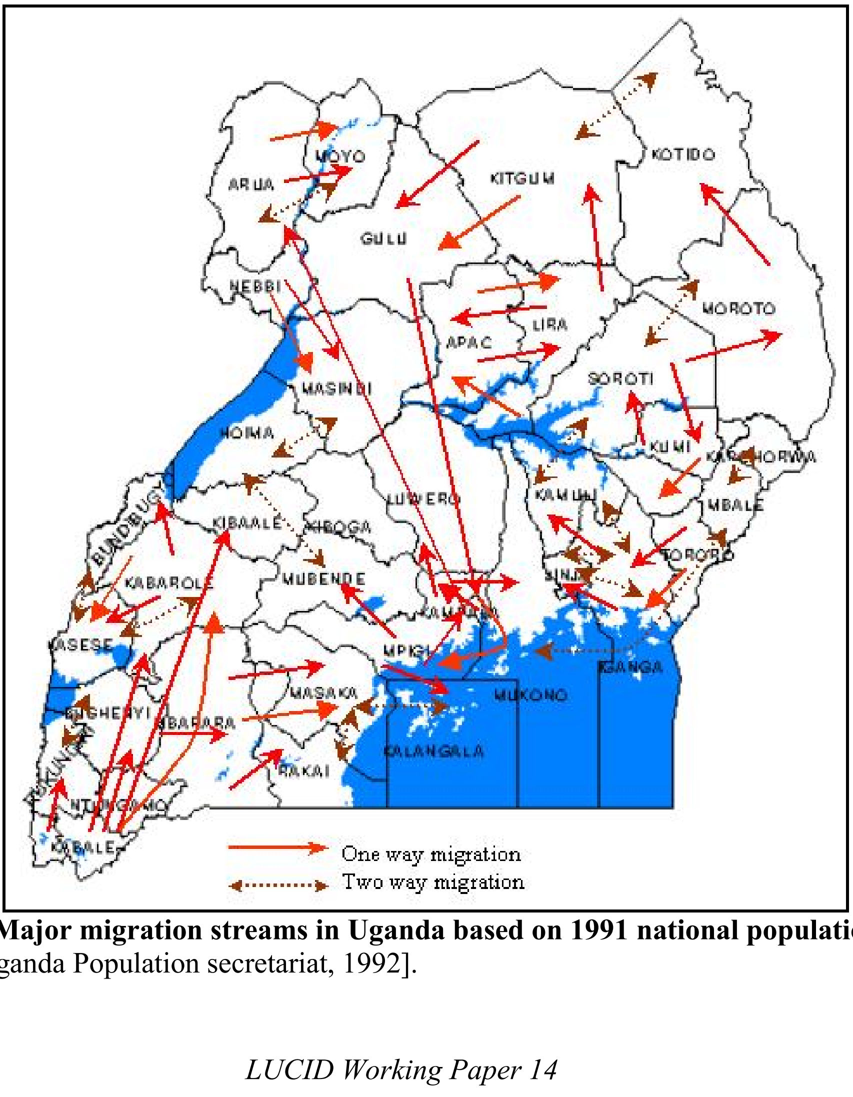


Figure 9. Major migration streams in Uganda based on 1991 national population census [source: Uganda Population secretariat, 1992].

Secondly, external factors/events also appear to have triggered a cascade of land cover/uses changes at the turn of the 19th Century in Uganda. This is exemplified by the influence of *culture*, *civil strife* and availability of external *markets*. As outlined in the historical account of the Lake Mburo/Koki areas (MacDonald, 1887; Bell, 1889), the introduction of agricultural pursuits in pastoral Koki was linked to intermarriages (cultural factors) with members of agricultural tribes mainly the Baganda. Again, due to the availability of external markets for iron bars, ironstone smelting is reported to be linked with deforestation of Kabale Mountains (Hamilton and Taylor, 1986) as well as the loss of woodland cover in Koki as suggested by Bell (1989). Another external trigger of land cover/use change in Ankole region was *civil strife* in Buganda. This is because at the turn of the 19th Century, the scattered agricultural settlements described by Bell (1989) were entirely occupied by Mohammedan (Muslim) Baganda. The Mohammedan Baganda settled in the Ankole region (area between present Mbarara town and Buganda border) when they were forced to flee their own country (Buganda) during the uprising they had earlier instigated. As Bell points out, the natives of Ankole region inhabiting the region were entirely pastoralists, while the Baganda were farmers (and still are today) and hence they opened up new agricultural farms, as did the Bakiga who migrated to new areas.

A third trigger that seems to be associated with land cover/use changes in several geographic areas of Uganda is the prevalence of disease. The Bakiga at first resisted government resettlement schemes because they (the Bakiga) perceived hot/humid areas as unhealthy and infested with malaria (Purseglove, 1950). According to Purseglove, the Bakiga preferred to stay in Kabale regardless of how overpopulated the region was. In an era of no modern drugs, one may conclude that areas free of fatal diseases such as sleeping sickness and malaria had their natural vegetation converted to subsistence farming many centuries ago. Indeed, pollen analysis of southwestern Uganda shows that deforestation occurred many centuries ago in the Kabale region (Hamilton and Taylor, 1986). The region is characterized by a temperate type of climate due to its high altitude and until recently, malaria was unknown in the region (Lindsay and Birley, 1996). Bell (1989) also reports that the presence of tsetse flies resulted in many regions being depopulated at the beginning of the 20th Century. As reported by Bell and others, the British colonial government in Uganda resettled inhabitants from large swathes of savannah belts (including present-day Lake Mburo, Queen Elisabeth, Murchison Falls and Kibale National Parks) due to the devastating effect of sleeping sickness spread by tsetse flies. It is logical to conclude that the presence of disease (mainly sleeping sickness and malaria) was (and to some extent still is) a major root cause of land cover/use changes in Uganda. Indeed, the devastating effects of the tsetse fly is led to the establishment of most national parks in Uganda (Kibale, Queen Elisabeth, Lake Mburo and Murchison Falls National Parks) when the British colonial government resettled the concerned inhabitants in areas free from the tsetse flies.

The fourth trigger of land cover/use changes in Uganda may be landlessness of a large section of an agrarian society. The landless people (in agrarian societies) are by default poor. One of the coping mechanisms, from this study, appears to be migrating to areas where there is cheap of free land. For example, according to Nabuguzi and Edmunds (1993), the Bakiga settled around Kibale National Park in 1950's to 1960's when the King of Tooro made an agreement with General Secretary of Kigezi to allow the Bakiga to take up free land between Kibale Forest and the King's subjects. Ideally, the free land given to the landless Bakiga was a buffer zone created to protect the crops of King's subjects from being raided by vermin that reside in present day Kibale National Park. This may be one of the causes of the significant land cover/use changes observed for areas adjacent to Kibale National Park. It is also true that there were significant land cover/use changes (1955-2000) in areas adjacent to LMNP probably due to recent migrations (due to cheap land) and late 1980's government resettlements of people who were displaced during the Luwero-Triangle War waged by Museveni.

E. CONCLUSIONS

Shock events, external factors, prevalence of disease and landlessness, together with high population growth may be regarded as major driving forces responsible for land cover/use changes observed in most regions of Uganda over the last 100 years. What has been presented in this case study may not be an exhaustive list of all the major driving forces of land cover/use changes observed in Uganda. However, the contribution of this study is that it is the first of its kind in Uganda and hence may be regarded to have made a significant contribution. Prior to this study, factors such as poverty and overpopulation might have been accepted as the default driving forces of land cover/use changes in Uganda. However, the study has shown that *shock events* such as droughts, external factors, government *policies, presence* or *absence of disease, migration*, and *landless* people in societies that are a) overpopulated, b) willing to adopt new cultural and technological norms and c) capable of living in harmony with immigrants result in significant land cover/use changes. While the author agrees with Lambin and Geist (2001) and NASA (2002) that quantitative spatially explicit data is crucial for understanding the driving forces of land cover/use changes, it is argued that historical and local qualitative knowledge is equally important, at least in the case of Uganda.

It is also noted that the consequences of land cover/use change go beyond the overall objectives of LUCID-GEF Project i.e. 'l*and use change as a tool for understanding biodiversity loss and land degradation'*. Additional research conducted by MUIENR (2002) revealed that knowledge of land cover/use changes is an indicator of societal conflicts, food insecurity and poverty (MUIENR, 2002). Therefore, the identification of the root causes of land cover/use change during this study will open new opportunities for understanding other key environmental and socio-economic processes, in addition to biodiversity loss and land degradation.

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