IMPACT OF LAND USE AND LAND COVER CHANGES ON WATER FLOWS: A CASE OF MALAGARASI RIVER CATCHMENT IN TANZANIA

BY

MAJALIWA MSTAFA ANDREA

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ABSTRACT

Malagarasi River catchment represents one of the largest and most significant transboundary natural ecosystems in Africa. The catchment constitutes about one third of the catchment area for Lake Tanganyika. There is growing concern: however. regarding land degradation in the catchment. particularly deforestation affecting the natural resource base and the river flow. This study utilized remote sensing and geographical information system tools. climatic data. available hydrological data and local resident's perception to determine the magnitude of the land-use and cover changes in the Malagarasi catchment. and the effects of changes on the river flows over the past 28 years. The results revealed that there has been considerable land-use and cover change. For the period under study (1984/86 and 2000/02). the analysis revealed an annual increase in forest cover and water areas by +3.24% and +2.95% per year respectively while. settlement/cultivation increased at +1.05% per year. Meanwhile. woodland and wetland vegetation/marsh declined by -0.09% and -2.51 per year respectively. The analysis of mean monthly flow indicated variations in peaking. The peak flow has changed from May for 1975-1980 to April for 1981-2002 periods. Early attainments of peak flow are related to the observed variations attributed to land use and cover change. The trend analysis on annual rainfall indicated no significant differences at 95% level of significance. The principal causes for land use and land cover change were found to include deforestation. forest reserve encroachment, expanding agricultural activities and population growth. Given the significance of the stream flow to the local people. a set of measures aimed at enhancing groundwater recharge are required to sustain the water resource and maintain a balanced dry-season flow in the catchment. Generally, an integrated catchment management approach, whereby the whole of the catchment can be holistically viewed and managed, would be desirable.

DECLARATION

I, **Majaliwa Mstafa Andrea**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted for a higher degree award in any other university.

.... 16/09/2009 ....

Majaliwa Mstafa Andrea — Date

(MSc candidate)

The above declaration is confirmed.

.... 28/09/2009 ....

Dr. J.J. Kashaigili — Date

(Supervisor)

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DEDICATION

To my beloved parents: my father Hezron Andrea Kalihose and my mother Therezia William Sanze, who tirelessly built my foundation in education. May Almighty GOD bless them indefinitely. AMEN.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

DALDO	District Agricultural and Livestock Development Officer
DANIDA	Danish International Development Agency
DRC	Democratic Republic of Congo
ERDAS	Earth Research Data Analysis System
FAO	Food and Agriculture Organization
FDC	Flow Duration Curve
GPS	Global Positioning System
IRA	Institute of Resource Assessment
IUCN	International Union for Conservation of Nature
NEMC	National Environment Management Council
SIMMORS	Sustainable Integrated Management of Malagarasi-Muyovozi Ramsar site
SPSS	Statistical Packages for Social Sciences
URT	United Republic of Tanzania
USAGE	United State Army Corps of Engineers
WCED	World Commission on Environment and Development

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Human activities in many parts of the world have greatly changed the natural land cover. Large tracts of natural vegetation cover have been converted into croplands or deserts, and natural wetlands have been drained and filled in order to feed and shelter expanding population (WCED, 1987; Monela and Solsberg, 1998). The concerns about land use and land cover change globally emerged due to realization that change of nature of land surface influence climate and those changes have impact on ecosystem, goods and services that are derived from it (Lambin *et al.*, 2003). One of the important land use changes is that the world's forest, grasslands and woodlands have declined and cropped land areas have expanded in the same magnitude (Skole and Tucker, 1993; Slayback, 2003). Tanzania's ecosystems have been vulnerable at the expense of human driving forces like of land for agriculture, pasture, logging, charcoal making and mining (Kidegesho, 2001; Ogungo and Njuguna, 2004).

Like many other developing countries, most of the population in Tanzania lives in rural areas and depend directly on the land for their livelihoods. This rural population is currently growing rapidly, and consequently inducing many effects on the resource base. Studies carried out in different parts of the country (Kashaigili, 2006; Munishi *et al.*, 2003) have ascertained that. A common concern addressed by many of these studies is the resource degradation brought about by the decrease in the area under natural vegetation and its conversion into other types of land use and land cover that are human-managed systems. One form of resource degradation believed to follow from land cover changes is disturbance in stream flow regimes of watersheds (Bewket and Sterk, 2003; Kashaigili, 2008). The underlying assumption is that, land under little vegetative cover is subject to high surface runoff, low infiltration rate and reduced groundwater recharge. The reduced infiltration and groundwater recharge, eventually, leads to lowering of water tables and intermittence of once-perennial streams. However, the justification for the above assumption should be based on sound empirical evidence (Bewket and Sterk, 2003).

The Malagarasi River catchment constitute one third of the Lake Tanganyika catchment area. The catchment has experienced rapid changes since 1970s, mainly resulting from extensive fire, deforestation, overgrazing and shifting cultivation as much of upper cover has been converted into agricultural land. According to DANIDA (1999), the changes are believed to be continuing as depicted from the increasing population, it is believed to result into an increase in flood flows, and decreased dry season flows of rivers while at the same time increasing levels of pollution and siltation. On the other hand, Masija (2000) noted that the increasing pressure on catchment and wetland has been claimed to be a threat to the ecosystems, as it contributes to the degradation of catchment, and have several impacts on the hydrology of the river cycles (Abass, 2007).

These contrasting research findings suggest that the impacts of land cover changes on water resource systems vary from place to place, depending on site-specific factors. Hence, there is clearly a need for empirical investigations into the problem. As stated by Calder (2002), the hydrological impacts of land use and land cover changes are still contentious issues and further research is necessary. In Africa in particular, Newson (1992) confirmed, that there is, as yet, only the thinnest body of empirical knowledge on the hydrological effects of land use and management. A study of stream flow patterns with respect to land cover dynamics enables assessment of sustainability of land use systems; because the stream flows are reflections of the ecological state of the entire watershed

(Lorup *et al.*, 1998). The information can also be employed to forecast the likely effects of any potential changes in land cover on water resource systems. Hence, such a study has practical relevance for devising strategies and policies for a sustainable land and water use.

1.2 Problem Statement and Justification

Vegetation cover plays an important role in preserving and maintaining water balance of many catchments. The cover permits more infiltration of precipitation into the ground, because root channels keep the soil loose and decaying organic material acts as a sponge (Ngana, 2002). Upon clearing the cover, the sponge effect is lost, and results into diminished water yield (Pereira, 1989). Any change in land use patterns, cover and area under cultivation will inflict pressure on the catchment water flow regime and thus put pressure on the state of the wetland (URT, 2006; Kashaigili, 2006).

While there is continuing decrease in water flow in the Malagarasi River, the exact mechanism leading to the decrease is unclear. Studies has shown that in recent years, natural resources destruction have been realized in the Malagarasi catchment (IRA, 2002), due to pressure (agricultural and grazing) and changes in land use pattern (Mahinya, 2005). Human influence is likely to be the cause of the change, though how exactly the activities have contributed to catchment encroachment is not yet clear.

Furthermore, the proximity of the railway in the central part of the Ramsar site and ongoing construction of Tabora – Kigoma trunk road is believed to have stimulated a commercial market which has resulted into over-exploitation of the resource (URT, 1995). Despite the past study conducted in the area pertaining land use (i.e. Mahinya, 2005); there is inadequate information on impacts of land use and cover changes on hydrological flow regimes. Therefore, this study assessed the extent of land use and cover change in the catchment, and the impacts of changes on the hydrology of the Malagarasi River and the wetland ecosystem. The findings from this study could help in informing policy and in formulation of strategies for proper interventions aimed at sustainable management of the Malagarasi River catchment and the Malagarasi - Muyovozi wetland ecosystem.

1.3 Objectives of the Study

1.3.1 Overall objective

The main objective of the study was to assess the land use and land cover changes in the Malagarasi river catchment and their impact on river flow regime including the Malagarasi-Muyovozi wetland ecosystem.

1.3.2 Specific objectives

The specific objectives of the study were to:-

i. To assess the land use and land cover changes between 1984/86 and 2000/02
ii. To assess the impact of detected changes on river flows regime for Malagarasi River
iii. To investigate the local peoples' perception on the changes in the catchment
iv. To recommend strategies for sustainable management of the Malagarasi river catchment and the Malagarasi – Muyovozi wetland ecosystem.

1.3.3 Research questions

i. What land use and cover changes has taken place in the Malagarasi river catchment for the period between 1980 and 2002?

ii. What is the relationship between river flows and the detected land use and cover changes?

iii. What are local people's perceptions on land cover and use and downstream flow change?

iv. What could be the strategies for sustainable management of the Malagarasi river catchment and the wetland?

1.4 Limitations of the Study

The study was planned to cover the whole of the catchment (Kigoma. Kibondo. Kasulu. Mpanda Bukombe. Uyui and Urambo) to the mouth of Malagarasi River. but due to constraints related to funds. time. facilities (transport). accessibility and the size of the area. this was not possible. Instead. only information from the study area (under Malagarasi-Muyovozi Ramsar site) which covers parts of lower catchment in Kigoma District was used to give some important information as a representative of the whole catchment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Land Use and Land Cover

According to Di Gregorio and Jansen (2000), land cover describes the physical states of the land surface including cropland, forest, wetlands, pastures roads and urban areas, whereas land use relates to the manner in which these biophysical assets are used by humans (Cihlar and Jansen, 2001). Since use depends largely on the land characteristics, there is a close relationship between land cover and land use. However, land cover observation does not automatically mean land use, because land cover and land use, though interrelated, are not identical. The land use choices made will vary in space and time and so will the resulting land cover (Cihlar and Jansen, 2001).

2.2 Land Use and Cover Change

Land use and land cover change entails the conversion from one land cover category to another (Riebsame *et al.*, 1994). Land use change can be either: (a) a change in the intensity or other attributes within an existing category (e.g., when residential density increases): or (b) a change to another category (e. g., from agricultural to residential). Land use and cover changes tend to occur simultaneously, and have important implications for water resource (FAO, 2000). Change in land use and cover could modify flow regime in the downstream by either increasing flows or decreasing flows for a certain period of time (Walker, 1998). Therefore understanding the linkages between land use and cover changes and changes in flow in the downstream is vital for sustainable catchment and environmental water management (Kashaigili, 2006).

2.2.1 Remote sensing and innovative mapping techniques

Remote sensing is the art and science of obtaining information about an object. area phenomenon through the analysis of data acquired by a device that is not in physical contact with the object. area or phenomenon under investigation (Lillesard and Keifer. 1994). Remote sensing basically involves two processes namely data acquisition and data analysis. The gathered data are then converted into useful information using various viewing and interpretation devices for visual analysis and using computer modules for digital image analysis Richards (1993) cited by Kashaigili (2006). In most contemporary land use studies. which employ remote sensing imagery. the foremost task is the observation of spectral reflectance characteristics of a measured radiation from the target object (Kashaigili. 2006). Analysts develop signatures based upon the detected energy's measurement and position in the electromagnetic spectrum (Mbilinyi. 2000). By utilizing the developed signatures in multi spectral classification and thematic mapping. the analyst generates new data for analysis (ERDAS. 1999).

2.2.2 Change detection

The goal of change detection is to distinguish those areas on digital images that depict change features of interest (c.g. forest clearing) between two or more image dates (Kashaigili. 2008). Numerous change detection techniques are available which achieve various levels of success (Kaufmann and Seto. 2001), but the method used depends largely on the landscape. the types of land cover changes. and the temporal and spatial resolution of the data. However there is no consensus regarding the best technique. Despite that. the post classification comparison technique is widely used in detecting the land cover change (Chen, 2000; Kashaigili, 2006).

Using post-classification technique is advantageously. because the image acquired at different times are separately classified. The method allows minimization of the effect of multispectral scenes acquired at different atmospheric conditions and using different sensors (Jensen, 1996). It was shown that the association of filtering mode with classification procedures improves accuracy of change-detection. Mode filter applied in three by three neighbouring with a threshold value in generally three. allows suppressing the isolated pixel or poor classified or the pixels due to noise. It replaces central value pixels by a majority value. Majority threshold corresponds to threshold of which going: majority value replaces central value pixels.

Generally, a change detection can be generated either from vector or raster based data. depending on the data sources and its intended uses. The overlay of vector data sources were used for change detection in this study. The overlay of two maps was done through intersection of features themes so that the boundaries and attributes of themes are combined to form the derivative output theme (Chang, 2002; Theobald. 2000).

2.3 Land Use and Cover and River Flow Linkages

Increasingly human actions at the landscape scale have been a principal threat to the ecological integrity of river catchment ecosystems, impacting on habitat, water quality, and the biota via numerous and complex pathways (Strayer *et al.,* 2003). Studies conducted elsewhere in the world have attempted to evaluate the effects of changes in land use and land cover on stream flow patterns. Van Lill *et al.* (1980) reported that afforestation of grassland (with *Eucalyptus grandis* and *Pinus patula*) reduced annual flows at Mokobulaan, South Africa. In their study in Iringa, Tanzania, Loerup and Hansen (1997) reported that low flow amount was larger in catchments under traditional smallholder agriculture than those under indigenous forest cover.

A study in an upland watershed in Sri Lanka by Elkaduwa and Sakthivadivel (1998) discovered that replacement of natural forests by agricultural land uses led to decreased base flows and increased surface runoff generation, while the annual water yield remained more or less unchanged. Sandstroem (1995) reported that low flow amount was higher in a catchment under woodland cover than from a catchment under cultivation and grazing in a semiarid region of Tanzania. The implication is that the cultivation and grazing uses led to reductions in the low flows. Similarly, Loerup *et al.* (1998) reported a decrease in the annual runoff in 'most of the six catchments' they studied in rural Zimbabwe with increases in population density and agricultural intensity, implying that the population pressure decreased the runoff of the catchments.

However, a study by Taylor (2001); Kumar (1998) found that there is evidence that changes to land cover itself can affect the micro-climate in certain regions. Progressive removal of land cover changes the surface albedo (the degree to which the land surface reflects the sun's energy) and can also reduce atmospheric humidity, which in turn affects cloud formation and precipitation. Thus, land clearance activities may have positive feedbacks that create localized reductions in atmospheric humidity and rainfall and pose ecological threat to the ecosystem (IRA, 2002).

Furthermore, research suggests that airborne dust and smoke from fires may cause reductions in rainfall (Rosenfeld, 2001). Activities such as grazing and agricultural cultivation that expose and disrupt topsoil can increase the amount of dust blown into the air *(ibid)*. Land clearing activities through burning sends up plumes of smoke (often visible on satellite images). Dust and smoke have relatively large particle sizes. These larger-sized nuclei have the effect of increasing the threshold for droplet formation in clouds, thereby reducing rainfall *(ibid)*.

2.4 Application of Remote Sensing in Land Use and Land Cover Assessment

Various natural resources professionals have done studies using remote sensed data. Mulongo (1993) used remote sensing (Landsat) to assess the rate of natural resources exploitation and the implication of existing land policy in the reserved lands of Mbole – Muyonzo in Zambia. In this study it was found that due to the uncoordinated nature of resource utilization and localized population pressure, resource degradation in terms of forest depletion due to bush clearing for cultivation had increased, which later caused serious decline of soil productivity.

Slayback (2003) studied land cover change in the Takamanda forest reserve in Cameroon using remote sensing. It was found that most of the forested areas converted into other land uses were located on the periphery of existing villages and areas of pre-existing secondary forest and the rates of forest clearing appeared to be increasing as the expanding patterns of forest conversion indicated. Riaza *et al.* (1998) used two sets of Landsat images to monitor changes in River Muni, Guinea. Results showed that most of the area, had suffered changes in vegetation cover over the 40 year period.

Shreier *et al.* (1994) used remote sensed data and historical land use/ land cover dynamics to study resources status in the Himalayan Nepal watershed using geographical information system. Under the study, forest, cropping system and socio-economic factors were investigated. Observations showed that during 1947 to 1990 periods, forest cover, shrubs and agriculture were the only land uses. Deforestation was significant in the years from 1972 to 1990 and was more critical in the middle mountains of Nepal. It was reported that geographical information systems then integrated with remote sensed data could be useful in identifying the impact of cover changes due to increased agricultural activities and grazing.

Land use and land cover transformations studies have also been conducted in Tanzania. Nindi (2004) did a study on dynamics of land use in Matengo highland southern Tanzania using remote sensing techniques for the period between 1984, 1989, 1991, 1994 and 2000. The study revealed that vegetation cover changes in Miombo woodland of Kibanda villages changed from 84% coverage in 1984 to 20% in year 2000 due to human activities (agriculture, grazing, and forest fire).

Monela and Solberg (1998) carried out a study of land use and land cover change and deforestation rates for the rain forests of the Nguru Mountain in Morogoro. They investigated deforestation rates between years 1949 – 1993. The findings showed that the continuous rainforest outside the forest reserve declined by about 1.3% per year since 1949 while continuous rainforest boundary was moved up the slopes and shortened by 37%. The encroachments for subsistence agriculture as well as establishment of settlement by indigenous people were found to be the main cause of rainforest degradation pressure.

Rugenga (2002) used remote sensing to study land use changes due to irrigation activities between 1955, 1976 and 1999 in the Great Ruaha River catchment in Iringa, Tanzania. The study identified seven main land use classes which included riverine vegetation, forest, woodland, scrub, settlement and abandoned land fields. The land use change was mainly observed along the Great Ruaha River and its tributaries. It was found that overpopulation, grazing and charcoal making were among socioeconomic factors leading to land use/land cover changes. Kashaigili (2006) also examined the land use and cover dynamics in relation to hydrological functioning of wetlands. The study revealed that increased irrigated areas during the dry season contributed to decreased water flow of the Great Ruaha River.

The above reviewed studies indicate a thorough feasibility of the remote sensing methodologies for the study of land use and land cover changes. Since remote sensing and GIS technology has proved to be valuable tools for identification and characterization of the catchment areas (Wu *et al.*, 2002), there is a need to employ the techniques to analyse land cover changes over the Malagarasi river catchment and assess the implication of the changes on the water flows and the Malagarasi-Muyovozi wetland ecosystem.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Areas Description

The study area is located at the eastern - central part of the Malagarasi-Muyovozi Ramsar along Malagarasi River catchment. Four main sites including Kasisi (05°03.246'S. 030°57.936'E). Malagarasi (05°06.013'S. 030°54.205'E). Mtegowanoti (05°01.293'S. 031°02.507'E). and Ilalangulu (04°59.388'S 031°06.609'E) within the Malagarasi - Muyovozi Ramsar site were involved in this study (Fig.1). The catchment lies within longitudes 3°15'S to 6°10'S and latitudes 30°40'E to 32°30'E (DANIDA. 1999).

3.1.1 Climate and topography

The climate of the area. just like the rest of the country. is tropical in nature characterized by the interaction of the southern monsoon winds as well as the southeast and northeast trade winds. The area receives rainfall with an average of 800 to1000 mm annually (DANIDA, 1999). The peak rainfall is in November to December and April to May (main rainy season) with marked variation from year to year. Temperature ranges from 12°C to 20°C in July /August and to as high as 32°C to 35°C in August and September (main dry season). Topography of the area ranges between 800m to 1600m above mean sea level with an average of approximately 1200m (IRA, 2002).

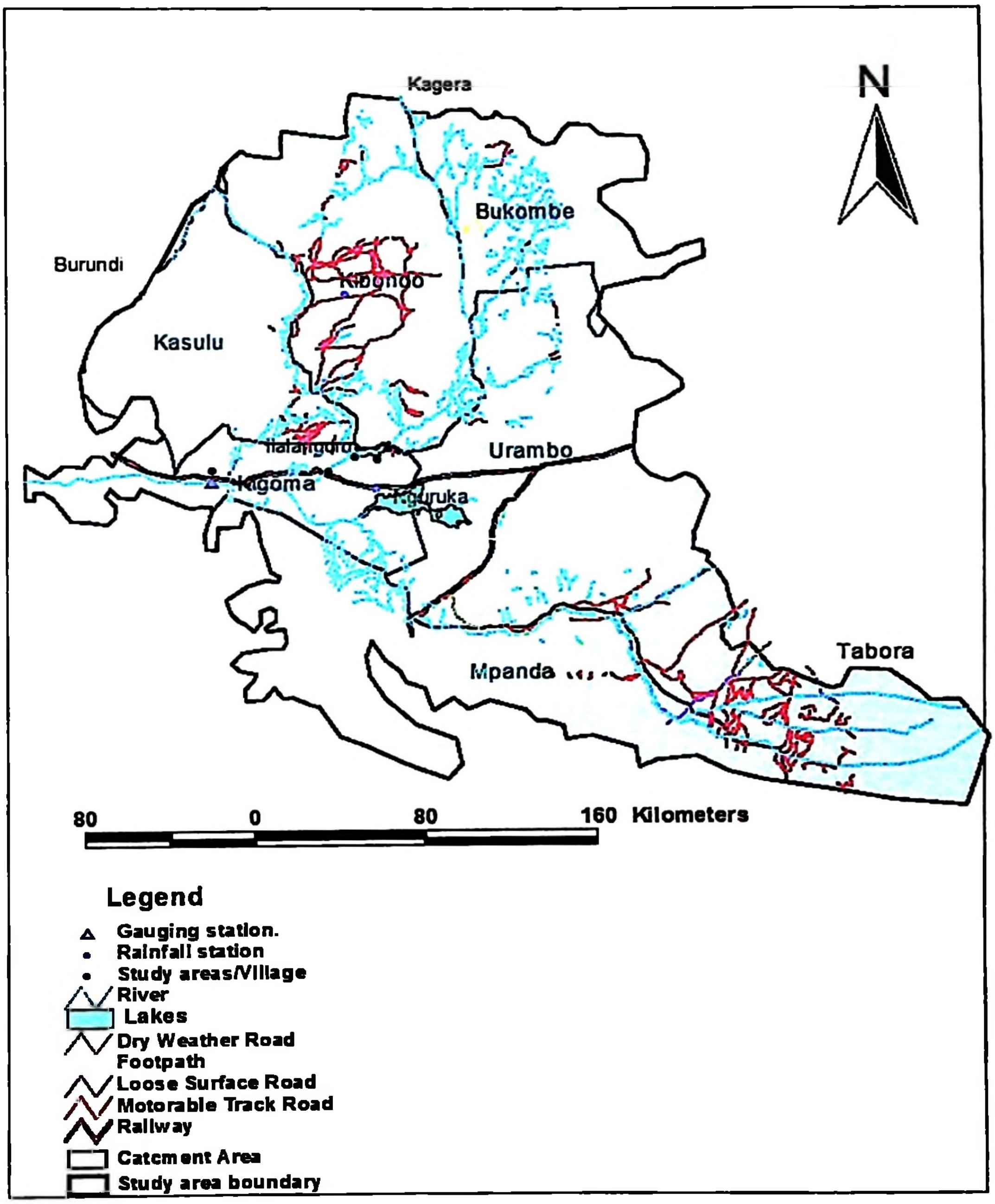

Figure 1: A map for Malagarasi River catchment showing rainfall, flow station and main centres

3.1.2 Land use and cover types in Malagarasi – Muyovozi Ramsar site

A large part of the Malagarasi Catchment is occupied by the wetland (Malagarasi-Muyovozi – Ramsar site) and Game Reserves (Moyowosi/Kigozi and Ugalla Game Reserves) (DANIDA, 1999). The major land uses are Game reserves conservation, recreational and tourist hunting including other licensed activities that are fishing and honey gathering. In the Forest Reserves, the principal land uses are nature conservation, bee-keeping, illegal logging and other forest product and seasonal grazing. In the game controlled areas (Gombe and Luganzo), the principal land uses are agriculture, settlement, fishing, seasonal grazing, also nature conservation and licensed trophy hunting. Other land uses include cultivation for subsistence (food crops -primarily cassava) and tobacco growing (for commercial purpose). In the surrounding areas (general lands), the principal land use are settlement, subsistence cultivation, fishing and seasonal grazing (Jones and Hill, 1994; NEMC/IUCN, 1994; Lyaluu, 1996). The woodland and grassland are the dominant land cover within the catchment.

3.1.3 Demographic characteristics

Kigoma District is among the fastest growing population in Tanzania. According to the 2002 Census, the population of Kigoma District stands at 490 816 of whom 225 002 are male and the rest female. The average household size is 6.8 against the national average of 4.9. The annual average population is 4.1% against the national average of 2.9%. This high growth has been attributed to the influx of refugees from DRC, Burundi and Rwanda (URT, 2003).

The study purposefully selected Nguruka, which is one of the 6 divisions in the Kigoma Rural District within the Malagarasi River catchment. The population of the areas is about 57 698 whereby (28 031 and 30 667 are males and female respectively), which is about 12% of the District population. There are 10 666 households with an average household size of 5.6 (URT, 2003).

3.2 Methodology

Both primary and secondary information were used. The primary data were collected by interviews using questionnaires. focus group discussion and participant observation while secondary data were obtained from literature survey of previous works (e.g. research reports. published and unpublished books. government reports. etc). records. maps covering the study area and journals.

3.2.1 Primary data collection

Primary data were collected from four villages selected purposefully for the study. These villages were Malagarasi. Kasisi. Ilalangulu and Mtegowanoti. A reconnaissance survey was carried out in November 2007 and involved assembling of data source materials (landuse maps. various report and publications) and testing of questionnaires (Appendix 1).

The choices of household for interviews were based on a simple random sampling technique. A total of 120 household (i.e. 30 households from each village) were interviewed (Table 1). to generate additional information in refining and support the interpretation of satellite images. A semi- structured questionnaire with both open-ended and close-ended questions was used to elicit information from the community. In addition, guiding questions were asked in focus group and key informants to capture in-depth understanding of historical resources use pattern in the area.

In complimenting the questionnaire interview. visual observations through transect walk were made to selected routes to "ground truthing" and maps. The transect walks (1km long and 500m apart) were used to identify the various human activities and different land use and cover at specific sample points. The waypoints were marked using a global positioning system (GPS) and used in map verification exercise, in which classes in imagery base map were correlated with actual ground data.

3.2.2 Secondary data collection

Secondary data were obtained through literature review. The information was gathered from other research findings and experiences from different case studies related to land use and cover changes in other countries and in Tanzania. Most of the secondary data were obtained from libraries (Sokoine University of Agriculture and Ubungo Maji, IRA, Lake Tanganyika Water Basin and internet).

3.3.3 Remotely sensed data, processing and change detection

Aerial photos and multi-spectral satellite images usually provide accurately snapshots of recent and past land cover condition (McHugh *et al.*, 2006). The assessment of Malagarasi river catchments area and land use and cover changes with time and ultimately detection of changes in order to relate the changes and flow regime response downstream, the analysis of remotely sensed data was done and involved the following steps:

3.3.3.1 Image selection and acquisition

Two different type of Landsat image, Landsat Thematic Mapper, and Enhanced Thematic Mapper plus obtained from different sensors were used in this study. These images covered the period of 1984/86 and 2001/02 (Table 1).

Table 1: Remotely sensed data used in the analysis of land-use/ cover change

Image	Path/Row	Acquisition date	Season
Landsat TM	171/63	13 June. 1984	Dry
Landsat ETM+	171/63	16 May. 2000	Wet
Landsat TM	171/64	13 June. 1984	Dry
Landsat ETM+	171/64	22 May. 2002	Wet
Landsat TM	172/63	12 July. 1986	Dry
Landsat ETM+	172/63	01 October. 2001	Dry
Landsat TM	172/64	12 July. 1986	Dry
Landsat ETM+	172/64	01 October. 2001	Dry
Landsat TM	170/64	31 August. 1986	Dry
Landsat ETM+	170/64	18 January. 2000	Wet

Note: TM = Thematic Mapper. ETM+ = Enhanced Thematic Mapper Plus

3.3.3.2 Image Processing

Image processing involved three stages: Image pre-processing. image rectification. and image enhancement.

Image pre-processing

The methods for the images analysis required the use of both visual and digital image processing. The images were extracted from the full scene prior to processing, using ERDAS Imagine Software version 9.2. Steps involved are summarized in Fig.2.

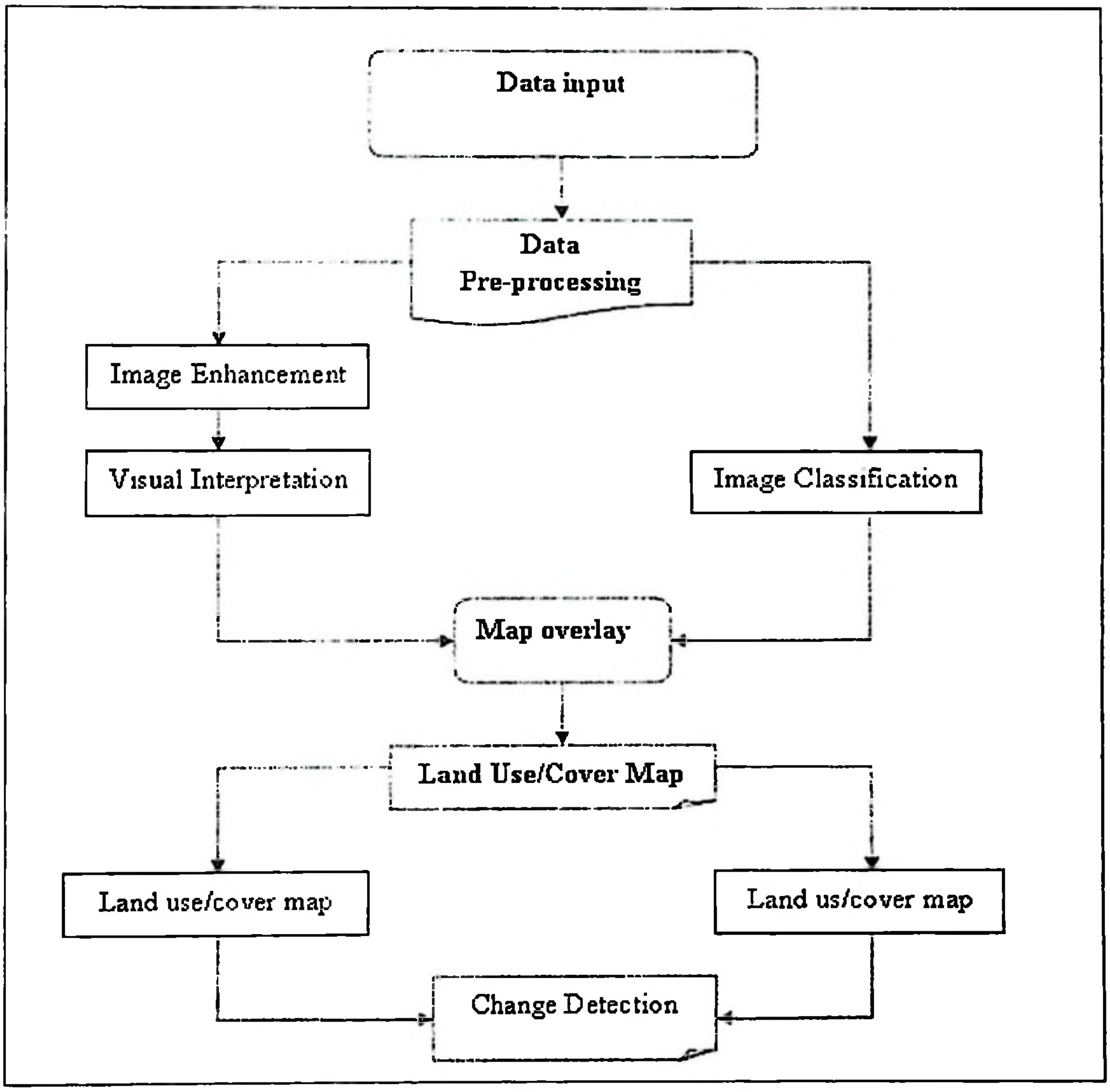

Figure 2: The image analysis flow chart

Image rectification

Image rectification aims to correct image data for distortions or degradation resulting from the image acquisition process. To ensure accurate identification of temporal changes and geometric compatibility with other sources of information, the image were coded to the co-ordinate and mapping system of the national topographic maps, i.e. UTM coordinate zone 36 South, Spheroid Clarke 1880, Datum Arc 1960, based on a previous georeferenced Landsat image of 3 August and 4 September, 1994 (IRA). Since the available satellite images had been already corrected for radiometric distortions and had no apparent noise, the created sub-scene was only subjected to geometric correction.

Richards (1993) explains that radiometric distortion refers to the distortion of the relative distribution of brightness over the image in a give band in relation to the ground scene. It also applies to the distortion of the relative brightness of a single pixel from band to band compared with the spectral reflectance character of the corresponding site on the ground. The radiometric distortion may result either from the scattering effect of the atmosphere on radiation or from instrumentation error.

The geometric correction allows to compensate for various distortion introduced by several factors including earth rotation effects, panoramic distortion (with field of view of some sensor), curvature of the earth, atmospheric refraction, relief displacement, variations in platform altitude, latitude and velocity and panoramic effects related to the imaging geometry (Lillesand and Kiefer, 1987; Richards, 1993).

Image enhancement

Enhancement usually reinforces the visual interpretation of the images (Kashaigili, 2006). In order to reinforce visual interpretability of images, a colour composite (Landsat TM bands four, five and three) was prepared and its contrast was stretched using Gaussian distribution function. The three x three high pass filters was applied to the colour composite to further enhance visual interpretation of linear features, e.g. rivers and vegetation features (Mbilinyi, 2000; Rajabu, 2006).

3.3.3.3 Image classification

Image classification is defined as the extraction of differentiated land use and cover categories from remotely sensed satellite data (Mbilinyi, 2000). Supervised classification, using Maximum Likelihood Classifier (MLC), remote sensing classification methodologies were utilized to create a base map for ground truthing. Supervised classification process involved selection of training sites on the image, which represent specific land classes to be mapped. Training sites are sites of pixels that represent specific land classes to be mapped (Kashaigili, 2006). They are pixels that represent what is recognized as a discernable pattern, or potential land cover class (ERDAS, 1999). The training sites were generated by on-screen digitizing of selected areas for each land cover class delivered from colour composite. Training was an iterative process, whereby the selected training pixels were evaluated by performing an estimated classification (ALARM command). Based on the inspection of results, training samples were refined until a satisfactory result was obtained.

3.3.3.4 Ground truthing

Ground truthing was done in order to verify and modify land covers described in the preliminary image interpretation (Rajabu, 2006). Ground truthing was accomplished during household survey and a hand-held GPS was used to locate sampled land cover observations. This was done during the dry season to make easy access of impassable areas. In principle, villages chosen for household survey were decided to be the training areas. Recognized features and their respective positions were recorded.

3.3.3.5 Creation of land cover maps

Generally two different mapping approaches for obtaining thematic classes from satellite data are possible: i) fully automated digital classification ii) semi-automated classification utilizing visual image interpretation with ensuing digitization of the mapping results (Gross and Hausler. 1998).

Digital image classification involves the numerical manipulation of image data. It is the process in which pixels with like values are grouped into classes based on predetermined decision rules and statistical probability theory (Mbilinyi. 2006). The objective is to produce thematic classes that represent actual land cover types on the earth's surface. The advantage of digital image classification is that it can provide efficient. consistent and repeatable routines for mapping large areas (Kashaigili. 2006). Visual interpretation involved the use of image characteristics such as texture. pattern and colour to translate image into land covers. The enhanced image colour composite was used in this operation. Visual image interpretation was considered feasible in this study because the knowledge of expert will be integrated during image interpretation

3.3.3.6 Image mosaic and sub-setting

Since the study areas span ever several image files. there was a need to combine the images to create one large file. This is called mosaicking. Mosaicking is the process of joining georeferenced images together to form a larger image or a set of images (ERDAS, 1999). The input images contained the same map and projection information with the same number of layers.

After mosaicking, subsetting was performed in order to breaking out a portion of a large image file into one or more smaller files. Often, image files contain areas much larger than a particular study area (Fig 3). In these cases, it is helpful to reduce the size of the image file to include only the area of interest (AOI). This not only eliminates the extraneous data in the file, but it speeds up processing due to the smaller amount of data to process.

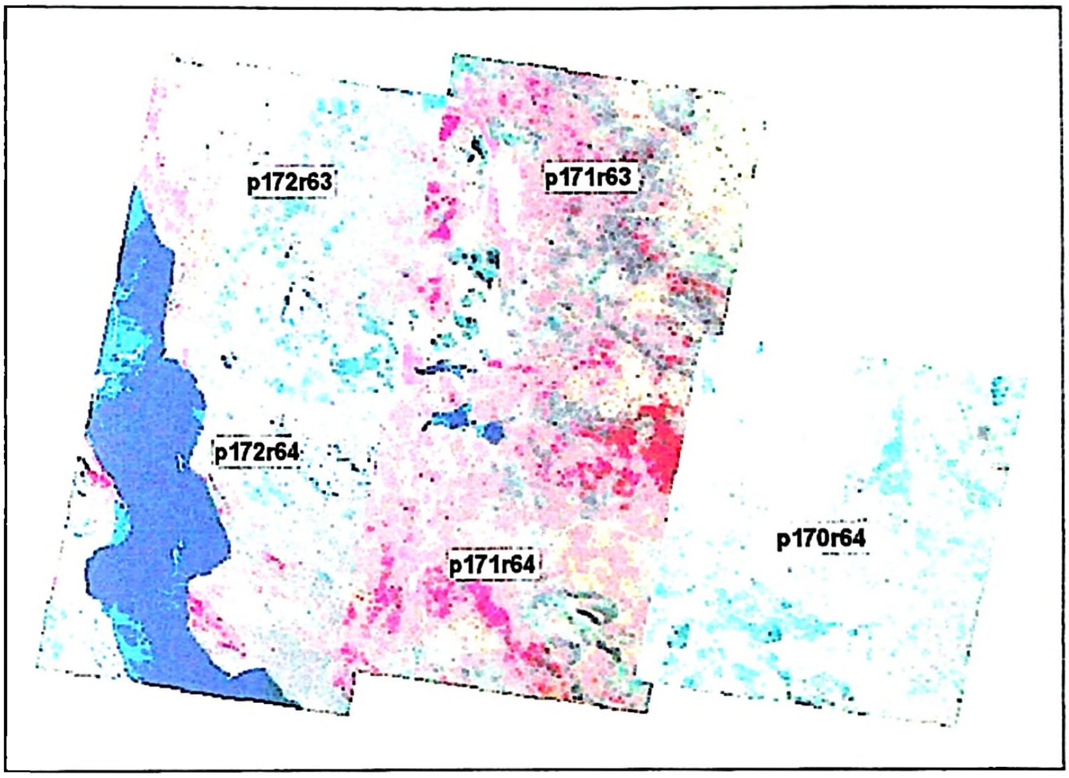

Figure 3: A mosaic map of different image scenes used in land cover change

3.3.3.7 Change detection analysis

Change detection is a very common and powerful application of satellite based remote sensing. Change detection analysis entails findings the type, amount and location of land use changes that are taking place (Yeh *et al.,* 1996 cited by Kashaigili, 2006). Various algorithms are available for change detection analysis and they can be grouped into two categories namely a) Pixel-to-pixel comparison of multi-temporal images before image classification, and b) Post- classification comparison (Jensen, 1996).

In this study, a post-classification comparison method was used to asses land use and cover changes. The method has been found to be the most suitable for detecting land cover changes (Wickware and Howarth, 1981). The approach identifies changes by comparing independently classified multi-date images on pixel-by-pixel basis using a change detection matrix (Yuan and Elvidge, 1998 cited by Kashaigili, 2006). The matrix produces a thematic layer that contains a separate class for every coincidence of classes in multi-date dataset.

3.3.3.8 Assessment of the rate of cover change

The estimation for the rate of change for the different covers will be computed based on the following formula (Kashaigili. 2006).

$$\%Change_{year\ x} = \frac{Area_{year\ x} - Area_{year\ x+1}}{Area_{year\ x}} \times 100\% \quad [1]$$

$$\%Annual\ rate\ of\ change = \frac{Area_{year\ x} - Area_{year\ x+1}}{Area_{year\ x} \times t_{years}} \times 100\% \quad [2]$$

Where: Area $_{years\ x}$ = area of cover at the first date.

Area $_{years\ x+1}$ = area of cover at the second date. and

t_{years} = period in years between the first and second scene acquisition dates

3.3.4 Climatic and hydrological data analysis

The historical daily water flow and rainfall data were analysed using MS Excel Packages. The available average flows data for Mbelagule gauging station (4A9) have been used to determine the flow characteristics of Malagarasi river catchment for the period of 1975 to 1980 and 1981 to 2002.

3.3.4.1 Rainfall analysis

Rainfall characteristics

Mean monthly rainfall

The mean monthly rainfall was obtained by dividing the sum of all the individual daily rainfall by the number of daily rainfall recorded for a particular month (Maria, 2005).

Mean monthly rainfall over the period of record

The mean monthly rainfall over the period of record was obtained by finding the mean monthly rainfall for each month for every year in the period of record. The sum of daily rainfall for each month, were divided by the number of days in the month, to get the mean rainfall for that month. Then, the sum of each year's monthly data for a particular month were divide by the number of years to obtain the mean monthly rainfall for that month for the period of record (Maria, 2005).

Annual rainfall

The annual rainfall information usually indicates the average rainfall for the calculated period of record. The total sum of each year rainfall data were divided by the number of years to obtain the mean annual rainfall for the period of record (Maria, 2005).

3.3.4.2 Trend analysis

Several tests for trend analysis are available. In this study the time series of rainfall and stream flow were analysed using one simple t-test for comparison of means.

3.3.4.3 Hydrological data analysis

Mean monthly flow

Mean monthly flow is the average flow for a given month of the year. To obtain these values the mean flow for each month for the entire period of record was calculated. Using Excel functions, the sum for each year's monthly data for a particular month were divided by the number of years to obtain the mean monthly flow for that month for the period of record. The monthly analysis information gave a better understanding of the pattern of stream flow (river) for the year, by illustrating the months that contain high flows, low flows, or average flows.

Mean annual flow

The hydrologic data by calendar years (January-December) was used to calculate the mean annual flow. Using the average function in Excel, mean annual flow was obtained by dividing the sum of all the individual daily flows by the total number day-records of the year.

Flow duration curve

The flow duration curve (FDC) showing the percentage of time that a given flow rate is equalled or exceeded were constructed using Microsoft Excel functions. The FDC were constructed from flow data of fixed time period (daily) based on the following steps (Fetter, 1994):

- Sorting the flow data in order of decreasing flow;
- Assigning a unique ranking number m to each flow, starting with 1 for the maximum flow to n for the minimum flow, where n is the number of flow measurements.
- The probability P that a given flow will be equalled or exceeded is defined by:

$$p = 100\frac{m}{n+1}$$

Where;

P = the probability that a given flow will be equalled or exceeded (% of time)

m = the ranked position on the listing (dimensionless)

n = the number of events for period of record (dimensionless)

- The flow-probability relationship is typically presented as a log-normal plot (Fetter, 1994).

3.3.5 Socio-economic data

The Statistical Package for Social Sciences (SPSS version 11.5) computer program was used in the analysis of quantitative data. With this program, frequencies and percentages were computed. Descriptive statistics were summarized and tabulation was employed to report all quantitative information. Frequencies and percentage were calculated to facilitate the drawing up of inferences related to socio-economic findings. The findings were therefore, presented, discussed and interpreted in the context based on research questions.

3.3.6 Land use/cover change and flow regime downstream of the river

Land use, cover change affects the water yield, and flow regime. Increased understanding between these two interactions is vital to ensure the sustainability of river and wetland resources. To gain an understanding, a time series of flow data, obtained from Mbelagule gauging station (4A9) was used to investigate temporal changes in the flow regime downstream of the river. The station has operated from 1975 to 2002 and there is no abstraction within the river.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Land use and land cover distribution 1984/86 and 2000/02

The main land use and land cover types in different years for the subset area of the Malagarasi River catchment are represented in Table 2 and in Fig. 4. 5. 6 and 7. The results indicate that in the year 1984/86 the woodland had a bigger cover coverage of 50.1% followed by grassland 17.33%. bushland 10.51%. bareland 9.76%. settlement/cultivation 5.30%. wetland/marsh 4.49%. water 0.67% and forest 0.63% of the total subset area of 8 093 301 ha. The area under forest which occupied 52 535.68 ha (0.63%) in 1984/86 increased to 83 171.8 ha (1.03%) in 2000/02. indicating an increase in cover area of about 0.38%. Bushland increased from 851 002.45 ha (10.51%) to 1 144 393.32 ha (14.14%). grassland increased from 1 402 296.67 ha (17.33) to 1 889 554.15 ha (23.35%) and settlement/cultivation increased from 429 119.96 ha (5.30%) to 510 155.54 ha (6.30%) between the two periods under consideration.

Table 2: Area coverage for different land use and land cover in the Malagarasi river catchment in 1984/86 and 2000/02

Cover type /land use	1984/86		2000/02		Difference	% change
	Cover Area (ha)	% cover coverage	Cover Area (ha)	% cover coverage		
FO	52 535.68	0.65	83 171.80	1.03	-30 636.12	-0.38
WD	4 054 761.7	50.10	3 989 114.24	49.29	65 647.42	0.81
W	54 547.95	0.67	83 472.34	1.03	-28 924.39	-0.36
BS	851 002.45	10.51	1 144 393.32	14.14	-293 390.88	-3.63
GR	1 402 296.7	17.33	1 889 554.15	23.35	-487 257.49	-6.02
WET	363 505.11	4.49	199 101.32	2.46	164 403.78	2.03
SET	429 119.96	5.30	510 155.54	6.30	-81 035.58	-1.00
BR	789 514.96	9.76	137 526.35	1.70	651 988.61	8.06
CL	14 099.77	0.17	39 826.97	0.49	-25 727.21	-0.32
CLS	81 917.12	1.01	16 985.29	0.21	64 931.83	0.80
Total	**8 093 301**	**100**	**8 093 301**	**100**	-	-

Note: FO= Forest: WD= Woodland: W= Water: BS= Bushland: GR= Grassland: WET= Wetland vegetation/Marsh; SET= Settlement/Cultivation: BR= Bareland/Burnscars: CL= Clouds: CLS= Cloud shadow

While forest, bushland, grassland and settlement/cultivation increased in total area, woodland, wetland and bareland areas registered a decline in area coverage between the two periods. Woodland declined from 4 054 761.67 ha (50.1%) of total cover area in 1984/86 to 3 989 114.24 ha (49.29%) in 2000/02; whereas wetland area declined from 363 505.11 ha (4.49%) in 1984/86 to 199 101.32 ha (2.46%) in 2000/02 and bareland declined tremendously from 789 514.96 ha (9.76%) in 1984/86 to 137 526.35 ha (1.7%) in 2000/02. The woodland continued to occupy the largest area followed by grassland, bushland, settlement/cultivation, wetland/marsh, bareland and both water and forest occupied 1.03% of the total area. The images in the remaining areas were covered by clouds and cloud cover and so could not be properly analysed.

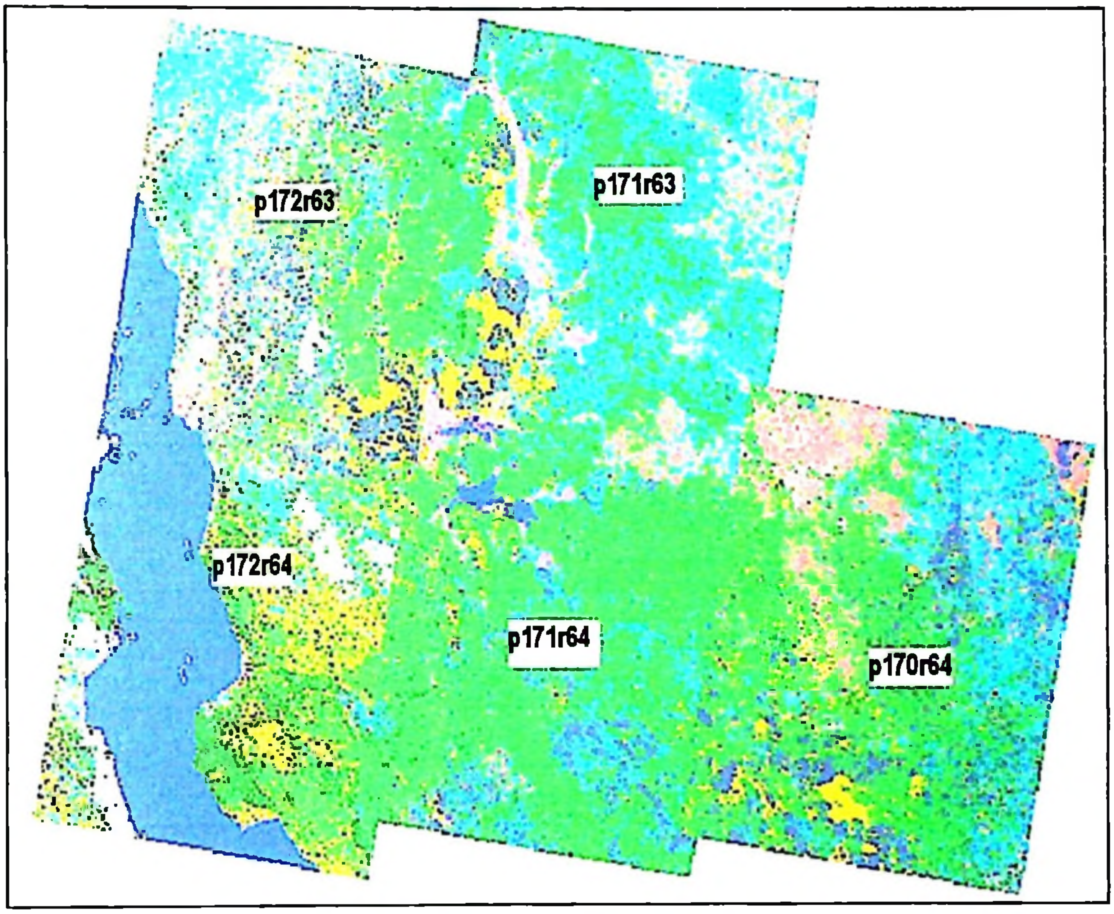

Figure 4: Mosaic composite of the study area windowed from Landsat imagery

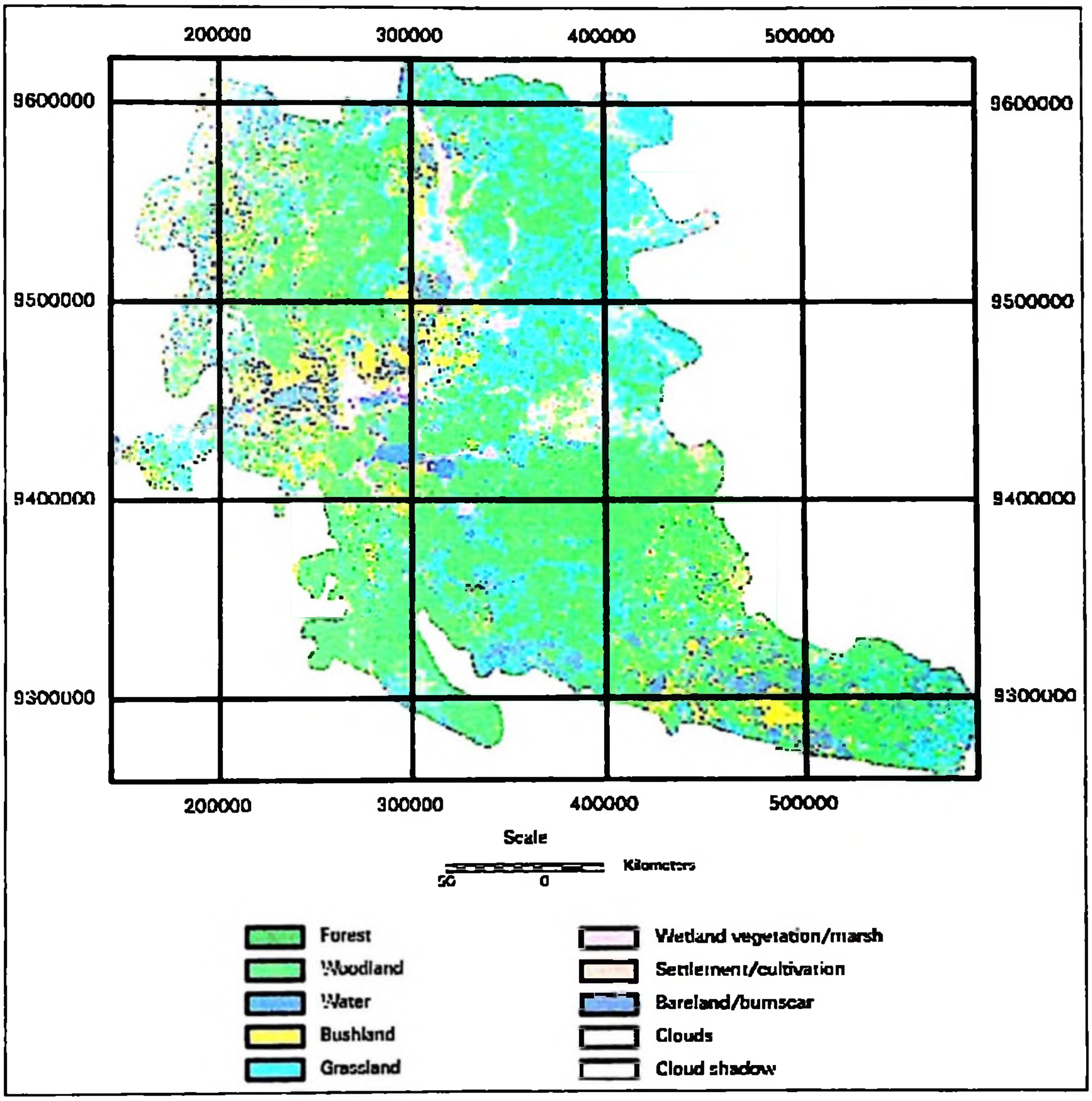

Figure 5: Land use and land cover map (1984/86)

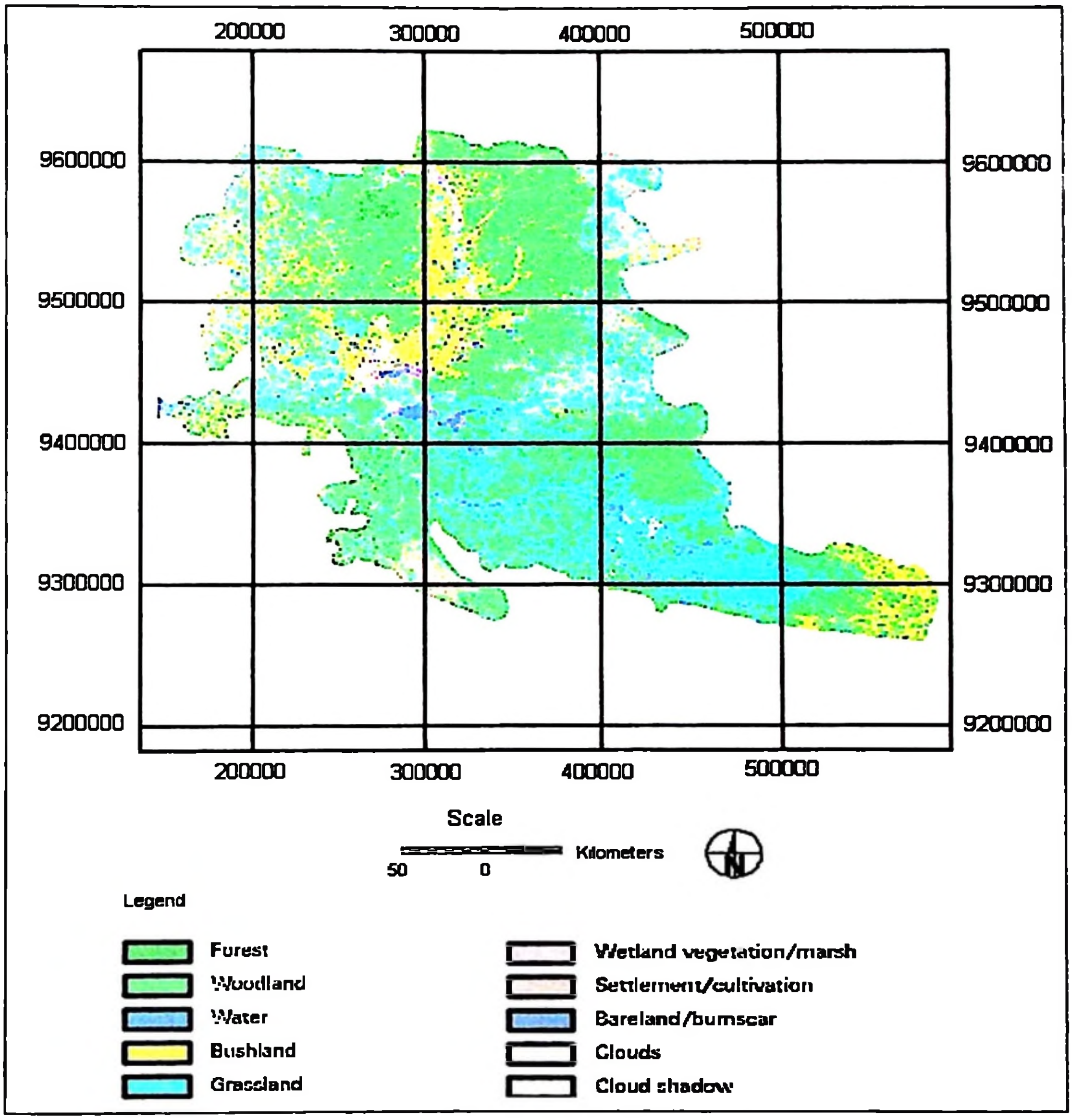

Figure 6: Land use and land cover map (2000/02)

4.2 Extent of Land Use/Cover Change for 1984/86 and 2000/02

Mbilinyi (2000) argued that, a simple analysis based on subtracting area may often be misleading and in principle, should be supplemented by an analysis of change detection matrix. In order to understand how the cover classes changed from 1984/86 to 2000/02, the change detection matrix showing the area conversion between cover classes were calculated and presented in Table 3.

Table 3: Changes detection matrix in different land use/cover coverage (ha) between 1984/86 and 2000/02

Cover (ha)	Cover (ha) 2000/02										
1984/86	FO	WD	W	BS	GR	WET	SET	BR	CL	CLS	Total
FO	(17 695.4)	19 625.8	186.7	4 788.8	5 926.6	2 656.9	904.1	588.0	54.8	108.8	52 535.7
WD	52 579.2	(2630 167.7)	7 905.0	272 514.5	844 317.1	47 427.9	147 483.1	36 154.7	10 949.1	5 263.5	4 054 761.7
W	76.5	882.2	(34 428.9)	1 346.6	721.3	16 252.2	109.3	264.9	165.0	301.2	54 548.0
BS	1 907.2	248 280.4	6 267.0	(263 214.3)	242 252.3	23 902.3	17 177.7	33 153.2	11 388.2	3 460.0	851 002.5
GR	3 203.6	671 781.3	10 820.8	227 721.1	(340 913.1)	17 678.7	101 161.8	24 051.6	3 502.2	1 462.5	1 402 296.7
WET	5 084.4	81 557.5	18 583.6	107 697.8	48 081.6	(73 726.0)	5 073.4	10 144.0	9 172.6	4 384.4	363 505.1
SET	89.0	85 047.7	103.2	38 344.9	114 769.1	1 004.9	(18 7852.2)	1 086.5	521.1	301.3	429 120.0
BR	1 162.3	222 482.7	4 677.2	195 174.5	272 263.3	14 391.9	44 250.4	(29 642.7)	4 031.6	1 438.4	789 515.0
CL	83.1	3 428.1	26.7	5 576.0	3 600.8	128.3	908.2	333.9	(8.1)	6.5	14 099.8
CLS	1291.2	25 861.1	473.5	28 014.8	16 709.0	1 932.3	5 235.4	2 106.9	34.3	(258.8)	81 917.1
Total	**83 171.8**	**3 989 114.2**	**83 472.3**	**1 144 393.3**	**1 889 554.2**	**199 101.3**	**510 155.5**	**137 526.4**	**39 827.0**	**16 985.3**	**8 093 301.0**

Note: FO= Forest; WD= Woodland; W= Water; BS= Bushland; GR= Grassland; WET= Wetland vegetation/Marsh; SET= Settlement/Cultivation; BR= Bareland/Burnscars; CL= Clouds; CLS= Cloud shadow

-Numbers in brackets indicate cover areas that remained unchanged between the two periods

Table 4 summarizes changes in different cover over the two time periods of 1984/86 and 2000/02. The percentage changed indicates the percentage area of a particular cover which changed to other covers while the percentage unchanged represents the percentage area of the original area of a particular cover which remained unchanged for a given period.

Table 4: Percentage changes of different land cover for the period of 1984/86 to 2000/02

Cover name	% Cover unchanged	% Cover changed
Forest	33.68	66.32
Woodland	64.87	35.13
Bushland	30.93	69.07
Grassland	24.31	75.69
Wetland Vegetation/Marsh	20.28	79.72
Settlement/Cultivation	43.78	56.22
Bareland/Burnscars	03.75	96.25

Considering the two periods under study (Table 4), the coverage by forest changed to other forms of cover by 66.32%, bushland by 69.07%, grassland by 75.69%, settlement by 56.22 from 1984-86 to 2000/02, while woodland decreased to 64.87%, wetland to 20.28% and bareland to 3.75%. The trend shows that the forest, bushland, grassland cover were improving toward year 2000/02 as compared to the period from 1984/86.

Table 5 present the detected changes in various cover for the period of 1984/86 and 2000/02 deduced from the change detection matrix. The arrow in each row indicates a conversion "from.....to".

Table 5: Detected changes in percentage cover from 1984/86 to 2000/02

Change (from-to)	1984/86 to 2000/02	
	Area (ha)	% of the cover
FO →WET	2 656.87	5.06
FO → SET	904.12	1.72
FO →BR	587.99	1.12
WD →FO	52 579.22	1.30
WD →BR+GR	1 116 831.57	27.54
WD → WET	47 427.85	1.17
WD → SET	147 483.08	3.64
WD → BR	36 154.71	0.89
WET → BS+GR	155 779.40	42.85
WET → SET	5 073.39	1.40

Considering the periods 1984/86 and 2000/02. 52 579.22 ha (1.30%) of woodland changed to forest. 1 116 831.57 ha (27.54%) to bushland and grassland. 47 427.85 ha (1.17%) to wetland vegetation/swamp. 147 483.08 ha (3.64%) to settlement/ agriculture and 36 154.71 ha (0.89%) to bareland/ burn scars. There is also significant change of 155 799.40 ha (42.85%) from wetland vegetation/swamp to bushland and grassland, implying encroachment of wetland vegetation by other swamp vegetations species and 5 073.39 ha (1.40%) changed to settlement/ cultivation. This gives an implication of increased area under dry season farming along the wetlands, river and lakes banks that has been noted in the catchment.

4.3 The Rate of Cover Change in the Malagarasi River Catchment

The temporal periods 1984/86 and 2000/02 have experienced considerable land use and land cover changes. Table 6 presents the changes in area of the different land use and land cover types in the catchment for the two periods under study. Fig. 8. 9 and 10 are maps showing the changes in woodland: wetland and forest covers between 1984/86 and 2000/02

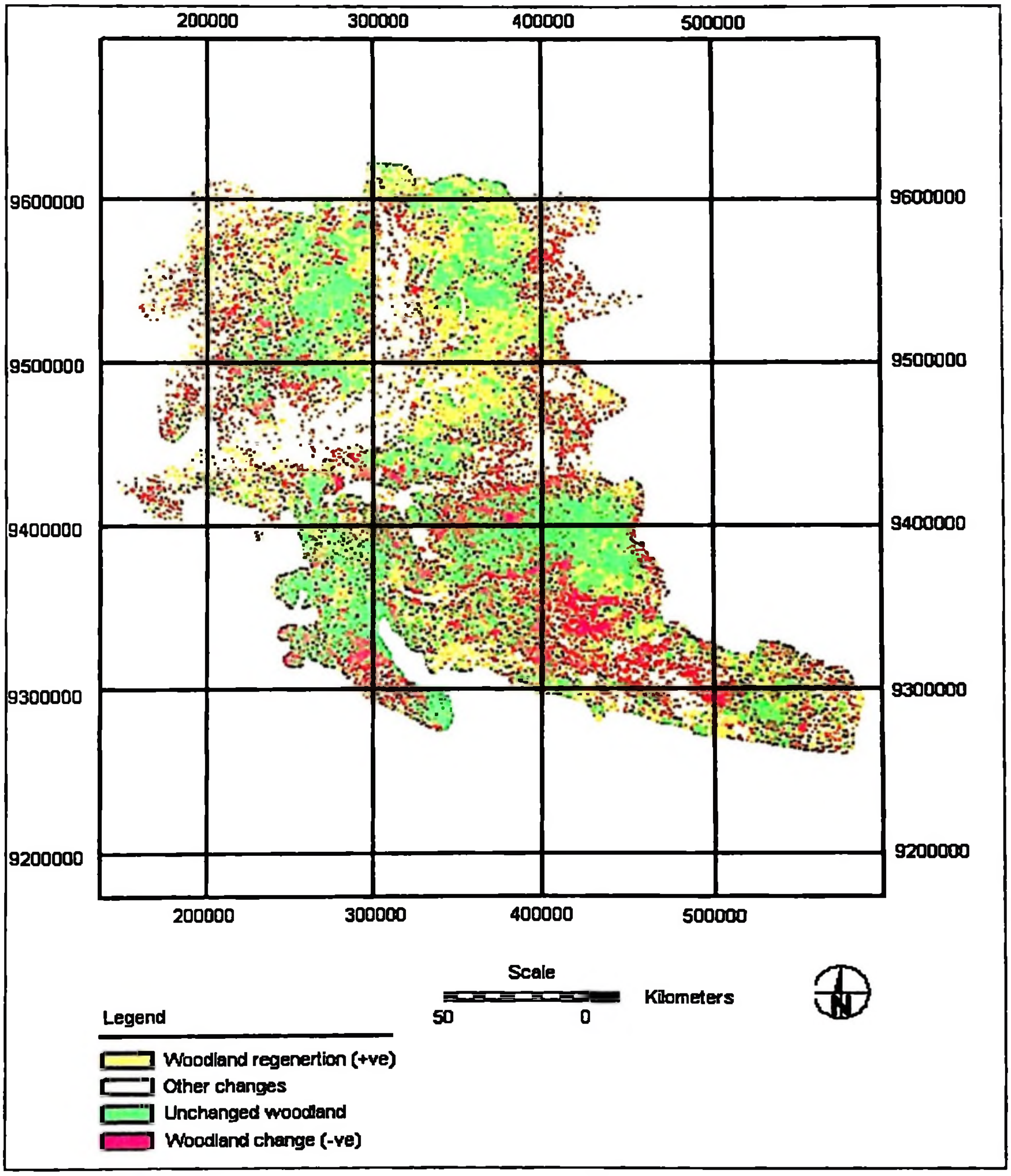

Figure 7: Land cover change for woodland from 1984/86 to 2000/02

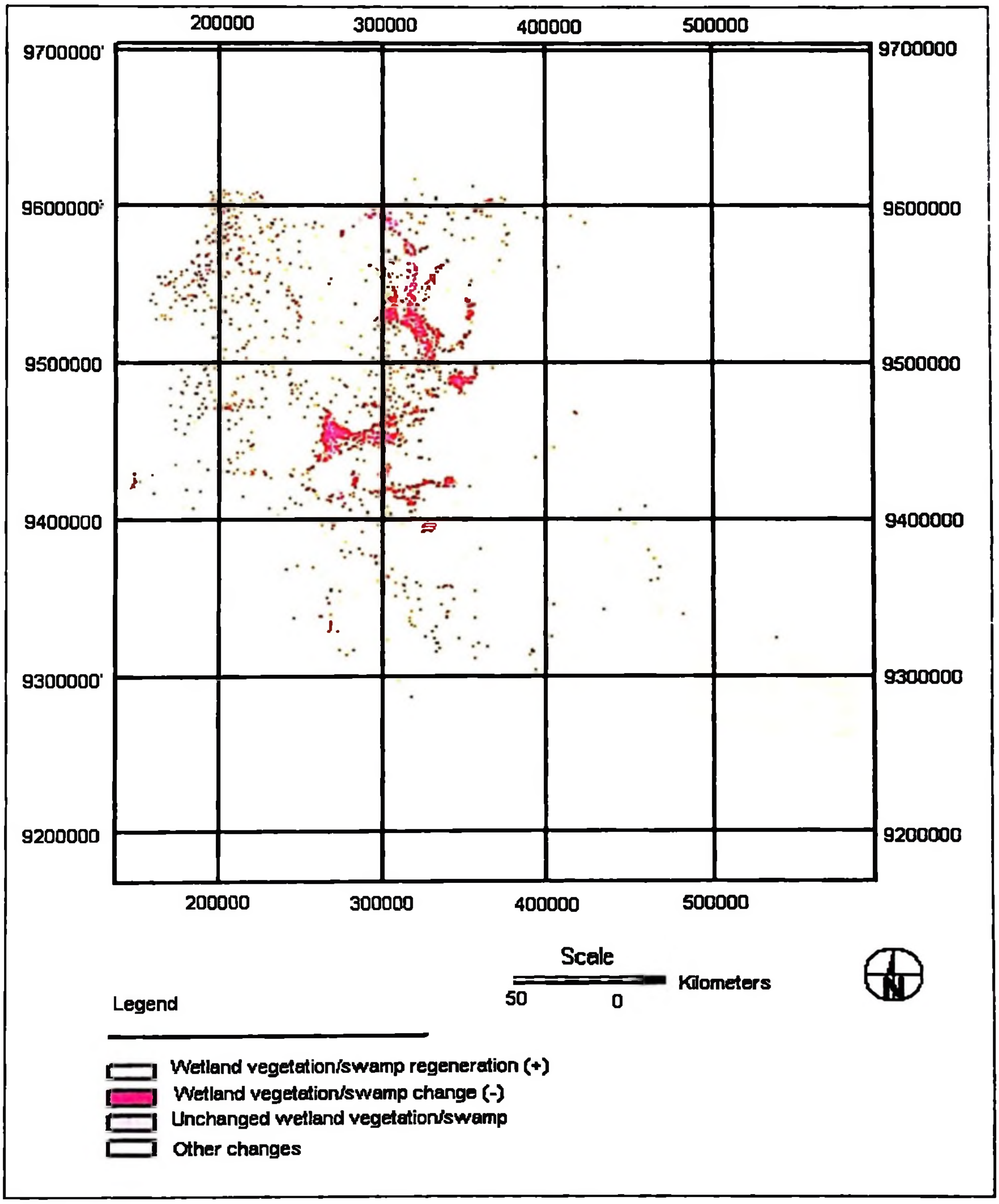

Figure 8: Land cover change for wetland from 1984/86 to 2000/02

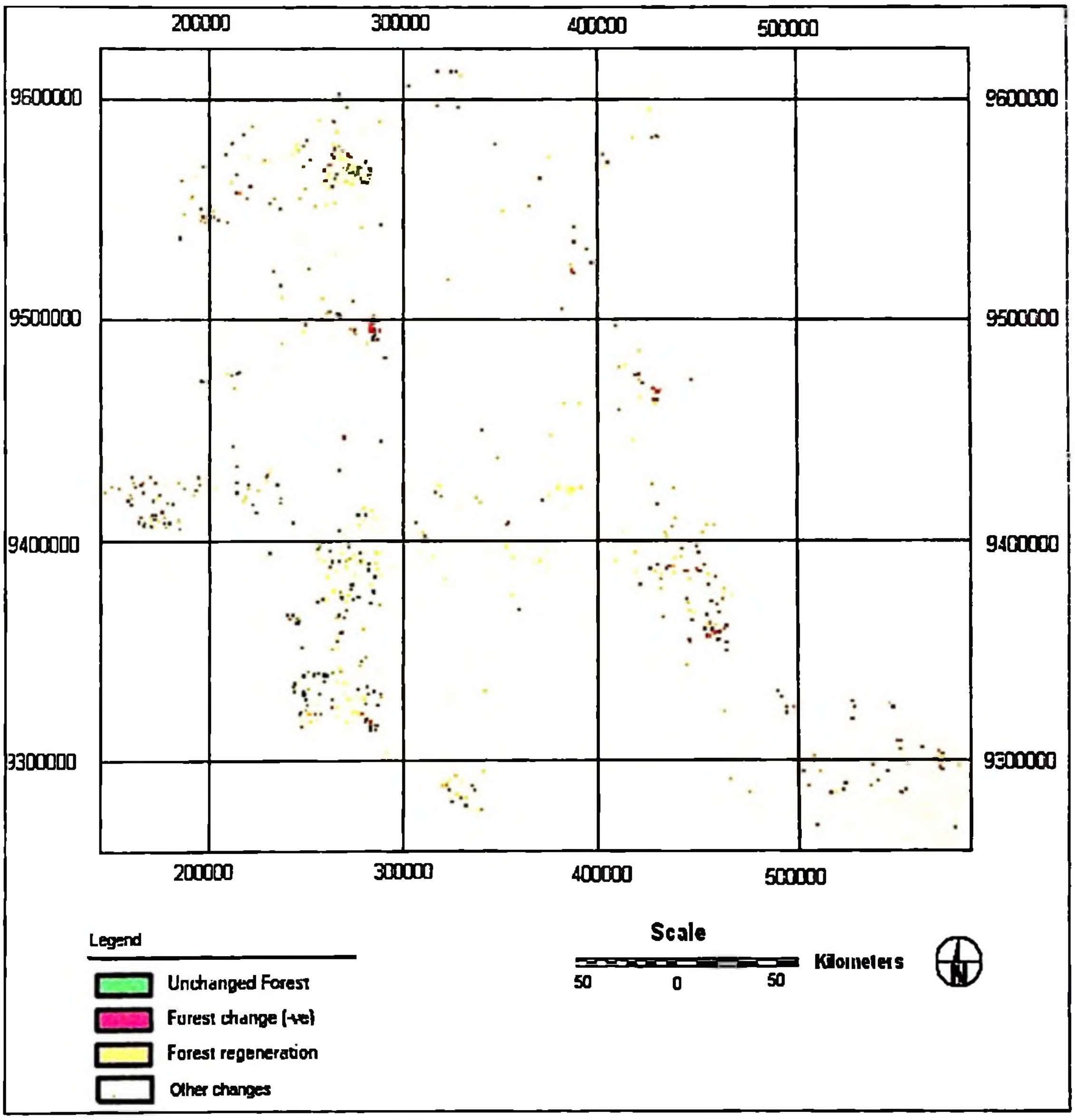

Figure 9: Land cover change for forest from 1984/86 to 2000/02

Table 6: Changes of different land use and land cover coverage (ha) in the Malagarasi river catchment between 1984/86 and 2000/02

Class name	1984/86	2000/02	Change period (18 years)		
	Area (ha)	Area (ha)	Difference	Annual rate of change (ha/yr)	% annual rate of change (%/yr)
Forest	52 535.68	8 3171.80	+30 636.12	+1 702.01	+3.24
Woodland	4 054 761.67	3 989 114.24	-65 647.42	-3 647.08	-0.09
Water	54 547.95	83 472.34	+28 924.39	+1 606.91	+2.95
Bushland	851 002.45	1 144 393.32	+293 390.88	+16299.49	+1.92
Grassland	1 402 296.67	1 889 554.15	+487 257.49	+27069.86	+1.93
Wetland vegetation	363 505.11	199 101.32	-164 403.78	-9 133.54	-2.51
Settlement/ cultivation	429 119.96	510 155.54	+81 035.58	+4 501.98	+1.05
Bareland/ burnscar	789 514.96	137 526.35	-651 988.61	-36221.59	-4.59

It is apparent from the Table 6 that while forest cover was increasing at the rate of 1 702.01 ha (3.24%) per year for the periods between 1984/86 and 2000/02, other cover type's woodlands, wetland vegetation/marsh and bareland were observed to decrease during the same period of time. The trends suggests an increase in coverage from one cover (e.g. woodland) to another (e.g. forest) which could be due to either decrease in human disturbances in the catchment after declaration of Malagarasi – Muyovozi RAMSAR site during 2000s or re-generation of bareland/burnscar to either bushland or grassland and may be from woodland cover, wetland vegetation to the forest cover.

Bushland and grassland cover area increased at a rate of 16 299.49 ha (1.92%) and 27 069.86 ha (1.93%) per year between 1984/86 and 2000/02. These major and rapid increases might be due to the rapid re-generation of lowland and bareland cover area within the catchment or due to clearance of trees (woodlands) for firewood and increased agricultural activities (tobacco farms and subsistence farming).

Wetland vegetation/marsh cover decreased at the rate of 9 133.54 ha (2.51%) per year between the two periods. The study (Table 6) has revealed the change of wetland vegetation to bushland and grassland of about 42.85% and to settlement/cultivation 1.40%. The expansion of settlement/cultivation reflected land use transformation in the catchment. This was also revealed during interviews with local people who have stayed in the area for a along period of time. About 55 % of the respondent reported cutting trees and fire burning to be serious problem in recent years (Table 10). The main factors mentioned as contributing to the trend of deforestation were commercial logging, charcoals production. population growth and the expansion of commercial farming and food crops production.

4.4 Accuracy for the Detected Changes and Limitations

In this study some variations on the detected changes have been noted. For example change from forest to wetland vegetation cover and change from water to woodland and forest cover. It is highly acknowledged that ecosystem dynamics response is not linear and depends on many factors but most arguably the variation in rainfall patter and distribution (Kashaigili *et al.*, 2006). A linear trend on rainfall in the Malagarasi Catchment revealed that there was no significant increase in rainfall amount between the two periods. It is possible that the variations are due to plant phenological effects and spectral resolutions. The different plant phenological effects are related to which season an image is acquired on the ground. Studies have shown that dry season is the most desirable period for image change analysis. As noted by Burns and Joyce (1981 in Kashaigili *et al.*, 2006) selecting the driest period of the year for change analysis will enhance spectral similarity due to excessive wetness prevailing during other periods of the year. The wet season spectral separability, which is responsible for class assignment, becomes somewhat difficult and may result into misclassification of some of the classes which results into under or over-classification. This is likely to be the source of variation in detected changes as images used for this study were obtained in both wet and dry season (Table 1).

4.5 The Hydrological Pattern of Malagarasi River

This study scrutinized the effects of land use and cover changes in the Malagarasi catchment on the water flows. This was due to the fact that in the southern floodplains of the lower catchment, Burundi Tutsi refugees and their cattle were settled in the area since early 1970's. Furthermore, the influx of refugees since 1994 were believed to have impacted on the resources of the Malagarasi river catchment and there has been more than 10 refugee camps hosting an estimated 280 000 refugees from Burundi and the DR Congo at various locations around the boundary of upper and lower catchment (normally 10-30 km from the boundary) intensified with cultivation in forest land and wetlands in surrounding areas. Due to these anthropogenic activities around and within the catchment there was a need to investigate their impact to cover change which may have negative impact to the water flow.

4.5.1 Annual rainfall and flow discharge

Fig. 10 and 11 present the time series of annual rainfall within the catchment, while Fig. 12 presents the time series of annual flow in the Malagarasi as recorded at Mbelagule

Station (4A9) for the from1975 to 2002. More rainfall was recorded in higher catchment (Kibondo station) as compared to that of lower catchment (Nguruka station) Fig.10 and 11. The mean annual flows (Fig. 12) showed a declining pattern from 1990 up to 2000 when the *El Nino* year (1998) is excluded. The dry season flow (June-October) (Fig. 13) shows a declining pattern especially since the 1989s and 1997 with the exceptional of the 1997/98 *El Nino* year. There has been increasing in flow during 2000's (Fig.13) indicating land use and cover change due to increased human activities such as deforestation, fire, cultivation and overgrazing (Table 10).

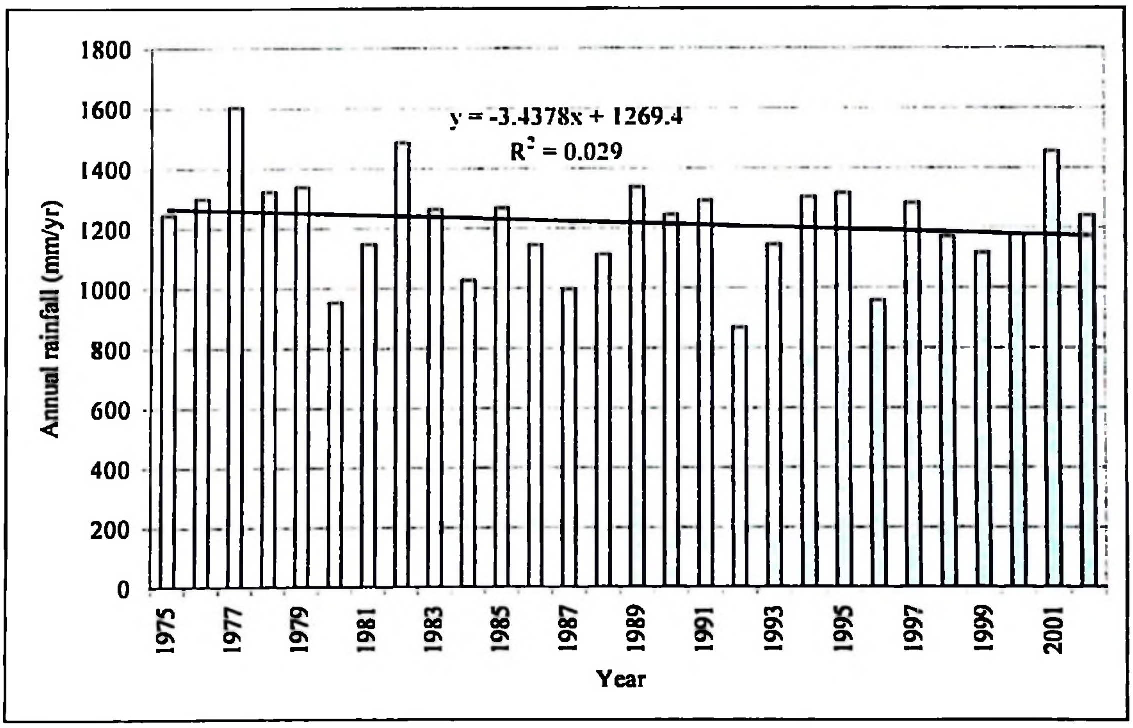

Figure 10: Annual rainfall at Kibondo station 1975 - 2002

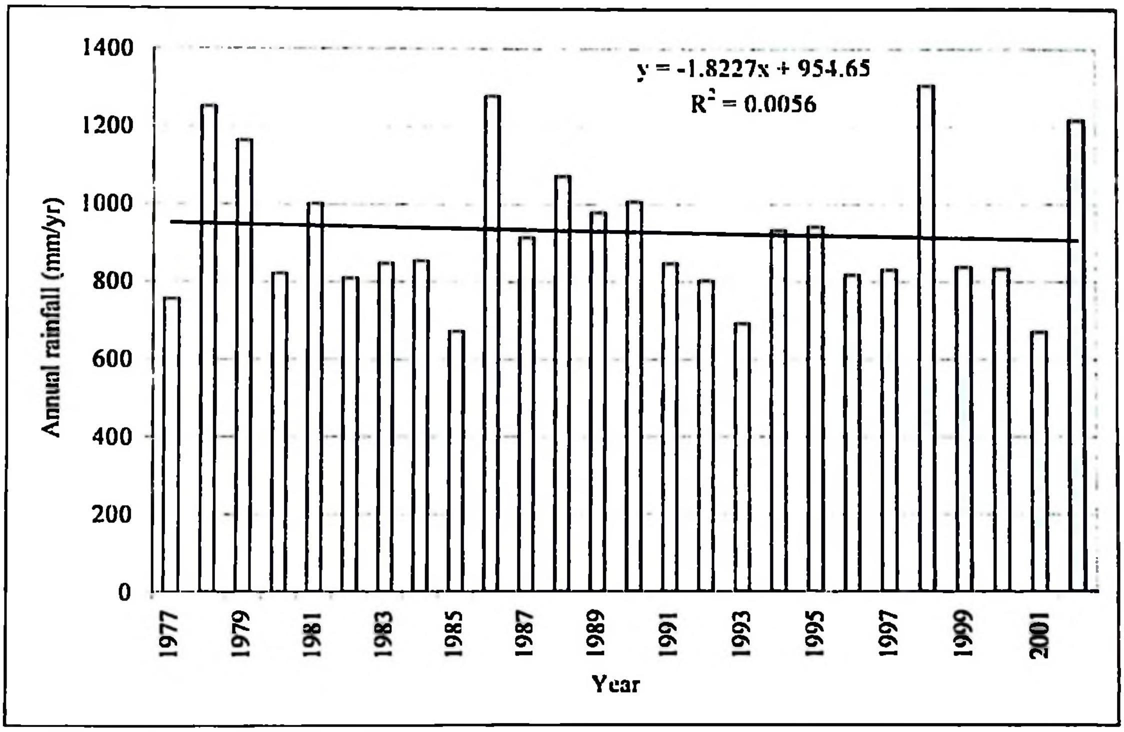

Figure 11: Annual rainfall at Nguruka station 1976 - 2002

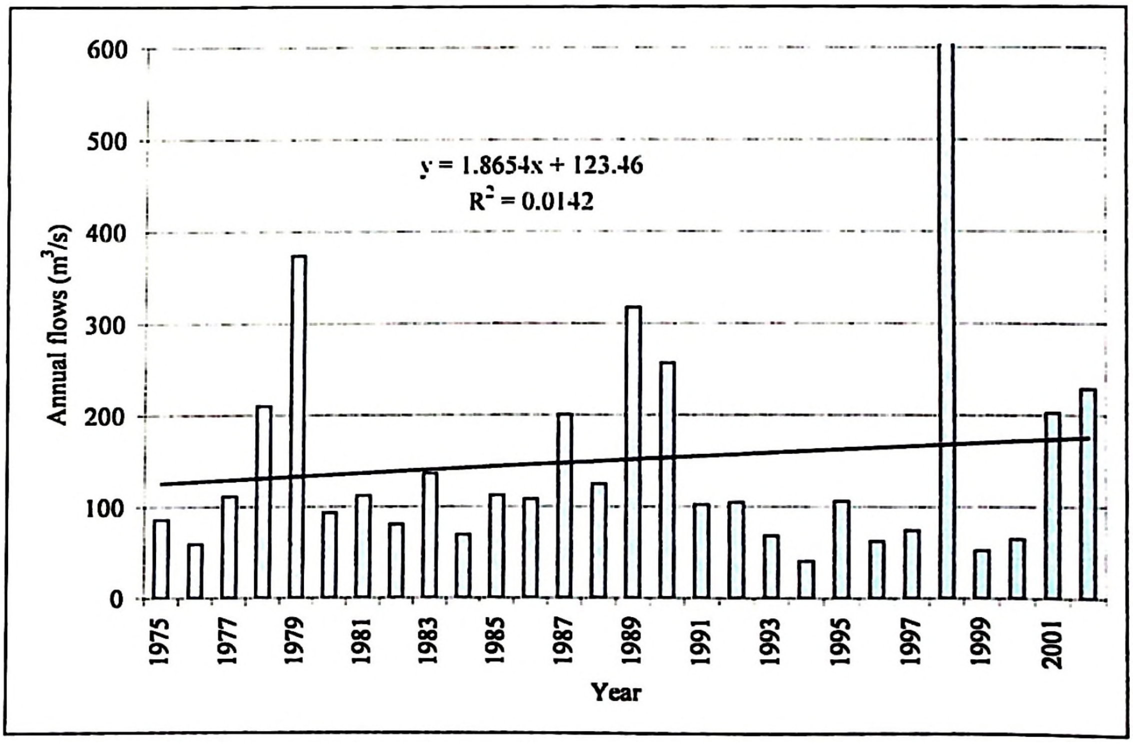

Figure 12: Annual flow in the Malagarasi River at Mbelagule Station (4A9)

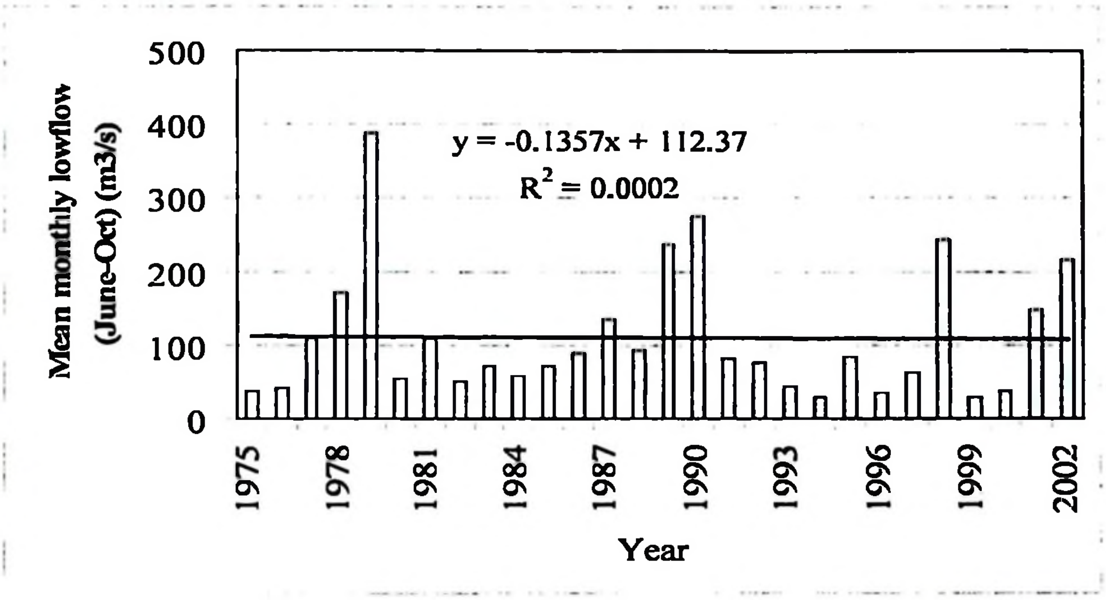

Figure 13: Dry season flows (June-October) in the Malagarasi River at Mbelagule Station 4A9 (1975-2002)

Table 7 presents results of trend analysis on rainfall over the Malagarasi catchment (Kibondo and Nguruka rainfall station). The slope of the trend line (Table 7) is negative indicating a downward declining trend, but not statistically significant at the 95% level of significance. This shows that the high runoff generated in wet season is associated with land use and cover change and is linked to the increased water flows in the river.

Table 7: Statistical trend in annual rainfall at Kibondo and Nguruka stations

Parameter Description	Start year	End year	No. of years	t-statistics	t-critical	Remarks
Kibondo	1975	2002	28	-1.160	2.056	Not a significant decreasing trend
Nguruka	1975	2002	28	-1.081	2.056	Not a significant decreasing trend

Table 8 present trends in annual and dry season river flow at Mbelagule station (4A9). The results indicate that there was no statistical significant increasing trend in the annual flows. The slope of the trend line for the dry season flows indicated a negative declining trend. but when tested did not reveal a statistical significant decreasing trend in the dry season river flows for the Malagarasi River at 95% level of significance.

Table 8: Statistical trend in annual and dry season river flow at Mbelagule station

Parameter Description	Start year	End year	No. of years	t-statistics	t-critical	Remarks
Annual flow at Mbelagule	1975	2002	28	0.784	2.056	Not a significant increasing trend
Dry season flow at Mbelagule	1975	2002	28	-0.842	2.056	Not a significant decreasing trend

The annual trend analysis on the effect of *El Nino* rains of 1998 on the flow regime was conducted and results are presented in Table 9, Fig.12 and 14. The analysis of annual flows with *El Nino* rains showed an increasing trend as portrayed by the slope of the trend line but statistically insignificant at 95% level of significance. The with *El Nino* rains consideration showed a declining trend as revealed by the slope of the trend line but was statistically insignificant at 95% level of significance.

Table 9: Trend analysis on annual flow with and without *El Nino* year of 1998

Parameter	Start year	End year	No. of years	t-statistics	t-critical	Remarks
Annual flow with *El Nino*	1975	2002	28	0.448	2.056	Not a significant increasing trend
Annual flow without *El Nino*	1975	2002	27	-1.199	2.060	Not a significant decreasing trend

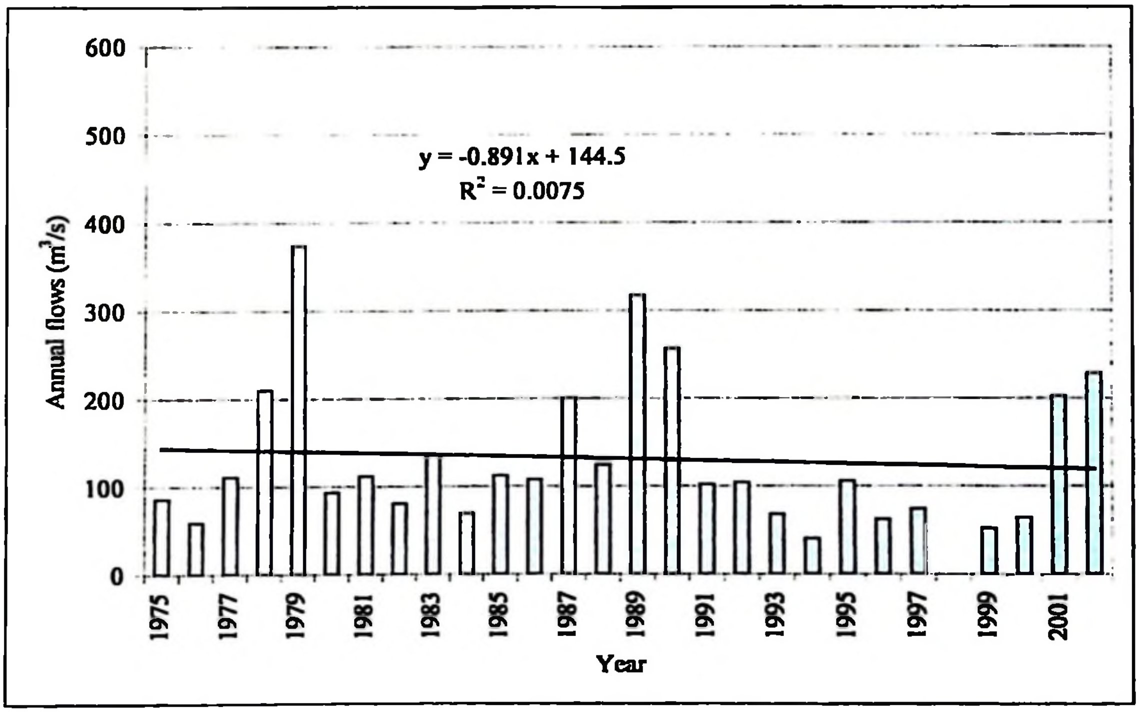

Figure 14: Annual flow in the Malagarasi River without El Nino year of 1998

Therefore, it can be argued that the detected changes in land use and cover have not statistically affected the river flows in the Malagarasi river catchment despite the negatively declining flows as revealed by the slope of the trend lines.

4.5.2 Mean monthly stream flow

Fig. 15 shows the monthly flow regimes for Malagarasi River (based on Mean monthly stream flow). There is slight change in the time of occurrence of peak flows for the 1981-2002 as shown in (Fig. 15) and it is possible that, this has contributed much to attainment of higher flows in April as compared to 1975-1980 periods which occurred in May (Fig. 15). The mean monthly flows including peak flow is higher between mid May and October for the 1975-1980 and lower between mid April and October for the years 1981-2002. The peak flow shifted from 369 m^3/s in May to 310 m^3/s in April. This implies that the flow regimes in the Malagarasi River is decreasing and is probably associated with the increasing cover change in the catchment.

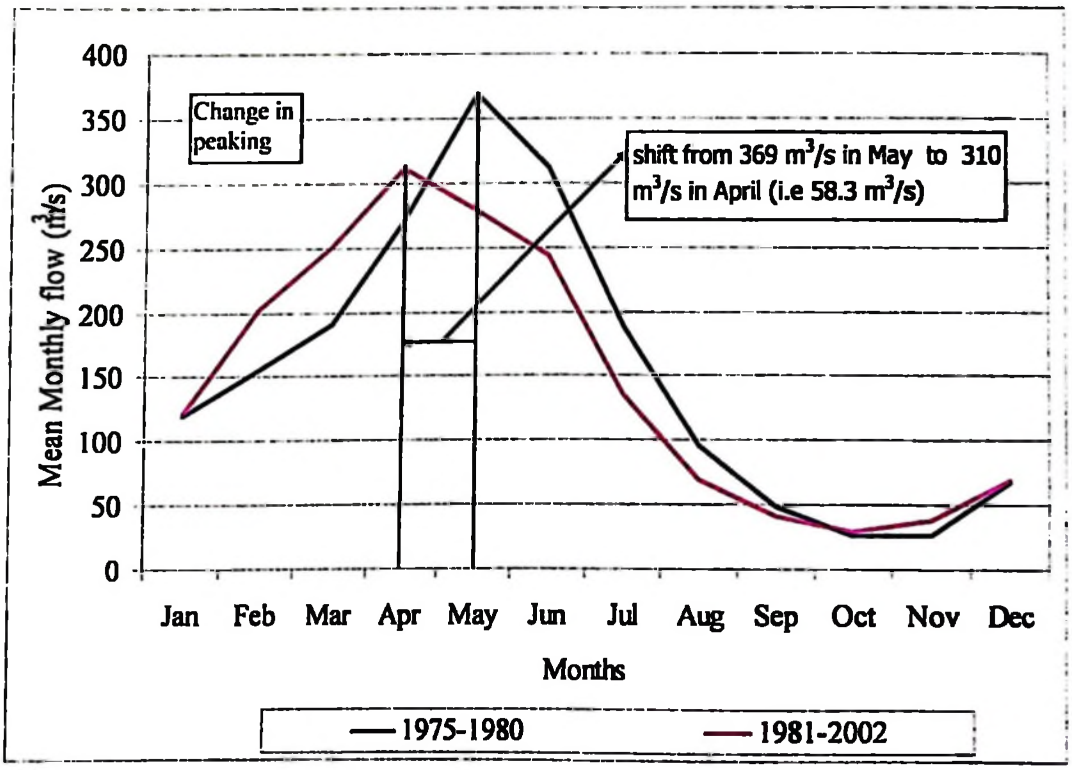

Figure 15: Mean monthly stream flow for Malagarasi River at Mbelagule station between 1975-1980 and 1981-2002

4.5.3 Dry and wet season flows

Fig. 16 shows the dry (June to October) and wet (November to May) season hydrographs for the Malagarasi River between the two period of 1975-1980 and 1981-2002. This study revealed that, during the dry season (June to October) stream flow decreased during both periods, with higher flow in 1981-2002 than that of 1975-1980.

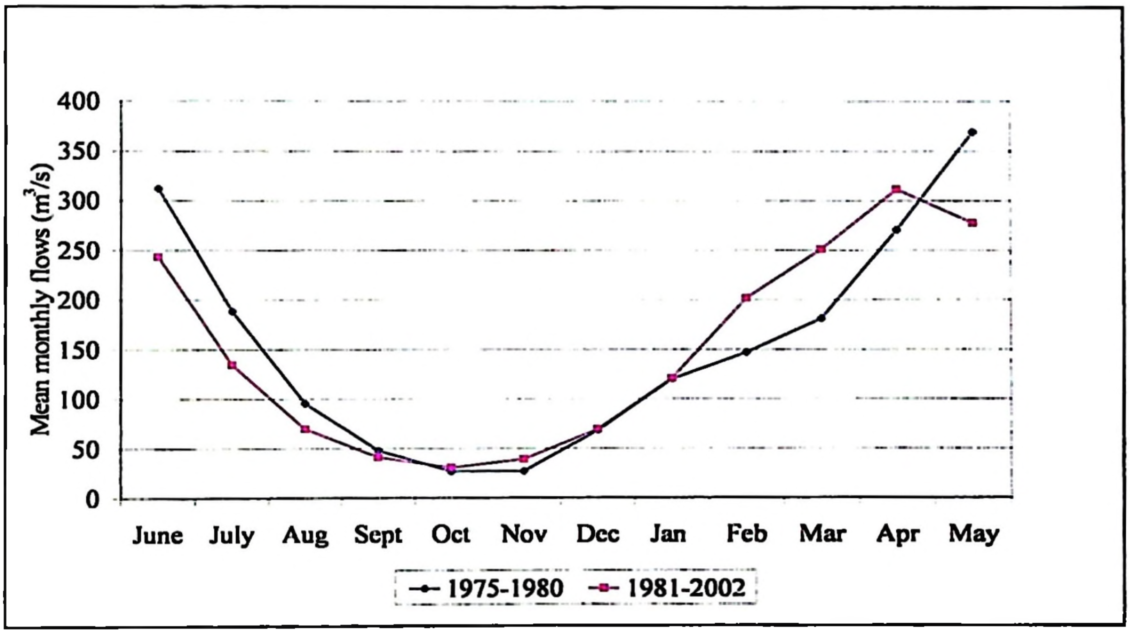

Figure 16: Mean monthly wet and dry season flow between 1975-1980 and 1981-2002

During the rainy season (November to May) the flow was high for 1981-2002 periods as compared to that of 1975-1980. This gives an indication that land cover change in the catchment during 1980-2002 contributed to early attainment of peak flow (April) as compared to that of May in 1975-1980 (Fig.16).

4.5.4 Flow duration curve for Malagarasi River

The flow duration curve (FDC) is a relationship between any given discharge/value and the percentage of time that the discharge is equalled or exceeded at a given location over some historic period. It is a plot of discharges (Q) versus the percent of time (t) during the period of the record of the trend in which the particular discharge is equalled or exceeded;

without consideration for chronology of the individual flow (USAGE, 1997; Post, 2004). It provides a graphical summary of stream flow variability (Smakhtin, 2001). Fig. 17 and 18 presents the mean monthly flow duration curves for Malagarasi River to illustrate the differences between flows in the two different time periods.

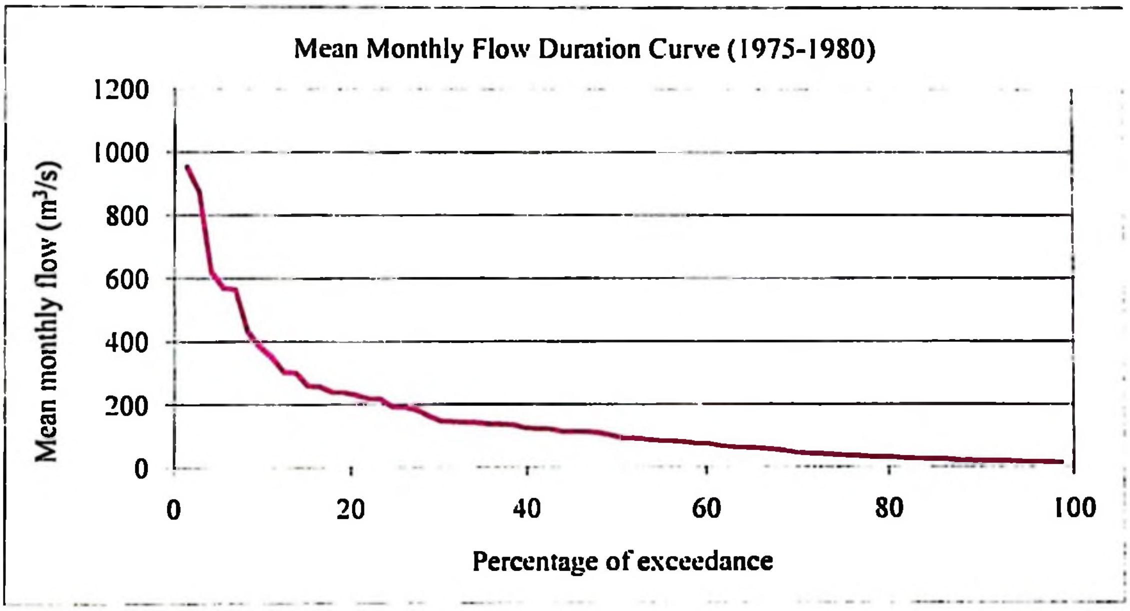

Figure 17: Mean monthly flow duration curve of Malagarasi River (1975-1980)

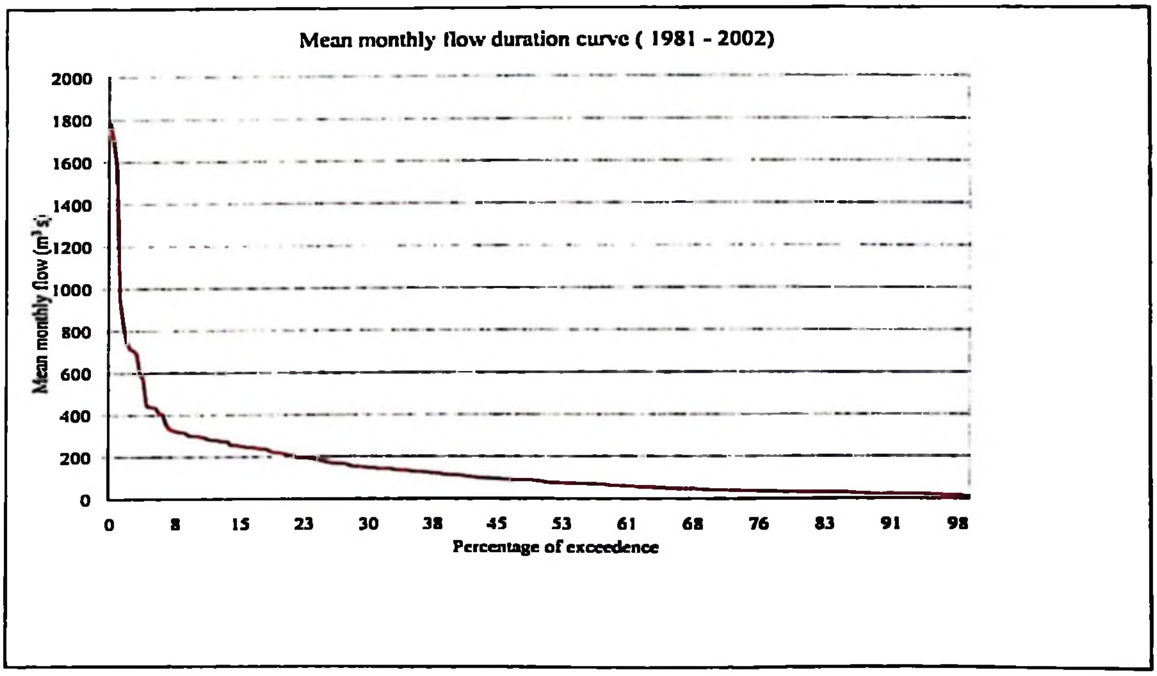

Figure 18: Mean monthly flow duration curve of Malagarasi River (1981-2002)

Flow duration curves are useful for determining the variability or flashiness of stream flow as well as how the discharge of a stream is sustained over time. These factors are determined by many variables including climate, watershed land cover and land use, soil type, and topography. Flow duration curves have been plotted for Malagarasi River at Mbelagule using mean monthly flow data (Fig. 18 and 19).

The slopes of flow duration curve are relatively steep at the higher discharges for 1981-2002 than for 1975-1980 indicating that flood discharges are infrequent or not sustained for long periods of time. In general the curves seem flatten out considerably indicating well sustained stream discharges over extended periods of time. This is partially attributable to the storage capacity within the watershed and surrounding area.

Table 10 shows flow characteristics extracted from the monthly flow duration curves (Fig. 17 and 18). The flow indices indicate that between Q_{10} and Q_{75} the flow was higher for the period of 1975-1980 as compared to that of 1981-2002. The upward shift of the flow duration curve reflects an overall increase in discharge in the latter time period. The changes in the shape of the flow duration curve and discharge rates are some of the possible indication of changes in precipitation (intensity, amount, seasonal timing, and duration etc.), watershed land cover/land use, and/or changes in the groundwater system.

Table 10: Indices of flow characteristics extracted from Monthly FDC

Period	Flow indices						
	Q_{10}	Q_{25}	Q_{50}	Q_{75}	Q_{90}	Q_{95}	Q_{99}
1975-1980	373.46	191.30	95.85	37.11	18.96	15.40	13.03
1981-2002	299.04	180.34	85.57	35.72	19.50	17.52	9.65

4.6 Linkages between Land Use/Cover Changes and Flow Regime

There is a clear link between the detected changes in land use and cover change on the hydrological regime for Malagarasi River (Table 2) and (Fig. 12. 13). The overall area coverage shows that there positive land use and cover change. Although the trend analysis did not reveal any statistical significant increasing or decreasing trend in river rainfall and flows: the change in river flow patterns associated with early attainment of peak flows in later period, the changing shape of the flow duration curve and the change in flow indices are good indicators that there has been negative impacts resulting from the changes in land use and cover in the catchment.

4.7 Respondent Perception on Changes in Land Use and Cover changes

People's perception on environmental change has been very important in setting a clear view of what the stakeholders perceive on utilization of natural resources (Rohr. 2002). Table 10 shows the local people perception on various problems that may be related to observed environmental changes in the Malagarasi River Catchment.

Table 11: Local people perception on the environmental problems in percentages

Problems	Very Serious	Serious	Moderate	Not Serious	Not a Problem
Deforestation	18	55	23	3	1
Availability of firewood	0	23	45	23	8
Drying of streams/river	4	20	26	25	25
Farming along river/lakes	1	9	20	31	39
Overgrazing	16	23	33	23	5
Changes in rainfall	42	18	20	17	4
Loss of soil fertility	48	43	8	2	0
Soil Erosion	1	7	29	18	46
Reduced Crop yield	46	45	8	1	0
Fire	31	55	13	1	0
Average (%)	**21**	**30**	**22**	**14**	**13**

4.7.1 Deforestation and Fire

Among the serious problems in the Malagarasi River catchment are deforestation and fire. About 55 % of the respondent reported cutting trees and fire to have been serious problems in the recent years (Table 10). The main factors mentioned by the respondents as contributing to the trend of deforestation were commercial logging, charcoals production, population growth and the expansion of commercial farming and food crops production. DANIDA (1999) reported agricultural development to dominate the majority of the upper catchment (expansion of tobacco plantation) but with increasing conversion and utilisation of the lower catchment. This could have significant long-term effects on the ecology of the wetland ecosystem. In their study Misana *et al.* (1996) reported that increased clearing of land for agriculture and grazing is a growing problem in Tanzania and these has increased pressure on fragile land and other biological resources in the area.

Another observed reason for deforestation other than those mentioned above is cutting of trees for tobacco curing. though 45% of the respondents admit availability of firewood as not a big problem. The study revealed that the problem of cutting trees has been intensified from the use of firewood for tobacco curing. The findings are consistence with that of Abdallah (2005). who reported similar observation in Iringa region that the use of firewood for curing tobacco is increasing each year. and that the situation has an implication to the cover changes of affected areas.

Since the activities are done in open access area (resource available to anyone) the ongoing harvesting of tree without taking into account of its replacement capacity may lead to the conversion of the land cover. and to the depletion as well as complete disappearance of riparian cover important for the catchment ecosystem. The study agrees with the FAO (1999) that general land forest basically denotes an open access regime with no tenure structure or formally guaranteed user rights and hence no incentives for systematic sustainable forest management are unlikely to elicit investment in maintenance or sustainable utilization. This is the case in the Malagarasi – Muyovozi area, where the general land is subjected to open access. The principle of open access to general land in the catchment is thus responsible for abuse in these lands, leading to land degradation (Mahinya, 2005).

4.7.2 Loss of soil fertility and reduced crop yield

Loss of fertility and reduced crop yield has been mentioned as contributing factors to the trend of environmental degradation in the Catchment. While was not easy for the community in the area to perceive it, the conversion has also implied that nature's capacity of reduction and retention of nutrients has diminished. A decline in agricultural productivity is the result, and has accompanied by serious household food insecurity (Mwakubo *et al.*, 2004).

Shifting cultivation (primarily food crops and mainly tobacco) and grazing land has been practiced in the basin for a long time and people have started experiencing gradual depletion of soil nutrients and organic matter. The reason behind has been a result of farming practices in which soil conservation practices are either absent or insufficient. Alex, (2002) and Fischer *et al.* (2001) studies in intensive cropping pointed out that, under continuous cropping with no external inputs, crop land will naturally become depleted of key nutrients (e.g. nitrogen, phosphate and potassium) and organic matter.

4.7.3 Perceptions on stream flow in the Malagarasi River Catchment

During the household surveys, the local people were of the opinion that water flowing in the river is much reduced as compared to the past 20 years. About 63% of the population reported reduced flow as an increasing problem if strong measures will not be taken by the government, and that immediate actions are required to save the river/lakes (Table 11). Elderly respondents with the memories from the past revealed that water in the river and lakes used to flood and fill some parts of the villages. In contrast, today the river doesn't flood, except during the wettest month of the year, mostly in April. Previous studies over the area by DANIDA (1999) revealed that competing and unsustainable uses of land-based resources in the upper catchment areas have affected downstream water flow into the Malagarasi River catchment.

Table 12: Respondents perception on the status of the river and river flow

Statement	Strongly agree	Agree	Not sure	Disagree
Water flow is extremely reduced	8	63	28	0
The reduction of water is caused by deforestation/farming	3	53	39	6
Water is reduced because of drying of lakes	8	50	43	6
Immediate action is required to save river/lakes	20	64	14	2
Average (%)	**10**	**58**	**31**	**4**

4.7.4 Factors contributing to environmental degradation

Amongst the mentioned factors contributing to environmental degradation. poverty, insufficient knowledge on environmental issues, population increase, illicit harvesting of forest products and poor law enforcement emerged as the major factors to the trend of land use and land cover changes in the Malagarasi river catchment (Table 12).

Table 13: Perception on factors contributing to environmental degradation in the catchment

Factors	Agree	Undecided	Disagree
Poverty	87	8	5
Poor law enforcement	85	10	5
Insufficient knowledge on environmental issues	83	9	8

Poverty ranked high among factors as most of the population in the catchment are poor (life standard). The immediate source of livelihood available in the catchment is based on direct exploitation of the catchment natural resources, be in forests, fisheries or most importantly land resources for agricultural production. Increasing resource extraction is likely to accelerate depletion of resources.

The population in Malagarasi Catchment has increased from about 24 800 in 1981 to about 57 698 respectively in 2002, with an average household 5.6 against National average of 4.9 (URT, 2003; Nkotagu and Simon, 2004). Further more: the presence of refugee camps hosting about 280 000 refugees at various locations around the boundary of the site has led to intensified cover changes surrounding the catchment. As a result of growing interferences in the catchment Nkotagu and Simon (2004) reported an increasing rate of lake shallowing.

This study has revealed that population increase in the catchment has challenges to the present land use and land cover change. Studies by (Mung'ong'o, 1995 cited by Nduwamungu, 2002) revealed that a household size is an important variable in determining sustainability of natural resources in an ecosystem. Similarly, finding from baseline studies conducted in Malagarasi-Muyovozi Ramsar site by IRA (2002) pointed out that there is a strong relationship between household size and environmental degradation in the area. This is due to the fact that large household tend to over-exploit their resources in order to meet their needs while so doing undermine their source of livelihood.

From personal observation, most of the households in the area had large number of family members including their dependants. This means that as the average household size increases, poses demand for more resources particularly clearing land for agriculture, and the situation is likely to cause land cover change which may also impair the water flow characteristics in the catchment.

Majority of the population are not aware of the existence of by-laws and regulation restricting cultivation in the water source and riparian zone (Table 13). However. personal observation and discussion with the key informants revealed that people knows the benefits associated with conserving the riparian vegetation in the catchment. The possible explanation is that people in the study area have insufficient knowledge on environmental issues. These findings are in line with other similar study in area (IRA. 2002) who noted a positive correlation between lack of environmental education and resource management in the site.

The low rate of literacy implied that education has a positive and direct influence on environmental degradation in the catchment. Education promote better management of household resources and reduces pressure on easily accessible natural resources like water. grazing land. forest cover in the catchment. and is an ingredient for sustainable natural resources management (Mahinya. 2005). It is among the factors that influence an individual perception for decision making (*ibid*).

Table 14: Peoples knowledge on rules/by laws regarding riverbanks conservation in Malagarasi river catchment

Response	% respondents
By-laws	
- Aware	18
- Not aware	82
Can list some rule/by-laws	Village rule/government
- At least one rule	14
- Can not list any but aware	5
- Not aware of any	81

4.7.5 Perception on rainfall amount and patterns in the catchment

As far as rainfall is concerned, 42% of the respondents agreed on the changes in rainfall amount and patterns as becoming a serious problem in the area (Table 11). During the discussion, people pointed out that rainy seasons in 1960-1970 were consistent and dependable, whereas today, it is no longer easy to tell when the rainy season will start. Past studies in the catchment has shown that rainfall regime in the area has an impact to both in size and depth of the lakes/river (Nkotagu and Simon, 2004). Since the studies have shown that rainy season was more prominent in the past as compared to today where the lakes/river have tended to change both in size and depth, it can then be hypothesized that various human activities within the catchment could have contributed to the changes occurring in both lakes and river. This study has revealed significant changes in rainfall pattern in the catchment.

4.7.6 Overgrazing along the river banks and the lake shores

In many areas of the catchment, particularly along the Malagarasi riverbanks and the lake shores, excessive livestock number has degraded riparian areas. As far as overgrazing is concerned, 16% and 23% of the respondents agreed that overgrazing has been a very serious problem in the area (Table 11). Though there was no reliable data on carrying capacity and number of livestock in the area, a good proportional of local people agreed that livestock have increased and overgrazing may become a serious in the future. These findings are in line with the study by Nkotagu and Simon (2004) who noted that the livestock grazing is uncontrolled and is among the overwhelming problem creating conflict (land and water) between farmers and pastoralist; and in addition threatening the catchment ecosystem.

This study also revealed that the catchment areas has been a focus for many agro-pastoralists and this seem to have been exacerbated by the drought conditions in Shinyanga, Ufipa and Urambo during 2005-06. The presence of Sukuma and Tutsi herds in the lower catchment areas is a physical case in point. Studies by Yanda and Shishira (1999) and DANIDA (1999), observed that the lower catchment of Malagarasi has been under severe overgrazing pressure since 2005/06. Increased grazing pressure along riverbanks and lake shores prevents natural regeneration of cover. Livestock affect both the soil structure and the land cover of herbaceous plants. Removal of land cover exposes soil to the elements erosion (wind and water), which when combined with soil disturbances by livestock, can speed erosive processes leading to reduction in infiltration and increased runoff (Lal, 2001).

The physical factors affected by grazing include both the magnitude and rate of change of the flow regime and size and amount of sediment transported by the river. The soil compaction caused by trampling prevents infiltration, which in turn prevents the groundwater recharge and increases surface runoff (Wissmar *et al.*, 1994; Ziemer and Lisle, 1999). Because water is transported to the river channel by way of surface runoff rather than through infiltration to the groundwater, the rate of change of flows also becomes more flashy (Poff *et al.*, 2006). As the surface sediments are exposed, they become more unstable and subject to weathering and erosion (Rosenfeld, 2001).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Analysis of satellite images revealed changes in land use and cover over the two decades in the Malagarasi River Catchment. The analysis indicated that the study area has undergone notable changes in terms of land use and land cover: including an increase in forest, bush land, grassland and settlement/cultivation areas.

The results indicated that the rainfall has not changed (not significantly increased or decreased): and flow is generally decreasing though not statistically significant. The analysis of mean monthly flow for the two periods (1975-1980 and 1981-2002). indicated variation during peaking. For 1975-1980. the peak flow was attained in May as compared to that of 1981-2002 which occurred in April. Early attainments of peak flow seem to be related to observed land use and cover change.

5.2 Recommendations

The following are the recommendations from this study:

i) Land use planning and improved agriculture technology packages have to be implemented in the villages surrounding the catchment to encourage and promote adoption of appropriate land use practices and improve productivity. This will reduce current shifting cultivation practices and encroachment in the catchment.

ii) Local communities residing in and around the catchment should be empowered with roles and responsibility to have full participation in the management of natural resources.

iii) There is a need to carry out livestock census in the catchment, as a big number of pastoralists moved to the area during drought period of 2004/05. This will come up with appropriate number (carrying capacity) required and minimize pressure on the resources.

iv) The study recommends further studies to be conducted to examine the causes of observed changes in the flow regime in the river by utilizing high-resolution data (possibly daily) for rainfall and river flows. This is very important in the management decision of river and the ecosystem in general.

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APPENDICES

Appendix 1: Questionnaire for Households

General Information

Name of numerator...Date...

District ....Division ....Ward ....

Village...................................Respondent's number ....

Resource Use: Historical view

1. Were you in this village during the past 30 years? 1. Yes..............2. No.................

If yes, can you tell us a brief history of vegetation cover in your village from seventies up to present? (e.g example, forest and converted into farm, grazing or settlement)

....

....

2. Do you see the following factors as a problem in your area?

Factors	Very serious	Serious	Moderate	Not serious	Not a problem
Cutting trees					
Availability of firewood					
Drying of steams and water source					
Farming along rivers					
Overgrazing					
Changing of rainfall pattern/amount					
Loss of fertility					
Soil erosion					
Dropping in crop yield					
Fire					

3. Considering the period from 1970s – 2007. how could you reflect the quantity of the following factors today compared with as in 1970s.

Factors	Very serious	Serious	Moderate	Not serious	Not a problem
Temperature					
Precipitation					
Trees vegetation					
Soil erosion					
Water sources					
Distance to source					
Food production					
Others (specify)					

4. Respond to each socio-economic factor below if it has influence to the environmental degradation (water source and vegetation) in your village

Socio-economic factor	Agree	Disagree	Undecided
Poverty			
Lack of environmental education			
Lack of laws/by laws and not implemented			

5. To what extent do you agree with the following statements about water flow in Malagarasi River basin during the dry/wet season?

Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Water flow is extremely reduced					
The reduction of water is caused by deforestation/farming					
Water is reduced because of drying of lakes					
Immediate action is required to save river/lakes					

6. Do you know any rule to protect water sources? List all rules you know regarding protection of water sources in the wetland.

Government rules	Village/Community rules

7. Which resources do you collect/obtain from the rivers/river banks/lakes?

Resources	Ranks	Use
Water		For domestic use only
Firewood		For domestic use only
		For domestic use and for sale
		For sale
Timber		For domestic use only
		For domestic use and for sale
		For sale
Fishing		For domestic use only
		For domestic use and for sale
		For sale
Honey		For domestic use only
		For domestic use and for sale
		For sale

8. What should be done to prevent further degradation of water sources/land cover?

Action	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Environmental education /awareness					
Control tree cutting					
Stop farming in water sources					
Decrease livestock number					
Enforce laws and by-laws					
Controls encroachment					
Create alternative income opportunities					

GUIDING QUESTIONS FOR FOCUS GROUP DISCUSSION

Composition of focus group discussion

- Member of the village government for the selected village
- Member of the village Natural Resources Committee
- Resourceful people in the village (preferably old people)

1. Probing questions to capture trend over time with regards to water and cover change.
2. Historical context for the use and alteration of catchments resources.
3. Trend in the river level flow and water demand
4. Resources obtained from wetland/river
5. Availability of firewood (for tobacco curing, domestic use). What proportional of collected firewood is for sale?
6. Mechanisms for the protection of riparian areas and catchments. How does their implementations affect the human uses on public lands and along rivers?
7. Changes with respect to grazing, and what effects do such changes have on catchment?

VILLAGE ADMINISTRATORS CHECKLIST

Size of the village

- The size of the village and sub-village
- The number of sub-villages (number of household)
- When the village was established.

Major socio-economic and production activities in village

- What are the major socio-economic activities in this village? Have these activities changed over the past 30 years?.

- Agriculture (Farming systems).
- Livestock keeping.
- Number of livestock
- Pasture and water
- Diseases
- Beekeeping
- Charcoal, fuel wood, building poles etc.

Environmental degradation (Water sources and vegetation)

- Land use history in the village and principal changes
- People awareness on the causes and impact of vegetation degradation. Are causes identified and discussed? What are they?
- Destructive activities
- Incidence of harvesting of resources in riverbanks. What are causes?
- Measures by village authority in managing wetland/river banks
- Are there any traditional rules regulating the use of resources
- Are measures enforced? Are regulations been modified with time?
- Do people have tendency of planting trees in your village?

KEY INFORMANTS CHECKLIST

- Trends and status of the environment (in terms of vegetation and water flow)
- Vegetation cover and river flow in 30 years ago
- Current cover change and river flow during dry month
- Causes for the changes
- Indicators of the changes
- Impact of cover change on water
- Farmers/local people perception about the change
- Do people have tendency of planting trees in your area?
- What methods do local people employ in conserving water sources?
- Reference materials – maps. books. journals etc.

DATA RECORD FOR TRANSECT WALK

Information to be recorded from direct field observation

- Vegetation type. density and condition
- Human activities on lower catchment and in river banks
- Farming activities (distance from riverbanks/river)
- Grazing activities
- GPS information (Coordinates. X and Y).