THE IMPACTS OF CHANGES IN VEGETATION COVER ON DRY SEASON FLOWS IN THE KIKULETWA RIVER CATCHMENT, NORTHERN TANZANIA.

BY

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ABSTRACT

While the decrease in water flows in most if not all non spring fed streams is obvious in the Kikuletwa River, Northern Tanzania; the exact mechanism leading to the decreases is somewhat unclear. The area has experienced a steady population growth, and it would seem rational to attach the decrease in the low flow to population increases and hence increase in water abstractions and withdraw. Nevertheless, the reasons may be manifold. Vegetation cover change seems to form part of such an explanation. Analysis of satellite images for 1970s to 2000 showed considerable change in land use/cover. In 1976, the land use/cover in the area was dominated by a forest like environment where by closed forest and open forest in total covered one-third (34%) of the area. In contrast, in 2000 much of the original forested areas have been cut or converted to farmlands, and thus the combined classes of closed forest and open forest occupied less than quarter (13%) of study area, which is about 68% decrease in forested cover. Analysis of low flow indices indicated no statistically significant changes in the long term average low flows. However, the study of local people perceptions confirmed declining low flows in many tributaries of Kikuletwa River. From local people perspective there has been a decrease in dry season discharge in most if not all streams of Kikuletwa River. There were no identifiable change in the rainfall amount, and the low flows could not directly be linked to water abstractions and withdraw. This study therefore associates the changes in the dry season flow to the identified land cover changes, which supports conclusive argument that the decrease in vegetation cover affects the rate of ground recharge and consequently reduces dry season flow.

DECLARATION

I, Hermegast Ambrose do hereby declare to the Senate of Sokoine University of Agriculture that, this dissertation is my own original work and it has not been submitted for a degree award in any other University.

Signature...

Date ....30-06-2006..............

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To the memory of my beloved uncle Emili Michaeli Munishi (Kyara or Zelazini) who is no longer with us to see the completion of my university studies though he wished to see me reach this stage.

May the almighty God rest him in eternal peace. Amen

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LIST OF ABBREVIATIONS AND SYMBOLS

ASL	Above Sea Level
DFF	Drought Flow Frequency
DFV	Drought Flow Volume
EFF	Flood Flow Frequency
EFV	Flood Flow Volume
FDC	Flow duration curves
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information System
GPS	Geographical Positioning System
ha	Hectares
LMIS	Lower Moshi Irrigation Scheme
Mm^3s	Million Cubic Metres per second
MSS	Multispectral Scanner
MW	Mega Watt
NYM	Nyumba ya Mungu Dam
PBWO	Pangani Basin Water Office
PRB	Pangani River Basin
TANAPA	Tanzania National Parks
TANESCO	Tanzania Electric Supply Company
TM	Thematic Mapper
TM^+	Thematic Mapper plus
TPC	Tanzania Planting Company
UCLAS	University College of Lands and Architecture Studies
URT	United Republic of Tanzania
USGS	United state geographical surveys
UTM	Universal Transverse Mercator
y^{-1}	Per year

CHAPTER ONE

1.0 INTRODUCTION

The perennial water of Kikuletwa River that flows from both Kilimanjaro and Meru Mountains is a source of life to millions of people living downstream. The river has an important ecosystem with unique resources and is among the most highly productive catchment in Tanzania. The Kikuletwa catchment is renowned for its agricultural values, centre for biodiversity conservation as well as an important source of water supply for various uses (Misana, 1999). The catchment biodiversity is almost unparalleled globally and the centre of a great deal of international interest and conservation concerns (Katigula, 1992). The fertile volcanic soils of the area are the basis of its agricultural economy, and turned it into the breadbasket of Tanzania. According to the Ministry of. Agriculture and Food Security (2003), northeast Tanzania in which the Kikuletwa catchment is found, contributes a significant part of the country's major staples (maize, rice and wheat), drought resistant crops (sorghum, millet and cassava) as well as other sub-staples (Irish and sweat potatoes and bananas). The catchment water flow contributes largely towards generation of hydroelectric power at the Nyumba ya Mungu dam (8 MW), Hale (21 MW), New Pangani Falls (45 MW) and Old Pangani (17.5 MW). All these power plants contribute about 17% of the total hydropower produced in Tanzania (Ngula, 2002). In addition, various large national projects such as the Tanganyika Planting Company Irrigation Scheme and Lower Moshi Rice Irrigation projects and many others, abstract water from the Kikuletwa River.

Over the last three decades however, the Kikuletwa River catchment has undergone major changes in land use/cover, population, agriculture, and socio-economic aspects (Missana, *et al.*, 2003). Much of the original forested zone have been cut and converted to farmlands. The catchment has seen, since the 1960s, changes from traditional farming and pastoralism to irrigation and plantation agriculture mixed with pastoralism (Shishira, 2002), which eventually led to reduced land cover in the catchment (Yanda & Shishira. 1999). At their core, these changes relate to an increasing population against a background of high levels of poverty. The threats faced by the catchment's resources are almost all related to over-exploitation.

1.1 Problem Statement and Justification of the Study

Vegetation cover for a long time, have played an important role in preserving and maintaining water balance of many catchment in the world. The vegetation cover permits more infiltration, or soaking 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 vegetation, the 'sponge effect' is lost through rapid oxidation of soil organic matter, soil compaction by grazing (Lal, 1997), resulting into diminished water yield (Pereira, 1989; Hamilton *et al.*, 1995).

While the decrease in water flows in the furrows and in the rivers is obvious in many tributaries of Kikuletwa River; the exact mechanism leading to the decreases is somewhat unclear. Most studies over the area attribute the decrease in low flows to the population increase and water use practices (Mujwahuzi, 1999; Yanda &

Shishira, 1999; Shechambo, 1999; Mwamfupe, 2002; Ngana, 2002; Shishira, 2002; Yanda, 2002). Thus, human influence is taken to be the cause of this decrease. How exactly the activities of humans have brought this effect about, is not yet completely clear. However, it is evident that there has been substantial population growth in most part of the catchment, and it would seem rational to attach water problem in the area to population increases and thus growing of water demand and degradation of water source catchments. Nevertheless, the reasons may be manifold. Vegetation cover change seems to form part of such an explanation. Many studies have emphasized the importance of investigating vegetation cover dynamics as a baseline requirement for sustainable management of natural resources (Brandon & Bottomley, 1998; Chen, 2000; Diouf & Lambin, 2001; Kuntz & Siegert, 1999; Lambin, 1994).

In this study, a number of different, but interrelated, factors were examined, although, specifically the study focused on influences brought about by vegetation cover change on dry season river flows. The study contributes to answer "why, when and how much" land cover changes contributed to observed variations in low flows in the Kikuletwa River. The study also investigated detrimental human activities focusing in the river ecosystem to determine their possible implication on the hydrological regimes.

1.2 Objectives

1.2.1 General objective

The overall objective of the study was to assess the extent of changes in vegetation cover and its impact on dry season flows of Kikuletwa River, northern Tanzania.

1.2.2 Specific objectives

The specific objectives of the study were to:

- map the spatial extent of various land cover in the Kikuletwa catchment.
- detect, delineate and map areas that have experienced vegetation cover change
- assess the possible relationships between dry season flow, rainfall and vegetation cover changes
- investigate local peoples' perception on changes of land use/cover and dry season river flow

1.3 Research Questions

The following research questions were set to guide the research;

- What is the status, historical rates and patterns of change in vegetation cover in the Kikuletwa River catchment?

- Are there any changes in flow regime in the Kikuletwa River catchment? If yes, what are the causes?
- Are the changes in flow regimes attributed to rainfall changes? If not, what are the probable causes?
- What are the relationships between dry season flow, rainfall and changes in vegetation cover?
- What are local people's perceptions on vegetation cover and stream flow changes?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Defining Land, Land Use, Land Cover, and Land Cover Change

Studies of land cover change do not always employ similar definitions of the principal terms land, land use, land cover and land cover change. Definitions and descriptions of these terms vary with the purpose of the application and the context of their use. It is, thus, necessary to look at a few definitions and descriptions of these terms that are more frequently used in the various studies, especially those offered by official sources of land and land use data.

2.1.1 Land

Land is result of natural resource attributes such as climate, land form, soil, vegetation, fauna, and water. Hoover and Giarratani (1999) state that land "first and foremost denotes space... The qualities of land include, in addition, such attributes as the topographic, structural, agricultural and mineral properties of the site; the climate; availability of clean air and water; and finally, a host of immediate environmental characteristics such as quiet, aesthetic appearance", among others.

The Food and Agriculture Organization (FAO) gives a more refined and holistic definition which was used also in the documentation for the Convention to Combat Desertification (FAO 1995) "Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below terrestrial surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)". UNCED (1993) cited in FAO (1995) states that "land is a physical entity in terms of its topography and spatial nature often associated with an economic value, expressed in price per hectare at ownership transfer.

It is worth noting that all definitions of land, though generally similar, differ as to the priority given to the attributes that characterize land. The natural sciences (FAO; 1995, Wolman; 1987) start from and detail the natural characteristics of land while the social sciences, more specifically economics (Hoover and Giarratani, 1999), start from the mere element of space and refer more abstractly to the natural features of a segment of space.

2.1.2 Land use and land cover

The terms land use and land cover are not synonymous and the literature draws attention to their differences so that they are used properly in studies of land use and land cover change. However, the distinction between land use and land cover, although relatively easy to make at a conceptual level, is not so straightforward in practice as available data do not make this distinction clearly all the time, a fact that complicates the analysis of either one of them.

According to FAO (2000), land cover is the observed bio/physical cover on the earth's surface. In other words, land cover describes the physical state of the land surface: as in cropland, mountains, or forests (Moser, 1996) and it embraces, for example, the quantity and type of surface vegetation, water, and earth materials (Meyer and Turner, 1994). Moser (1996) noted that, the term originally referred to the type of vegetation that covered the land surface, but has broadened subsequently to include human structures, such as buildings or pavement, and other aspects of the physical environment, such as soils, biodiversity, and surfaces and groundwater.

Land use on the other hand, is the arrangements, activities and inputs that people undertake on a certain land cover type (FAO, 2000). According to Meyer and Turner (1994) land use refers to the human purposes that are associated with land cover. Land use is the way in which, and the purposes for which, human beings employ the land and its resources: for example, farming, mining, raising cattle, recreation, urban living, lumbering, etc. Land use relates to land cover in various ways and affects it with various implications. Meyer and Turner (1994) assert that, a single land use may correspond fairly well to a single land cover, conversely, a single class of cover may support multiple uses (forest used for combinations of timbering, slash-and-burn agriculture, hunting/gathering, fuelwood collection, recreation, wildlife preserve, and watershed and soil protection), and a single system of use may involve the maintenance of several distinct covers (as certain farming systems combine cultivate land, woodlots, improved pasture, and settlements). Land use change is likely to cause land cover change, but land cover may change even if the land use remains unaltered" (Meyer and Turner, 1994). Moser (1996) adds the important point that changes in land cover by land use do not necessarily imply a degradation of the land. Indeed, it might be presumed that any change produced by human use is an improvement, until demonstrated otherwise, because someone has gone to the trouble of making it. Indeed, this has been the dominant attitude around the world through time. There are, of course, many reasons why it might be otherwise. Many shifting land use patterns, driven by a variety of social causes, result in land cover changes that affect biodiversity (Riebsame, *et al.*, 1994a). Damage may be done with the best of intentions when the harm inflicted is too subtle to be perceived by the land user. It may also be done when losses produced by a change in land use spill over the boundaries of the parcel involved, while the gains accrue largely to the land user.

2.1.3 Land use/cover change

In the analysis of land use/cover change, it is first necessary to conceptualize the meaning of change to detect it in real world situations. Land use and land cover change is defined as the conversion from one land cover category to another (Riebsame, *et al.*, 1994a). At a very elementary level, land cover change means (quantitative) changes in the areal extent (increases or decreases) of a given type of land cover. Land use change can be considered as 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). Changes in land cover driven by such land use changes can be divided into two types: modification and conversion. Modification is a change of condition within a cover type (from, say, unmanaged forest to a forest managed by selective cutting). It involves alterations of structure or function without a wholesale change from one type to another; it could involve changes in productivity, biomass, or phenology (Skole, and Tucker, 1993). Land cover conversion entails a shift in the relative proportions of land classes within a given area, such as urban expansion into formerly agricultural land, or clear-cutting of forests for conversion into croplands or pastures. It is land conversion that has received most notice, as it tends to be more localized and immediate in impact and therefore draws greater attention. Land use and cover change tend to occur simultaneously, and both can have important implications for water resources (FAO, 2000).

2.2 Land Degradation and Riparian Areas

2.2.1 Land degradation

Land degradation can mean different things to different people. However, for the purpose of this study, land degradation is defined as the loss of vegetation cover and lowering in rank of various vegetation types hence leading to different forms of soil erosion and desertification. A report by the Australian Department of Environment, Housing and Community Development (ADEHCD) (1978) defined land degradation as damage to land attributes (vegetation and soil) due to incorrect land use or unsuitable land management. Burrow (1991) defines land degradation as simply a reduction in rank or status for example, a degradation and/loss of soil or change of closed forest to open forest or open to bush, scrub or grassland. There are several aspects of land degradation viz: soil physical degradation which includes crusting, deterioration of structure, reduced porosity, bulk density and infiltration capacity.

2.2.2 Riparian areas

Riparian ecosystems are the zones along water bodies that serve as interfaces between terrestrial and aquatic ecosystems. They are zones that influence and are strongly influenced by an adjacent aquatic environment (Manci 1989, Minshall *et al.*, 1989). In recent years, there has been an interest in modifying wetland definitions to incorporate all riparian areas (Johnson *et al.*, 1984). Riparian areas are wetlands that occur adjacent to rivers and streams. They often extend beyond the "wetland" boundaries established by most wetland definitions.

Riparian vegetation is extremely important because of the many functions it serves. The riparian zone provides water catchment values, which offers needed conditions for stable river flows. It traps sediment and pollutants, helping keep the water clean. Vegetation protects a streambank from erosion by reducing the tractive force of water, and protecting the riverbank from direct impacts, and by inducing deposition (Minshall *et al.*, 1989). Cooler, shaded streams have less algae and are able to hold more dissolved oxygen, which fish need to breathe. Standing riparian forests is habitat for insects that sometimes drop into the water, providing food for fish.

2.3 Factors Responsible for Land Use/Cover Change

Generally, changes of the environment happen naturally, but mostly occur faster and are of greater magnitude when induced by human activity. Globally, land cover today is altered principally by direct human use: by agriculture and livestock raising, forest harvesting and management, and urban and suburban construction and development. Meyer and Turner (1996) suggest that humans (both deliberately and inadvertently) alters land cover in three ways: converting the land cover, or changing it to a qualitatively different state; modifying it, or quantitatively changing its condition without full conversion, and maintaining it in its condition against natural agents of change. However, land cover can be altered by forces other than anthropogenic. Natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover.

2.4 Factors Affecting Dry Season Flow

Dry season flow are maintained by the release of water from groundwater storage and/or surface water discharge from melting glaciers, lakes, wetlands, and flow from channel banks (Smakhtin, 2001). These water sources can be thought of as storage reservoirs within the basin. The amount of precipitation ultimately defines the amount of recharge that occurs in the storage reservoirs, while the release of water is more a function of physiographic characteristics such as climate, topography, soils, and geology (ibid). During the dry season, many natural processes can affect low flows, including "the distribution and infiltration characteristics of the soils, the hydraulic characteristics and extent of aquifers, the rate, frequency and amount of recharge, the evapotranspiration rates from the basin, distribution of vegetation types, topography and climate"(ibid).Additionally, human activities can both increase and decrease low flows. These activities include: groundwater withdrawal, drainage of valley bottom soils for agriculture or construction, clearing or planting, urbanization (creation of impervious surfaces), direct river withdrawal and returns, irrigation returns flow, industrial discharge, dams and impoundments (Smakhtin, 2001).

A heated battle on the hydrological role of vegetation was fought on the pages of the forestry journal of the former Dutch East Indies (Tectona) some 60-70 years ago. Protagonists of the 'sponge' theory vigorously opposed the 'infiltration theory' which stated that: "base flow is governed predominantly by geological substrate rather than by the presence or absence of a forest cover" (Roessel, 1939abc). The 'traditional' stance is aptly summarised by Valdiya and Bhartarya (1989) with respect to environmental conditions prevailing in the Kumaun Himalaya in northern India: Modification of the natural dynamic regime and the increases in area occupied by impervious surfaces such as paving areas and settlements, all contribute to gradually reduced rainfall infiltration. Various watershed experiments in different catchments of Tanzania have been carried out to show the importance of vegetation cover and the extent of the problems where cover is reduced or removed (Lundgren, 1983). Lundgren (1978) demonstrated the important role of vegetation in maintaining soil and water processes.

There exists a strong body of opinion that sees the expansion of irrigation especially in highlands as causal in reduced dry season flows (January - February and July -

September) in the tributaries of Kikuletwa (Mujwahuzi, 2001; Mwamfupe, 2001; Ngana, 2001; Ngula, 2002). The argument backed up by numerous analysis of long term data for rainfall which shows that average annual rainfall have not significantly changed. If the amount of annual rainfall remained the same, they attribute the decline to be caused by the water abstraction. Those studies however, lack quantitative figures on time and the actual amounts of water abstraction. The studies also lack data on the amount and numbers of furrows receiving water in the dry months.

In the uplands, the areas under irrigation have not much increased for quite sometime. Much of the land in the upper and middle zones is entirely utilized that there is no further room for expansion (Soini, 2002a). This study therefore does not agree in totality with the view of relating to the reduction in low flow in Kikuletwa River to the water abstraction only. The argument supported by Katigula (1992) who claimed that …"the likeliest cause of the decrease of water in both the furrows and in the rivers in dry season discharge has been the increase in diversion of water from the rivers and possibly a change in land cover".

2.5 Remote Sensing & Innovative Mapping Techniques

Remote sensing is the acquisition of data about an object or scene by a sensor that is far from the object. Lillesard and Keifer (1994) defined remote sensing as any process whereby information is gathered about an object, area or phenomenon without being in contact with it. Today, remote sensing image data of the earth's surface acquired by spacecraft platforms is readily available in a digital format. The great advantage of having data available digitally is that it can be processed by computer either for machine assisted information extraction or for the enhancement by an image interpreter.

Resolution is an important term commonly used to describe remotely sensed imagery. These resolution characteristics help to describe the functionality of both remote sensing sensors and remotely sensed data (Brandon & Bottomley, 1998). There are four distinct types of resolution that must be considered. These four types of resolution are spatial, spectral, radiometric, and temporal resolution. Spatial resolution is the minimum size of terrain features that can be distinguished from the background in an image, or the ability to differentiate between two closely spaced features in an image. Spectral resolution refers to the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a sensor or sensor band is sensitive or can record. Wide intervals in the electromagnetic spectrum are referred to as coarse spectral resolution, and narrow intervals are referred to as fine spectral resolution. Radiometric resolution refers to the dynamic range, or numbers of possible data file values in each band. This is referred to by the number of bits into which the recorded energy is divided. The data file values range from 0, for no energy return, to 255, for maximum return, for each pixel. Temporal resolution is a measure of how often a given sensor system obtains imagery of a particular area, or how often an area can be revisited. The temporal resolution of satellites is on a fixed schedule which allows for repetitive views. Landsat 5 for example can view the same area of the globe every 16 days (Wilkie *et al.*, 1996).

Remote sensing has become an important tool applicable to developing and understanding the global, physical processes affecting the earth. Khanna (1989) noted that remote sensing techniques offer an efficient, rapid and cost effective method of survey; monitoring and management of natural resources, their depletion, degradation and contamination. 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. Mbilinyi, (2000) examined Land Degradation of Ismani Divison, Iringa Region, Tanzania using GIS, verified that remotely sensed data and GIS could be used for identifying causes and consequences of the land degradation and increased agricultural expansion.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 The Study Area

3.1.1 Location of Study Area

This study was conducted in the Kikuletwa River catchment. The catchment is located in the northwestern part of Pangani River basin which originates from both Kilimanjaro and Meru mountains between 3^{o}–5^{o} south of equator (Figure 1). The river drains into Nyumba ya Mungu (NyM) reservoir. The major tributaries forming Kikuletwa River are Ngarenaro, Usa, Makumira, maji ya Chai, Sanya, Kikafu, Karanga, Weruweru, and Kware river.

The Kikuletwa catchment has an area of 9.320 km^2, thus it was necessary to select a small area for in-depth ground truthing. The effective area for ground truthing was selected southwest of Mt Kilimanjaro, restricted by the catchment of Karanga in the east, Mt Kilimanjaro in the north, the Kikafu catchment in the west and by the gauging station at TPC Kikuletwa (IDD1) in the south.

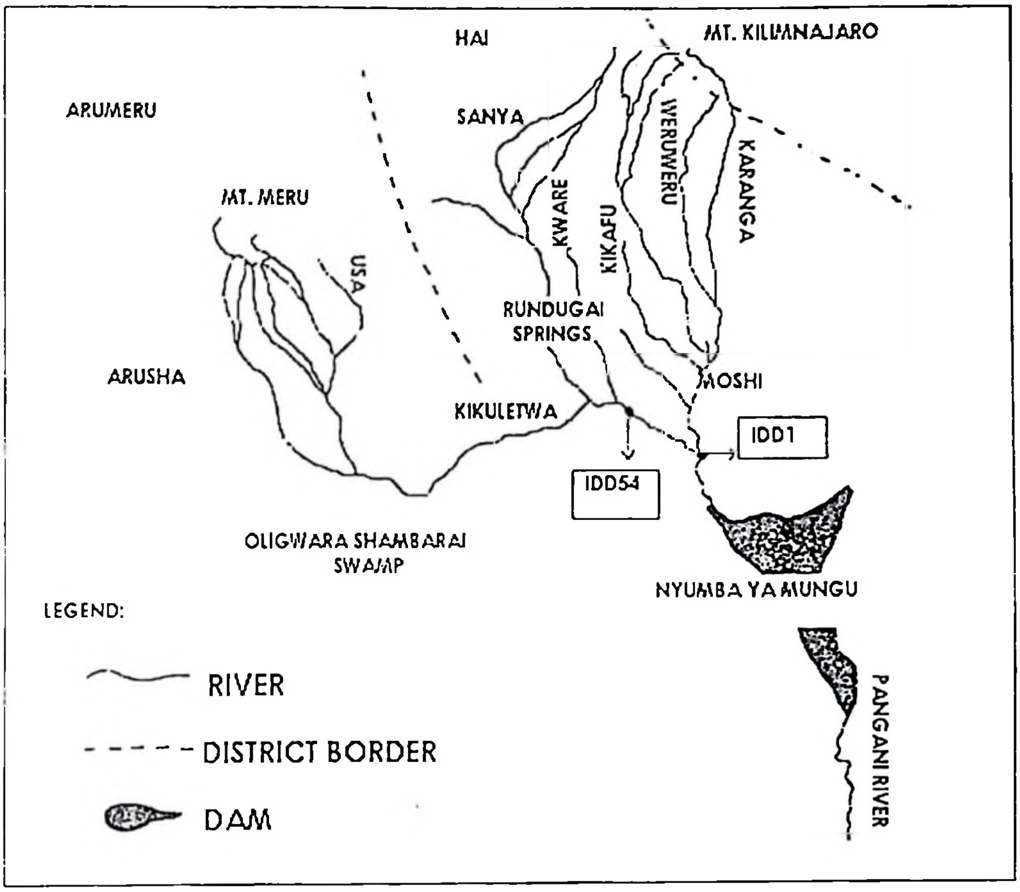

Figure 1: Map of the study area showing main tributaries in the Kikuletwa River catchment northern Tanzania.

3.1.2 Farming

Agricultural activities in the Kikuletwa catchments depend on rainfall and irrigation. Irrigation activities are practiced in both highlands and lowlands. The highland people practice what is referred to us traditional irrigation by the use of furrow or Mfongo system. In the lowlands areas, irrigation plays a very crucial role because rainfall is very erratic and unreliable. Although the precipitation in the lowlands is low i.e between 500 to 1000mm, the areas have access to considerable surface water resources from rivers flowing from the highlands. The large irrigation scheme in the lowlands are the Tanzania Planting Company (TPC) (17.000 ha), the Lower Moshi Irrigation Scheme (LMIS) (2.300). the Kilimanjaro Agricultural Development Programme (KADP – 6.320 ha), and the Burka Coffee Estate (Sahib, 2002).

Land use system in the area is based on kinship structures which are patrilineal in terms of ownership and inheritance. The farmlands are divided into two types of tenure. The first is *'kihamba'*, which is inherited from the father to the sons. The farming system in the Kihamba zone is agroforestry system. In the agroforestry system the different crops are grown in vertical layers that are trees on the highest level for fuel, animal fodder and shade, and coffee mixed with banana plant, fruit and fodder trees on the next layer. Underneath the coffee and bananas layer are variety of shade tolerant crops such as vegetables, maize, potatoes, beans, yams, and fodder grass.

The second type of Chagga land tenure is the *'shamba'*, and is typically restricted to the lower slopes of the mountain where rainfall is much less reliable, and irrigation commensurately more important. The main crops in the low-lying areas are maize intercropped with beans, finger millet, sorghum, cotton or cassava grown in the rainy season. From October to February the dominant crops are vegetables such as tomatoes, peppers, cabbage and onions. Shamba land is also the source for supplies of grass for livestock by alternating natural grass with seasonal crops.

3.1.3 Topography and soil

The land above Nyumba ya Mungu reservoir varies in elevation from approximately 700 to 5895 meters above sea level. The mountain slopes is one of the volcanoes lying in the rift-valley with the soil parent material being composed of very permeable volcanic deposits, and only a small part of the precipitation contributes to direct surface flow (Geological Survey, 1960). The remaining precipitation either evaporates or ibnfiltrates the permeable volcanic rocks and recharges the groundwater. This by far explains the presence of big natural springs in the lower parts of Kilimanjaro.

The soil in the catchment shows great variation because it has been developed from volcanic materials of different ages. In high altitudes brown colored entisol and loam with good drainage, high base saturation and high cation exchange capacity are dominant. Clay and sandy loams with good drainage are dominant in the lowlands (Geological Survey, 1960).

3.1.4 Climate

The average rainfall ranges from 1000 mm to 1700 mm and it varies with elevation and aspect. More rainfall is received on the southern and eastern sides of the mountain (O'kting'ati, *et al.*, 1984). The highland area is considered to be that land lying between 900m, such as the slopes of Mounts Meru and Kilimanjaro, which receive between 1,200 and 2,000 mm of rainfall annually. Precipitation decreases from the lower forest boundary down to the plains, where it is less than 700 mm annually. Short rains (October-December) and long rains (April-May) together contribute about 70% of the precipitation in the area.

Temperatures are closely related to altitude. The extraordinary height of the mountain causes the air temperature to vary greatly. In general, the temperature falls about 0.5°C for every 100m increase in altitude. From the alpine environment at the summit, the temperature is below zero throughout the year. On the way down the slope the temperature ranges from about 15°C – 30 °C with the minimum temperature (12° – 17°) in July. The hot season lasts from October – March with high humidity and temperatures going up to 40 °C in the lowlands.

3.1.5 Vegetation

The vegetation cover in the Kikuletwa River catchment changes in response to the changing elevation giving a unique combination of vegetation zones. The vegetation of the lower altitudes are characterized by the *Newtonia buchananii*, *Macaranga* important changes overtime on how and why the river flow has been changing, the extent to which vegetation cover has changed and trend in rainfall patterns and reliability. The study however, may be limited in scope due to data sources being in varying scales and that the variables studied here are a small subset of variables affecting river flow and vegetation degradation.

3.2.1.1 Remotely sensed data

Three different Landsat images Mult-Spectral Scanner. Thematic Mapper and Enhanced Thematic Mapper-plus obtained from different sources were used in this study. These images covered the period of 1976, 1987 and 2000 (Table 1). The availability of an older image was restricted by cloud free conditions. Two images were acquired in February and one for January of each respective year. January and February is the driest months in Kikuletwa River catchment (Asnani, 1993; Camberlin and Okoola, 2003). Ancillary data for the study area such as topographical maps were purchased from Survey and Mapping unit of Ministry of Agriculture.

Table 1: Remotely sensed data used for the study

Image	Path/Row	Acquisition date	Source	Cloud cover
Landsat MSS (Band 1-4)	P80r62	24th January 1976	USSG	1.0%
Landsat TM (Band 1-7)	P168r62	25th February 1987	SUA	4.0%
Landsat ETM+ (Band 1-8)	P168r62	21st February 2000	Mapping unit	Free

3.2.1.2 Hydrological data

The discharge data for daily flow were obtained from Moshi water office and department of water resources engineering of the University of Dar es Salaam. The selection of stations for dry season flow analysis considered the length of the discharge series and availability of information of good quality. According to Macha (Kilimanjaro Region Hydrologist), Kikuletwa at TPC (hereafter called station 1DD1) and Kikuletwa below TANESCO (hereafter called 1DD54) gauging stations have the longest data series and few missing data. The stations have also most available information from other researchers and previous studies. The two stations were also preferable because of their location just at the mouth of Kikuletwa River and thus drain large part of the catchment. The length of the observations and quality of the data for the rest of the stations in the catchment, are doubtful and of limited time span.

3.2.1.3 Household surveys

Primary data were collected in the Machame transect from which three villages, one from each of three farming (upper, middle and lower) zones were purposefully selected. These villages were Foo village, Nshara village and Kimashuku village. A pre-field quick tour of the study area was carried out in December 2004 and involved assembling data source materials namely topographic maps, landuse maps and various report and publications. During the pre-field visits, the questionnaire were pre-tested in Foo village and modified to remove questions that seemed to provide similar answers to get a final questionnaire (appendix I).

The choices of household for interviews were based on a simple random sampling technique. A total of 60 households i.e. 20 households from each of the three villages were interviewed. The sample size chosen were kept small due to the nature of the research i.e. to generate additional information used in refining and supporting 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. Individual interviews were conducted using households as a unit of study. In addition, guiding questions were asked in focus group and to key informants such as long term residents and people who have knowledge on vegetation change 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 truth" preliminary assumptions and maps. The walk was used to identify the various human activities and the different vegetation cover categories at specific sample points. The waypoints were marked using a global positioning system (GPS) and later downloaded in Idrisi32 and used in map verification exercise, in which classes in imagery base map were correlated with actual ground data.

3.3 Data Analysis

3.3.1 Satellite Images

3.3.1.1 Interpretation of satellite images

The dissimilarities encountered among the different remote sensing data (i.e. dates, geometry, image characteristics, resolutions or scales, and a try and error for training sites) may have influenced the accuracy of image classification. This was reflected, for example, in differentiating open forest from cultivated (agroforestry) land and grassland from bare or fallow land. These problems may have not been addressed adequately in this study. However, seasonal effect was minimised to some extent by using remotely sensed materials taken at almost the same periods i.e. January and February. It should however be noted that similar period may not necessarily have similar weather conditions, especially now when seasonal rainfall pattern is no longer similar for different years. But generally speaking, the selected moths showed a stable long term seasonal indifferent.

The following steps were used to create satellite-based land cover maps for the Kikuletwa River catchment.

Step 1: The Satellite images georeferenced to the coordinate system (WGS84 projection) were obtained for the periods 1976, 1987 and 2000.

Step 2: Easily identifiable ground points, such as road junctions and river networks were used in RESAPLE function of IDRISI32 to transform images band by band to the map coordinates i.e. UTM zone 37 south.

Step 3: False colour composite was made by assigning band 4, 5 and 3 for TM and 4, 2 and 1 for MSS in red, green and blue respectively. After compositing, training statistics were generated to enable IDRIS software to identify similar signatures in the image. All the seven bands were used to create signatures based on the training sites.

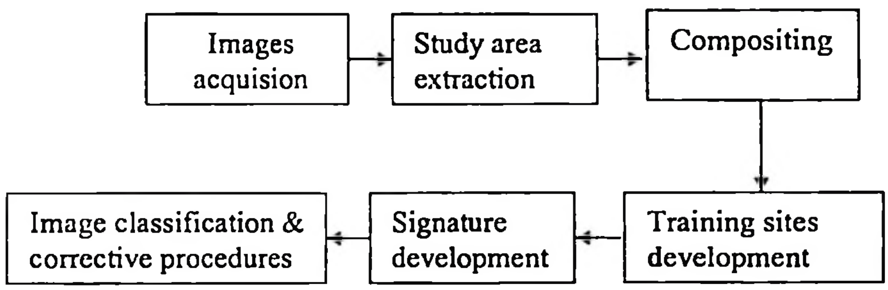

Figure 2: Image classification methodological flow diagram

Step 4: A base map with only 11 classes was produced using the Maximum Likelihood Module of IDRISI32. The map was subjected to iterations of field checking and corrective processing until a land cover map with meaningful vegetation discrimination was obtained.

Step 5: Following image classification, the area for each land cover type was calculated for each data set.

3.3.1.2 Image classification techniques

Image classification is defined as the extraction of distinct classes or themes, land use and land cover classification categories, from satellite imagery. According to Jensen (1996) digital image classification is the process of assigning pixel to classes. Analysts develop signatures based upon the detected energy measurement and position in the electromagnetic spectrum. Signatures are refined by improved ground-truthing and accuracy assessment analysis. Approaches to classification are generally referred to as supervised or unsupervised depending on whether or not ground sampling has been used as input to the classification.

Unsupervised image classification is a method in which the image interpreting software separates the pixels in an image based upon their reflectance values into classes or clusters with no direction from the analyst. The analyst then combines and re-labels spectral classes into real land cover type as unambiguously as possible using maps and field-based knowledge. The benefits of producing unsupervised classifications is that the user does not need extensive knowledge of the terrain and it is useful for estimating the number of distinct clusters in an image.

Supervised classification is the process of using a known identity of specific sites (through a combination of fieldwork and personal experience) in the remotely sensed data, which represent homogenous examples of land cover types to classify the remainder of the image. These areas are commonly referred to as training sites (Jensen, 1996). Training sites are areas the analyst identifies that exemplify each land-cover type in the image to be classified. These sites are used to 'train' the software classifier to 'recognize' each cover type so that all pixels in the image may be assigned to their appropriate cover class (ERDAS, 1999). A signature is a set of statistics that defines the spectral characteristic of a target phenomenon or training-sites. It is equivalent to the human concept of color, and is crucial in interpreting multi-spectral reflectance data detected through remote sensing. After the signatures for each land cover category have been defined, the software then uses those signatures to classify the remaining pixels (ERDAS, 1999).

Classification methods offered by IDRISI32 for assigning points to one of the established classes are: Parallelepiped (PIPED), Minimum Distance to Means (MINDIST), and Maximum Likelihood (MAXLIKE). They differ only in the manner in which they develop and use a statistical characterization of the training site data. Of the three, the Maximum Likelihood procedure is the most sophisticated, and is unquestionably the most widely used classifier in the classification of images.

The Maximum Likelihood classification (MAXLIKE) is based on the probability density function associated with a particular training site signature. The classifier uses training data to estimate means and variances of the classes. Pixels are assigned to the most likely class based on a comparison of the posterior probability that it belongs to each of the signatures being considered. MAXLIKE is also known as a Bayesian classifier since it has the ability to incorporate prior knowledge using Bayes' Theorum.

The parallelepiped classification (PIPED) is based on a set of lower and upper threshold reflectances determined for a signature on each band. To be assigned to a particular class, a pixel must exhibit reflectances within this reflectance range for every band considered. The parallelepiped procedure is the fastest of the classification routines. It suffers from inability to classify points that fall outside of the range of values found in the training set. The minimum distance to mean classification (MINDIST) is based on the mean reflectance on each band for a signature. Pixels are assigned to the class with the mean closest to the value of that pixel. A problem is that points that do not belong to one of the pre-determined categories are assigned to one of them anyway. To account for differences in the variability of signatures, MINDIST allows band-space distances to be normalized. MINDIST is commonly applied when the number of pixels used to define signatures is very small or when training sites are not well defined.

Within the scope of this study, the particular method of change detection applied was the post-classification comparison. The cross operation (crosstab) process of mapping land use/cover change over time begun with mapping the present (2000 satellite imagery), then looking back in time to map the past (1976 imagery).

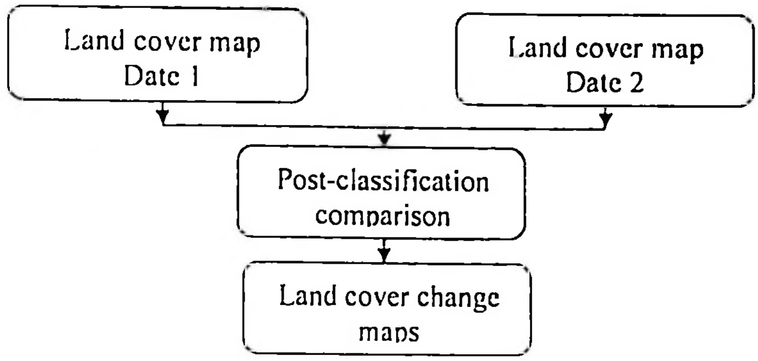

Figure 4: Change detection methodological flow diagram

The conversion of forest cover to lower forms of land cover and agricultural lands were the primary focus of this study. And, because the final classes resultant from the cross operations were quite numerous, and considering the study objective, it was decided to confine the change analysis to transition between classes of natural or semi-natural vegetation (forest, and bush land), to cultivation fields (annual crops and agroforestry), and sisal and paddy plantations.

The satellite image for 1987 could not be used adequately because of clouds and shadow effect that obscured vegetation (mostly closed forest cover) in the northern end of the study area and therefore these classes were not used in the discussion. The actual areas of change, both in absolute values and percentages of the total (study) area are presented in Table 2.

3.3.1.3 Change detection analysis

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Essentially, it involves the ability to quantify temporal effects using multi-temporal data sets (Singh, 1989). Many change detection methods have been developed and used for various applications e.g. post-classification comparison, image differencing, image rationing, image regression, and principal component analysis (Chen, 2000). However, they can be broadly divided into: post-classification and spectral change detection approaches (Singh, 1989; Lunetta & Elvidge, 1999).

Post classification is among the most widely applied techniques for change detection purpose. In post classification change detection approach two images from different dates are classified and labeled and the area of change extracted through the direct comparison of the classification results (Lunetta & Elvidge, 1999). A main advantage of post-classification is that it bypasses the difficulties associated with the analysis of images acquired at different times of year or sensor (Chen, 2000). Among the post classification techniques, image differencing is the most widely applied change detection algorithm (Singh, 1989). It involves subtracting one date of imagery from a second date that has been precisely registered to the first. According to Coppin and Bauer (1996), image differencing appears to perform generally better than other methods of change detection. Recent studies by Singh (1989) or Coppin and Bauer (1996), as cited in Petit *et al.*, (2001) have identified image differencing as the most accurate change detection technique

3.3.2 Assessment of the rate of deforestation

In assessing the rate of deforestation; deforested areas were considered to be areas that changed from closed forest and open forest to cultivated fields, grassland and scrubland. This study did not take into account the aspect of afforestation activities which are taking place in the area. The deforestation rate for a given land area was calculated as follows (Veldkamp, *et al.*, 1992):

Deforestation rate (% $year^{-1}$) = $\{[(F_1 - F_2)/F_1]/N\}*100$ ------- 1

Where

F_1: Forest area at the beginning of reference period
F_2: Forest area at the end of the reference period
N: Number of years in reference period

3.3.3 Analysis of dry season flow

The characteristics of interest were the dry season daily deficit flow volumes and frequencies. In order to investigate the dry season flow (low flow) discharge changes over the years, the average figure for the dry months were calculated, the pronounced low flow months are January-February and August–September. Flow duration curves (FDCs) were used to study characteristics of average flows and to define low flow threshold. An FDC index $Qp(D)$ was defined as a flow that occurred in D consecutive days, which has been equaled or exceeded by *p%* of the record period. Threshold of low flow for a season is defined as $0.0m^3/s$. (Smakhtin, 2001, Valimba, 2004b).

The change-point analysis was applied to the low flow months and the persistence of low flows was defined as the number of days in which flows are below a predetermined flow threshold and is referred to herein as deficit flow frequency. Deficit volumes are the cumulative flows below the same threshold values. This was performed to identify the presence of the abrupt changes in the average values of the time series. Analysis of low flow duration curves considered the flow that has been exceeded or equaled 70% (Q70) of the time when it flows appropriately to define the drought thresholds. This method has been commonly used in the studies of low flows (Mimikou and Kaemaki, 1985; Smakhtin *et al.*, 1995; Valimba 2004). A narrative of the procedure can be found in Mutreja (1995).

The shift analysis was performed to identify existence of break in the time series data. In detecting breaks, two tests were performed, the Mann-Whitney's test (Pettitt, 1979.) and the segmentation of the hydrometeorological series (Hubert's, 1989). The former test is referred to as the non-parametric data referring method and the later as the non-parametric data dependent method. The Pettitt's test assigns values (-1, 0 and 1) for differences between the time series elements while Hubert's procedure uses exact values of the difference in the analysis and it is therefore more sensitive to outliers. However, the Pettitt's test provides only a singe change-point and repeated series segmentation was performed to obtain other change-points. The detailed descriptions of the two tests can be found in Valimba (2004a).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 The Spatial Extents of the Different Land Cover Classes

The main land use and land cover types in different years for Kikuletwa area are presented in Table 2 and in Figure 4 & 5. Results showed that, in 1976, the land use/cover in the study area was dominated by closed forest, open forest; and scrubland occupying 50% of the area. However, in the year 2000, the combined classes of closed forest, open forest and scrubland occupied only 33% in total. In 1976, cultivated (annual crop) land was the largest land use occupying 22% of the study area followed by open forest (18%), closed forest (16%), and scrubland (16%). Others were grassland, riverine vegetation, settlements and water bodies occupying 7.4%, 8%, 1.5%, and 0.3% respectively. The information in the remaining areas was obscured by clouds and shadows.

Table 2: Main land use/cover in Kikuletwa area 1976, 1987 and 2000.

Land use\cover types	1976		1987		2000	
	Ha	%	Ha	%	Ha	%
Closed forests	73,554	16.0	No data	-	32,493	7.0
Open forests	81,532	18.0	No data	-	29,717	6.0
Cultivated (agroforestry)	41,104	9.0	39,489	9.0	30,949	7.0
Cultivated (annual crops)	101,952	22.0	105,480	23.0	143,875	31.0
Plantations	13,482	3.0	22,432	7.0	24,672	5.0
Scrubland	74,330	16.0	110,074	24.0	91,246	20.0
Grassland	34,529	7.0	64,451	14.0	74,587	16.0
Riverine Vegetation	22,809	8.0	15,461	2.0	10,887	2.0
Settlements	6,803	2.0	7,009	1.5	7,426	2.0
Waterbodies	1,410	0.3	2,257	0.5	4,673	1.0
Others	13,071	3.0	37,967	8.0	14,052	3.0
Total	464,576	100	464,576	100	464,576	100

In 2000, cropland was still the largest land cover/use occupying 31%, followed by scrubland (20%), and grassland (16%). Others were, closed forest, open forest and cultivated (agroforestry) occupying 7%, 6.4% and 6.7% respectively. Areas used for annual crops and grassland increased while closed forests, open forests, and cultivated (agroforestry) land decreased. The combined land covers area of closed forest, open forest and cultivated (agroforestry) in 1970s forms about 43% of the total area. These three combined land cover decreased from 196190 hectares (43%) in 1970s to 103159 ha (20%) in 2000 while areas used for annual crops increased from 101952 ha (22%) hectares to 143875 hectares (31%) in the same period. Generally, the results reveal a trend of conversion of land covers from higher grades (forests) to lower forms of vegetation covers.

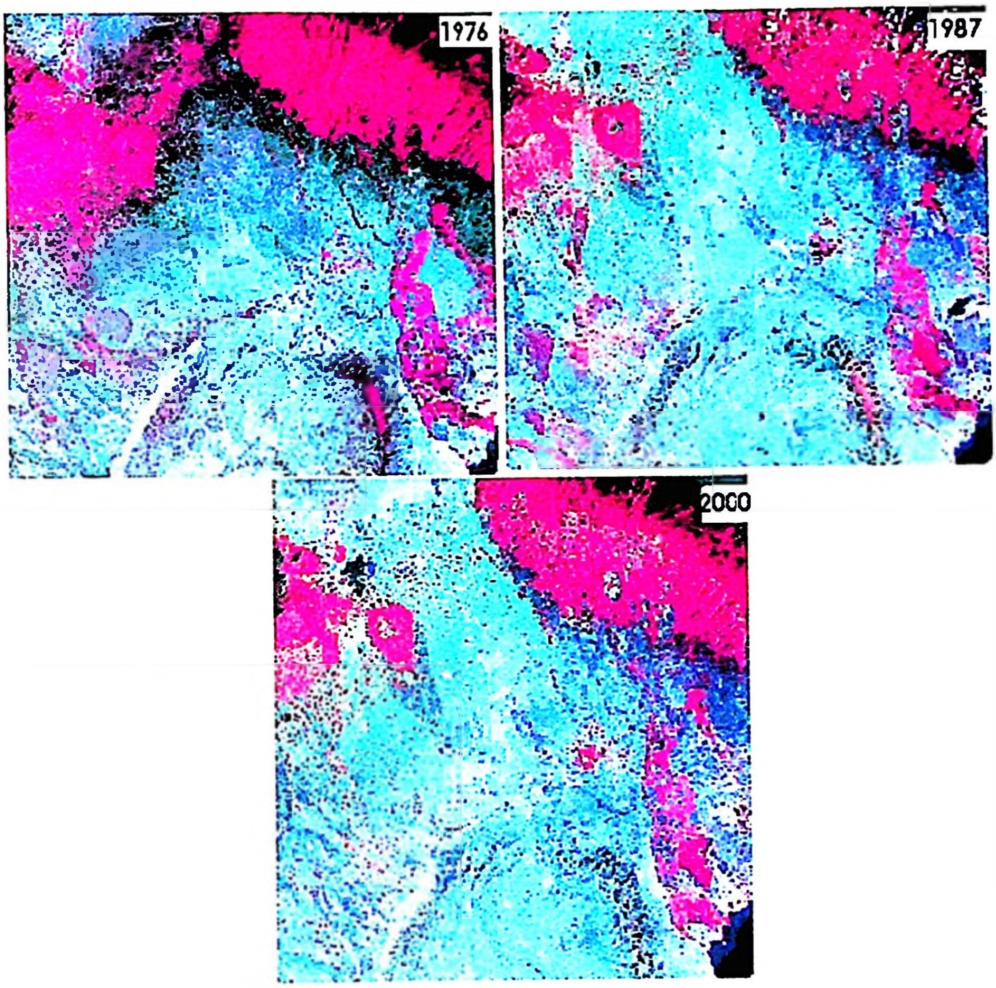

Figure 4: **Composite of the study area windowed from Landsat imagery of 1976, 1987 and 2000.**

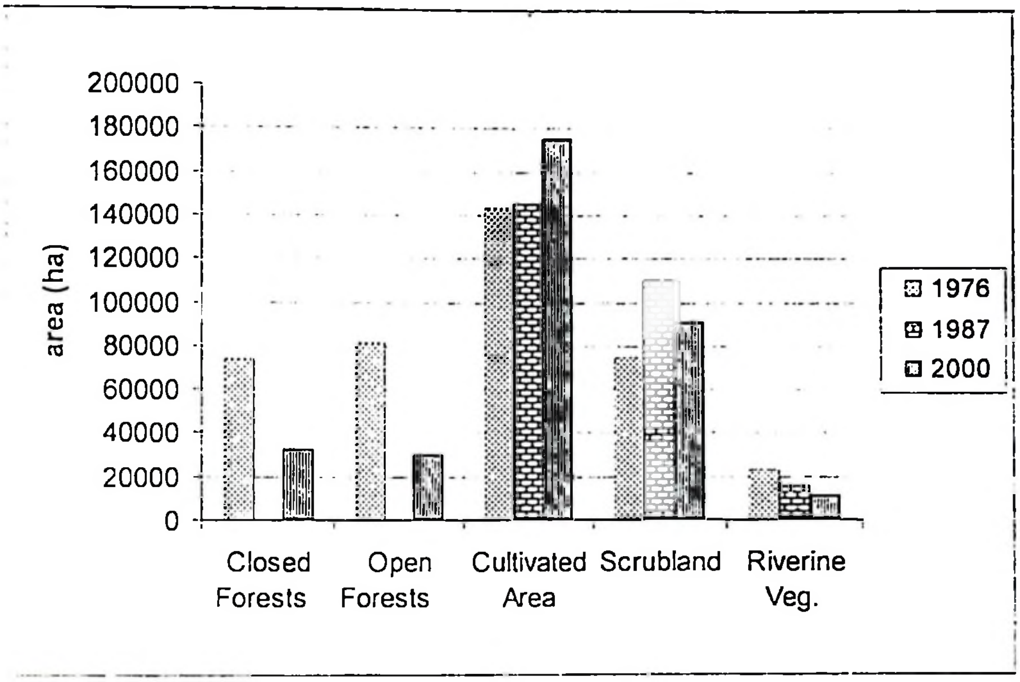

Figure 5: Histogram showing land use/cover changes for the years 1976, 1987 and 2000 in the Kikuletwa River catchment.

4.2 Changes in Land Use/Cover in the Kikuletwa River

Between 1976 and 1987 (Table 3), cultivated (agroforestry) area decreased by 1615 ha (4%), while area for annual crops increased by 3528 ha (5%). Plantation (Sisal and Paddy) area increased by 8950 ha (66%), while scrubland increased by 35744 ha (48%). On the other hand, grassland increased faster by 29922 ha (87%), while riverine vegetation decreased by 7348 ha (32%).

Between 1976 and 2000, closed forest decreased by 41061 ha (56%). open forest decreased by 51815 ha (64%), cultivated (agroforestry) land decreased by 10155 ha (25%). while cultivated (annual crops) land increased by 41923 ha (41%). Area under sisal and paddy (plantation) increased by 11190 ha (83%). while scrubland increased by 16916 ha (23%). Grassland more than doubled from 34529 ha in 1976 to 74587 ha in 2000 with an increase of 116% and riverine vegetation decreased by 11922 ha (53%) in the same period.

Table 3: Changes in different land use/cover coverage (ha) in the Kikuletwa area between 1976, 1987 and 2000

	Coverage in hectares			Cover change					
				1976-1987		1987-2000		1976-2000	
	1976	1987	2000	Ha	%	Ha	%	Ha	%
Closed Forests	73554	-	32493	-	-	-	-	4106b1	56
Open Forests	81532	-	29717	-	-	-	-	51815	64
Agroforestry	41104	39489	30949	1615	4.0	8540	22	10155	25
Annual crops	101952	105480	143875	-3528	5.0	-38395	36	-41923	41
Plantations	13482	22432	24672	-8950	66	-2240	10	-11190	83
Scrubland	74330	110074	91246	-35744	48	18828	17	-16916	23
Grassland	34529	64451	74587	-29922	87	-10136	16	-40058	116
Riverine	22809	15461	10887	7348	32	4574	30	11922	52
Built-up areas	6803	7009	7426	-206	3.0	-417	6.0	-623	9.0
Waterbodies	1410	2257	4673	-847	60	-2416	107	-3263	231
Others	13071	37967	14051	-24896	190	23916	63	-980	8.0
Total (ha)	464576	404620	464576						

4.3 Rate of Land Use/Cover Change in the Kikuletwa River Catchment

Table 4 shows the rate of land use/cover change in the Kikuletwa River catchment. Open forest decreased at a rate of 4181ha (5%) per year between 1976 and 1987, and 416 ha (1%) per year between 1987 and 2000. Some forested areas are now under cultivation or degraded types of vegetation. The causes of these include forest cutting for timber, charcoal and construction wood.

Table 4. Changes of different land use/ cover coverage (ha) in the Kikuletwa River catchment between 1976 and 2000

Land use/ cover	Temporal period					
	1976–1987 (11 years)			1987–2000 (14 years)		
	Area	%	Rate ha (y^{-1})	Area	%	Rate ha (y^{-1})
Open Forests	-45993	-5.0	-4181	-5822	-1.0	-416
Cultivated (agroforestry)	-1615	-0.4	-147	-8540	-1.0	-342
Cultivated (annual crops)	+3528	+0.3	+321	+38395	+2.0	+1536
Plantations	+8950	+6.0	+814	+2240	+3.0	+90
Scrubland	+35744	+4.0	+3249	-18828	+1.0	-753
Grassland	+29922	+8.0	+2720	+10136	+2.0	+405
Riverine Vegetation	-7348	-3.0	-668	-4574	-2.0	-183
Settlements	+206	+0.3	+19	+417	0.0	+17
Waterbodies	+847	+6.0	+77	+2416	+9.0	+97

Cultivated (agroforestry) area decreased at a rate 147 ha (0.4%) per year between 1976 and 1987, and 342 ha (1%) per year between 1987 and 2000. The decrease in area under agroforestry cover during this period might be due to cutting of trees and reduction of perennial crop cover resulting from shifts in cropping pattern and crop type. Unreliable prices, bad climatic conditions and land scarcity have made farmers to diversify crop production through introduction of various annual crops. The prices of coffee have been falling constantly since the 1970s (Gillingham, 1997). As a result, coffee bushes have been neglected and little by little coffee trees are being uprooted. Many homesteads have now vegetable gardens in their immediate surroundings. Kirsti, (1997) pointed out that, the cultivation of vegetables has substantially increased since the mid 1980s, due to their potentially higher profits than traditional cash crops such as coffee. The agroforestry zone has changed from a closed forest like environment, to open forest and farmland. No doubt that, uprooting coffee bushes and other big trees in favour of maize, vegetables and cattle feed grasses, have implications in terms of land cover and water uses.

Area under cultivation with annual crops such as maize and beans rose steadily at the expense of other land covers throughout most of the study history. Annual crops area increased at a rate of 321 ha (0.3%) per year between 1976 and 1987 and between 1987 and 2000 at a rate of 1536 ha (2%) per year. This may be attributed to the expansion of family size as well as maize cultivation replacing coffee as a cash crop. Other reasons may be the introductions of lowland irrigation, which facilitate opening up of farms in areas that formerly under bushes. This is similar to what was observed by Allen and Barnes (1995) that, the most important causes of environmental degradation in tropical Africa is expansion of subsistence agriculture and extraction of trees for fuelwood.

Scrubland mostly in the low lands, increased at a rate of 3249 ha (5%) per year between 1976 and 1987, and at a rate of 753 ha (1%) per year between 1987 and 2000. The spreading out of scrubland at a decreasing rate between 1987 and 2000 might be due to continue expansion of farming activities and tree cutting for charcoal/firewood in lowlands. Grassland area mostly in the lowlands has been increasing at a rate of 2720 ha (8%) per year for the period of 1976 to 1987, and continued to increase at a slower rate of 405 ha (2%) per year for the period 1987 to 2000. These major and rapid increases might be due to cutting of trees and increasing agricultural activities and demand for grazing lands. Other reasons may be climatic changes and drought. Riverine vegetation decreased at a rate of 668 ha (3%) per year between 1976 and 1987, and 183 ha (2%) per year between 1987 and 2000. Among causes for decrease in riverine vegetation include tree cutting for various purposes, uprooting of coffee bushes, cultivation into stream banks and animal grazing.

4.4 Hydrological Patterns

Figure 6 and 7 show the average discharge flows of the driest months of January and February. The long run average discharge portrays increasing trend at IDD54 (Kikuletwa at TANESCO). The linear trend for Kikuletwa at TPC (IDD1) was almost a strait horizontal indicating no changes in the long term flows. Some deviations can be seen in the late 1960s and 1980s. It can be concluded therefore that even with data updated to 2005, the long term low river flow at IDD1 and IDD54 has not changed. Other previous studies (Sarmett and Faraji, 1991; Ngana, 2002) have observed the similar trends. According to Ngana, (2002) dry season discharge has been reduced for the rivers that do not have their main sources from large springs below the mountain. Sarmett and Faraji (1991) analyzed changes in dry season river discharge of four rivers (the Njoro juu, Rau, Kikuletwa and Mue rivers) originating on Mount Kilimanjaro in the period 1950s to 1970s. According to this study, the Njoro juu and the Rau displayed decreasing tendencies, while the two others do not.

on Mount Kilimanjaro in the period 1950s to 1970s. According to this study, the Njoro juu and the Rau displayed decreasing tendencies, while the two others do not. The writers concluded that the decrease in dry season discharge is probably common to most if not all non-spring fed rivers on Mount Kilimanjaro.

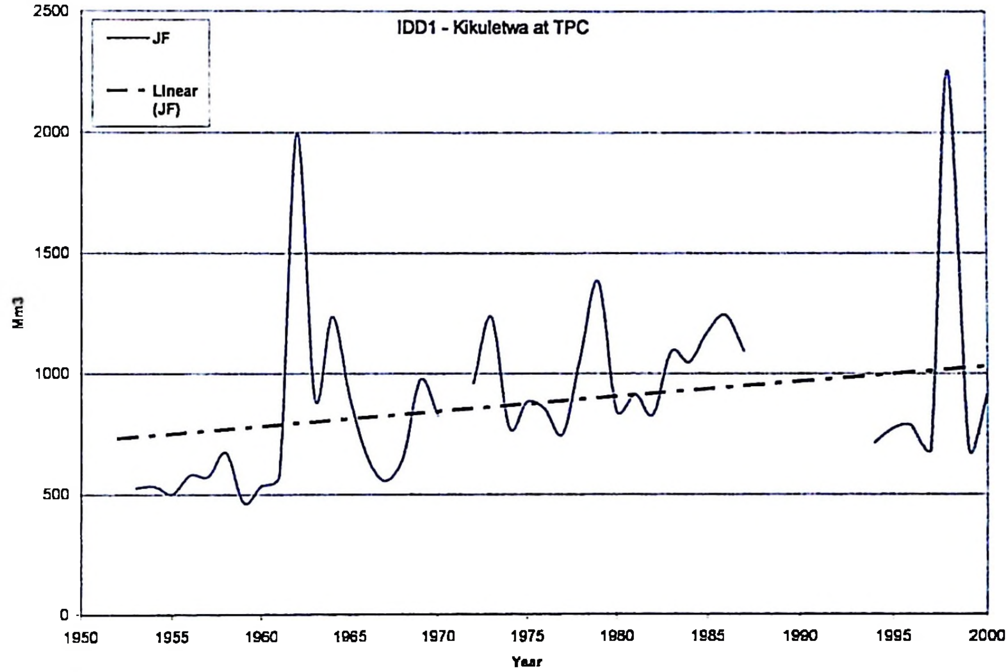

Figure 6: **Daily average dry season discharge (January – February) at IDD1 from 1952- 2005 in the Kikuletwa River at TPC gauging station.**

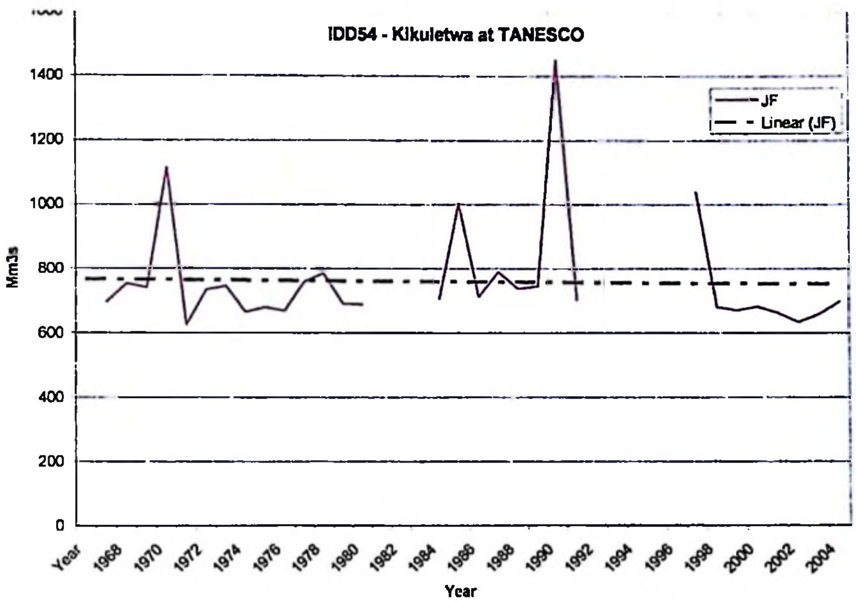

Figure 7: **Daily average dry season discharge (January - February) at IDD54 from 1967-2005 in the Kikuletwa River at TANESCO station.**

The low flow indices indicated no statistically significant long term changes in the average dry season flows. Generally, a change in volumes regime at IDD1 station for January and February indicated an increased linear trend in mean flows (Table 5). No changes were observed on average volume and frequencies of number of dry days in a month at IDD54 throughout the period that data were available (Table 5).

Table 5: Summary of the change-point analysis of the average low flow indices in the Kikuletwa River.

Station	Location	Period	Flow Index	Year of change in average flow		Mean flow
				Pettit test	Hubert test	
IDD1	Kikuletwa at TPC	January-February (dry months)	Vol	1961	1953-1961	547
					1963-1997	906
					1999-2005	870
			Freq	No change	No change	-
		August – September (dry months)	Vol	1970	1952-1958	468
					1959-1977	874
					1978-1986	1202
					1987-2000	840
			Freq	No change	No change	-
IDD54	Kikuletwa at TANESCO	January – February	Vol	No change	No change	-
			Freq	No change	No change	-
		August-September	Vol	No change	No change	-
			Freq	No change	No change	-

The results from low flow discharge analysis might however be influenced by the presence of big natural springs located above the gauging stations IDD1 and IDD54. The two gauging stations receive quite stable amount of water about $11 m^3/s$ from the Rundugai natural springs (Røhr and Killingtveit, 2002). According to Røhr (2002), the glaciers are like natural dams, they store the snow in the wet season and melt in the dry season and bring water flow to the rivers. But this is not the case in the lower moshi springs, as the origin of the water in these springs is unknown. Rainfall patterns on Mt. Kilimanjaro, which lies immediately to the north of the springs, appear to have no bearing on its output (Røhr and Killingtveit, 2002). The recharge takes place somewhere else, most probably from snow melting at the higher elevation of Mount Kilimanjaro (Røhr, 2002). The proportion of contribution from

It is however questionable as to whether low flow volumes on all tributaries of Kikuletwa River have not changed overtime. In other words, is it true that same amount of water is flowing in rivers as it was in the past? And what mechanisms feed the springs?. To understand this, it would require analysis of stations located above the Rundugai springs. However, during the course of this study it was very difficult to find reliable and dependable data from stations other than IDD1 and IDD54.

4.5 Linking Dry Season Flow to Changes in Rainfall and Land Use /Cover

Since no hydrological model was used, the effects of changing land use/cover in the dry season flow are discussed in connection with changes in rainfall, and local people perceptions. Several studies on rainfall amount and pattern for stations in the Kikuletwa catchment area have indicated no significant long term changes in the average rainfall in the Kikuletwa catchment (Sarmett and Faraji, 1991; Ngana, 2002; Rohr and Killingtveit, 2002; Valimba, 2004). Statistical flow analysis of Kikuletwa River catchment at IDD1 and IDD54 gauging stations, showed no identifiable changes in the amount and frequency (days) of dry season flows (Table 5).

This means that, from statistical analysis neither rainfall nor dry season flow have significantly changed. To confirm the results, household interview and literature search were adopted. During the household surveys, the local people were of the opinion that water flowing in the rivers are much reduced and that many permanent rivers and streams are now intermittent. The findings are supported by several previous studies over the area, which, have observed a decrease in dry season discharge in most if not all non-spring fed rivers (Sarmett and Faraji, 1991; Ngana, 2002; Røhr and Killingtveit, 2002; Valimba, 2004). This study concludes therefore that there has been reduction in dry season flow for most tributaries of Kikuletwa River above the major springs located in the lowlands.

Basically, three factors may influence long term dry season flows of any river. These are changes in precipitation, water abstraction (surface and groundwater) and physiographic (impervious surface) characteristic of terrain. Other factors may include ice melting and dam impoundments.

Increase in water abstraction for irrigation might have contributed in reducing the amount of dry season flow. There is however insufficient data to conclude on the water consumption trend for irrigation in the Kikuletwa River catchment. Many studies in the area suggest increased in the water demand and consumptions due to high population growth and the expansion of agricultural land into the dryer areas. However, the suggested trend needs to be quantified as many furrows were found dry. According to Mwamfupe (2001), the traditional furrows which pass nearly every Kihamba has the following drawbacks: much water is lost at the point of abstraction because of the materials (banana logs) used to divert water into the irrigation furrows; furrows are poorly constructed with weak banks, causing water to break out. It is not typical for farmers to construct return furrows to the water source. Facilities to regulate water intake and flow are rare, and the efficiency is as low as 20% for most of the furrows.

During this study it was observed that, many streams and rivers located upstream (some of them just at the forest boundary where abstraction is known to be zero), have less water now than it were in the past. One of the farmers during the household survey complained: *"what is lacking is not land, but water –we want to irrigate but water is no longer available"*. People of Foo village near the forest reserve, when asked to comment on trends of water flowing in the rivers, were in agreement with the view that rivers are now carrying less water than in the past. Tagseth (2002), drawing on data from three locations in southern Moshi Rural District, argues that the amount of water abstracted actually declined between 1940 and 1993, as did the number of furrows.

As there were no identifiable change in the rainfall amount, and the fact that people reported less water flowing in the rivers which could not be directly linked to water abstractions and withdraw, the changes in the dry season flow could be associated with the identified land cover changes. This dissimilar conclusion between peoples' perception and statistical analysis is to a certain extent a time bound judgment. People in most cases compare recent changes i.e. that have occurred on a short to medium timescales (a decadal or a centurial), while with computer statistical analysis, a long term trend is considered probably in the expense of shorter fluctuations. On a decadal timescale, there has been low precipitation since the El-Niño phenomenal of 1996/97 up to recent, and this is probably the reason for peoples' conclusion of low flow/precipitations.

This study therefore supports conclusive argument that the increase in vegetation cover would positively contribute to water yield in the catchments in addition to its protective role of the environment. Similar argument was also put forward by Gichuki *et al.*, (1998) in a study of flow regime for Mount Kenya. He attributed the changes in flow to land use and management changes that have reduced infiltration and ground water recharge. The results from catchment experiments in the southern highlands of Tanzania, and Great Ruaha River in particular, also supported the views that clearing of forest reduce infiltration (groundwater recharge). Extensive studies in the Great Ruaha River (SMUWC, 2000) observed deforestation in the highlands as among factors responsible for reduced low flow in the Great Ruaha River. Munishi and Temu (1992) attributed the reduction of water flow in Mtera and Kidatu Hydro Electric Power dams to unsustainable agriculture and deforestation in the upper catchment of the Ruaha River.

4.6 Peoples' Perception on Changes in Land Use/Cover and Dry Season Flow

4.6.1 Perceptions of environmental problems

People's perception on environmental change has been very important in setting a clear view of what the stakeholders perceive on the utilization of natural resources (Rohr, 2002). Table 6 shows the local people perception on various problems that may be related to observed environmental changes in the Kikuletwa river catchment. Majority of local people agreed to changes that have occurred in land use as shown by the land use/cover change analysis.

Table 6: **Local people's perception of the environmental problems in the Kikuletwa River catchment (%population).**

Statement	Very Serious (1)	Serious (2)	Moderate (3)	Not Serious (4)	Not a Problem (5)
Deforestation	78	15	7		
Availability of firewood	52	23	24		
Drying of streams and rivers	80	13	7		
Farming along rivers	53	35	12		
Overgrazing	38	28	27	7	
Changes in rainfall	73	22	5		
Loss of soil fertility	53	33	13		
Soil erosion	22	22	42	3	2
Reduced crop yields	58	20	22		
Average (%):	56	23	18	1	0.2

4.6.2 Deforestation

Amongst the catchment's most serious problem is deforestation. About 78% of the respondent reported cutting of trees to be a very serious problem (Table 6). The main factors mentioned as contributing to the trend of deforestation were population growth, high demand for fuelwood, commercial logging, charcoal production, and changing from perennial to seasonal crops. A study by Øyan (2000), on the slopes of Kilimanjaro mentioned deforestation due to illegal cutting of trees for timber and fuel-wood as one of the major problems. Additional threats to the forest reserve come from charcoal making. Lambrechts *et al.*, 2002, observed about 125 charcoal kilns in the forest reserve on the mountains southeastern slopes.

Apart from illegal felling of trees, especially Camphor which is highly preferred for timber, the collection of firewood is considered as a big threat. About 52% of the population admits that availability of fuelwood for domestic use is a problem. The shortage of firewood has been due to clearance of forests for cultivation, timber, and fragmentation of land due to increasing population. The problem of firewood has been intensified from the use of firewood for making local brew. In comparison, felling of trees for firewood is a bigger problem than felling of trees for timber. This is so, because firewood is an important source of day to day energy and is also becoming important source of income, while cutting of trees for timber mainly is a local businesses that concern only a few (Øyan, 2000). It should be noted however that, illegal timber harvesting target selective large trees species and thus seriously affects vegetation structure leading to biodiversity loss. When this study was being conducted, Kilimanjaro region was in the grip of a severe drought. Drought will put additional pressure on the forest and water, as formerly reliable water sources dry up, agriculture across the region are affected. When food is scarce and it's the dry season, more people move into the forests to look for food.

4.6.3 Perceptions on stream flow in the Kikuletwa River catchment

During the household surveys, the local people were of the opinion that water flowing in the rivers are much reduced and that many permanent rivers and streams are now intermittent. About 80% of population reported drying of rivers and streams as a very serious problem (Table 6). In total, about 93% of the population reported reduced water in the streams. This presents majority consensus among people over the decreases of water in furrows and in rivers. Long-term residents with memories of past conditions said that water in many rivers in the upland used to fill the rivers and covered the stones in the rain season. In comparison, today, most of the upland rivers fail to flood even in 'normal' years. It is only in the wettest years when stones are covered. Most commonly, people talk of how rivers which used to flow all year round across the Moshi-Arusha main road, no longer flow in the dry season nowadays. The village chairman of Foo village near the forest reserve, Mr. John Mushi, when asked to comment on trends of water flowing in the rivers, he had the following to say '*This is the forth year gone without enough rains. A generation ago, our village area was characterized by reliable rain, thick fog and generous streams. The rivers were full, Mushi says, and coffee and bananas thrived. Now the rains are irregular, many streams run dry, and a staple food doesn't thrive as it once did. When I was young, Mushi says, there weren't droughts like this one. We didn't go hungry. Now there's too much sun, it's too hot and people are going hungry. Fireplaces now sit dormant in local homes, residents no longer wear sweaters even during the coldest months and dry spells last multiple years instead of just one*'. Several previous studies over the area, have observed a decrease in dry season discharge in most if not all non-spring fed rivers (Sarmett and Faraji, 1991; Ngana, 2002; Rohr and Killingtveit, 2002; Valimba, 2004). From the local people perception point of view, this study confirm a reduction in dry season flow for most tributaries of Kikuletwa River above the major springs located in the lowlands.

Farmers could attribute decline in amount of water flowing in the furrows and rivers to land cover and deforestation. About 65% of people interviewed strongly believe that the amount of water in the Kikuletwa River is less today due to deforestation (Table 7). Others pointed to the planting of non-native species such as Eucalyptus on the water sources in the highlands as among the contributing factor to drying of rivers. Although non-native species were not mapped as part of the methods of this study, exotic trees and fodder species were observed during ground-truthing and field visits. Some species of Eucalyptus trees have competed vigorously for water and nutrients with native riparian trees. Residents have observed a marked decline of native trees in areas where Eucalyptus dominates.

Table 7: Percentage of farmers agreeing or disagreeing with statement about the status of the rivers and river flow

Statement	Strongly Agree (1)	Agree (2)	Not Sure (3)	Disagree (4)
River X is important source of water	70	30		
River X is drying up	77	23		
Drying of river X is caused by deforestation	65	27	2	7
Average (%):	71	27	1	2

X = stand for the name of nearby river

4.6.4 Perception on rainfall amount and pattern

Rainfall is a major determinant of river discharge. As far as rainfall is concerned. 72% of the respondents agreed that changes in rainfall amount and pattern are becoming a very common and serious problem in the Kikuletwa River catchment. Majority of the population pointed out that rainfall seasons in 1970s were consistent and dependable, whereas today, it is no longer easy to tell when the rain season will start. The ranking of rainfall patterns showed decreasing rainfall trend from 1970s. While the year 1970 scored 10, 1980s, 1990s and 2000 scored 9, 8 and 6 respectively. This was in agreement with individual answers given during household surveys (Table 6) which indicated significant decrease in rainfall amount.

4.6.5 Human utilization of the riparian ecosystem

Riparian zones in the Kikuletwa River catchment are used for growing crops like fodder, yams, maize, and banana. The zone also supplies other products such as sand, gravel, firewood, and timber (Table 8). Firewood was reported as the most collected item from rivers/stream banks by 80% of the population. Fodder was second in rank by 75% agreeing to have collected fodder from riverbanks. Further, about 63% of the population reported to have collected building materials such as sand and gravel. In most cases, the collected resources are for domestic uses or inter-household trade. Though, quantification of the possible effects of sand mining activities was outside the scope of this study, it was learnt that uncontrolled sand mining activities has left deep pits and caves along rivers and thus undermining the stability of riverbanks, slow down water flow and exposing streams to more evaporation.

Table 8: Major resources collected/obtained from the rivers/riverbanks in the Kikuletwa River catchment and their uses.

Resources	% respondents	Rank	Use (%)	Use
Firewood	80	1	62	Domestic only
			30	Domestic use and sale
			7	Sale
Timber	40	4	25	Domestic only
			62	Domestic use and sale
			12	Sale
Fodder	75	2	75	Domestic only
			22	Domestic use and sale
			2	Sale
Building materials	63	3	42	Domestic only
			58	Domestic use and sale
			0	Sale

Timber harvesting ranked low in the series. The low response may suggest that timber resources are much reduced or probably fairly protected by the law. Only a few households collected nothing from the rivers either because of prohibition by the village authority or lack of access. According to the district forest officer, Mr Mshana (Pers. communication), tree cutting along rivers ecosystems has been a big problem, despite risking fines from a minimum of TShs 20,000 to 300,000. Because cutting of live trees is prohibited and collecting of dry wood is allowed, it is a common practice for people to cut down trees at night and wait to collect them when dry.

4.6.6 Detrimental land-use practices in riparian ecosystems of streams

In many areas of Kikuletwa River, riparian areas have been degraded by farming activities. Participatory mapping and trend analysis through focus group discussions showed that there were more trees and intact riverine vegetation 30 years ago than there is now by a factor of 3. Deforestation in the riparian ecosystems was attributed to illegal tree cutting, farm expansion and overpopulation. Similar conclusions were made by O,kting'ati & Kessy (1991) adding that dramatic increase in forest clearing along riverbanks for expansion of agricultural production particularly in the middle and upper zones occurred in the 1960s. Transects walks along selected rivers showed that cultivation in highlands is more commonly on what can be defined as prohibited areas, compared to the lowlands.

Excess livestock numbers and associated overgrazing are frequently held among reasons and causal factors for environmental degradation, especially in the riverbanks. Though there was no reliable data available on trends of livestock population the area, a good proportion of the local people agree that livestock have increased and overgrazing is becoming a serious problem (Table 6). With prolonged drought in Masailand, the plains have of late become the target for transhumance pastoralism. Resident farmers usually keep a few cattle, but also large herds owned by Masai can be found in the lowlands. Yanda *et al.,* (1999), observed the lowland areas to be under severe overgrazing pressure. Increased grazing pressure along riverbanks prevents natural regeneration of vegetation and where there are reforestation efforts, livestock are blamed for damaging planted trees.

4.6.7 Factors contributing to environmental degradation

The main factors that were mostly mentioned as contributing to the trend of environmental degradation in the Kikuletwa River catchment were poverty, population growth, lack of environmental education, indiscriminate tree cutting, commercial logging, excessive fuelwood collection and lack or poor enforcement of laws/by-laws (Table 9).

Table 9: **Farmers perception on social-economic factors contributing to environmental degradation in the Kikuletwa River catchment.**

Socio-economic factor	Agree	Undecided	Disagree
Poverty	98	2	0
Population increase	88	9	3
Lack of environmental education	83	5	12
Lack of laws/by-laws and poor law enforcement	85	0	15

Poverty ranked high among the factors. Most of the populations in the catchment are unemployed. The immediate source of livelihood available in the catchment is based on direct exploitation of the catchment's natural resources, be it forests, fisheries or, most importantly land resources for agricultural production. Increasing resource extraction is likely to accelerate depletion of resources and hence increased poverty. Currently, abject poverty is widespread in the area, although the situation is far from famine like.

The population on the slopes of Mount Kilimanjaro increased from about 267,700 in 1948, to about 840,000 in 1988, and to about 1,053,204 in 2002 (Census, 2002). The average population density in the catchment is 300 people per km^2 with the lowlands experiencing rapid population growth in recent decades (Mwamfupe, 2002). In the highlands the population density is 900 people per km^2 with average farm holdings of about 0.2 ha per household (Mwamfupe, 2002). The growing human population has induced different impacts on resource use such as excessive utilization of natural fuel wood, overgrazing or conversion of land to agriculture and resulting into shortage of land, water and grazing area (Yanda, 2002). Mtalo and Ndomba (2002) found a high rate of erosion from Mt. Kilimanjaro where about 24 tonnes of soil per hectare of catchment flows into the Nyumba ya Mungu reservoir every year. These observations agreed with Malthusian or more recently Neo-Malthusian view that increasing demographic pressure results in overuse of reasonable quality land/ or the misuse of marginal, often easily degraded land.

Majority of the populations are aware of the existence of by-laws and regulations restricting cultivation in the riparian ecosystems (Table 9). Besides, they know the benefits associated with conserving riparian vegetation but also recognized the associated costs. Even the village authority, confirmed the statement by adding that cultivation along river banks is prohibited through by-laws. However, enforcing the laws that prohibit cultivation in riparian ecosystems, which may deprive the majority of the population about 10-50% of their land, means putting more stress on people already stressed by land scarcity. This statement has also been confirmed by Øyan (2000) when interviewing village authorities on lack of by-laws.

"we have got the names of all the persons who are cultivating along the river but we can't take them to court because there is no land for compensation---so we go on advising".

These observations support an argument that cultivation on restricted and prohibited areas in the river banks is a result of conscious decision-making and not a result of irrational behavior based on ignorance and lack of knowledge (Øyan, 2000).

Table 10: Villagers knowledge on rules/by laws regarding riverbanks conservation in the Kikuletwa River catchment.

Response Item	% Respondents
Bylaws	
- Aware	97
- Not aware	3
Can list some rules regarding riverbanks conservation	
- At least 1 rule	58
- Can not list any but aware	39
- Not aware of any	3

4.6.8 Other causes of land use/land cover changes

There may be also other causes of land cover changes, not covered by this study. Mbonile, *et al.*, (2002), describes other factors including colonial and post-independence government policies, institutional factors, legislation, as well as socio-cultural, and economic factors. The issue of farms in lowland being owned/cultivated by people residing far in the highlands was also mentioned among factors contributing to environmental degradation. People in highlands were blamed for not taking enough efforts in conserving their land in the lowlands as compared to their counterparts e.g. planting trees. Highland residents seem less attached to the low land areas they own and do not get affected on the same scale to those residing in the lowlands. There is obvious sign of overuse of the lowlands in terms of over enthusiastic removal of fodder and firewood. Resources such as grasses and crop residues are being ferried by farmers who use them to feed their livestock in the highlands, by so doing they drain the soil nutrients from the lowlands.

4.7 Summary Points from the Main Discussion

- Kikuletwa River catchment reveals a trend of conversion of land covers from higher grades (forests) to lower forms of vegetation covers.
- Between 1976 and 2000. closed forest decreased by 41061 ha (56%), open forest decreased by 51815 ha (64%), cultivated (agroforestry) land decreased by 10155 ha (25%), while cultivated (annual crops) land increased by 41923 ha (41%). Area under sisal and paddy plantation increased by 11190 ha (83%), while scrubland increased by 16916 ha (23%). Grassland more than doubled from 34529 ha in 1976 to 74587 ha in 2000 with an increase of 116% and riverine vegetation decreased by 11922 ha (53%) in the same period.
- Statistical flow analysis of Kikuletwa River catchment at IDD1 and IDD54 gauging stations, showed no identifiable changes in the amount and frequency (days) of dry season flows over the past 50 years.
- Local people opinion indicated a reduced dry season river flow. About 93% of the population reported reduced water in the streams.
- There was insufficient data to draw the trend on water abstraction for irrigation. Local people reported declined amount of water abstracted, as well as the number of furrows.
- Amongst the catchment's most serious problem is deforestation. About 78% of the respondent reported cutting of trees to be a very serious problem. The main factors contributing to the trend of deforestation are population growth, high demand for fuelwood, commercial logging, charcoal production, and changing from perennial to seasonal crops.

- Local people attributed decline in stream flow to deforestation.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

Analysis of extreme flow (low flow) in the Kikuletwa River catchment at IDD1 and IDD54 using the Mann-Whitney's test (Pettitt) and the segmentation of the hydrometeorological series (Hubert's) indicated no statistically significant changes in the average low flows (frequency and volumes of low flows) over the past 50 years.

The local people knowledge indicated a decrease in dry season river flow in most if not all non spring fed streams of Kikuletwa River catchment, though not evidenced by low flow analysis or a rainfall trends. This dissimilar conclusion between peoples' perception and statistical analysis is to a certain extent a time bound judgment. People in most cases compare recent changes i.e. that have occurred on a short to medium timescales (a decadal or a centurial), while with computer statistical analysis, a long term trend is considered probably in the expense of shorter fluctuations. On a decadal timescale, there has been low precipitation since the El-Niño phenomenal of 1996/97 up to recent, and this is probably the reason for peoples' conclusion of low flow/precipitations.

Analysis of satellite images showed considerable change in land use/cover over the three decades in the Kikuletwa River catchment. The vegetation cover/use analysis revealed three important changes, firstly, the forests and bushy vegetation degrading into lower forms of land cover such as grassland. Secondly, perennial tree cover mostly in cultivated (agroforestry) zone being replaced by annual/seasonal crop cover, and thirdly, riverbank forest cover being replaced with cultivated farms planted with yams, banana and fodder for cattle. These changes have left the soil surface without an adequate vegetation cover. The principal causes of land use/cover change were found to includes poverty, population growth, deforestation, forest reserve encroachment, commercial and illegal logging, and changing agricultural practices in the agroforestry zone. Now a days due to population growth, the farms are quarter the size they used to be. Illegal logging is rampant all over the mountain, and, along with human-triggered fires, has contributed to the deforestation on Kilimanjaro. The expansion of subsistence agriculture and extraction of trees for fuelwood degrade further the environmental of Kikuletwa River catchment.

As there were no statistical identifiable change in the rainfall amount, and the fact that people reported less water in rivers which also means less water available for abstractions, the changes in the dry season flow were associated with the identified land cover changes.

5.1 Recommendation for Further Studies

This study recommends a comprehensive study to include hydrological variables, socio-economic factors, and institutions context related to water management, and the interaction between land use and land cover change in the Kikuletwa River catchment. Special studies on sensitive ecosystems such as Oligwara Swamps, Kirua swamps, and Lake Jipe, where there is scanty knowledge on the interaction between the socio-economic and the hydrological systems are recommended.

It seems that low flow trends were not significant probably because of contributions from springs of unknown origin in the lowlands. If non spring streams were studied the trend could have been different. This study recommends gauging and further studies of non spring fed streams and rivers. It also recommends detailed studies on origin, occurrences and contribution of natural springs on river flows.

It was further noted that water abstraction for irrigation during low season might have effect on river flows. The study of high flows is recommended to see how the hydrograph behave reflecting more surface runoff during the rainy season as compared to the situation before. Such information will provide more realistic reflection of the situation because it is the time when irrigation is minimal.

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Appendix I: QUESTIONNAIRE

GENERAL INFORMATION

Name of Enumerator.. Date:...............................

Name of Interviewee (optional).................................... Village:............................

Ward.............................District...............................Age ....

Education...............................Marital status .... Sex..................

RESOURCES USE: HISTORICAL VIEW

1. Where 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? (For example, forest or bush land cleared/converted into farm, grazing or settlement area)

....

....

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

Factor	Very serious	Serious	Moderate	Not serious	Not a problem
Cutting of trees					
Availability of firewood					
Drying of streams and water sources					
Farming along rivers					
Overgrazing					
Changing in rainfall amount/pattern					
Loss of soil fertility					
Soil erosion					
Dropping in crop yields					

3. Considering the period 1970s -2000s How could you reflect the density/quantity of the following factors today compared with as in 1970s

Factor	Much incr	Increased	The same	Decreased	Much decreased	Don't know
Temperature						
Precipitation						
Trees/vegetation						
Soil erosion						
a) Water sources						
b) Distance to source c) Number of furrows						
a) Food production						
c) Frequency in farm irrigation						

4. Respond to each socio-economic factors below if it has influence to the environmental degradation (water sources and vegetation) in your village by either agree or disagree

Socio-economic factor	Agree	Undecided	Disagree
Poverty			
Lack of environmental education			
Lack of laws/by-laws and not implemented			
Other factors (Specify)			

5. To what extent do you agree with the following statements about --X----river? (X=Mention the name of nearby river)

Statement	Strongly Agree	Agree	Not sure	Disagree	Strongly disagree
River X is drying up					
The drying of river X is caused by deforestation					
River X is important as a source of water					
Immediately action is required to save river x					

6. List all the rules that you know regarding protection of the water sources:

Government rules	Village/Community rules

7. Which resources do you collect/obtain from the rivers/riverbanks? Rank as mentioned

	Resources	Rank	Use
	Water		For domestic use only
			For domestic use and for irrigation
	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
	Fodder		For domestic use only
			For domestic use and for sale
			For sale
	Foodstuff (fish, fruit, honey,)		For domestic use only
			For domestic use and for sale
			For sale
	Others e.g. building materials		

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

Action	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Environmental education/awareness					
Control tree cutting					
Stop farming in water sources					
Decrease livestock					
Enforce laws/by-laws					
Improve migration possibilities					
Plant tress					
Create alternative income opportunities					
Others (specify)					

GUIDING QUESTIONS FOR FOCUS GROUP DISCUSSION

Composition of focus group discussion (4 members from each group):

1. Members of the Village government for the selected village
2. Members of the Village Natural Resources Committee
3. Resourceful people in the village (preferably old people)

- Probing questions to capture trend over time with regards to water and vegetation cover change:
- Historical context for the use and alteration of catchment resources
- Trends in river level flows and water demand?
- Resources obtained from river and riverbanks?
- Who, how and where obtained

By the means of illustration, sketch resource map over time (trends in resource condition)

- Availability of the firewood? What proportional of collected firewood are for sell?
- Mechanisms for the protection of riparian areas and catchment. How does their implementation affect the human uses on public lands and along rivers? Comments on how best can the water sources/catchment be managed.
- Changes with respect to grazing, and what effects do such changes have on catchment?

VILLAGE ADMINISTRATOR'S CHECKLIST

Size of the village

- The size of the village and sub-village (number of household)
- The number of sub-villages
- 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 changes over the past 30 years?
- Agriculture (farming system)
- Livestock keeping
- Number of livestock
- Pasture and water
- Diseases
- Beekeeping
- River and riverbanks products (charcoal, fuel wood, poles, fodder, mining)

Environmental degradation (water sources and vegetation)

- Land use history in the village and principle 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 riverbanks
- Traditional rules regulating the use of water sources
- Are measures enforced? Are regulations been modified with time?

- Do people have tendency of planting trees in your village?

KEY INFORMANTS/OFFICERS CHECKLIST

- Trends and status of the environment (in terms of vegetation and river flow)
- Vegetation cover and river flow in 1970s
- Current vegetation cover and river flow during dry months
- Cause/Activities for the change
- Indicators of the change
- Impact of vegetation cover change on water
- Farmers/local people perception about the change
- Do people have tendency of planting trees in your area?
- Methods local people employ in conserving water sources? Are they effective?
- Overlapping mandates
- List of flora & fauna of the area to be surveyed (secondary source).
- Reference materials: Maps, books, journal, etc

DATA RECORD FOR TRANSECT WALK

Information to be recorded from direct field observation

- Vegetation type, density and condition
- Human activities on catchment and in riverbanks
- Farming (distance from riverbanks)
- Grazing
- Sacred land
- GPS information (Coordinates, X & Y)

Appendix II: General Characteristics of the Survey Respondents

Characteristic	Percent
Gender	
Female	26
Male	34
Marital status	
Married	47
Single	8
Windowed	5
Age	
Under 25	1
25 – 40	16
41 – 59	13
60 and over	30
Education	
Primary education (standard vii)	40
Secondary education	13
Colleges and institutions of higher learning	7

Appendix III: A map shown the types of major land cover/use change derived from Landsat satellite images of 1976, 1987 and 2000.