TOWARDS COMMUNITY ENVIRONMENTAL EDUCATION USING CURRENT INSTITUTIONAL RESOURCES, GIS AND REMOTE SENSING, AND LOCAL KNOWLEDGE: A CASE OF THE NANDI HILLS AND NANDI FORESTS, WESTERN KENYA

By

Julius Gordon Tanui

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PROMOTER: Prof. Paul Webb

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DECLARATION BY CANDIDATE

I, Julius Gordon Tanui, hereby declare that the work in this thesis is my own original work and all sources used or referred to have been documented and recognized. I further declare that this thesis has not been previously submitted in full or partial fulfillment of the requirements for an equivalent or higher qualification at any other recognized education institution.

.............................................  .............................................

JULIUS GORDON TANUI  DATE
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DEDICATIONS

This thesis is dedicated to:

My dearest caring wife Josephine;

My three little angels Cathleen, Celine and Carynn; and

My beloved son Joshua Gordons Jnr.
ABSTRACT

The Nandi Hills and Nandi Forests in Nandi County, Kenya are major water catchments for Lake Victoria. However, these resources have faced significant decline and degradation in recent times, thereby impacting the hydrological quality and quantity in the Lake Victoria Basin. This study was informed by the observed degradation of the Nandi Hills and Nandi Forests, epitomized by the receding forest cover, drying up of previously permanent streams, instances of mudslides and rock falls, and downstream flooding. The study therefore sought to interrogate the current institutional environmental and educational arrangements and practices which are pertinent to the sustainable management of the Nandi Hills Forests, the perceptions and understandings of the local population in terms of forest resources and land use, and the information that can be provided by GIS and Remote Sensing data, in order to produce a heuristic for planning community environmental education in the Nandi County. To achieve this, a mixed methodological design which incorporated both qualitative and quantitative data was embraced. The mixed method approaches used in this study were the concurrent triangulation and nested/embedded designs. A four-tier analysis was carried out once all the data had been coded and grouped. The analysis covered three categories of the population in the study area; namely the households, institutions and community groups, and analysis of Landsat images for change detection. The study reveals that there are several state and non-state institutions that are involved in the management of the Nandi Hills Forests and that their efforts have seen an improvement in the perceptions of the local population in terms of the importance of environmental management of the forests. Analysis of the Landsat images has revealed receding natural forest cover. The contribution of informal, local and indigenous knowledge to sustainable management of the Nandi Hills Forest was notable (85% of the population attribute their knowledge on forests and forestry to informal knowledge sources). These results informed the development of a heuristic to enable the adoption of strategies using readily accessible, though loosely applicable, information for problem solving in developing and implementing community environmental education practices for effective forest management and conservation practices that are responsive to the needs of the Nandi Forest community.
ACRONYMS

ACM - Adaptive Co-Management
CAAC - Catchment Area Advisory Committees
CBNRM - Community-Based Natural Resource Management
CBO - Community Based Organization
CBS - Central Bureau of Statistics
CEE - Community Environmental Education
CF - Community Forestry
CFM - Community Forest Management
CIFM - Community Involvement in Forest Management
CIFOR - Centre for International Forestry Research
CMS - Catchment Management Strategies
CPF - Collaborative Partnership on Forests
DDC - District Development Committees
DEO - District Environment Officers
DFRD - District Focus for Rural Development
EMCA - Environment Management and Co-ordination Act
FAO - Food and Agriculture Organization
FGD - Focus Group Discussion
GFRA - Global Forest Resources Assessment
GIS - Geographic Information System
IEE - International Environment Education
IFF - Intergovernmental Forum on Forests
IPF - Intergovernmental Panel on Forests
ITTO - International Tropical Timber Organization
IUCN - World Conservation Union
KEFRI - Kenya Forestry Research Institute
KFS - Kenya Forest Service
KNPC - Kenya National Population Census
KWS - Kenya Wildlife Service
MaSL - Metres above Sea Level
MDG - Millennium Development Goals
MEMR - Ministry of Environment and Mineral Resources
NDDP - National and District Development Plans
NEMA - National Environment Management Authority
NGO - Non Governmental Organization
NMK - National Museums of Kenya
NTZA - Nyayo Tea Zone Authority
NWFP - Non-Wood Forest Products
ODI - Overseas Development Institute
PFM - Participatory Forest Management
PNG - Papua New Guinea
PPCSC - Permanent Presidential Commission on Soil Conservation
PRA - Participatory Rural Appraisal
RDA - Regional Development Authorities
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>RRA</td>
<td>Rapid Rural Appraisal</td>
</tr>
<tr>
<td>RS</td>
<td>Remote Sensing</td>
</tr>
<tr>
<td>SFM</td>
<td>Sustainable Forest Management</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNCED</td>
<td>United Nations Conference on Environment and Development</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>UNFF</td>
<td>United Nations Forum on Forests</td>
</tr>
<tr>
<td>WCS</td>
<td>World Conference on Science</td>
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<tr>
<td>WRMA</td>
<td>Water Resources Management Authority</td>
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<td>WRUA</td>
<td>Water Resource User Associations</td>
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CHAPTER ONE

INTRODUCTION AND OVERVIEW

1. INTRODUCTION

Forests serve diverse ecological functions and provide numerous environmental and socio-economic benefits to society (Food and Agriculture Organization [FAO], 2009). Despite the importance of trees and forest resources to human existence and economic development, current trends show that forest fragmentation, degradation, inadequate regeneration, and mismanagement are threatening the supply of vital ecosystem services and provisions (Temu & Ogweno, 2007). Studies conducted by the Food and Agriculture Organization (FAO) show that, in the year 2005, forests covered 3.9 billion hectares (about 30% of the world's total land area), housed over 80% of the world's biodiversity and supported over 1.2 billion people (FAO, 2006).

Forest loss is caused by a complex set of social and economic pressures and it remains a main feature and concern, contributing to losses of biological diversity and degradation of water catchment and subsequent impairment of livelihoods (Alvarez, 2007). Among the major factors contributing to forest degradation are conversion of forests to farmland and poor forest management, including inappropriate logging, forest fires, and increased harvesting of wood fuels and other forest products for household use (World Resources Institute, 2000; Glenday, 2006).

The impact of large forest destruction on water has been of great concern among scientists, environmentalists, policy makers, and the general public. FAO (2009) asserts that
history and modern studies have shown that misuse of forest resources has caused adverse watershed condition and that activities, development, and utilization in forested areas inevitably destroy forest canopies and disturb forest floors. Temu and Kiwia (2008), in their research purport that these actions may affect water quantity through their impacts on transpiration and canopy interception losses, infiltration rate, water holding capacity, and overland flow velocity, the loss of soil-binding effects from the root systems, the increase in overland flow, and the accelerated decomposition of organic matter. Kenya’s closed canopy forests are estimated to cover 1.24 million hectares, which is just about 2% of the country’s land area. Recent estimates, based on remote sensing, indicate that Kenya’s forest cover stands at a critical 1.7 per cent (United Nations Environment Programme [UNEP], 2001). This is against, the minimum international recommended forest cover of 10 %. Despite the low closed canopy forest cover, the Nation’s forests are important natural assets for their economic, environmental, social and cultural values.

The past several decades have seen increasing awareness of the explosive growth in environmental problems throughout the world, and environmental education has emerged as a vital tool in achieving environmental sustainability (Pandey, 2005). Furthermore, almost all of the principal recent blueprints for coping with the World’s pervasive environmental predicament have stressed the value of environmental education (Tomar, 2007). Forest management has become more complex as there are now multiple objectives to attain, multiple criteria and constraints to address, and a number of modern technological advances such as Geographical Information Systems (GIS) and Remote Sensing to consider (Warnecke et al., 2002).
2. **PROBLEM STATEMENT**

The Lake Victoria catchment area has continued to degenerate over the years with its resultant state not only being a national concern but a source of international disquiet due to the alarming environmental degradation indicators from the wider Lake Victoria Basin. At the 6th World General Assembly in 1994, the Water Sector Reforms in Kenya Paper underscored the fact that the problem facing our water resources are climate variability and environmental degradation. The paper indicated that both climate variability and environmental degradation have resulted in catchment degradation, drying up of rivers, receding of lake levels, heavy siltation in our dams and pans meant for both hydropower generation and water supplies, degradation of water quality, increased water use conflicts due to competition of the little available water resources, damaged roads, railway lines, bridges, buildings, farmlands, water intakes and people displaced due to flash floods. Causes which have accelerated environmental degradation in Africa lie in a chain of events and population pressures compel African societies to deplete natural resources to meet their immediate needs for survival (Otiende et al., 1991).

In the Kenyan context, the rising human population in the Nandi Hills forests (a major water catchment area for Lake Victoria) has incrementally changed the structure and characteristics of the downstream hydrological balance (Mwiturubani, 2010). Such changes jeopardize the ability of the Lake Victoria watershed to meet growing societal needs, as well as the capacity to support the large variety of terrestrial and aquatic life forms (Mwakubo & Obare, 2009). The Nandi Hills fall within the upper Lake Victoria North Catchment Area (Government of Kenya, 2002) and is one of the sources of rivers and streams for the Lake Victoria Basin. However, continual encroachment of humans into the Nandi North and South Forests, unsustainable timber exploitation, shifting cultivation, urban expansion, and other human
activities, are posing increasing threats to this ecosystem. As in many developing countries in the tropical and subtropical regions, Nandi County has lost substantial portions of its forest cover due to conversion of forested land into agricultural land in order to feed local populations (Singh 1991). These findings suggest that one of the main challenge for the Nandi Hills forests may be the human population residing within it and its environs. The population of Nandi Hills has been increasing rapidly and by the year 2009 the population had increased to 752,965 people (Kenya National Bureau of Statistics [KNBS], 2010) in comparison to what it was forty years earlier in 1969, namely about 209,068 people.

Sound forest management practices, backed by updated forest legislation and policy, and strong institutional arrangements are necessary in order to ameliorate and turn around the degradation of the Nandi forests (Governments of Kenya, 2003). Recognition of this issue and the fact that environmental education has been recognised as a vital tool in achieving environmental sustainability, have motivated this study. The study focuses on the development of a synergistic heuristic approach to the management of available resources, which could lead towards environmental education for sustainable management of the Lake Victoria water catchment areas.

3. **OBJECTIVES OF THE STUDY**

The purpose of this study is to provide an insight into the current institutional environmental and educational arrangements and practices which are pertinent to the sustainable management of the Nandi Hills Forests, the perceptions and understandings of the local population in terms of forest resources and land use, and the information that can be provided by
GIS and Remote Sensing data, in order to produce a heuristic for planning community environmental education in the region. More specifically, the study sought to:

- Find out which formal and informal environmental education practices are in place that may influence the management and conservation of the Nandi Hills Forests;

- Map the spatial temporal variations in land use in the forest and the forest catchment area by using current GIS, Remote Sensing data, and observations in order to provide an overall understanding of the physical situation in the Nandi Hills;

- Profile the local community members’ perceptions and understandings of land use utilization practices in the forests and surrounding areas in the Nandi County; and

- Integrate the findings into a potentially viable Community Environmental Education heuristic (experience-based technique for problem solving and speeding up the process of finding a satisfactory solution) for the sustainable management of Lake Victoria’s water catchment areas.

4. RESEARCH QUESTION

It is against the introductory background and problem statement that this research is framed. It seeks to explore a heuristic which will assist planners design and implement community environmental education that takes into account existing possibilities for environmental education as well as the understandings and perceptions of local populations. In doing so, the principal research question is presented as:
Can the current institutional educational arrangements, available GIS and remote sensing data, and the knowledge and perceptions of the local community in terms of forest resources be combined to provide a heuristic which could contribute to the planning of interventions aimed at community environmental education to support the sustainable management of the Nandi Hills forests?

The sub-questions that need to be answered in order to answer the principle question are:

- What are the formal and informal environmental education and management practices that exist which could be meaningfully integrated into the heuristic?

- What is the extent of spatiotemporal variability in land use in the forests and their catchment areas?

- What knowledge and perceptions do the local community members have in terms of the current utilization practices in the forest resources of Nandi Hills and Nandi Forests?

5. **SIGNIFICANCE OF THE STUDY**

Irregular rainfall patterns in the catchment area, and frequent flooding of the lower river valleys, reflect the challenges facing the remains of the tropical rainforest which once extended all the way from the Congo Basin (Enger et al., 1992). The vital role Nandi Forests plays in this system cannot be overemphasized and prevention of their further destruction is crucial for the sustainability of the ecosystem and livelihoods in the surrounding areas (Birdlife International, 2011). These observations, and more specifically rock falls, receding forest cover and drying up
of previously permanent streams, among other environmental degradation in the Nandi Hills Forest, have motivated this study.

As it is widely agreed that environmental education is the most effective means that society possesses for confronting the challenges of environmental degradation (Palmer, 1998), this study is an attempt to provide the necessary impetus both for the local community, the government and non-governmental institutions to understand and become involved in an integrated manner in the conservation of what remains on this ecosystem. It is an attempt to synergize the data on the reality of spatiotemporal variation with perceptions of the local community and those of formal environmental education and current role players, to produce a heuristic for the conservation and management of the Nandi Hills catchment area that is likely to be effective.

6. DEMARCATION OF THE RESEARCH

Demarcating a study enables the research to be focused and manageable. This study focuses on exploring the opportunities that exist and which can be developed in the area of community environmental education towards sustainable management of the Nandi Hills. As such, the focus is on the Nandi Hills and Nandi Forest, the governmental and non-governmental organizations that operate may have an influence on the ecosystem, spatiotemporal mapping of the characteristics of the area, and the perceptions and understandings of the local population living in the area. The study examines existing practices in community forest management and existing formal and traditional approaches to land use in order to develop an integrated community driven heuristic for the sustainable management and conservation of the resources of the Nandi Hills Forests.
7. **RESEARCH DESIGN AND METHODOLOGY**

A research design is the advance planning of the means and methods to be adopted for collecting the relevant data and their analysis in line with the objective of the research and the availability of staff, time and money (Kothari, 2009). It is also the arrangement of conditions for collecting and analyzing data in a manner that aims to combine relevance to research purpose with the economy of procedure (Claire et al., 1962).

Research is located within philosophical ideas which are often concealed and need to be identified as they influence the mode of inquiry (Creswell, 2009). The underpinning philosophical ideas which determine the type of problems that should be investigated and the way in which they should be investigated are termed paradigms (Babbie & Mouton, 2008). The term paradigm means a theoretical model that is universally accepted at a particular moment and which provides the framework in which one situates one’s research (Mouton, 2001).

This study embraced a mixed methodological design which incorporated both qualitative and quantitative approaches. The mixed methodological approaches used in this study were the concurrent triangulation and nested/embedded designs. The methods were used concurrently and the mixing of qualitative and quantitative occurred during the analysis and interpretation of the data. The approach was to observe, describe and record dimensions of land use and land cover changes among households, community group and forest management institutions in the study area. The embedded design was applicable in the acquisition and interpretation of satellite data for spatiotemporal variability and change detection procedure. This allowed for correlation of quantitative data with qualitative data to explain land use and land cover changes over a time scale of 20 years. Co-relational and triangulation designs were also used to help gauge community perception about land use, forests and water resources. A four-tier analysis covering
the four categories of the population in the study area; namely the households, institutions, community groups, and analysis of Landsat images for change detection was carried out once all the data had been coded and grouped. Descriptive statistics related to the identified variables were calculated using Microsoft Excel and SPSS Computer Packages.

7.1. Location of the design

The design of this study is located in the ‘describe’ quadrant of Cronje’s (2011) elaboration of Burrel and Morgan’s (1979) model of research paradigms (see chapter six). This location implies that the researcher asks the question ‘What are the elements of …. ?’, in order to answer ‘How should they be combined or related?’ (Cronje, 2011).

7.2. Methodology

A mixed method approach using both qualitative and quantitative methodologies was used in order to add value and diverse perspectives to the study. The data were generated concurrently and both the qualitative and quantitative methods were used for the analysis and interpretation of the data.

7.3. Sample and setting

The study was conducted in the Nandi County (formerly, greater Nandi District in the Rift Valley Province) of Kenya. The specific study sites were the locations of forest resources and water catchment areas with rivers that drain into the Lake Victoria. The area was selected because of its strategic location as a catchment area for a trans-boundary natural resource, Lake Victoria, the main source of water for the Nile communities in Sub-Saharan Africa. Households in the area, the District Forest Officer for South Nandi and Nandi North Districts, the Kenya Wildlife Service (KWS) Officers for this region, members of the provincial administration and
other line ministries like Ministry of Environment and Mineral Resources (MEMR) officers and other stakeholders were targeted for sampling. Time series satellite imagery, recent LANDSAT and RASTER imagery, existing maps, reports, etc. were sampled based on availability.

The local community population sampled was the true households according to the 2009 population census (KNBS, 2010). The sample unit for data generation was the household, which was chosen for this study as the lowest identifiable social institution within which production and consumption activities take place. The choice of this sampling unit was predicated on the premise that forest management and utilization is directly related to the household size and need for forest resources. Convenience sampling (American Statistical Association [ASA], 2003) was employed as data were collected from people who were easy to access, those who volunteered to be questioned and those who attended the Participatory Rural Appraisal (PRA) sessions. Judgmental sampling was used in the selection of respondents for the PRA sessions and interviews based on their proximity to the forest areas within Nandi Hills (within a radius of 50 kilometres). Community members were invited to PRA sessions through the provincial administration offices and self-selection took place as not everyone who received the information chose to come to the meetings. A form of quota sampling also took place as only community members who were 18 years of age or older were selected. The rationale for the choice of this approach was premised on the need to engage those who could meaningfully contribute to the study and the need to economize on time and cost of collecting information.

7.4. Research instruments

In order to answer the research questions, data were collected by use of a questionnaire, an oral interview schedule guide, mechanical devices and an observation checklist.
7.4.1. **Questionnaire**

With the help of the Provincial Administration and opinion leaders within the community, the principal access roads in the villages were identified and used as transects. Research assistants used the established transects to navigate as they administered the questionnaires to the heads of the families, as the major decision makers within the households.

7.4.2. **Oral interview guide**

Open-ended and semi-structured interview schedule guides were used to obtain information from the line ministries’ officers and the civil society personnel with interests in forest management in Nandi Hills’ area. Interviews were held as face to face interpersonal interaction allowed for richer data to be generated and enabled the researcher to focus on aspects that are identified during the process as being important to the study (Kerlinger, 1973).

7.4.3. **Mechanical device**

A digital camera was used to capture real-time data on land use, the extent of visible degradation and the other relevant data related to this study. A hand held GPS was used during ground truthing for the collection of ground control points for map analysis. This was done through the collection of waypoints and routes/tracking.

7.4.4. **Observation checklist**

An observation checklist was used to document the extent of land degradation in the study site. Aspects of degradation informed the objective that looked at land use change and its impacts on sustainable environmental management.
7.4.5. Data collection and analysis

The data collection approaches used included Rapid Rural Appraisal, direct observation, questionnaire administration, oral interviews, examination of Forest inventory maps, satellite data and the review of already documented information. Satellite images were classified based on general natural spectral pixilation (unsupervised classification) and different classes generated to show spatial temporal variation over time. This provided the basis for documenting land use changes in the study site.

7.4.6. Validity and reliability

In an attempt to ensure valid and reliable data, the questionnaires were pretested by a small number of community members drawn from five divisions (Kabiyet, Tinderet, Kaptumo, Aldai and Kapsabet Divisions) in the study area such that two respondents were interviewed per division. This was done to ensure that tools tested what they are intended to (validity) and that they consistently measured the variables in the study (reliability). Pre-testing was done to test for difficulty in understanding the questions and the respondents were encouraged to ask any questions about items they are not clear about. Unclear items were reviewed, reconstructed and adjustments made to the final questionnaire. Any important corrections, clarifications, suggestions and omissions highlighted during the pre-testing exercises were used to improve the final instrument.

8. OUTLINE OF THE STUDY

The study has been divided into nine chapters such that chapter one is basically an introduction encompassing the statement of the problem, objectives and significance of the study, summary outline of the methodology, and definition of terms. Chapter two elucidates
literature and works previously done on institutional options for environmental education in forest management and in particular reviews literature on formal environmental education, indigenous knowledge, institutions and policy implications in forest management.

Chapter three explicates on status of forests as watersheds and concepts in forest management in Kenya and beyond. This is undertaken with some key aspects reviewed chapter two on awareness and education being interwoven with dimensions of forest management. In particular, it brings out works done on the extent and status of forests, effects of deforestation on watersheds, community and sustainable forest management. It concludes by highlighting a conceptual framework for sustainable water catchment area management.

The fourth chapter reviews literature on spatial temporal variations in land use and its implications on forest ecosystems and in particular; land use change, change detection methods, application of GIS and remote sensing in environmental management, condition and trends in land use in Kenya. It concludes by bringing to light the land use changes and spatial temporal variations in Kenya.

Chapter five brings to the fore the setting of the study area. It casts the study area in light of the African, Kenyan and local context and further elaborates on the key characteristics of the site. These include the physical, ecological and socioeconomic setups of the study area.

The sixth chapter is dedicated to underscoring the research design and methodology employed in the study. In particular, it focuses on relevant research paradigms the research design embraces in the study, the sample and setting of the study, the data collection instruments and the data analysis criteria. The chapter goes further to elucidate the ethical considerations in the research, points out the dynamics of validity, reliability and triangulation pertinent in the
study and concludes by acknowledging the methodological constraints that characterized the study.

Chapter seven presents the results of the study, encompassing: the institutions which contribute to the management of the Nandi Hills forests, and the land use in the Nandi Hills district as revealed by GIS, remote sensing and ground truthing. It goes further to present interview data, which provided information on issues of land ownership, land size occupied by households, as well as householders’ perceptions of forest use, their current status and their potential, and the sources of their knowledge.

Chapter eight discusses the findings of the study by drawing attention to the research questions by attempting to answer them. It begins by discussing on environmental education and conservation in and around the Nandi Forests, then expounds on the findings on the extent of spatiotemporal variation in land use in the Nandi County and the impact of the changes. Perceptions of the community on forests and forest resources are also discussed in this chapter and the chapter ends by drawing up an integrated community environmental education heuristic for sustainable forest management. The ninth chapter wraps up by drawing attention to the main findings of the study, the fundamental conclusion to the study, outlining the limitations of the study and making recommendations for further study.
CHAPTER TWO

ENVIRONMENTAL EDUCATION AND THE MANAGEMENT OF FORESTS IN KENYA

1. INTRODUCTION

This chapter emphasizes the contribution environmental education has made in terms of the sustainable management of forests in Kenya and highlights the pivotal role of various institutions in the propagation of environmental education and forest management. While some note that environmental education is as old as the existence of humankind (Waswa, Otor & Mugendi, 2006), the notion of environmental education has rapidly evolved since Carson (1962), through her well-known title ‘Silent Spring’, which drew the attention of the world towards the chemical poisoning of the environment. In 1969 the Journal of Environmental Education was first published, and in 1972 the first United Nations Conference on the Environment (UNCED) was held in Stockholm, which led to the establishment of UNEP in Nairobi, and the UNESCO-UNEP International Environment Education Programme (IEEP) was put into action at the United Nations Educational, Scientific and Cultural Organization (UNESCO) Secretariat in Paris, France in 1975 (Waswa et al., 2006). The IEEP became relevant both in school and out of school, encompassing all levels of education and directed towards the general public, in particular the ordinary citizen, with a view to educating the populace as to the simple steps that might be taken within individual means to manage and control the environment (Tomar, 2007).
2. FORMAL ENVIRONMENTAL EDUCATION

Pandey (2005) suggests that the past several decades have seen increasing awareness of the explosive growth in environmental problems throughout the world. One indicator of this awareness has been the proliferation of new journals devoted to environment and conservation. For example, at least six journals aimed specifically at teachers of environmental studies now exist, viz. the *Journal of Environmental Education* which was first published in 1969 in Washington DC; the *Environmental Education Report & Newsletter*, first published in 1973 in Hanover, New Hampshire; *Connect* (first edition 1976) in Guilford, England; and *Environmental Education Information* (first print in 1981) in Manchester, England.

Environmental offerings at undergraduate schools and at some professional schools have expanded enormously in the USA and the National Environment Education Act (USA) provides for substation support for Environmental Education in local primary and secondary school systems and at the tertiary level (Disinger & Roth, 1992). However, graduate environmental programs are said to be faltering for lack of sufficient federation funding (National Environmental Advisory Council, 2005). Outside of developed countries the status of Environmental Education is far from desirable (Knamiller, 1983). Relatively little formal Environmental Education has permeated developing countries despite considerable efforts in recent decades by UNESCO, UNEP and the World Conservation Union (IUCN) (Tomar, 2007). This is not surprising, considering that economic conditions in many developing countries are often not only dismal but also worsening year by year; for example, gross national product per capita has been declining continually for many years in 90 or more developing countries (World Bank, 2004). With the overall educational infrastructure grossly inadequate in much of the Third
World, resources to institute appropriate environmental education are, for the most part, simply not available, even when this education is recognized as a desirable innovation.

All of the principal recent blueprints for coping with the World’s pervasive environmental predicament have stressed the value of environmental education. Palmer (1998, p. 78) has urged that “environmental education should be included in and should run throughout the other disciplines of the formal education curriculum at all levels – to foster a sense of responsibility for the state of that environment and to teach students how to monitor, protect, and improve it.”

The IUCN, in partnership with UNEP and the World Wide Fund for Nature, has also stressed that “governments, through central and local education authorities, should review the present state of Environmental Education (including social education) and should make part of all courses at primary and secondary, and many at tertiary level” (Pandey, 2005, p. 23). He reflects the views of the World Resource Institute the IUCN and UNEP when he states that “at the national level, ecological literacy belongs alongside other basic skills. National curricula on biodiversity should emphasize biodiversity’s contributions to community health and welfare, as well as to ecosystems, and should tie ecological, economic, and social themes together” (Pandey, 2005, p. 23).

The United Nations Conference on Environment and Development [UNCED] (1992, section 36.1), agrees, writing that “education is critical for achieving environmental and ethnical awareness, values and attitudes, skills, and behaviour consistent with sustainable development and for effective public participation in decision making” and a distinguished group of 22
university presidents from 13 developing countries pledged to have their institutions play educational leadership roles in the necessary quest for a sustained future (Pandey, 2005).

According to Matiru (1999), there is need for forums where government officials and community representatives can discuss their expectations of increased community participation. She further points out that presently, a number of NGOs, CBOs and voluntary organizations are making good strides in enlightening the common citizen on laws and their rights in Kenya and this upsurge of environmental lobby groups has resulted in more awareness of the local citizens on environmental issues that affect them and the community at large.

The latest front in the area of environmental education and education in general is the growth of Information and Communication Technologies (ICTs). This has had significant direct and indirect impacts on forestry and has been central in accelerating the pace of globalization (Edoho, 1997). The Internet and mobile communications have created unprecedented opportunities for those who were traditionally outside the global information loop, including small and medium-sized enterprises. ICTs have increased labour productivity, reduced costs and increased returns. Online stores provide marketing opportunities for wood product and service suppliers. ICTs have also fostered institutional change in forestry (Hetemaki & Nilsson, 2005). The increased ease of information sharing and global networking diminishes the power of vertically structured organizations and fosters the development of small organizations. ICTs have helped to promote transparency and accountability on an unprecedented scale, as very little information can be kept away from public access and scrutiny. ICTs have also facilitated awareness-raising about forest-related issues such as deforestation, biodiversity loss, forest fires and the marginalization of indigenous communities (Hetemaki & Nilsson, 2005; Nyrud & Devine, 2005).
INDIGENOUS KNOWLEDGE

Traditional knowledge is defined as “a cumulative body of knowledge, practice and belief, handed down through generations by cultural transmission and evolving by adaptive processes, about the relationships of living beings (including humans) with one another and with their forest environment” (Berkes, 1999, p. 9). Such knowledge, which developed long before the advent of formal forest science, is the mainstay of many forestry practices (Bicker et al., 2004). The UN Conference on Environment and Development in 1992 catalysed interest in the contribution of indigenous knowledge to a better understanding of sustainable development and the UNCED highlighted the urgent need for developing mechanisms to protect the earth's biological diversity through local knowledge (UNCED, 1992). Many of the documents signed at UNCED reflected the need to conserve the knowledge of the environment that is being lost in communities. Similarly, the World Conference on Science (Budapest, 1999) recommended that scientific and traditional knowledge be integrated in interdisciplinary projects dealing with links between culture, environment and development in areas such as the conservation of biological diversity, management of natural resources, understanding of natural hazards and mitigation of their impact.

People with a long history of intimate contact with natural ecosystems, such as tropical forests, are typically very knowledgeable about the uses of native species. This knowledge, and the species themselves, may be used in new ways to support the improvement of farming systems in and around a conservation area, for the benefit of local communities. All too frequently, western science and indigenous knowledge are represented as two different, competing knowledge systems, characterized by a binary divide, a divide arguably evolving out of the epistemological foundations of the two knowledge systems. Hence, they may be treated as discrete entities,
separable from each other in space, which of course, if the case, preclude dialogue and learning between them (Mohan & Stokke, 2000). Although a number of observers have suggested that this divide may indeed be false or, at least, not as marked as might be supposed (Bell, 1979; Chambers, 1979; Bebbington, 1993; Briggs et al., 1999; Leach & Fairhead, 2000), the binary notion still persists. Western science is seen to be open, systematic and objective, dependent very much on being a detached centre of rationality and intelligence, whereas indigenous knowledge is seen to be closed, parochial, irrational, primitive and emotional (Howes, 1979; Howes & Chambers, 1979; Warren, 1991; Agrawal, 1995; Mitchell, 1995; Ellen & Harris, 2000; Herbert, 2000).

Consequently, whereas western knowledge systems are part of the whole notion of modernity, indigenous knowledge is part of a residual, traditional and backward way of life, a view that may be reinforced by the concentration of work on indigenous knowledge on people in low- and middle-income countries. For Indigenous peoples and local communities, concern over the preservation and maintenance of traditional knowledge is not only motivated by the desire to conserve 'biodiversity' as an end in itself, but also by the desire to live on their ancestral lands, to preserve their traditional livelihoods, to safeguard local food security and, to the extent possible, exercise local economic, cultural and political autonomy (Langton, 2003).

Traditional ways of gleaning forest products for human use need not conflict with conservation aims if they are sustainable. To achieve this, the impact must be considered of each form of exploitation on the potential yields of other forms, and on biodiversity and ecosystem structure in general (World Conservation Union [IUCN], 1993, 1994). Project designs should provide for research and management planning to balance the demands of each kind of production, while also putting in place measures needed for monitoring and enforcement. These
reasons provide a basis for including indigenous knowledge and informal environmental education in this study and, as such, issues of gains and drawbacks of indigenous knowledge are discussed below.

Development professionals consider indigenous knowledge as an invaluable and underutilized knowledge reservoir, which presents developing countries with a powerful asset (Richards, 1995). In the past few decades, traditional environmental management knowledge practices have been the focus of attention. A post-modernist paradigm supports this paradigm since it calls for the decentralisation of views on social reality in order to create a more inclusive science (Blaikie, 1995; Richards, 1995). The significance of indigenous knowledge and practices has been witnessed as:

- **A pool for advocacy:** Indigenous peoples’ groups have risen from local levels to become effective actors and advocates at the global level through coalitions presenting a unified front and delivering consistent messages in international meetings and processes. Their organized efforts have led to progress in recognizing and restoring the rights of indigenous peoples to forest land. The adoption in 2007 of the United Nations Declaration on the Rights of Indigenous Peoples, although non-binding, was a milestone (FAO, 2009).

- **Natural Resource Management Systems:** The development of traditional knowledge systems, covering all aspects of life, including management of the natural environment, has been a matter of survival to the local communities who generated these systems (United Nations Forum on Forests [UNFF], 2004).
• Sources of Innovation: Africa is endowed with rich and highly diverse biological resources. These resources provide a wide range of natural products such as those derived from bio-prospecting, intermediate products (e.g. natural dyes, colourants, oils, biochemical compounds, medicinal and food extracts, etc.) and final products (e.g. timber, handicrafts, nuts, fruits, perfumes, medicines, etc.). Many of these products are collected for subsistence use. Some of them have served as an important source of innovation for the pharmaceutical, biotechnology, cosmetic and agrochemical industries. Over the years, the World Health Assembly has adopted a number of resolutions drawing attention to the fact that most of the populations in various developing countries around the world depend on traditional medicine for primary health care, that the work force represented by practitioners of traditional medicine is a potentially important resource for the delivery of health care and that medicinal and food plants are of great importance to the health of individuals and communities (Ngassa, 2003).

• Survival Mechanisms: ‘Traditional medicine’ refers to ways of protecting and restoring health that existed before the arrival of modern medicine. As the term implies, these approaches to health belong to the traditions of each country, and have been handed down from generation to generation. Traditional systems in general have had to meet the needs of the local communities for many centuries, e.g. in relation to health needs. Humans throughout the ages have relied on plants as the source of food, clothing construction materials, cosmetics and medicines (Cichoke, 2001).

African traditional knowledge may be unique to a given African community, culture or society, and may possibly be seen to contrast with the knowledge generated within the modern learning system (Langton, 2003). Langton’s assertion continues to point out that there are
instances where traditional knowledge is used at the local level by communities in Africa as the basis for decision-making pertaining to food security, human and animal health, education, natural resource management, and other vital activities. Traditional knowledge provides alternatives to modern science, especially in health care. For example, South Asian Ayurveda and Chinese indigenous medicine are increasingly practiced throughout the world, and the use of plant-based pharmaceuticals is growing rapidly. There is growing acceptance that in order to improve the livelihoods of poor marginalized indigenous communities, it is essential to understand their traditional knowledge – their values, perceptions and knowledge of their local ecological conditions (Asia Forest Network, 2008).

Similarly, while advances in modern science and technology have had significant impacts on the forest sector these technologies remain inaccessible to many in Africa and there is a continued dependence on indigenous or traditional knowledge in managing forests and other natural resources (Parrotta & Agnoletti, 2007). Langton and Ma Rhea (2003), assert that, traditional methods of irrigation and crop production, and maintenance of seed stock and cultivars, have maintained food and grazing resources, and traditional water management systems have been critical to societies across all ecosystems.

Indigenous knowledge is of growing interest to forest science as it is increasingly recognized that indigenous resource-management systems can help to improve the framework for sustainable forest management (Borrini & Buchan, 1997). Low-input traditional land-use practices are particularly attractive in the context of declining energy supplies and increasing impacts of climate change (UNEP, 2007).
The oral and rural nature of traditional knowledge has made it largely invisible to the development community and to modern science and, where recognized, indigenous knowledge has often been dismissed as unsystematic (Hubbard, 2001). As a consequence, it has not been captured and stored in a systematic way, with the implicit danger it may become extinct. This brings in a crucial aspect of documentation of indigenous knowledge. The documentation of traditional and Indigenous knowledge is fundamental to the capacity of traditional knowledge holders to promote, protect and facilitate the proper use of their knowledge. Accurate documentation also enables nations and other interested parties to enter into agreements and contracts with traditional knowledge holders that will strengthen the capacity of these communities to develop economically sustainable livelihoods (World Bank, 1998).

However, to assume that ‘development’ in some way perished in the late 1980s/early 1990s, as suggested by some on the neoliberal right and the cultural left, may be premature, with writers such as Hart (2001) suggesting that, by the end of the 1990s, ‘development’ had returned, if indeed it ever went away. This not only involved redefining development in the context of social capital and social development, for example, but also the deployment of indigenous knowledge as part of the armoury of some mainstream development agencies (Eyzaguirre, 2001; World Bank, 1998). Central to this process has been the increasing institutionalization of indigenous knowledge through conferences, development plans and a broad, sometimes grudging, acceptance by the development community of its assumed inherent value as part of a shift in addressing the direct concerns of the poor (Hubbard, 2001; Shepherd, 2001; Warren, 1991, 1992; World Bank, 2000). It may even have reached the status of ‘a new populist rhetoric’ (Agrawal, 1995, p. 415). Without doubt, there is a conviction in many quarters of the need to tap into the stock of indigenous knowledge if appropriate planning and land management strategies
are to be developed in a sustainable way (Chokor & Odemerho, 1994; De Boef et al., 1993; Okali et al., 1994). Such conviction has contributed to this institutionalization, despite the apparent difficulty that, whilst indigenous knowledge seems to reject western science’s claims to universality and spatial transferability, at the same time its institutionalization casts it as an object that can be made essential, archived and, indeed, itself transferred.

The importance of the literature in these fields cannot be underestimated; the issue of sound documentation lies at the heart of the problem. That problem can be described as the urgent need to recognise, protect and maintain the knowledge, innovations and practices of Indigenous peoples and local communities relevant to the capacity of a community to undertake conservation and sustainable use of biodiversity (Langton & Ma Rhea, 2003). The threats to traditional knowledge and practices include not only those that threaten subsistence and traditional lifestyles, such as large-scale economic and commercial developments (e.g. militarisation, agro-industrial cropping and forestry, etc.) and associated population removals, land dispossession and urbanisation of subject populations, but also bio piracy, misappropriation and unauthorised commercialisation of traditional knowledge, practices and resources. A community cannot build its capacity to mobilise its knowledge if there is no recognition that it is owned by them. African studies concerning indigenous environmental management practices stress the role of different techniques in risk avoidance and effective resource use. It is, however, recognised that this system of knowledge and practices is threatened by socioeconomic and historical pressures (Richards, 1995).

With the social, economic, political and institutional change, indigenous knowledge provides opportunities but also faces challenges according to FAO (2009). These challenges include:
• Domination, marginalization and assimilation: Despite increasing recognition of their rights, indigenous people are systematically marginalized in many countries, including by narrowly focused development programmes. As vast tracts of forests that sustained indigenous communities are converted to other uses, forest-based livelihoods and the associated knowledge are soon lost;

• Selective appropriation: Realization of the economic potential of traditional knowledge (particularly in the rapidly expanding pharmaceuticals and health and beauty care markets) has led to systematic efforts to identify and commercialize it – taking the knowledge out of its social and cultural context and raising issues of intellectual property rights and fair compensation for knowledge holders; and

• Rediscovery: Increasing emphasis on protecting the rights, cultures and technologies of indigenous communities can create a favourable environment for the natural evolution of traditional knowledge. Developments in the international policy arena, such as the passage of the UN Declaration on the Rights of Indigenous Peoples, specifically recognize the need to respect traditional knowledge and practices.

Indigenous knowledge and community-based innovation are dynamic. Options for action include creating incentives to improve the capacity of formal research organizations to work with local and indigenous people and encouraging collaboration in conservation (International Assessment of Agricultural Knowledge, Science and Technology for Development [IAASTD], 2008).
4. INSTITUTIONAL EDUCATIONAL ARRANGEMENTS IN FOREST MANAGEMENT

According to FAO (2009), institutions are key factors in sustainable resource management and societal adaptation to social, economic and environmental changes. As in other sectors, the overall trend in forestry is towards a pluralistic institutional environment, attributable to two divergent trends: globalization and localization. Increased cross-border movement of capital, labour, technology and goods resulting from globalization has necessitated adaptation by existing institutions and the establishment of new ones. At the same time, local communities have become more involved in resource management through decentralization and devolution of responsibilities. Matiru (1999) believes that substantial efforts are required to revamp the institutional framework to strengthen the science and technology base of forestry in Africa; otherwise, major breakthroughs are likely to bypass the African forest sector or at best will benefit only a small segment of the population.

Government forestry agencies remain the dominant force in the sector and more than 80% of global forests are under public jurisdiction (FAO, 2006). Government forestry departments are often among the oldest of the civil services and many originally focused on enforcing regulations, with the main objective of protecting and managing the forests to supply forest products and generate revenue for government (Hamilton & King, 1983). They traditionally integrated multiple functions from wood production to processing and trade as well as forestry research, education, training and extension. Challenges of reduced public expenditure, mounting expectations of different stakeholders and increasing conflicts over the use of forest resources are stirring public agencies to rethink their management objectives, functions and structures (FAO, 2008). The evolution in focus can be loosely described as moving from policing
the forests to managing them to facilitating management by others (Nair, 2004). In some cases, reform has been superficial; for example, limited to changes in ministerial responsibility (in particular shifting between agriculture and environment ministries) or to structural but not functional change (World Bank, 2001). Many public agencies are unable to develop the human resources needed in order to manage forest resources in an increasingly complex environment (Nair, 2004; Temu, 2004), and many lack sufficient capacity for long-term strategic planning or open sharing of information, with a tendency to be reactive to short-term pressures and concerns (often mirroring the larger public administration).

On the other hand, increasing awareness and concern about social and environmental issues imply an increasing role for civil society organizations in forestry. Campbell (personal communication, 2008) believes that a shift towards institutional and economic complexity should mirror more effectively the ecological and cultural diversity of forests and peoples. Such complexity is needed in order to help forests fulfil their integrating role in a dispersed, diversified and distributive forest economy and civil-society actors inject much-needed disorder into intentionally neat power equations.

Civil society’s demand for transparency and good governance is bringing about fundamental changes in Africa as postulated by the FAO (2008). Although decentralization of authority and participatory approaches to resource management are finding wider acceptance, conflicts undermine social and economic development in a number of countries (Nair & Dykstra, 1998). Nevertheless, community involvement in natural resource management has a long history in Africa, and policy and legal changes in recent years have helped to accelerate devolution (White & Martin, 2002).
In Kenya initial concern on environmental policy formulation was voiced in the 1965 Sessional Paper No. 10 on African Nationalism and its Application to Planning in Kenya, which recognised that in order to effectively conserve the environment, education and legislation was important (Government of Kenya, 1965). Otiende et al. (1991) concur that the Sessional Paper No. 10 of 1965, having pointed out the need to conserve the environment, was a step in the right direction. He however continues to assert that the well-being of future generations would depend on the adoption and implementation of policies which were expected to ensure the conservation of natural resources and create enjoyable physical environment. This formed the foundation for latter legislative and educational initiatives by the government and non-state actors to enhance forest management.

According to the Kenya Forestry Master Plan (1994), some of the services provided by forests include: - fuel wood, charcoal, construction materials, timber, curving wood, hives, weapons, tools and domestic implements, grazing and fodder, medicine, honey, foods, animal products, ropes, mats, bags, baskets and pots, minerals, water, habitation, cultivation, ritual and ceremony, leisure and holiday, and research. The findings of an empirical study in Kenyan, Ugandan, and Tanzanian Lake Victoria watershed by Obare, Mwakubo and Birungi (2006), provide evidence of important linkages between incidences of households’ vulnerabilities, livelihoods, and institutions in the use and management of wetlands in the Lake Victoria watershed, and that the dynamism associated with these facets can be characterized as general and location specific in effects and outputs. It would be necessary hence to highlight on the relevant institutions and substantive policies that have impacted on forest management in Kenya.
4.1. Management and planning institutions in forest management in Kenya

Kenyan forests have suffered immense impacts not because of lack of institutions but more because of implementation gaps and institutional weaknesses. Because governments own or control three-quarters of all global forest resources, some 3 billion hectares, and regulate private and community-owned forest management, their responsibility in addressing illegal operations in the forest sector is crucial (White & Martin, 2002). This sub-section highlights on the institutions involved in the management and conservation of forests in Kenya.

4.1.1. National Environment Management Authority

The authority was created by the Environment Management and Co-ordination Act of 1999, as the oversight body for environmental management and co-ordination matters (Government of Kenya, 2000), and its mandate including:

i) Co-ordinate the various environmental management activities being undertaken by the lead agencies and promote the integration of environmental considerations into development policies, plans, programmes and projects with a view to ensuring the proper management and rational utilization of environmental resources on a sustainable yield basis for the improvement of the quality of human life in Kenya;

ii) Take stock of the natural resources in Kenya and their utilization and conservation;

iii) Establish and review in consultation with the relevant lead agencies, land use guidelines;

iv) Examine land use patterns to determine their impact on the quality and quantity of natural resources;
v) Carry out surveys which will assist in the proper management and conservation of the environment;

vi) Advise the government on legislative and other measures for the management of the environment or the implementation of relevant international conventions, treaties and agreements in the field of environment, as the case may be;

vii) Advise the government on regional and international environmental conventions, treaties and agreements to which Kenya should be a party and follow up the implementation of such of such agreements where Kenya is party;

viii) Undertake and co-ordinate research, investigation and surveys in the field of environment and collect, collate and disseminate information about the findings of such research, investigation or survey;

ix) Mobilize and monitor the use of financial and human resources for environmental management;

x) Identify projects and programs or types of projects and programs, plans and policies for which environmental audit or environmental monitoring must be conducted under this Act;

xi) Initiate and evolve procedures and safeguards for the prevention of accidents which may cause environmental degradation and evolve remedial measures where accidents occur;

xii) Monitor and assess activities, including activities being carried out by relevant lead agencies, in order to ensure that the environment is not degraded by such activities, environmental management objectives are adhered to and adequate early warning on impending environmental emergency is given;
xiii) Undertake, in co-operation with relevant lead agencies, programmes intended to enhance environmental education and public awareness about the need for sound environmental management as well as for enlisting public support and encouraging the effort made by other entities in that regard;

xiv) Publish and disseminate manuals, codes or guidelines relating to environmental management and prevention and abatement of environmental degradation;

xv) Render advice and technical support, where possible, to entities engaged in natural resource management and environmental protection so as to enable them to carry out their responsibilities satisfactorily;

xvi) Prepare and issue an annual report on the state of the environment in Kenya and in this regard may direct any lead agency to prepare and submit to it a report on the state of the sector of the environment under the administration of that lead agency;

xvii) Perform such other functions as the Government may assign to the Authority or as are incidental or conducive to the excise by the Authority of any or all of the functions provided under this Act.

Although having been institutionalized, the National Environment Management Authority (NEMA) still has to grapple with issues of self-interests, political interference and inadequate legitimate authority to undertake environmental management.

4.1.2. Regional development authorities

The management planning for the country’s river basins is vested in Regional Development Authorities (Matiru, 1999). To date there are six Regional Development Authorities constituted by Acts of Parliament i.e. Tana and Athi Rivers Development Authority (Cap. 443); Lake Basin Development Authority (Cap. 442); Kerio Valley Development
According to the statutes, the functions of the regional development authorities include rendering assistance to operational agencies in their application for funds and causing the construction of any works necessary for protection and utilization of the water and soils of the area. The activities of River Basin Development Authorities, especially those concerning the construction of hydro-electric dams and irrigation projects along the rivers have implication especially for riverine forests. Coupled with land use changes upstream and the degradation of catchment areas, these projects result in altered volume and regularity of water flow and siltation levels which affect both riverine forests and the ecology at the river mouth which in turn affects the flora and fauna, for example, Mangrove forests and marine life.

Riverine forests, supported by underground water seepage, are found in localized areas such as Dodori and Boni forests, with some patches along Turkwell River, Athi/Galana and the Tana rivers covering less than 1% of Kenya’s total forest estate. Riverine forests owe their dynamism, structure and composition to river processes and the water regime (Nkako, 1999). The Turkwell Gorge Hydro-electric dam, managed by the Kerio-valley Development Authority along the Turkwell River in Turkana has also had an impact on the riverine forests due to changes in the water flow and flooding levels.
4.1.3. Memoranda of Understanding between government institutions

In Kenya various government institutions and departments have signed Memoranda of Understanding (MoU) in an effort to reduce conflicts arising from overlapping mandates for the management of natural resources (Matiru, 1999). Government institutions that have entered into MoUs include the Forest Department (FD), the Kenya Wildlife Service (KWS), National Museums of Kenya (NMK), the Fisheries Department (FD), the Nyayo Tea Zone Authority (NTZA) and specific local Authorities.

The objectives of the Memorandum of Understanding between the Kenya Wildlife Service and the Forestry Department, for example, signed on 5th December, 1991 are to:

i) Conserve forest biodiversity by preserving select examples of different forest types, areas of endemic or threatened species of flora and fauna, and areas important for the maintenance of genetic diversity;

ii) Maintain the functioning of ecological processes: regulation of water flow, soil conservation and the nutrient cycle;

iii) Exploit economically and sustainably the potential of forest products, tourism and recreation;

iv) Provide a basis for conservation education, extension and research;

v) Protect and preserve selected sites and areas of special interest;

vi) Minimize threat to human life and damage to tree plantations, agricultural crops and livestock by wildlife; and

vii) Generate revenue to be re-invested in forest conservation and management.
4.1.4. Nyayo Tea Zones Development Corporation

The Nyayo Tea Zones Development Corporation (NTZDC) was established through a Legal Notice, No. 285 of 1986 under the State Corporations Act (Government of Kenya, 1986). Its main objectives are to:

i) Protect indigenous forests currently threatened by human encroachment and over exploitation thereby contributing towards global environmental and biodiversity conservation;

ii) Provide alternative source of earnings through employment in intensively managed Nyayo Tea and fuel wood plantations; and

iii) Develop rural infrastructure through the construction and maintenance of roads, bridges, leaf buying centres, tea factories (where currently none exist), staff houses, telephone communication, electricity and water supplies.

The Nyayo Tea Zones are established in gazetted Forest Reserves. Mapping of the zones is currently in process. Out of approximately 6,154 ha of forested areas which were cleared for the tea zones, an estimated 4,000 ha are currently under tea. Areas that were cleared in Nyayo Tea Zones but found to be unsuitable for tea cultivation are currently being put under fuel wood plantations (Nandi, Kakamega Forest, Kaptagat/Kiptaberr) especially planting of the two species of eucalyptus, *Eucalyptus saligna* and *Eucalyptus grandis*. These plantations are being maintained with local communities through a non-resident *shamba* system whereby young trees are intercropped with vegetables and other food crops.
4.1.5. Permanent Presidential Commission on Soil Conservation

The Permanent Presidential Commission on Soil Conservation (PPCSC) was established in 1981 as a Department in the Cabinet Office of the Office of the President. The PPCSC has the task of co-ordinating all agencies involved in soil conservation activities (Government of Kenya, 1981). Its terms of reference include to:

i) Review the present legislation on soil conservation, afforestation and flood control and to advise on their adequacy and effectiveness;

ii) Advise in consultation with other relevant agencies on areas that should be declared ‘Protection Catchment Areas’ and to recommend on the measures to be taken to regulate the management of such protected areas;

iii) Advise on the measures to be taken to protect water courses with a view to preventing river siltation;

iv) Submit specific recommendations at every stage after deliberating on specific items; and

v) Continually evaluate the performance of government agencies charged with the responsibility of implementing soil conservation, afforestation and flood control programmes and advise on the adequacy or otherwise of government machinery for planning and implementation of programmes in this area.

PPCSA published a survey report in October 1999 entitled ‘Reconnaissance Survey of Forest Blocks in the West and East of the Rift Valley’. The report outlines the status of forests in the selected areas with emphasis on indigenous forests and associated threats. The report also gives recommendations for enhanced management of the forests, including income generating activities towards self-sustenance (Government of Kenya, 1999).
4.1.6. District Focus for Rural Development

The District Focus for Rural Development (DFRD) came into effect in 1983 and the main objective of this strategy was the adoption of a bottom-up approach to planning, whereby districts are given autonomy in setting their priorities (Government of Kenya, 1983). This strategy is unlike the previous top-down approach where ministry headquarters set district development agenda. At the district level, co-ordination is carried out through various Development Committees, from District Development Committees (DDC) to Sub-Location Development Committees. Members of the DDCs include District Commissioners (as Chairpersons), District Development Officers (as Secretaries), Department Heads of all Ministries, Members of Parliament, ruling party’s District Chairpersons, Chairpersons of Local Authorities, Clerks to Local Authorities, Chairpersons of Divisional Development Committees and representatives of development-related parastatals, NGOs and self-help groups. Environmental management under this structure has been facilitated by the establishment of the District Environment Officers (DEO) in 1989 and District Environment Protection Officers in 1993 (United Nations Development Programme, 1999).

One of the implications of the DFRD structure to forest management is that the DDC, as the main development planning body at the district level, reviews and approves development plans and can make requests to the relevant ministry for the excision of forest land in response to pressure from the residents. For example, the Kilifi DDC had requested for the excision of Arabuko Sokoke Forest for settlement of squatters in the district.

4.1.7. Water Resource Management Authority

The Water Resource Management Authority (WRMA) is a state corporation under the Ministry of Water and Irrigation established under the Water Act 2002 and charged with being
the lead agency in water resources management (Government of Kenya, 2002). The Water Act 2002 stipulates the duties of WRMA to include;

i) Water apportionment and allocation,

ii) Catchment protection and conservation,

iii) Water resource assessments and conservation,

iv) Delineation of catchment areas,

v) Gazetting water protected areas,

vi) Protection of wetlands,

vii) Gazetting water schemes to be state and community owned,

viii) Establishing Catchment Management Strategies (CMS)

ix) Collecting water use and effluent discharges.

In order for WRMA to undertake its stipulated responsibilities, the Act provides for decentralized and stakeholder involvement. This will be implemented through regional offices of the Authority based on drainage basins (catchment areas) assisted by Catchment Area Advisory Committees (CAACs). At the grassroots level, stakeholder engagement will be through Water Resource User Associations (WRUAs).

4.1.8. Kenya Forest Research Institute

The Kenya Forestry Research Institute was established in 1986 under the Science and Technology Act (Chapter 250) to carry out research in forestry and allied natural resources. The institute has a role to play in influencing polices on forest resource management. Since 1998, the Institute has continued to restructure its research programme by:
• Consolidating 17 discipline-oriented divisions into six programmes as contained in Kenya Forests Master Plan;
• Adopting multidisciplinary research approach;
• Focusing on problem oriented research;
• Decentralizing research activities to facilitate improved interaction and linkages with the local users;
• Improving facilities in six centres in representative ecological zones of the country;
• Adopting focused capacity building;
• Developing beneficial partnerships;
• Decentralising dissemination of research findings and seed distribution;
• Reducing staff from 1600 in 1998 to 990 in 2008 without compromising the performance of the Institute. This has resulted in increase of funds for research and maintenance of facilities.

4.2. Substantive policies

Although there have been strides since 1965 to formulate and legislate policies and laws to sustainably manage Kenya’s forests, just as other developing countries it tends to have an overabundance of regulation (World Bank, 2004). Regulatory proliferation is usually an indicator of weak policy framework which does not adequately address the long-term vision for the forestry sector (Eboe, 2002). This multiplies the risk of legal inconsistencies, contradictions and overlapping jurisdictions and complicates the understanding of the regulatory regime affecting the sector. All this in turn allows for more discretionary decisions and, therefore, increased opportunities for corruption (FAO, 2005).
Certain policies, legislations and bylaws are seen to be directly impacting on forests and generally water catchment areas in Kenya. However, it is worth noting that it is only the Forest Act has direct bearing on the issue of additions and excision of gazette forests. The other policies and legislations described in this sub-section may affect forests or partially forested land in general. Some of them having been revised and amended over time to address the ever-changing environmental, social and economic needs of the society. Enumerated as follows, these policies and legislations address from specific to a wide range of forest-related spheres.

4.2.1. *The Kenya Forest Act, 2005*

The Kenya Forest Act (Government of Kenya, 2005) which was accented to by the President of the Republic of Kenya in November 2005 provides for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country. This Act and its provisions thereof are geared towards the sustainable management and conservation of the country’s forest resources through the Kenya Forest Service (KFS). The Act has been revised in several occasions for purposes of making it more relevant in the management and conservation of forests in Kenya. A highly conspicuous dimension in the 2005 Act is the greater recognition of stakeholder participation in decision-making on issues affecting forests. Section 45 of The Act provides for the registration of Community Forests Associations (CFAs) for purposes of participating in the conservation and management of a state forest or local authority forest (Government of Kenya, 2005, p.38)
4.2.2. The Kenya Water Act, 2002

The Kenya Water Act was passed as An Act of Parliament to provide for the management, conservation, use and control of water resources and for the acquisition and regulation of rights to use water; to provide for the regulation and management of water supply and sewerage services …and for related purposes (Government of Kenya, 2002). After being passed by parliament and consequently enacted in 2003, this act provides for the decentralization of powers from the national to the regional and local level; the separation of water resources management from water service provision as well as the institutional separation of policy, regulatory, asset holding and operational functions. The Act divests the Minister in charge water affairs of regulatory functions over the management of water resources. This becomes the mandate of a new institution, the Water Resources Management Authority (the Authority), established in section 7 of the Act. The Authority is responsible, among other things, for the allocation of water resources through a permit system. The framework for the exercise of the water resources allocation function comprises the development of national and regional water resource management strategies which are intended to outline the principles, objectives and procedures for the management of water resources. The Water Act 2002 has introduced comprehensive and, in many instances, radical, changes to the legal framework for the management of the water sector in Kenya. These reforms revolve around the following four themes: the separation of the management of water resources from the provision of water services; the separation of policy making from day to day administration and regulation; decentralization of functions to lower level state organs; and the involvement of non-government entities in the management of water resources and in the provision of water services (Mumma, 2005). This was a move in the right direction and geared towards a more professional and an
institution-specific approach which would enhance appropriate and a more localized and customized procedures in water catchment management and conservation.

4.2.3. The Environmental Management and Co-Ordination Act, 1999

This Act received presidential assent on 6\textsuperscript{th} January, 2000 and commenced on 14\textsuperscript{th} January, 2000, which was a great milestone achievement in promoting sustainable forest management in the country. The act provides legal, institutional frameworks and procedures for management of the environment as well as modalities for conflict resolution (Government of Kenya, 2000). The act provided an avenue for the harmonization of about 77 existing sectoral statutes, which address the various aspects of the environment. This has presented improved legal and administrative coordination of the diverse sectoral initiatives in order to improve the national capacity for the management of the environment. This is in view of the fact that the environment constitutes the foundation of national economic, social, cultural and spiritual advancement.

The general principles of the act include:

- The entitlement of every person in Kenya to a clean and healthy environment;
- Everyone in Kenya having the duty to ensure a safe, clean and healthy environment;
- The entitlement to a clean and healthy environment includes the access by any person in Kenya to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes; and
- If a person alleges that the entitlement to clean and healthy environment has been, is being or is likely to be contravened in relation to him, then without prejudice to any other
action with respect to the same matter which is lawfully available, that person may apply to the high court for redress.

4.2.4. The National Water Policy, 1999

Kenya’s first National Water Policy was passed by Parliament in April 1999. The main objective of this water policy is the supply and distribution of water resources throughout the country in a sustainable, rational and economical way. This policy has implications for the forestry sector in its objective with regard to environmental protection. It recognizes the fact that increased human activities, especially in water catchment areas has resulted in the reduction and deterioration of forest cover area and constitutes a threat to the country’s water resources. The policy proposes to address these issues through the protection of water catchments, river basin management and practices that take into account the role forests and soil conservation measures play in conservation of water resources. Furthermore, it states that water catchments need to be identified and delineated, and water catchment preservation and protection programmes instituted in collaboration with the relevant Ministry in charge of forests (Government of Kenya, 1999).

4.2.5. Kenya Forest Policy, 1994

The Policy received Cabinet approval in 1994 and replaced the one effected by Sessional Paper No. 1 of 1968. The policy aims to provide continuous guidelines to Kenyans on sustainable management of forests and potential forest land. It takes into cognizance existing policies relating to land-use, wildlife, environment, agriculture, energy, industry, regional development, among others. The need to conserve soil, water, biodiversity, and other forest
resources on gazetted forests, other protected forest lands, on farms and in arid and semi-arid lands, are also discussed in the policy.

The policy seeks to separate the management of forest plantations from that of indigenous forests. It advocates for commercialized forest management to monitor and guide the forestry activities of the public, private and farm-forestry sub-sector. The Forest Policy addresses research, as it is an essential component of forestry development. The Kenya Forestry Research Institute (KEFRI) is listed as the principal institution mandated to conduct forestry research. Ecotourism is also addressed as one of the factors that could have negative effects on the ecosystem if not well planned. The policy calls for the harmonization of traditional forms of forestry management and ecotourism.

4.2.6. Chief’s Authority Act, Cap. 128 of 1970 (revised 1988)

This Act empowers Chiefs to enforce various environmental conservation provisions within the limits of their jurisdiction, including control of the use of tree resources on private land. Their powers relevant to forest management include (Government of Kenya, 1988):

- prohibiting the destruction of vegetation
- regulating the cutting of timber and prohibiting the wasteful destruction of trees
- control of grass fires
- ordering the execution of work or services for the conservation of natural resources
- Empowering the Minister to remove member(s) of a tribal community who have land reserved for them, if they unlawfully occupy or cultivate any land other than the reserved land.
The Chief’s Authority Act is one of the principal statutes through which the Provincial Administration implements government policies and development priorities. This Act has been criticized because of the broad powers it confers which can be abused.

Pandey (2005) asserts that one of the most formidable and ever more interactive challenges facing human today is coexisting with the other living creatures on earth. Meeting this challenge will require appropriate education, both formal and informal. Everyone who is responsible for education policy or entrusted to carry it out should be made aware of the legally binding agreement entered into by their government regarding environmental education, the current status of environment in both developed and developing countries, the authoritative encouragement and guidance offered by major environmental organizations and others and the conceptual basis upon which all Environmental Education must rest if it is to achieve its purposes.

5. **CHAPTER SUMMARY**

This chapter focused on formal and informal environmental education and indigenous knowledge and practices in Kenya. It also highlighted the institutional educational arrangements in forest management with an emphasis on substantive policies and planning institutions in forest management in Kenya. These issues are presented in order to provide a framework for reviewing the current situation in the Nandi Hills region of western Kenya and to contribute to the development of a heuristic which considers all stakeholders to guide future attempts to introduce environmental education in the region.
CHAPTER THREE

STATUS OF FORESTS AS WATERSHEDS AND CONCEPTS IN FOREST MANAGEMENT

1. INTRODUCTION

This chapter focuses on appreciating the status and importance of forests both globally and in Kenya. It appraises existing concepts and theories on forest management and the emerging trends in conservation, including climate change which poses a major challenge to forests. There is now clear evidence that climate change is occurring in regions where forest-based communities and forest ecosystems are vulnerable (Intergovernmental Panel on Climate Change [IPCC], 2007; Juday et al., 2004) and that its impact on the supportive and regulative processes of forests and on how people use forest resources are difficult to predict. The best response to the uncertainty climate change presents is to maintain or increase the functioning and resilience of all forests as a matter of urgency; a challenge which provides opportunities for increased cooperation with forest stakeholders at national and international levels (FAO, 2009).

2. EXTENT AND STATUS OF FORESTS

The Global Forest Resources Assessment 2005 (FAO, 2006) emphasized that forest area provides the first indication of the relative importance of forests in a country or region. Forest area is relatively easy to measure, and this variable has therefore been selected as one of the 48 indicators for monitoring progress towards the Millennium Development Goals agreed by the United Nations (particularly Goal 7 – Ensuring environmental sustainability). The structure and
composition of forests are increasingly influenced by global phenomena such as the presence of introduced species, climate change, and anthropogenic alterations of biogeochemical cycles (Dale et al., 2001; Honnay et al., 2002; Newman, 1995; Simberloff, 2000; Vitousek et al., 1997). Major transformations of forest ecosystems have occurred or are underway, in many cases resulting in substantial losses of timber values or commercial extinction of valuable tree species, along with a reduction in native biodiversity (Hoekstra et al., 2005; Laurance, 1999; Liebhold et al., 1995; Simberloff, 2000). In addition to global influences, forests are also being shaped by regional and local forces.

Forests provide an array of economic resources, and different harvesting techniques are prone to achieve manifold yields from the same environment. The incredibly robust management techniques are those which shun open-access utilization of resources, through tenure and usufruct mechanisms allowing for long-term and exclusive access by individuals or communities (Caldecott et al., 1994). They continue to elaborate that where such techniques have been embraced, the necessity for exterior intervention may be reduced to technical counsel and monitoring, to guarantee sustainable harvests. Barring such harvesting may lead to economic loss to the local people and trigger their antagonism. Alternatives in such a case may comprise traditional utilization of segments inside conservation areas, buffer zones bordering them, or community lands in a different place, which may all be accessible for particular types of persistent exploitation by locals. Moreover, forests often experience the cumulative and often fragmentary impacts of development stresses such as road-building, oil and gas development, urban and suburban encroachment, and agriculture (Forman, 2000; Schneider et al. 2003; Trombulak & Frissell 2000; World Resources Institute, 2000). This combination of disturbance and developmental pressures can reduce biodiversity and diminish the capacity of forests to
continue providing ecological goods and services of the same quantity and quality in perpetuity (Costanza et al., 2000; Toman & Ashton 1996). In response to these concerns, many ecologists have argued that resource managers should focus on maintaining ecological resilience, defined here as the capacity of natural systems to absorb disturbances without undergoing change to a fundamentally different state (e.g., Holling, 1973; Holling, 1986; Peterson et al., 1998).

Whenever a resource is exploited, several different interests are put into conflict. Two major ones are economic interests and environmental interests. Economic factors are easy to measure. The cost of exploitation and financial return for this expenditure are the primary issues. The environmental viewpoint is often difficult to put into monetary terms and must often rely on ethical and biological arguments to temper the economic arguments. Modern forest management practices in many parts of the world involve a compromise between these two points of view (Enger et al., 1992).

2.1. Global forest outlook

Data on the status of and trends in area of forest are crucial to decisions related to forest and land-use policies and resource allocations, but they need to be combined with information on the health and vitality of forests and their socio-economic and environmental functions and values. The GFRA 2005 (FAO, 2006), further points out that forests cover 30% of the total land area with the total forest area in 2005 being just under 4 billion hectares (ha), corresponding to an average of 0.62 ha per capita. However, the area of forest is unevenly distributed. For example, 64 countries with a combined population of 2 billion have less than 0.1 ha of forest per capita. The ten most forest-rich countries account for two-thirds of total forest area. Seven countries or areas have no forest at all, and an additional 57 have forest on less than 10% of their total land area.
2.2. **Africa forest outlook**

Africa accounts for just about 16.1% of the global forest cover which is around 0.64 million ha. Although the tropics boast of the largest area under forest, they are faced with the largest rate of deforestation (FAO, 2009). Forest loss caused by a complex set of social and economic pressures is a concern, contributing to losses of biological diversity, degradation of forests, and have contributed significantly to global warming (Glenday, 2006; Haili, 2007). Among the major factors contributing to forest degradation are conversion of forests to farmland and poor forest management, including inappropriate logging, forest fires, and increased harvesting of wood fuels and other forest products for household use (Glenday, 2006; World Rainforest Movement [WRM], 2006).

Progress towards sustainable forest management in Africa appears to have been limited during the last 15 years despite some indications that the net loss of forest area has decreased and that the area of forest designated for conservation of biological diversity has increased minimally and the continued, rapid loss of forest area (the largest of any region during this 15-year period) is particularly disconcerting (FAO, 2006).

2.3. **Forest status in Kenya**

In Kenya, gazetted forests represent less than 2.5% of the total land area. The country has about 37.6 million ha of natural woody vegetation outside forests, consisting of 24.8 million ha of bush land, 10.8 million ha of wooded grassland and 2.1 million ha of woodland. A further 9.54 million ha of woody vegetation is found on farmland and in settlements (Kenya Forestry Department, 2001). Kenya’s closed canopy forests are estimated to cover 1.24 million hectares. This is just about two per cent of the country’s land area and these are largely confined to the wetter, cooler parts of the country. According to Ogweno and Oduori (2001), these forests can be
classified into four types: (a) Coastal Forest (b) Afro-montane forest comprising east and west
mountain forests (c) Guineo-Congolan upland forests and (d) the small outlier forests in dry
zones, like the Kitui and Machakos hill tops and the Taita hills. Also to be included here are
forest patches in Western Kenya and riverine forests. Recent estimates, based on remote sensing,
indicate that Kenya’s forest cover now stands at a critical 1.7 per cent (UNEP, 2001). This is
against the minimum international recommended forest cover of 10 % (see figure 3.1).
Figure 3.1:

The distribution of forests in Kenya (Source: Kenya Forest Service, 2010)
Despite the fact that the amount of closed canopy forest cover in Kenya is low, the nation’s forests are important natural assets for their economic, environmental, social and cultural values. Forestry and wood processing industries are estimated to provide direct employment to 35,000 people (Gathaara, 1999). Forests are therefore an integral part of national development. Although forest products and services in Kenya are estimated to contribute about €90 million to the economy, and although the forest sector employs 50,000 people directly and another 30,000 indirectly, the forests nevertheless tend to be undervalued (Emerton & Karanja, 2001) and accordingly they are often poorly managed.

The Mau forest provides sustenance to more than 150,000 families that live in and within 2 kilometres of its boundary. Each year, these families utilize forest resources such as fuel wood, building materials, food, vegetables, honey, fodder, and other non-timber forests products. The Mau Water Tower represents the upper catchment of all but one of the main rivers west of the Rift Valley, which are the source of over 60% of the water flowing into Lake Victoria (see figure 3.2 below).
Figure 3.2

*Nandi Forests in the Context of Mau Forest Complex (Source: Kenya Forest Service, 2010)*
The Mau Forest Complex have been heavily impacted by official forest excisions, as well as the illegal, irregular and unplanned settlements; the most affected are the eastern Mau and South Western Mau Forest Reserves where 35,301 ha and 22,797 ha respectively have been excised representing 54.3% and 27.3% of their total area respectively (Akotsi, Gachanja & Ndirangu, 2006). Classified images by the Kenya Forest Service (see appendices H, I and J) show a progressive decrease in natural forest cover in the wider Nandi Forests from 1990 to 2010. A detailed change detection and analysis is undertaken in chapter seven of this study.

3. **EFFECTS OF DEFORESTATION ON WATERSHEDS**

The influence of forests and forest alteration on water yield and timing is complex. Where forests were the original land cover, the protective effect consists in maintaining as far as possible the ‘natural’ flow regime, which inevitably consisted of both flooding and low flows to which stream channels and associated biota adjusted (FAO, 2006). With human intervention and occupancy, there is a need for better understanding of the forest/water interaction. With regard to floods, it is now quite clear that forests reduce storm-flow peaks and delay them better than other land cover, but that this effect occurs close to a forest and diminishes further downstream in the watershed (Hamilton & King, 1983). On major rivers, headwater forests have little or no effect in reducing flood intensity in the downstream reaches (Hewlett, 1982; FAO, 2005).

But close to the protective forest, the frequent, lower intensity storms are ameliorated more than with other land covers or land uses. Forests absorb larger amounts of soil moisture than other vegetation, owing to greater canopy evaporation and deeper roots. However, forest removal has at times been advocated to increase water availability. Indeed, where reforestation has occurred in grasslands or semi-arid areas, the water demand by these forests has in some
cases been a harmful and unintended consequence. This has led to oversimplified and exaggerated popular articles against the use of trees for water regulation. Often, tree removal leads to significantly low flows during the dry season, but the other protective usefulness are lost if trees are eliminated ‘to make more water’ (Hamilton & King, 1983).

Watershed degradation has led to greater recognition of the numerous ways watersheds support human well-being through ecosystem services and, consequently, to greater value being placed on them, maintains Hamilton et al. (2008). These services may include provision of freshwater for various uses, regulation of both water and sediment flows, and maintenance of natural flow regimes that support entire ecosystems and ways of life. Pandey (2005), points out that those populations dependent on forests always contribute to species endangerment by overexploiting forest produce in the absence of livelihood alternatives and so there is need for involving people and their knowledge base for protection and management of biodiversity.

The Mau Complex forest ecosystem has an effect to a total population of about 11 million (about 40% Kenyan population) people in Rift Valley and Nyanza provinces. The Mau forest is a major water catchments area for Lake Victoria. All the major rivers in the region originate from the forest and include rivers like Njoro, Molo, Kipchorian, Nyando, Sondu Miriu, Kiptaret, and Timbilil. For effective productivity of the lake and sustenance of fish industry, conservation of the Mau forest is crucial. Soil degradation and vegetation deterioration both have a marked effect on the water regimes of catchments areas and rivers. Due to deforestation on catchment areas like Mau Forest, water infiltration level has declined (Shivoga, 2004). Significant losses of protective forest cover in river catchment can result in increasing extremes of wet and dry season flow to an extent of affecting the viability of activities like irrigation (Chemelil, 2004). The silt loads damaging pumps and deposition of clay in irrigation channels are both expensive
consequences of degraded water catchment areas due to deforestation (Government of Kenya, 1972; Onyando, 2004; Shivoga, 2004).

Specifically, the Nandi Hills forests continue being at a risk of overexploitation due to their valuable tree species. The demand for the trees, such as the Elgon Teak, is so high that it takes only hours for one to earn millions from the valuable wood products of the tree that takes between 250 to 300 years to mature. In Nandi South District, this tree has been rapidly reduced in the forests, because of insatiable demand by local residents. Loggers target the tree for its quality timber for furniture and other wood products (East African Standard, 2008).

3.1. Cloud forests and precipitation phenomenon

These forests occur on mountains or upland areas that are bathed in frequent or persistent fog, particularly where wind-driven cloud intersects directly with the surface. Occurring particularly in the tropics, cloud forests are common on large mountains in the interior, at elevations of 2000 to 3000 m. On coastal ranges, they can occur at about 1200 m and on small oceanic islands may occur even at 500 m (Hamilton, Juvik & Scatena, 1994). In addition to normal vertical precipitation, these forests have another source of water: the interception and water-stripping of horizontally moving fog, which can add hundreds of millimetres of water per year to the ecosystem and its watershed (Bruijnzeel & Hamilton, 2000). Cloud forest trees are usually mossy and more heavily laden with bromeliads, orchids, ferns, lichens and liverworts (epiphytes), which act as a ‘net’ for capturing horizontal precipitation from fog or cloud and adding it as fog drip or stem flow to the watershed budget.

The higher evaporation rate and greater aerodynamic roughness of forests compared with agricultural and pastureland increase atmospheric humidity and moisture convergence, but
enhanced rainfall in forested areas cannot be attributed to forests themselves. Other natural factors (and possibly climate change) may have a far greater impact on rainfall than any change in land use would have (FAO, 2006) and research on how forest cover affects rainfall remains inconclusive (Kaimowitz, 2004). However, cloud forests may be exceptions, where cloud-water deposition may exceed interception losses (Calder, 2003). The effects of mountains and trees on the interception of rainfall may explain observed differences; something which may be of importance locally as in Kenya most of the forests fall into the category of cloud forests and play a vital role in terms of water balance and provision of water downstream.

3.2. **Catchment area dynamics**

Partial or complete removal of tree cover increases the total amount of water in streams flowing from the catchment area largely because of decreased evapo-transpiration by trees, which act as deep-rooted ‘water pumps’ (Bruijnzeel, 1990; Hamilton & King, 1983). Higher water yields continue throughout the year, with the greatest percentage increase (often a doubling of pre-removal flow) occurring in the dry season. Light, selective harvesting or removal of non-wood forest products has little or no impact on stream flow, but the effect increases with the amount of trees removed, up to clear-cutting (Bruijnzeel, 1990). Yield increase seems desirable during stream flow shortages in the dry season, but can present a problem during the wet season, when increased flows make flooding a hazard. Effects on flow occur close to the forest area being cut, but only for short-duration/low-intensity rainfall events (which are usually also the most frequent).

Watershed protection is one of the most important environmental services involving forests and has received considerable attention for payment schemes. These schemes involve payments to upstream land users for improving water quality and quantity through appropriate
land-use practices. Such arrangements tend to be most effective in small watersheds, where service providers and beneficiaries are able to interact and the information flow is relatively smooth. At larger scales, more complex arrangements become necessary. In most cases, the payments are from utility companies to land users. Since water is indispensable and tangible, users are generally willing to pay for improving the quality, quantity and regularity of its supply. Moreover, it is easy geographically to identify the providers and beneficiaries of the service (FAO, 2009).

Hewlett (1982) reviewed the evidence from watershed research worldwide and reported that no cause and effect was demonstrated between forest cutting in the headwaters and floods in the lower basin. No conflicting information has been published since, more than 20 years later. A publication by FAO and the Centre for International Forestry Research (Food and Agricultural Organization & Centre for International Forestry Research, 2005) asserts that: Although forests can play a certain role in delaying and reducing peak floodwater flows at local levels, scientific evidence clearly indicates that forests cannot stop catastrophic large-scale floods, commonly caused by severe meteorological events. This in no way diminishes the need for proper management and conservation of upland forests. But it does point toward the critical need for integrated approaches in river-basin management that look beyond simplistic forest-based ‘solutions’. There are many very good reasons for rehabilitating watersheds, including reducing soil loss, keeping sediment out of streams, maintaining agricultural production and increasing forest wildlife habitat, but achieving substantial flood reduction is not one of them (Hamilton & Pearce, 1987).

In some cases, changes in land use have an impact on the hydrological regime of a river basin; for instance, forest clearing has a direct impact on the infiltration rate and recharge of
aquifers. In many other cases, however, the relation between land use and the hydrological regime is not so clear. For example, the impact of wetland protection on flow regimes is still subject to debate; some research suggests that wetland protection increases peak flows and reduces base flows, while other research indicates increased water storage capacity, leading to reduced peak flow (Bullock, 1992).

Research shows that land use affects the infiltration of water into the soil, and any change in land use that compacts soil or diminishes its porosity will increase runoff and peak flow during rainfall events, and will possibly also increase flooding (Kaimowitz, 2004). These findings hold for only small areas, however, at large scales the extent, intensity and distribution of storm events are likely to have much larger impacts on runoff than land-use changes have.

Since most of the freshwater used by humans originates from precipitation in upper watersheds, the impacts of global climate change have become a major issue in mountain research. According to Uhlenbrook, Wenninger and Lorentz (2005), such impacts depend on rainfall changes and on land-use practices. For instance, a slight increase in event-precipitation is likely to have a much larger impact on runoff and flood discharge when inappropriate watershed management practices are applied. Land-use changes are changing watershed landscape patterns, ecosystem function and climate dynamics; they affect biodiversity and hydrology and the transport of latent heat, carbon dioxide, nutrients and pollutants. Although global change is largely driven by nature, humans have become a significant environmental force with vast implications for watershed systems. Humans are not only subject to environmental change, but also constitute one of the main driving forces behind that change (Huber, Bugmann & Reasoner, 2005).
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The Nandi Hills forests have continued to experience encroachment due to settlements of landless residents and expansion of agricultural activities. There is also uncontrolled logging of trees for timber production and charcoal burning. There is also human encroachment in the wetlands, negatively affecting the biodiversity of the ecosystem (Government of Kenya, 2001b). The rapid population growth over the years has also played a role in endangering the catchment area the more.

4. COMMUNITY FOREST MANAGEMENT

Since the early 1970s, when a fairly narrowly circumscribed set of activities consisting of woodlots for fuel and ‘social forestry’ in India (Overseas Development Institute, 2005), there have come a wide range of activities variously called Community Forestry (CF), Adaptive Co-Management (ACM), Community-Based Natural Resource Management (CBNRM), Community Involvement in Forest Management (CIFM) and Participatory Forest Management (PFM). Community resources usually vary in type and or size depending on the laws and policies of different countries. However, the concept of community participation in resource management and conservation has been identified as a key pillar in the sustainability of the world’s natural resources. For many, community management mitigates the ‘tragedy’ of free-for-all exploitation and inefficiencies or injustices of top-down conservation. Expected conservation and social benefits include sustainable supply of ecosystem goods and services; community empowerment; poverty reduction; and more penetrating, relevant, efficient, and just forms of resource governance than top-down, centralized governance (Agrawal 2005; Ribot 1999).

According to Richard Gauld (2000, p. 224), “introduction of community forest management in the developing world might be the greatest revolution since the start of scientific
forestry, at least relative to centralized state control.” Moss et al. (2005), further asserts that the inclusion of communities in the management of state owned or formerly state owned forest resources has become increasingly common in the last 25 years. Many countries have now developed, or are in the process of developing changes to national policies and legislation that institutionalize Participatory Forest Management (PFM). According to Andy et al. (2002), indigenous and other communities are increasingly acknowledged for being important stewards of the global forest estates. This relatively new development provides a historic opportunity for sustainable forest conservation and economic development of some of the world’s poorest regions.

Since the late 1980s, some governments of major forested countries have begun to reconsider and reform forest ownership policies. These transitions are driven by three primary considerations. First, governments are increasingly aware that official forest tenure systems in many countries discriminate against the rights and claims of indigenous people and other local communities. Although the data are incomplete, it is estimated that some 60 million highly forest-dependent indigenous forest people live in the rain forests of Latin America, West Africa and South East Asia (World Bank, 2001). An additional 400 million to 500 million people are estimated to be directly dependent on forest resources for their livelihoods. Around the world, indigenous people have legitimate claims to more forest areas than governments currently acknowledge. In South and Southeast Asia alone, several hundred million people live on land classified as public forest.

International conventions and national political movements are driving governments to recognize the traditional ownership claims of indigenous peoples and recognize legal ownership and land use rights held by them and other local communities (Colchester, 2001). This growing
recognize the rights of indigenous and other local communities is not simply an issue of justice. There is also an increasing convergence of economic development and environmental protection agendas. Without secure rights, indigenous and other local community groups lack long-term financial incentives for converting their forest resources into economically productive assets for their own development (Worah, 2002). There is growing evidence that local community-based entities are as good, and often better, managers of forests than federal, regional and local governments. In addition, biologists and protected area specialists are beginning to change perspectives on human interactions with nature, acknowledging that the traditional management practices of indigenous peoples can be positive for biodiversity conservation and ecosystem maintenance. This positive outcome is best gained by devolving control of forest land to communities (Lori, & Susanna, 1997). A recent review by Wunder, (2001), of property rights and deforestation in Ecuador, for example, found that community ownership often provides a disincentive to forest conversion.

A third reason for this transition, as per White and Martin, (2002), is the growing recognition that governments and public forest management agencies often have not been good stewards of public forests. While many countries have proven that public ownership can be effective in protecting and managing forests, others have not developed the governance structures and management capacities necessary to ensure effectiveness. While exploitation is a legitimate use of public forests, in many places forests have been abused to finance political elites and curry political favours. The findings from a number of recent studies on illegal logging and corruption are staggering; illegal logging on public forest lands is estimated to cost forest country governments at least $10 billion to $15 billion a year, an amount greater than total World
Bank lending to client countries and greater than total annual development assistance in public education and health.

To ensure the existence of humankind and the sustainable utilization of the earth’s resources, deliberate action needs to be channelled towards the conservation of the vital support systems of the entire Earth ecosystems. Forests in this case form quite a crucial part of this wider arrangement that if man does not deliberately conserve and sustainably manage them, he risks being plunged into an irreversible predicament. Miller (2001) asserts that about 50–80% of in the moisture and air above tropical forests come from trees via transpiration. If large areas of these forests are cleared, average annual precipitation drops and the region’s climate gets hotter and drier. This process can eventually convert a diverse tropical forest into sparse grassland or even a desert.

In his article, Tragedy of the Commons, Hardin (1968), describes the dilemma in which multiple individuals acting independently in their own self-interest can ultimately destroy a shared limited resource even where it is clear that it is not in anyone's long term interest for this to happen. Hardin asks for a strict management of global common goods via increased government involvement and/or international regulation bodies. In direct counter to Hardin’s ‘Tragedy of the Commons’ thesis (Hardin 1968), which blames common property (systems of communal resources ownership) for the overuse of common-pool resources by rational self-interested individuals at the expense of the common good, common-pool resources scholars blame open access or ‘res nullis’ – absence of any property rights defining the users and rules (Feeny et al., 1990). Common-pool resources are “goods that can be kept from potential users only at great cost or with difficulty, but that are extractable in consumption and can disappear,” whereas commons are resources that involve some level of joint access or ownership (McKean,
2000, p. 28). These scholars often prescribe local institutions to regulate resource use and curb free-riding behaviour under common property regimes – “property-rights arrangements in which a group of resource users share rights and duties towards a resource” (McKean, 2000, p. 28). These rights arrangements often embrace ‘design principles’, which are lists of conditions, deemed to improve institutional success (Ostrom, 1990). Following this argument, forests and forest resources should be used at rates below their sustainable yields or overload limits by reducing population, regulating access or both. However it is difficult to determine the sustainable yield of a forest, partly because yields vary with weather, climate and unpredictable biological factors, and because getting such data is expensive (Miller, 2001).

Relationships between community-based property rights and environmental services that benefit the general public are drawing new attention. Governments’ traditional approach to conservation has been the creation of official protected areas, either by delineating an area of existing public property or by using the right of eminent domain to expropriate land. Not only has this approach often abused legitimate community rights, but it has often led to mixed results, largely because governments often lack the incentives, resources and political will needed to protect and sustainably manage natural resources that are public property. At the same time, valuable public services provided by the private forests of indigenous and other communities have often been taken for granted by the wider public that benefits (Andy et al., 2002)

In as much as community natural resources management (CNRM) was introduced and emphasized in Africa by the early 1990s (FAO, 1999a), it has not met its targeted objectives. CNRM follows the compelling theoretical notion that empowering communities to use their knowledge and resources to solve local environmental problems can make resource governance more penetrating, relevant, efficient, equitable, and lasting than at least centralized regimes
(Ribot 1999; Agrawal 2005). However, disaffection with failures of centralized conservation may have allowed an uncritical embrace of “participation” (Cook & Kothari 2001). For instance, “conservation is often simplistically assumed to always be the shared local goal” (McCay, 2002, p.371), and local goals are assumed to be consistent with broader goals. Increasingly, studies now indicate that expected conservation and social goals are rarely realized (e.g., Campbell et al., 2001; Kellert et al., 2000). In fact, growing evidence of failure has sparked a backlash against CNRM in Uganda, Ghana, Indonesia, and Nicaragua (Ribot, 2002).

Regulation of land-use practices alone has not ensured continued provision of services. It places a disproportionate share of the conservation costs on upstream land users without giving them corresponding access to benefits. For example, States often claim ownership of forested areas and protect watersheds through policies that exclude local populations from resources on which they have traditionally relied. This may lead local people to engage in what have suddenly become illegal practices, or to occupy more marginal land areas (Blaikie & Muldavin, 2004; Tomich, Thomas & van Noordwijk, 2004).

Market-based arrangements are a way for upstream land users to recover the costs of maintaining forest cover, and a way of funding other land management practices to protect watershed services. They are also advocated for landscape approaches to conservation, which require the creation of incentives for conservation on privately held land. Market-based approaches in which payments are contingent on achieving desired outcomes can lead to more efficient resource allocation and more cost effective solutions. However, there are a number of scientific and institutional challenges to their implementation, the transaction costs of which may make these approaches impractical. Among the challenges is that of demonstrating and quantifying the actual benefits to those who are asked to pay for them. This requires an
understanding of complex ecosystem processes, over time in specific places, the identification of effective management actions to maintain these, and reasonable assurance that buyers will have access to benefits in the future. Finding the most efficient and effective approaches also requires the capacity to learn and adjust to new information (Hamilton et al., 2008)

4.1. Successful community forestry in Mexico

Molnar & White (2001) have emphasized that: Mexico is one of the few countries in the world where the vast majority of forests are privately owned by indigenous and other communities. Even so, there are important barriers to effective community forestry stemming from inadequate policies, technical support and markets. There are approximately 8,000 communities who own 44 million hectares of forest or an average of 5,000 hectares per community. The legal status of these lands derives from the creation of ejidos as land reform blocks transferred to producers from large landowners after the Revolution, recognition of traditional claims of indigenous groups to ancestral territories, or lands to which they fled after conquest. Many of the social systems governing these communities predate the Spanish conquest although they have been strongly modified by cultural contact. A constitutional amendment proposed in early 2001 attempts to regulate indigenous self-governance rights, including land and forest use, but this amendment has been criticized as not ratifying basic principles of indigenous rights.

Despite official community ownership, until 1986 government unilaterally granted access to commercial value community forests to private concessionaires and then to parastatals, giving communities little voice over management decisions and transferring limited benefits from logging. This approach, combined with historical agricultural and forest policies biased in favour of large private industry and urban dwellers, created a situation whereby indigenous and ejido
communities remain among the poorest people in Mexico and community-based forest industries account for less than 18% of the registered national forest industry capacity. The 1986 Forest Law and subsequent modifications in 1992 and 1997 suspended the concessions system and increased opportunities for communities to direct their own forest enterprises, including extraction, provision of services and processing, as long as they prepared legal management plans for their forests. Less than a quarter of all communities and *ejidos* have active management plans, related to the cost of preparing such plans and encouraging illegal logging. The poor quality of original territorial surveys of community boundaries leaves many inter-community conflicts over boundaries and encourages substantial investment of community funds to police their lands and advance their claims in court.

Despite these limitations, some 500 communities and *ejidos* have developed quite successful integrated forest enterprises, generating local employment and technical expertise and providing an alternative to labour migration and deforestation. Some communities hold strong cultural values that lead them to invest profits in social services and infrastructure and conservation of biodiversity rich areas. The forest sector has an enormous potential to provide economic, environmental and social services, with opportunities in timber and non-timber forest products and small-scale tourism, but the sector has yet to receive equal treatment as agriculture or keeping cattle. These findings suggest that the role of social forestry in Mexico as a development strategy that addresses poverty alleviation, economic development and environmental protection is worth consideration.
4.2. Challenges to effective community ownership in Papua New Guinea

Papua New Guinea (PNG) contains the largest intact tropical rainforest wilderness in the Asia Pacific region and the third largest on the planet. Some 90 to 97% of its forests are owned by some 8,000 traditionally autonomous tribal groups (Government of the Papua New Guinea, 2006). Despite state-recognized local community ownership, government and industry continue to wield tremendous influence, often taking advantage of limited community capacities to defend local interests against outside entrepreneurs. Almost half the country’s accessible forests are already committed to industrial logging and over 30 proposed timber projects threaten the rest. Some community leaders participate in corrupt deals that advance their own interests at the expense of their communities (Barry, 2002). Rapid deforestation, widespread corruption and illegal logging have led to a moratorium on all new logging concessions in PNG and new support for community-based forestry management initiatives (Government of the Papua New Guinea, 2006).

Recent experiences in Africa have revealed similar challenges imposed on local communities by the state in implementing community-based forestry management. Although Uganda and Tanzania now legally recognize community ownership, as in most other countries that have enacted similar reforms, Okoth (2001) maintains that there is no legal guidance on the principles and rules for formally recognizing and governing these areas. Tanzania has gone farthest, in devolving formal registration of Village Land Forest Reserves to local communities with or without the explicit support of the central forestry administration.

Relationships between community-based property rights and environmental services that benefit the general public are drawing new attention. Governments’ traditional approach to conservation has been the creation of official protected areas either by delineating an area of
existing public property or by using the right of eminent domain to expropriate land (Burnham, 2000). Not only has this approach often abused legitimate community rights, but it has often led to mixed results, largely because governments often lack the incentives, resources and political will needed to protect and sustainably manage natural resources that are public property. At the same time, valuable public services provided by the private forests of indigenous and other communities have often been taken for granted by the wider public that benefits. At the same time it is still widely believed by political and economic elites in many nations that local communities should not or will not use their forest assets for economic development.

White and Martin (2002), further affirm that official efforts on national levels, therefore, to protect and maintain publicly valuable environmental services often have not been harmonized with local communities’ rights and incentives to manage their private property. Nor do these strategies acknowledge the role of indigenous peoples as a living repository of cultural norms and technical knowledge that shapes the biodiversity of ecosystems, which can be an important element in biodiversity conservation and in carrying out ex situ conservation.

5. SUSTAINABLE FOREST MANAGEMENT

The term ‘sustainable forest management’ can be traced to the non-binding ‘Forest Principles’ and Chapter 11 of Agenda 21, which were prominent outputs of the United Nations Conference on Environment and Development (UNCED, 1992). Sustainable Forest Management (SFM) represents a new paradigm for forestry (Peng, 2000). Although sustainable forest management (SFM) is now widely accepted as the overriding objective for forest policy and practice, it is not easily defined (Shvidenko et al., 2005). However, recent studies clearly distinguish the terms ‘sustainable development’ and ‘sustainability’ (Dovers & Handmer, 1993).
Brundtland’s commission report on sustainable development refers it as ‘the development which meets the needs of the present without compromising the ability of future generations to meet their own needs’. Contrarily, sustainability refers to the ‘the ability of a human, natural, or mixed system to withstand or adapt to endogenous or exogenous change indefinitely’ (Dovers & Handmer, 1993). Further, sustainability in ecological terms implies that essential life-support systems be maintained over time without degrading their quality (Alberti, 1996).

In the case of forest ecosystems, maintaining integrity in terms of its structure, function, composition and ecological processes, along with the environmental service the forests provide, is of particular significance. To achieve sustainability as well as sustainable development strategies (Brundtland, 1987), a resource inventory along with factors underlying resource degradation at various levels are needed. Generally, the health and wellbeing of the people and the forest ecosystem together determine the progress of management practices towards the sustainability (Dovers & Norton, 1994; Maser, 1994; Verma et al., 2000). Hence, the guiding objective of the Forest Principles in SFM is to contribute to the management, conservation and sustainable development of all types of forests and to provide for their multiple and complementary functions and uses. Principle 2b (UNCED, 1992) specifically states, “Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual needs of present and future generations.”

The concept of sustainable forest management has continued to evolve since 1992 through international forest policy dialogue within the Intergovernmental Panel on Forests (IPF), the Intergovernmental Forum on Forests (IFF) and the United Nations Forum on Forests (UNFF) and through a large number of country-led and eco-regional initiatives aimed at translating the
concept into practice. These include the development of criteria for and indicators of sustainable
forest management supported by international organizations including FAO, the International
Tropical Timber Organization (ITTO), the United Nations Environment Programme (UNEP) and
other members of the Collaborative Partnership on Forests (CPF). Sustainable forest
management is also the main theme of the FAO Strategic Plan for Forestry, whose mission is “to
enhance human well-being through support to member countries in the sustainable management
of the world’s trees and forests.” (FAO, 1999b, p. 1)

Understanding and quantification of dynamics associated with forest loss and the factors
that influence these dynamics provides the basis for the sustainable use of forest resources and
the conservation of their environmental values (Geist & Lambin, 2001). Of particular importance
is that at periodic intervals the forests are subjected to large-scale natural and anthropogenic
disturbances, whose relationship and interaction with environmental variability and change is
imperfectly understood (Fleming et al., 2000; Li, 2000). Operationalizing sustainability in terms
of identifying strategies that reduce forest loss is considered of prime significance in tropical
regions. Social and economic benefits from sustainable use of biodiversity can provide powerful
incentives to conserve it, provided that two conditions are fulfilled (IUCN, 1993). Firstly, the
people most likely to have a direct impact on the biodiversity concerned should receive what
they perceive as a fair share of the benefits from the use. Secondly, there should be a clear
connection between the benefits obtained from using the resources and conservation of them.
This will often involve:

- Respecting and promoting traditions of local communities that are compatible with
  conservation of biodiversity;
• Providing economic, institutional, biological and other technical assistance on request;

• Developing community-level education programmes on the uniqueness of local biodiversity;

• Cooperating with rural communities to develop sustainable use projects that demonstrate the value of maintaining local biodiversity; and

• Assisting in the development of markets, and promoting access to those markets on favourable terms, for the products of sustainable management of biodiversity.

Despite, or perhaps because of, the long maturing process of the sustainable forest management concept, it is difficult to define explicitly what sustainable forest management is. However, several recent international meetings have suggested that there are seven thematic elements in sustainable forest management (FAO, 2006).

5.1. **Thematic elements of sustainable forest management**

To be able to apply the concept of sustainable forest management as clearly and as simply as possible, it is necessary to describe it in terms of guiding principles, criteria and corresponding indicators (Vermaet et al., 2000). For example, an overview by the Food and Agriculture Organization of such initiatives (Lanly, 1995) shows a consensus on the characterization of sustainable forest management through seven criteria. The seven thematic elements of sustainable forest management are as described below and are based on the nine ongoing regional/international processes on criteria and indicators for sustainable forest management and have been acknowledged by FAO member countries and the UNFF.
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i) **Extent of forest resources**

The theme expresses an overall desire to have adequate forest cover and stocking, including trees outside forests, to support the social, economic and environmental dimensions of forestry. For example, the existence and extent of specific forest types are important as a basis for conservation efforts. The theme encompasses ambitions to reduce deforestation and to restore and rehabilitate degraded forest landscapes. It also includes the important function of forests and trees outside forests to store carbon and thereby contribute to moderating the global climate.

ii) **Biological diversity**

The theme concerns the conservation and management of biological diversity at ecosystem (landscape), species and genetic levels. Such conservation, including the protection of areas with fragile ecosystems, ensures that diversity of life is maintained, and provides opportunities to develop new products in the future, including medicines. Genetic improvement is also a means of increasing forest productivity, for example to ensure high wood production levels in intensively managed forests.

iii) **Forest health and vitality**

Forests need to be managed so that the risks and impacts of unwanted disturbances are minimized, including wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. Such disturbances may impact social and economic as well as environmental dimensions of forestry.

iv) **Productive functions of forest resources**

Forests and trees outside forests provide a wide range of wood and non-wood forest products. This theme expresses the ambition to maintain an ample and valuable supply of
primary forest products, while at the same time ensuring that production and harvesting are sustainable and do not compromise the management options of future generations.

\textit{v)} \quad \textit{Protective functions of forest resources}

The theme addresses the role of forests and trees outside forests in moderating soil, hydrological and aquatic systems, maintaining clean water (including healthy fish populations) and reducing the risks and impacts of floods, avalanches, erosion and drought. Protective functions of forest resources also contribute to ecosystem conservation efforts and have strong cross-sectoral aspects, because the benefits to agriculture and rural livelihoods are high.

\textit{vi)} \quad \textit{Socio-economic functions}

The theme covers the contributions of forest resources to the overall economy, for example through employment, values generated through processing and marketing of forest products, and energy, trade and investment in the forest sector. It also addresses the important forest function of hosting and protecting sites and landscapes of high cultural, spiritual or recreational value, and thus includes aspects of land tenure, indigenous and community management systems, and traditional knowledge.

\textit{vii)} \quad \textit{Legal, policy and institutional framework}

The theme includes the legal, policy and institutional arrangements necessary to support the above six themes, including participatory decision-making, governance and law enforcement, and monitoring and assessment of progress. It also involves broader societal aspects, including fair and equitable use of forest resources, scientific research and education, infrastructure arrangements to support the forest sector, transfer of technology, capacity-building, and public information and communication.
The complexity of sustainable forest management makes the extent of its achievement not to be a definitive one (FAO, 2006). However, there are many good signs and positive trends, but many negative trends remain. While intensive forest plantation and conservation efforts are on the rise, primary forests continue to become degraded or converted to agriculture at alarming rates in some regions. As the analyses of the thematic areas above illustrate, the answer to sustainable forest management also depends on the scale and perspective applied.

Implementation of sustainable forest management, which addresses the economic, social and environmental functions of forests, is an important approach to ensuring a balance between the objectives of production and conservation. Traditional methods for assessing the above criteria and associated changes and impacts on forest ecosystems have typically treated the socioeconomic and ecological effects independently (Dale et al., 1993). To understand deforestation process in general and factors affecting sustainable forest management practices, data on physical changes of forest cover have to be linked with socioeconomic data and candidate driving forces that govern these changes (Geist & Lambin et al., 2001; Moran, 1993). Maintaining critical ecosystem functions is a key pillar of sustainable forest management. ‘Close-to-nature silviculture’ and the ‘ecosystems approach’ are essentially variants of sustainable forest management, giving greater emphasis to environmental services.

While the concept of sustainable forest management is accepted as the framework for managing forests in most countries, its implementation differs considerably among them. Barriers to its adoption are relatively few where institutions are well developed and society is able to meet the higher costs, as is the case in many developed countries. However, in low-income situations, sustainable forest management faces far more constraints, reflecting limited ability and willingness to pay for the additional costs involved in adhering to the social and
environmental criteria. Consequently, in the tropics, the proportion of forests that are sustainably managed remains very low (ITTO, 2006).

6. CONCEPTUAL FRAMEWORK FOR SUSTAINABLE WATER CATCHMENT AREA MANAGEMENT

Sustainable Water Catchment Area Management (SWCAM) is a multi-faceted concept incorporating several paradigms, which when consolidated can result into an effective medium for making available water catchment resources without compromising future abundance of these resources. This study therefore attempts to link the diverse facets of Environmental Education, Community Forest Management (CFM), GIS and Remote Sensing to Sustainable Forest Management (SFM) as the key driver of SWCAM (Figure 3.3)

With reference to the study area of this research, the Nandi Hills and Nandi Forest, SFM comes in as a pivotal element for driving the wheel of SWCAM. SFM can be viewed as a system which aims at satisfying the needs of society for various forest goods and services through the application of forestry, environmental management, ecological, social, economic and business principles and methods in the wise utilization, renewal and development of forest resources without significant degradation of the inherent capacity of the forests to provide goods and services on an uninterrupted basis (Revilla et al., 1999).
Figure 3.3

*Conceptual Framework for SWCAM (adapted from Rebugio & Camacho, 2005)*
6.1. Drivers of SWCAM

As illustrated Fig. 3.3, this study considers integrated water catchment area management anchored on SFM for the study area. SFM then becomes a key ‘wheel’ driven by Community Environmental Education (CEE), GIS & RS. In the event that CEE, GIS & RS are actualized CFM will be immensely dependent on them (CEE, GIS & RS).

6.1.1. Sustainable forest management

Research in natural forests now focuses more on integrating environmental, social and economic objectives according to the principles of sustainable forest management. A number of national, regional and international initiatives focus on the development of criteria and indicators for measuring progress towards sustainable forest management, outlining the nature of technology to be adopted. Implementation of sustainable forest management requires substantial strengthening of the science and technology base. To this end, much research focuses on ecosystem structure and functioning, the spatial and temporal linkages among ecosystem components and processes, and their relation to the immediate and larger social and economic context. However, implementation of such research remains a challenge (Centre for International Forestry Research, 2004), especially in developing countries.

Albeit the implementation challenges of research, especially in developing countries, this study brings in GIS & RS as a technology base. This technology shall immensely support and be supported by CEE in the achievement of the environmental, social and economic objectives of SFM and ultimately the attainment of SWCAM.
6.1.2. **Community environmental education**

Community Environmental Education should be achievable through the exploitation of both the indigenous and conventional environmental education approaches available and which is considered to be ‘workable’ by the local community. Involving the community relies on their ability to interact with basic technologies involving GIS & RS and also get better equipped with tools for CFM (Foody, 2001).

6.1.3. **GIS & Remote sensing**

The use of these technologies in SFM is an approach which involves assimilation of GIS techniques by incorporating spatial (thematic maps) and non-spatial (attribute defined) data for effective utilization and management of forest resources. They also allow the conceptualization of an integrated approach to create a forest information database and RS utilities to arrive at an effective management model for forest officers and other concerned users and planners. In this case, GIS & RS play a major role in making available information to be disseminated through CEE.

6.1.4. **Community forest management**

CFM is viewed in this framework as being both dependent on and depended upon by CEE, GIS & RS in the wider concept of SFM. Strategies to be adopted in CFM is disseminated to the local community through CEE, while GIS & RS are tools that illustratively reveal or map the spatial-temporal variations in land use that would be key in SFM.

6.2. **Indicators of SFM**

The effective implementation of SFM should address the economic, social and environmental functions of forests; hence it is an important approach to ensuring a balance
between the objectives of production and conservation. Maintaining critical ecosystem functions is a key pillar of SFM since by this; the forests can be able to make economic sense to the local community without putting their availability to future generations in jeopardy.

7. **CHAPTER SUMMARY**

The chapter highlights the status and importance of forests both globally and in Kenya. It elaborates on various concepts and theories on forest management and the emerging trends in conservation, including climate change which poses a major challenge to forests. The prominence this chapter gives to the community, when it comes to effective management of forests as vital reservoirs of sustainability, illustrates the need for foresight in dealing with forests and forest resources. A conceptual framework that attempts to elaborate the inter-linkages between community environmental education, and GIS and Remote sensing in enhancing sustainable forest management CFM is also presented.
1. **INTRODUCTION**

The term 'temporal' in spatial analysis has ubiquitous latent meanings, each of which requires a diverse approach for the provision of a supporting analysis. Lately, work in spatio-temporal information is about versioning transaction (Halls, 1995). Some researchers use GIS in search of an understanding of item relationships across time, past, present and future; and their focus is how real-world attributes interact in space and time (Fisher & Unwin, 2005). Others have tried to formalize a conjecture of spatio-temporal thinking working from a theoretical construct (Claramunt et al., 1997; Hermosilla, 1994; Qian et al., 1997), while Worboys (1998) and Miller and Halls (1996, 1995) use a predicament directed approach. It is important that anyone who is involved in attempting to develop and environmental education programme towards sustainable management be **faux** with such techniques and the data that are generated and are readily available from such approaches. As such these GIS, Remote Sensing, land use change, global trends and conditions, and trends in Kenya, are discussed in this chapter.

2. **GIS, REMOTE SENSING AND SPATIAL TEMPORAL CHANGES**

Geographic Information System (GIS) is computer-based software, hardware and systems designed to allow users to assemble, administer, scrutinize and envisage spatially referenced data and associated qualities (Cowen, 1998). It may be the most significant technology manager of
resources to have been acquired in recent times (Franklin, 1994). A blend of GIS and Remote Sensing methods enhances the pace at which immense amounts of spatial and temporal data are analysed and broken down for faster and informed making of decisions.

Vogt et al. (1997), asserts that the extensive use of Geographic Information System (GIS) and Remote Sensing mechanics has permitted researchers and managers to take a wider view of ecological processes and patterns. The techniques of remote-sensing have been applied successfully for forest monitoring and mapping and have made it possible to cover great areas consistently and cheaply (Coppin et al., 2004). The ever varying composition and structure of landscape can be easily substantiated by using GIS together with remotely sensed data. When these tools for spatial information are put together with statistical models, planners and managers have a means for investigating the impacts of different management practices on trend and process (Vogt et al., 1997).

Latest technologies in the remote sensing field address procedural challenges such as the parameter structure, height, density and make-up of forests. Airborne radiance detection and changes using lasers can evince highly precise approximations of tree cover and also height; it can even evaluate the outline of individual trees. Ranging Space-borne radar has brilliant ways to arrive at approximates of biomass and stand volume and can go through clouds, defeating some of the demerits of ocular satellite sensors. Latest spectral sensing systems can compute a wide selection of land and vegetation distinctiveness, making it probable to evaluate a range of forest features – helping to improve mapping of forest cover, pests and diseases (Hestira et al., 2008).

GIS offers a tool for bringing together distinct themes of information and showing the physical, social and biological dimensions to describe and map ecosystems. Fresh progress in
GIS technology comprises of the capability to amass and manage bulky data sets and to execute spatial and statistical analyses. GIS can provide contribution to both stationary and dynamic ecological models. For instance, a fixed replica may be used to make erosion approximations based on soil category and topography characteristics, whereas a complex GIS model could be used to symbolize a spatial landscape at varying time durations (Stow, 1993).

At the global stage, GIS and global navigation satellite systems gives forest managers increasingly defined information on the character and the situation of forest resources, which can be processed rapidly. Fresh modelling and image software linking GIS and remote sensing provides high-class digital models of future forest landscapes to depict changes that might be as a result of natural mechanisms, such as climate variations, or human involvement, such as thinning, planting, and harvesting. Such creations make possible the engagement of communities in forest resource management and decision making (Sheppard & Meitner, 2005). Baltzer et al. (2007) point out that, further than forest management functions, remote sensing methods have the potential to provide data to the scientific society about forest conditions, central to the comprehension of sustainable land use.

Remotely sensed data is normally stored in a database and can be analysed using GIS developed for the collection, storage, and analysis of substances and events when geographic position is an imperative characteristic, or is vital to the analysis (Turker, 2000). GIS is a strong system with all-around ability, such as analysis of spatial attributes, visualization, and management of spatial databases, which assists managers make adept decisions about resources and the running of these resource entities and equips researchers with great mechanized tools for responding to these questions (Baltzer et al., 2007). These tools make it much simple to evaluate and analyse data for unique studies and reporting and new modes of analysis that were not
feasible previously are now achievable (Stow, 1993; Schreier & Dech, 2005). The software can rapidly search throughout map information, excavating for features with definite attributes or inspecting spatial interactions among objects and can, by design, swiftly answer specified questions. GIS technology maintains almost all new innovations, including vehicle global navigation systems, support systems for decisions, dynamics of ecosystems, together with production systems for maps and charts (Aranoff, 1989).

A remote sensing instrument records responses which are premised on many attributes of the ground, including artificial and natural cover. An expert uses the aspect of shadow, site, tone, texture, pattern and association to attain land cover information (Ryerson & Rencz, 1999). However, remotely sensed images by a range of sensors flown aboard various platforms at varying heights over the terrain and at different moments of the year does not lead to an easy grouping system, and it is believed that no sole classification can be utilized with all forms of imagery. To date, the most triumphant attempt in mounting a general categorization scheme well-suited for remote sensing data has been prepared by Anderson et al. (1972) and is also known as United States Geological Survey (USGS) classification design. Other contemporary classification schemes presented for use with remotely sensed data are chiefly adjustment of the above classification system (Mesev, 2007). Since the commencement of the first remote sensing satellite in 1972, terrestrial variations studies were carried out on diverse levels for diverse spatial data users.

Change evaluation is the practice of spotting out discrepancies in the nature of an object or event by studying it at different moments (Singh, 1989). Detection of Change is an important process in managing resources and development of urban areas since it offers a quantitative study of the distribution of spatial structures and the population in interest. The following are
aspects of detecting change which are vital in natural resources monitoring (Macleod & Congation, 1998):

- Detecting if change has happened
- Identification of the nature of change
- Measuring the extent of change
- Assessing the nature and pattern of the change

The base-point of using remote sensing information for detecting change is that land cover leads to changes in values of radiance that can be remotely sensed (Turker, 2000). Methods of performing change detection with satellite data have become ubiquitous as a result of increased flexibility in manipulating data and the increasing power of computers and a large range of digital change detection methods have been developed over the last few decades. Singh (1989) summarizes eleven different change detection formulas that were found to be stored in the literature by the year 1995. These include:

- Temporal change delineation.
- Post classification and delta comparisons.
- Multidimensional feature space analysis.
- Composite scrutiny.
- Differencing of images.
- Linear data transformation.
- Vector change analysis.
- Regression of imagery.
- Temporal biomass index
Chapter Four: Spatial Temporal Variations

- Subtraction of background
- Rationing of images

In some cases, land cover change may result to socio-economic and environmental impacts (Bradley & Mustard, 2005). Hence data on spatial temporal changes are of significance to planners in investigating the results of land use variations on any particular area. Such data are of benefit in administration of resources and to agencies that prepare and assess land use trends in modelling and forecasting future changes.

A number of studies have shown that LANDSAT Mapper has been sufficient for general synoptic coverage of huge areas, which decreases the need for costly and intense land surface surveys carried out for confirmation of data (Lulla, 1983). Satellite imagery can also offer more regular data collection than aerial photographs which, however, may present more geometrically precise maps (Paulsson, 1992).

3. LAND USE CHANGE

The rate, extent and spatial attainment of human conversion and change of the earth’s land surface can be exceptional (Lambin et al., 2001), however, some regions around the world are presently undergoing speedy, wide-raging alterations in land cover (Coppin et al., 2004; Mas, 2004). Land cover adjustment has been known as a vital driver of universal environmental change (Petit, 2001). According to Foody (2001), change in land cover is a chief component of global change with a superior effect than that of climate change. Causes of such fluxes are natural as well as anthropogenic or a combination of the two. Escalating land use changes at the price of rapid rates of deforestation in the tropics are leading to drastic alterations in the chemical, physical, and biological distinctiveness of ecosystems in the tropics. Land use changes
Chapter Four: Spatial Temporal Variations

lessen the magnitude of natural habitats for instance forests and their structural assortments resulting in manifold ecological impacts. The ecological impacts of large scale forest decrease include loss of biodiversity (Shukla, 1990), soil conditions degradation (Buschbacher, Hull & Serano, 1988) and balance changes of greenhouse gases within the biosphere, which may in turn accelerate climate change (Dale et al., 2001).

As a result of increasing appreciation of the impacts of global land cover change, the presence of timely and consistent Land Use Land Cover (LULC) information is becoming much significant than ever in sustaining decision making mechanisms at different levels, both within and across countries (Foley et al., 2005). Increasing global environmental change and an added prominence on sustainable development (Bradley & Mustard, 2005; Leitao & Ahren, 2002) suggest that spatial data will play a principal role in altering existing environmental patterns through relevant policy formulation and implementation. Jansen and Gregorio (2002) submit that land cover data form a central base for a number of applications; including rangeland and forest monitoring, figures for investment and planning, conservation of biodiversity, desertification monitoring and climate change assessment.

Although spatial data are significant in the process of managing resources and decision making, there is still no widespread land cover information at global and local scales (Chandra, 2005). The situation is graver in developing countries where there is inadequacy and unavailability of data due to the time consuming and costly nature of processing these data (Richard & Haack, 1996). This has been as a result of infrastructural limitations, civil and military instability; inexistence of trained manpower, equipment or finance to collect information in the right way; or fast changes in the resource foundation not detectable by conventional data collection methods (Defries & Townshend, 1999). However, with extensive application of data
on land cover, the availability of data is being assisted by improving technologies in geographic information systems and remote sensing.

### 3.1. Forest resources

The Global Forest Resources Assessment (GFRA) 2005 stresses that forest area represents the first indication of the virtual importance of forests in a nation or region (FAO, 2006), while an approximation of forest area alteration over time provides an indication of the need for land other uses, and may provide pointers to possible major environmental instability in forest ecosystems. Forest area is comparatively easy to measure, and this variable has been selected as one of the 48 pointers for monitoring progress in realization of the Millennium Development Goals provided by the United Nations (Goal 7 – Enhancing environmental sustainability). Information on the status of and patterns in area of forest are essential to decisions related to land-use and forest policies and allocations, the health and potency of forests and their socio-economic and ecological values and functions.

Watershed dilapidation has led to a larger recognition of the abundant ways in which watersheds support human welfare through ecosystem provisioning and, consequently, to greater worth being placed on them (Hamilton et al., 2008). These services can include provision of freshwater for a range of uses, regulation of sediment and water flows, and preservation of natural flow systems that support complete ecosystems. Pandey (2005) notes that those populations depending on forests constantly contribute to species destruction by overexploiting forest generations in the absence of alternative livelihood options and that it is essential to involve local populations and work from their knowledge base towards conservation and management of biodiversity.
3.2. Land use and land cover

Land use and land cover are routinely used interchangeably in many change detection studies (Seto et al., 2002). Land use is used to refer to the human utilization of the land, or the instant actions modifying land cover (Bradley & Mustard, 2005; Meyer & Turner, 1992). Land use can consist of mixed land covers; and it is conceptual model constituting a merger of social, cultural, economic and strategy factors which have diminutive physical magnitude with the respect to reflectance asset, and hence has restricted relationship to remote sensing (Rogan & Treitz, 2004). Again, land cover refers to the vegetation type that exemplify a particular place, or the real distribution of vegetation, deserts, ice and other material features of the land, including those created by human actions (Meyer & Turner, 1992). According to Jansen and Cihlar (2001), land cover is made up of the biophysical features of the terrestrial environment, characteristically based on a categorization system consisting of distinct classes and formulated for a precise purpose. Land use however refers to the mode in which these biophysical assets are used and the intent with which particular lands cover was formed.

Ecosystems are continuously transforming; leading to adjustments in the surface constituent of vegetation cover and substantive spatial progress of a vegetation bodies over time (Coppin et al., 2004). In addition, land cover changes are frequently conceived as plain and permanent conversion from one form to another (Mertens & Lambin, 2000). Dissimilarity has however been made between land cover alteration and land cover adjustment; with the former referring to the entire replacement of land cover with another and the latter signifying the more understated changes that affect the makeup of land cover without changing its general classification (Coppin, 2004; Meyer & Turner, 1992). Land cover modification is more rampant than land cover conversion and both can be human induced or of ordinary origin.
3.3. **Sources and effects of change**

The pace of change can either be remarkable as exemplified by fire; or on going, such as biomass amassing (Coppin et al., 2004). Correspondingly, land cover changes are usually viewed as non-constant in space, leading to compound landscape mosaics and mixtures of cover modes (Mertens & Lambin, 2000). Land cover changes are so pervasive that, when collected globally, they extensively affect key structures of the Earth systems (Lambin et al., 2001; Lambin et al., 2003). Land cover has a large influence on many crucial environmental processes and as a result any transformation in it can have marked effect on the environment at home to global scales. Anxiety about LULC change came up on research agenda on global environmental alteration several decades ago with the realization that land processes persuades climate. In the 1970s it was largely renowned that land cover change modifies facade albedo and thus causing surface-atmosphere vigor exchange; while in the 1980s, terrestrial ecosystems as sinks of carbon were highlighted (Lambin et al., 2001).

It is broadly recognized today that land cover transformation causes soil erosion and amplifies surface run off and flooding, climate change and carbon dioxide concentration (Lambin et al., 2003). Land cover variation contributes radically to earth-atmosphere exchanges and loss in biodiversity, it is a foremost factor in sustainable development and human reactions to global change, and its measurement is essential for incorporated modelling and measurement of environmental problems in general (Turner et al., 2004). Land cover changes have, for example, important influences on water and climatic systems that impact notably on global biogeochemical movements (Boyd, 2002) and biodiversity loss (Mas, 2004). LULC changes also establish, in part the susceptibility of places and people to economic, climatic or socio-political perturbations (Lambin et al., 2003).
The current emphasis on sustainable development provides the impetus for monitoring and assessing the process of change in land cover. Existing data play an important function at regional and global level in the designing and implementation of policies (Turner et al., 2004). These policies are aimed at realizing sustainable resource utilization, reverting depressing environmental conditions, conserving biodiversity and endangered species and promoting biological continuity threatened by growing human population and rising of human activities. However, land cover change is still feebly documented at present (Meyer & Turner, 1992) but since the International Geosphere-Biosphere Program identified it as the heart of the field of study, it has claimed wider attention from a range of scholars internationally (Xu et al., 2002).

3.4. Predicting change

In order to comprehend and predict the change procedure, one needs to observe and characterize spatial trends of LULC transformations (Petit, 2001). While the study of land cover modification is inclusive of description and classification of land changes, observance of change, and mechanism of motivating forces, the definitive goal of scientists is to construct models that can be used to predict changes and their effects (Xu et al., 2002). As noted before, an assortment of methods of LULC study have been generated and applied, such as remote sensing, GIS, and statistical schemes (Xu et al., 2000).

Traditionally LULC analysis has been anchored on aerial photography and ground surveys (Mas, 2004; Richard & Haack, 1996). These methods are often complicated, time consuming and pricey. Nevertheless, due to their high resolution, and ease of access, aerial photographs remain an important tool in surveying and mapping of resources (Arnberg & Sebego, 2002). Field studies on the other hand permit the observation and description of the course of land cover even though they are not satisfactory in amassing and analysing spatial-
temporal trends of LULC at a summative stage (Petit et al., 2001). According to Defries and Townshend (1999), assessment of land cover data from ground cover sources have demonstrated substantial divergences. This is a situation where diverse datasets of the same place show different geographical phenomena at the same position in space. The inconsistencies result from differing definitions and categorization of cover types, conflicting interpretation of land cover designations, perplexity between natural and human modified vegetation, and the actual incongruity about the geographical coverage of types of land cover (Defries & Townsend, 1999).

Furthermore, field studies alone cannot make available predictions of future trends of change. As a result, remote sensing became a key method in LULC monitoring (Cobly & Keating, 1998; Collins & Woodcock, 1996; Petit et al., 2001). Since the launching of the first 1972 satellite (Richard, 1996; Defries & Townshend, 1999), remote sensing through space borne technologies has been providing critical data for the analysis of regional and global terrestrial cover (Petit et al., 2001). Remote sensing has also provided a substitute method of land cover change detection with the benefit of capabilities of great regional to global coverage, elevated spatial and temporal resolution and ease in access (Jansen & Gregorio, 2003). As analysed by Defries and Townshend (1999), space borne data offer the basis for geographically referenced world land cover categorization that is reliable, replicable over time, and potentially more dependable than ground sources. The use of satellite data for mapping land cover at a great scale commenced with African regional studies (Turker, 2000) and in southern parts America (Townshend et al., 1987) and became a primary source for both inert depictions of land cover and recognition of land cover change.

As natural and human made landscapes are complex and in a state of unrest, it is imperative that these changes are documented and comprehended (Coppin et al., 2004). Remote
sensing and field methods have been used in the study of LULC, and in a wider sense, for the quest of both biophysical and anthropogenic features. Remote sensing has also become more valuable due to ability to cover extensive areas, high spatial and temporal resolution and inexpensive accessibility of remote sensing information (Collins & Woodcock, 1996).

3.5. **Digital change detection**

Digital change detection pertains to the systematic stages from acquiring images to pre-processing, then classification and finally, change detection. Conventionally, this type of remote sensing started in the early 1960s with feeble analysis of wide-spectral scanner data and digitized aerial images (Lillesand et al., 2004), and since the introduction of Landsat-1 in 1972, image processing has seen remarkable growth to date. The whole development from acquiring data to the final obtaining of the intended information involves assorted steps and every juncture is important as it can have considerable impacts on the ultimate results. Successful carrying out of change detection analysis using the technology of remote sensing requires careful determination of the sensor, environmental attributes and image processing modes (Lu et al., 2003); and a malfunctioning to understand the effects of these parameters can lead to erroneous results.

3.6. **Data acquisition and pre-processing**

Data should be acquired from a sensor that obtains data at roughly the same time of day, and on centennial dates. Same date images eradicate diurnal angle of the sun effects while centennial dates images reduces the influence of cyclic sun-angle and phonological dissimilarities (Jensen, 2005). Unprocessed digital images frequently have some arithmetical distortions due to variations in the attitude, altitude, atmospheric refraction, earth curvature, relief displacement, and nonlinearities in the brush off of a sensor (Lillesand et al., 2004). These discrepancies should be corrected to make certain the accuracy of the eventual results.
Atmosphere impacts on the radiance received by the sensor by dispersion, refracting, absorbing light; and modification for these effects, as well as for sensor additions and offsets, lack of solar radiance and solar zenith angles are important. These must be inputted in the in radiometric rectifications procedure that are used to translate satellite document digital counts to ground transmissions (Chavez, 1996). Using multi-date image satellite datasets calls for obtaining sensors at different times are analogous in terms of radiometric distinctiveness (Mas, 2004). Adaptation of digital figures and surface reflectance is a prerequisite for any quantitative analysis of wide-temporal images; and some methods like Dark Object Subtraction (DOS), comparative calibration and second imitation of the satellite indicator in the solar spectrum have been developed for atmospheric moderation (Lillesand et al., 2004).

3.7. Image enhancement

The main target of image enhancement is promoting visual multi-pretability of an image by ever-increasing the obvious distinction between materials in the panorama (Lillesand et al., 2004). This makes certain that features emerge clear and increases the capacity to make out diverse features. Different methods are used in image enhancement with the inclusion of principal mechanism analysis methods, for example Kauth-Thomas models and vegetation index (Jensen, 2005; Lillesand et al., 2004).

3.8. Principal components analysis

Principal apparatus analysis is a method that converts the inventive remotely sensed data into substantially diminutive and easier to understand set of inconsistent variables that correspond to most of the information existing in the original data (Jensen, 2005). Major components analysis is as a result a data compression method which allows outmoded data to be compacted into fewer bundles. It is a straight transformation which coordinates multivariate data
by converting and/or revolving the axes of the original characteristic space, so that the data can be shown without correlation in new space aspects (Lasaponara, 2006).

3.9. **Spectral vegetation indices**

These are extensive, radiometric scales that show comparative abundance and bustle of green vegetation (Jensen, 2005). These indices are used to create eventual images by mathematically bringing together Digital Numbers (DN) ideals of unlike bands; and usually use the converse relationship between the red and the almost-infrared associated reflectance with the vigorous green vegetation. SVIs utilize the acknowledged attribute shape of the green spectrum by putting together the low reflectance in the noticeable element of the spectrum with the elevated reflectance in the partially infrared (Rendeaux et al., 1996). These vegetation indices operate by complementary strong chlorophyll pigment incorporation in the red in opposition to the high reflectivity of plant substances in the NIR (Elvidge & Chen, 1995).

The indices have been classified into two components; orthogonal and ratio based indices (Lawrence & Ripple, 1998). In Ratio based vegetation index, there is Simple Ratio (SR), Normalized Difference Vegetation Index (NDVI), and other modified editions of NDVI intended to address its fragility to factors such as soil changes and atmospheric patterns (Lawrence & Ripple, 1998). Orthogonal vegetation indices depend on being linear in the spectral space through which bare soils of varying brightness shall lie, together with the Kauth-Thomas model being the most used.

3.10. **Image classification**

Wide-spectral image classification is the practice of organizing out pixels to limited numbers or classes based on the information file attributes. The core objective of image
categorization procedures is to classify all the values of pixels in an image into terrestrial cover groupings or themes (Lillesand et al., 2004). The goal of image pixel cataloguing is premised on the fact that diverse features have varying reflectance. The sorting process pertains to pattern acknowledgment in the image, with spectral trend considered as more proficient scientifically, though temporal and spatial trend recognitions can be utilized too.

Supervised and unsupervised categorization models are the most extensively used classification models. Supervised and unsupervised algorithms normally use hard classification logic to produce a category map that is made up of hard distinct classes (Jensen, 2005). Before sorting is carried out, the specific goal classes needs to be identified. This calls for the use of a scheme made up of taxonomically correct descriptions of groups of information organized according to logical criterion (Jensen, 2005). Homogeneous classification systems have been developed and used by different researchers to aid in classify land cover classes. The main function of standardization of arrangement schemes is to ensure standardization, and compatibility of different research works with soaring degree of precision.

Supervised classification constantly requires a preceding knowledge of the study area to make certain selection of the training points. According to Jensen (2005), when using a supervised groupings, the identity and position of some of the land cover types are identified through a combination of interpretation of aerial photographs, field work, map analysis and individual experience. Sites for training spectral distinctiveness are used in preparing the algorithms for the land cover mapping of the image.
3.11. **Accuracy assessment**

The need for testing accuracy of spatial data from remote sensing methods and used in GIS investigation has been renowned as a critical component of countless projects (Congation & Green, 1993). Congation and Green (1991) emphasise that if the output of remote sensing data is to be used in decision-making process, then significant quantities of its values must be known. The most widespread accuracy measurement of elements includes general accuracy, producer’s precision, user’s exactness and kappa equation (Lu et al., 2003).

One of the most universal methods of expressing categorization precision is the preparation of a classification fault milieu (Lillesand et al., 2004). A fault matrix is an assortment of numbers set in columns and rows that express the number of trial units assigned to a scrupulous category in one classification comparative to some of sample units assigned to a given category in another organization (Congation & Green, 1991). The fault matrices relate, on a category by category foundation, the relationship between acknowledged reference data and the corresponding results of the mechanized classification. The matrix is able to recognize exclusion and commission errors in the categorization as well as the producer’s and the user’s precision.

4. **CHANGE DETECTION METHODS**

Digital adjustment detection involves the quantification of temporal events from multi-date imagery that is commonly acquired by satellite multi-spectral sensors and detectors (Coppin et al., 2004). In general, change detection pertains to the appliance of multi-temporal data information to substantially analyse the temporal impacts of the events (Lu et al., 2003).
Preceding literature has revealed that image variation, major component analysis and classification relations are the most widespread methods used for terrestrial change detection. Change detection modes have been classified generally into image geometric, alteration and classification. The algebra class includes differencing of images, image waning, image rotating, plant life index differencing, transformation vector analysis and backdrop subtraction. These methods involve calculation of two or more images of about similar radiometric characteristics; where subtraction led to both positive and negative standards in areas of change and absolute values in areas of no little variation (Green et al., 1998).

4.1. **Image differencing**

In this technique, spatially referenced images obtained at varying times are subtracted to create a lasting image which stands for the change between dates (Mas, 2004). This would lead to datasets with values representing change area and nil without change (Coppin et al., 2004). Making use of an 8-bit image, the prospective range of differences vary from -255 to 255. In the algebra change detection class, image differencing is commonly practiced. Noticeable red band image differencing has proven to be appropriate for change detection in harsh environments, but it is not apparent this is true in environments such as wet tropical regions.

4.2. **Vegetation index differencing**

This technique involves eliminating parts of images which have been transformed to the various vegetation indices for varying dates in the study. The foremost benefit of vegetation index differencing is that differences in the spectra provide indicators of physical effects (Lu et al., 2003).
4.3. **Principal components analysis (PCA)**

PCA comprises of two referenced images to form a new multiband image consisting of bands from date to date (Lillesand et al., 2004). The chief advantage of these variations is to enhance data absoluteness and insisting diverse information in the derived mechanisms. Later, a PCA based on variance matrices or a homogeneous PCA based on examination of connection matrices can then be conducted.

4.4. **Post-classification comparison**

Post-categorization analysis is common of these techniques and it comprises of autonomously produced spectral results from various ends of time intervals, followed by a segment by segment relation to detect land cover change (Coppin et al., 2004). Besides, the arithmetic which is applied on the categorized images to establish those pixels with a variation between the two dates, figures can be brought together to convey the exact nature of terrestrial changes between two satellite images (Lillesand et al., 2004). An advantage of these techniques lies in the fact that the images are disjointedly classified hence minimizes the problem of radiometric labelling between dates. However, the precision of post categorization assessment depends on the accurateness of original image classification. Improper classification and registration errors that may exist in the unique images are composite and the results realized using post categorization relations are regularly judged as inadequate (Coppin et al., 2004).

5. **GLOBAL TRENDS**

Land cover change is probably the most exceptional form of global change in environment since it occurs at temporal and spatial scales directly applicable to our daily survival. The changes in land use, particularly when joined with climate change and variability,
could impact on ecosystems and natural resources in complex ways. Over an extended period, almost 1.1 million km$^2$ of woodland and forest and 5.4 million km$^2$ of pasture and grassland have been transformed to other utilities in the recent centuries. According to Foley et al. (2005), during this duration, cropland has expanded by 10 million km$^2$. Humans have transformed massive parcels of the Earth’s surface: 10 to 15% presently is conquered by urban-industrial and agriculture areas (Vitousek et al., 1997).

Climate inconsistencies have transformed land use practices in different parts of the world, highlighting differences in societal susceptibility and pliability. Research on land use and climate change requires the development of new models connecting the geophysics of climate with the socioeconomic drivers of land use (IPCC, 2007). Given a scientific understanding of the progression of land use change, the impacts of different land use decisions, and how they will be convoluted by a changing climate and increasing climate variability becomes an area of concern for research (IPCC, 2000). This research element should provide the scientific foundation for land use decision-making and projections of future land use, as well as substantial benefits beyond climate change evaluation and alleviation by supporting a wide collection of issues significant to public users of this information.

Changing land use patterns or transformations, motivated by a multiplicity of socioeconomic causes, often lead to land cover changes that affects biodiversity, global temperatures, greenhouse gases accumulation and emissions, water budgets and other bio-geophysiochemical processes (Meyer & Turner, 1994). Other than anthropogenic factors, natural phenomena also affect or alter land cover. Natural events such as weather and climatic fluctuations, epitomized in flooding, wild fires and ecosystem changes, may also pioneer adjustments on land cover (Honnay et al., 2002). Globally, however, land cover is altered primarily via anthropogenic uses
such as: suburban construction and development, agriculture and livestock raising, forest resources harvesting and management. There are also subsidiary impacts on land cover from other human activities such as forest and lakes damaged by acid rain from fossil fuel combustion and crops near cities damaged by tropospheric ozone as a result of automobile exhaust (Meyer, 1995).

Ground methods of land cover and land use mapping are often not financially feasible, time consuming, and labour demanding, with results in them rarely being done with maps and soon become obsolete (Foley et al., 2005). Monitoring changes and time series analysis are difficult when using conventional methods of surveying (Olorunfemi, 1983). However, as noted previously, satellite remote sensing techniques have been developed which have proved to be of great significance in the preparation of accurate land cover and land use measures for monitoring at any selected temporal scale, and these techniques have become the most cost- and time-effective basis for acquiring data worldwide (Seto et al., 2002).

6. CONDITIONS AND TRENDS IN KENYA

The area of land in Kenya is about 582,646 km² with roughly 80% being semi-arid and arid lands. These areas receive less than 700 mm of rain each year. The country is further ramified into agro-climatic zones by the use of a humidity indicator (Sombroek et al., 1982). This index utilized is rainfall done annually expressed as a percentage of possible evaporation. Some areas with less than 50% index have a high agricultural prospective and are classified into three zones. These are about 12% of Kenya’s terrestrial area. Partially-humid to dry regions have humidity index of less than fifty per cent. These are grouped into zones of 1 to 4. They are
commonly known as savannah lands and are about 88% of the land area of Kenya (de Leeuw et al., 1991).

Approximately eighty percent of Kenya’s (about 40 million) population is therefore saturated in only ten per cent of the land that is moderate and high-productive agricultural land surface (Rutten, 1992). Kenya’s economy is mainly agricultural driven and over 70% of Kenyans are involved in some subsistence and/or profit-making agricultural practices. Hence, a good amount of the country’s land is being used for agricultural activity relative to other countries. The quantity and quality of land at hand for rain-based agriculture is quite low. And the allocation of land between land owners is highly tampered with (Emerton et al., 2001).

Land shortage in Kenya can be accredited to, i) constraints in climate, ii) soaring gini-coefficient levels, and iii) insufficiency of non-agricultural alternatives for the populace and task force. The reaction of the agricultural segment has been expected: growth into the arid and semi-arid regions (ASAL) where there is low population pressure. Draining and irrigation of the not many wetlands in these insignificant areas have to some extend been the major coordinating actions resulting to the development of agriculture into these ASALs. Major results of this reaction include expansion, irrigation of arid and semi-arid lands, and drainage of wetlands, agriculture along deltas and riverbanks, and transformation of forest into farmland.

6.1. Land use change and spatial temporal variations in Kenya

In Kenya, land has varied meanings according to diverse people: To pastoralists and farmers, land is property to be owned and a basis of livelihood and accessing it is a major concern (Orodo, 1997). The influential deem land as a marketable item from which to make profits via market conjecture mechanisms (Ojang’ & Ogendo, 1973). Often, administrators and
politicians view land as a valuable entity whose boundaries echo a social, political and cultural identity (Ntsebeza, 2005). To agencies involved in development, land offers goods and services needed for people's wellbeing and opulence. These views roughly decode into different, and habitually competing, land needs in Kenya. No sole definition can sufficiently reflect the differing perceptions.

Natural resources vary in quantity and quality across time. The chief land-cover types within Kenya are savannas, forests, wetlands, saline and fresh water bodies, deserts and grasslands. These are utilized for pastoralism, agriculture, mining, communications, nature reserves, water catchments, rural and urban settlements, recreation tourism and industry. Others include fishing, cultural sites, energy and forestry (Sombroek et al., 1982). Of the overall land cover, approximately two per cent is under native and exotic forests. Almost twelve per cent of the land has high rainfall maintaining the production of coffee, tea, pyrethrum, floriculture and horticulture, and subsistence crops such as wheat, maize, potatoes, dairy farming and pulses. The arid and semi-arid area covering approximately thirty two per cent of rainfall and supports varied livestock and crop rearing. Irrigated agriculture of flowers has in the latest past come up as a chief type of land use besides agro-pastoralism. Above fifty per cent of the overall land cover is arid or semi-arid with tremendously low and unreliable rainfall. Extensive use is made of land for widespread nomadic systems and livestock production (Sombroek et al., 1982).

Some portions of the country have restricted mineral capacity. Others have been preserved for industrialization and urbanization. Saline and fresh water bodies sustain the fishing industry. Deplorably, they are also utilized for waste sites for industrial and urban waste. Rivers are the main source of electric power upstream while the junior parts of the key rivers have made irrigated agriculture possible. The unreserved grasslands and savannahs are home to wildlife
conservation and livestock production, but have become a major focus for advancement in dry-
land farming (Government of Kenya / UNEP, 1997).

6.2. Land use change and forest resources

The areas under forests in Kenya are about 2.3 million hectares of which 1.60 million hectares are gazetted. The non-gazetted land area which is about 0.76 million hectares is ramified into about three hundred units of forests. Forty percent of the units lie on about 100 hectares. The tight canopy of native and alien forest species lies on approximately 1.20 million hectares; plantations stretch to about 0.16 million hectares (Government of Kenya, 1999a). Congested canopy forests without the gazetted forest reserves extends to about 0.18 million hectares. The Kenyan government has anticipated a further 0.5 million hectares through gazettement and afforestation.

The cover of Kenyan forests has differed across space and time. In 1897 the only officially recognised forest area was the ‘Wood Strip of the Akamba’ that extends about 2 miles on every side of the railway line in Uganda. The strip was founded on the umbrella of the ‘Akamba Forests and Woods Regulations’. By 1932, forty-two different forests had been allocated as government areas of forests which went up to about 1.05 million hectares later in 1940 (IUCN, 1998). During the time of independence documented forests were about 1.8 million hectares that represents 3.5% of the overall area of land. A survey done aerially in the year 2000 evinces that these group of forests have reduced considerably (Kenya Forest Working Group/East African Wildlife Society, 2001). A number of native and exotic forests exist in the highlands of Central Kenya where there is high rainfall, fertile soils and limited human settlements. In the arid and semi-arid regions (ASALs), forests exist in isolated mountain ranges and in thin bands adjacent to rivers.
6.3. Land use and forest depletion in Kenya

In spite of the fact that many Kenyans have become responsive to the aesthetic, environmental, and commercial worth of forests, thick-canopy forests have been degraded (Government of Kenya, 1999a). By the year 1981, a total forest record showed a number of documented and non-documentated areas in threat of expurgation. Over a period of about 20 years forested areas have been reduced by 16%. The directory of endangered forests includes the Karura and Ngong Forests. Earlier forest degrading was the result of an effort by the government to make room for agriculture and also to create homes for the landless. A decrease in the pace of depletion of forests in the mid and early 1970s from about 18% to approximately 6% per year was the result of local efforts conservation efforts complemented by those of the global community (Matiru, 1999).

Clearing of forests has been an ecologically and spatially distinguished process changing across time and reflected the comparative power and the capability of various groups to find access into Kenya’s forest resources (Emerton & Karanja, 2001). Between the years 1990 and 1995, the cover of forests changed by 17%, mainly as a result of the settlement of landless people. Systematic analyses also show that a number of blocks of forests were illegally acquired by the then land owners (Akotsi et al., 2006). Recently the decrease of forests through removal, pressures in population and change in climate is approximately at about to 5,000 hectares annually, while depletion through forest excisions and fires is estimated at almost 15,000 hectares each year (Government of Kenya, 1999a).
6.4. The case of Nandi County, Nandi Forests

Land cover change detection and its variations are required so as to comprehend global change in environment. Of deep interests are the impacts of rain forest in the tropics ramifications which changes due to the extent and strength. The growth in ramification is related either to human or natural sources (Geist & Lambin, 2001). Both biodiversity influences are immensely important in the tropics (Gaston & Blackburn, 2000). The activities of the East African BIOTA are presently concentrating on the Nandi Forest and its fragments (Kohler, 2004). Retrieval of information about land cover change and therefore forest ramification and disturbance is conducted for the larger area of Nandi Forest and connected areas of forests. Here, the findings from satellite data form a chief contribution of processing spatial-information for registering man-made influences on these forests through time. The various ecological and/or biological subprojects of East African BIOTA allow investigation of local variations in ecosystems and biodiversity in relation to global environmental change (Kohler, 2004).

The forests of the Nandi District are on an escarpment of between 200m and 300m in elevation. Recently, there has been a continuous debate on whether such islands of forests would have become a wider area of forest if not they have been owned and managed by the Guinean Congo rain forest (Kokwaro, 1988). These forests exist in one of the earth’s most populated rural settings (Blackett, 1994) with an average population density of 600 per km² on land which is vigorously used for home-based agriculture. The forest reserves play a significant role in providing for their basic needs of local people such as building material and firewood (Kokwaro, 1988). An increase in illegal and legal activities since colonial times in the early 20th century to date have led to forest depletion and have resulted in only relatively small patches of compact
forests are remaining, with the much tampered with Nandi Forest deemed to have decreased to only about 120 km² by the year 1980 (Kokwaro, 1988).

7. CHAPTER SUMMARY

This chapter highlighted on the spatial temporal changes in land use in a couple of aspects including land use and land use change, and approaches in estimation of land use change. GIS and Remote Sensing mechanism have also been reviewed and a situational assessment of the Nandi Hills Forests has also been highlighted on; based on previously undertaken studies. The next chapter continues to elaborate on the study area.
CHAPTER FIVE

AREA OF STUDY

1. INTRODUCTION

This chapter presents the area of study. It covers aspects of the physical, ecological, economic and the social aspects of the Nandi Hills Forests, and draws attention to details of the locality in which the research was done.

2. PHYSICAL ASPECTS

This subsection discusses the location, extent, topography, drainage, geology, soils and climatic characteristics of the study area, namely the Nandi Hills, Nandi North and Nandi South Forests.

2.1. Location and extent

2.1.1. Nandi North Forest

The Nandi North forest is located within Nandi North District of the western parts of the Rift Valley Province of Kenya. This forest lies on the edge of the Nandi escarpment about 5 km East of the Kakamega Forest. It stretches for more than 30 km from North to South and is no more than 5 km wide for most of its length. The forest is centred on coordinates: 0°20’N and 35°0’ E with an approximate area of 10,500 Ha (BirdLife International, 2011).
2.1.2. **Nandi South Forest**

The Nandi South forest falls within the Nandi South District which was carved out of the greater Nandi in 2003. This area is a mid-elevation forest lying just west of Kapsabet town and south of the main Kapsabet-Kaimosi road. South Nandi was once continuous with Kakamega forest and the two forests are still no more than a few kilometres apart at their closest points. The South Nandi Forest has an average area of 18000 ha and is centred on coordinates 0°8’ S and 35°0’ E (Nature Kenya, 2009).

2.1.3. **Nandi Hills**

Nandi Hills is a highland area of lush green rolling hills at the edge of the Great Rift Valley in the former Rift Valley Province of Kenya and is part of the once extensive Nandi South Forest.
Figure 5.1

The study area in Africa’s context (Source: Gregorio & Latham, 2002).
Figure 5.2

Processed map showing Nandi Hills and Nandi Forests in Kenya’s Context
Chapter Five: Area of Study

Figure 5.3

Processed map showing Nandi Hills and Nandi Forests in the local context
2.2. **Topography and drainage**

2.2.1. *Nandi North Forest*

The topography of Nandi North forest is characterized by rolling hills of the Kapsabet plateau and highlands. The forest land rises from 1300 to 2500 Metres above Sea Level (MaSL) in the highlands. The topography is apt for growth of natural forest and acts as a watershed to numerous rivers (Government of Kenya, 2001b). It is drained mainly towards the east by the Kigwal and Kimondi River systems, which flow through the South Nandi forest and then westwards into the Yala River and Lake Victoria.

2.2.2. *Nandi South Forest*

The topography of Nandi South Forest is dominated by Nandi Escarpment and the Kano Plains at the foot of the escarpment. The altitude ranges from 1400 to 2400 Metres above Sea Level (MaSL). The forest is drained by the Kimondi and Sirua Rivers, which merge to form the Yala River flowing into Lake Victoria (Birdlife International, 2009).

2.2.3. *Nandi Hills*

The topography of Nandi Hills is generally made up of rolling hills at the edge of the Great Rift Valley. Rivers and numerous streams drain from the hills into Lake Victoria via the River Yala.

2.3. **Geology and soils**

2.3.1. *Nandi North Forest*

Nandi North forest is underlain by an outcrop of basement rock system, very distinct in the northern sections of the forest. Sandy and clay-loams are the main soil types found in the forest and a few areas have humic nitisols. These well drained friable soils of the forest are
derived from undifferentiated basement system rocks and are moderately fertile and are generally suitable for production of various crops. Other regions like Ngecheck are rocky (Government of Kenya, 2001b)

2.3.2. Nandi South Forest

Nandi South Forest’s landscape is gently undulating and underlain by granitic and basement complex rocks, which weather to give deep, well-drained, moderately fertile soils characterized by traces of rugged hills with shallow fragile soils the soils that are generally clay loam (Government of Kenya, 2001b)

2.3.3. Nandi Hills

The Nandi Hills is characterized by volcanic rocks that have given the soils in the area a volcanic soils signature. These volcanic soils are well drained and are very fertile thus good for agriculture. This has been the reason for clearance of forest cover to create more land for agriculture.

2.4. Climate

2.4.1. Nandi North Forest

The Nandi North Forest has a cool and moderately wet climate. It receives a mean rainfall of an average of 1500mm per year. The rainfall is bimodal with dry spells experienced between December and March. The distribution of rainfall is affected by topography and the south-westerly winds from Lake Victoria. The temperature within and around the forest ranges from between 18-25°C
2.4.2. **Nandi South Forest:**

The Nandi South Forest on the other hand receives higher precipitation which varies between 1,600-1,900 mm per year and is dependent on altitude. The month of March marks the onset of rains which continues to November with no clear cut distinction between the long and short rains. The area experiences average temperature range of 18-25°C.

2.4.3. **Nandi Hills**

The Nandi Hills section of the study area has a cool and wet climate that is highly influenced by the hilly terrain. There are two rainy seasons during the equinoxes and the temperatures vary between 18°C and 24°C.

3. **ECOLOGICAL ASPECTS**

This subsection gives an overview of the ecological situation in the Nandi Hills and Nandi Forest. It covers vegetation and wildlife and their relationship to forest resource utilization.

3.1. **Vegetation**

3.1.1. **Nandi North Forest**

The vegetation of Nandi North Forest, though sometimes classified as tropical rainforest, is less floristically diverse than that of Kakamega Forest because of higher altitude. Biogeographically, it occupies a transitional position between the lowland forests of the Zaire basin and western Kenya and the afro-montane forests of the Kenya Highlands. The dominant tree species in the forest include *Solanum mauritianum, Neobotonia macrocalyx, Diospyros abyssinica, Croton macrostachyus, Syzgium guineense* and *Celtis Africana* (Bennun & Njoroge, 2001)
3.1.2. **Nandi South Forest**

The vegetation of South Nandi is a mix between the lowland forests of West and Central Africa (the easternmost outlier of which is Kakamega) and the montane forests of the Central Kenya Highlands. It is actually a transitional zone. Biogeographically, South Nandi is often considered an eastern extension of Kakamega. However, it is higher in altitude than Kakamega and floristically less diverse. Common trees include *Tabernae montanastapfiana, Macaranga kilimandscharica, Croton megalocarpus, Croton macrostachyus, Drypete s Gerrardii, Celtis africana, Prunus africana, Neoboutonia macrocalyx* and *Albizia gummifera*.

3.1.3. **Nandi Hills**

The vegetation of the Nandi Hills, although highly depleted, has a close resemblance to that of Nandi South area.

### 3.2. **Wildlife**

3.2.1. **Nandi North Forest**

North Nandi Forest is an unusual and important forest. It contains many bird species that have very limited ranges in Kenya: a number occur only here and in Kakamega (Birdlife International, 2009). The forest remains a relatively narrow strip, under severe pressure from illegal timber extraction, charcoal burning, forest grazing of livestock, and unsustainable removal of forest products (firewood, honey and medicinal plants).

3.2.2. **Nandi South forest**

The South Nandi Forest has antelopes that are hunted heavily in the eastern sector, where the surrounding human population is lowest. Monkeys and other small forms of wildlife can also be found within the forest. Birds are also trapped seasonally, particularly *Coturnix delegorguei* in
the grasslands (Bennun & Njoroge, 2001). Honey gathering, seemingly a sustainable activity, also constitutes a conservation threat.

4. **ECONOMIC SITUATION**

This subsection presents the major economic activities, the major land uses and forest resources utilization for socioeconomic development. The major economic activities in the study area are dairy and agriculture. In the Nandi South Forest, agriculture accounts for over 90% of household sustenance system, with 54% of the household income being derived from agriculture (FAO, 2000). The case of Nandi North Forest Catchments agriculture, principally crop and dairy activities drive the economy (Government of Kenya, 2001a). The key food varieties are maize, Irish potatoes, sorghum and millet, while tea, coffee and pyrethrum are the cash earners. Most of these crops are grown under mixed farming conditions. In the Nandi hills, the high altitude influences the rainfall patterns and provides adequate rainfall for farming and agriculture which is the economic base of the people. Besides agriculture, there is horticulture which also brings in the economic empowerment to the people. Cattle-raising is practiced to a large extent here. The economic potential of the area is immense and it has not been fully exploited (Government of Kenya, 2001b).

Poverty in the study area afflicts about 50% of the population; residents in the Nandi Hills and Nandi Forest water catchment areas (Government of Kenya, 2003). Under-utilization and inequitable distribution of resources, high cost of farm inputs, poor and inadequate education and unemployment have been identified as the major causes of poverty in the study area. As a consequence, the poor have been driven to encroaching into the forested areas and even to settle on steep slopes of more than 55°, a figure that is 10° more than what is recommended by the
Ministry of Agriculture (Government of Kenya, 2001b). This has detrimentally affected land use especially in relation to cultivation on steep slopes and forest cover depletion through encroachment.

The study area is of great economic importance at the local as well as at the national level especially in agriculture and forestry (Government of Kenya, 2003). Non timber products from the forest such as wild honey, fruits, medicinal plants and edible animals support livelihood systems of the local population. However, with increasing population and increasing human needs, the harvesting of forest resources is now unsustainable (Mathu, 2007). The forest trees are now being cleared to create more land for agriculture, grazing and illegal timber harvesting, especially of the Elgon Teak tree species (Adhola et al., 2009).

5. **SOCIAL ASPECTS**

This subsection focuses on the population dynamics of the Nandi Hills and Nandi Forests and attempts to link forest resource utilization with issues of population.

5.1. **Population density**

According to the Central Bureau of Statistics (2003), the projected population density is 285 persons per square kilometre in areas with the greatest potential for agriculture, 276 persons per square kilometre in medium to high potential areas, and lower potential areas have a population density of 162 persons per square kilometre. A dense and rapidly growing human population in the Nandi Hills and the surrounds of the Nandi Forests has resulted in increased pressure on land (Bennun & Njoroge, 2001). Several large excisions have taken place and human settlement has moved past the pegs marking the forest boundaries (Adhola et al., 2009).
5.2. **Population composition**

The population of Nandi County stands at 752,965 people, the sex ratio is 1:1 with a population growth rate of 2.9% annually and the bulk of the population (68%) is youthful (0-25 years) (Government of Kenya, 2005; KNBS, 2010)

6. **CHAPTER SUMMARY**

This chapter clarifies and outlines the setting of the study in the African, Kenyan and local contexts. Further to this it presents characteristics of the study area, which include: physical, ecological and socio-economic characteristics of the area of study. These characteristics later on in the study provide an overview in which to frame the findings of the research in chapter seven and the subsequent discussions on these findings in chapter eight.
CHAPTER SIX

RESEARCH DESIGN AND METHODOLOGY

1. INTRODUCTION

Research, which is defined by Singh and Bajpai (2007) as the systematic and objective recording and analysis of controlled observations that may lead to generalizations, principles or theories, resulting in prediction and possibly ultimate control of events, requires a precise methodological framework. This framework should clearly exemplify the design and methodological procedures that the research embraced. Kothari (2009) states that a research design is the advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analysis in line with the objective of the study, as well as the availability of staff, time and money. According to Claire et al. (1962), a research design is the arrangement of conditions for collecting and analysing data in a manner that aims to combine relevance with the economy of procedure. On the other hand, decisions regarding what, where, when, how much and what means a problem is solved constitutes a research methodology. Bogdan and Tailor (1975) hold that in terms of the social sciences methodology refers to the process, principles and procedures by which we approach problems and seek answers. It is a way to systematically solve the research problem.

This chapter reviews different research paradigms, discusses the design of the research, the nature and source of data, and describes the population, sampling methods, data collection
instruments and procedures, the tools of data analysis and their presentation. It also considers the validity and reliability of the data as well as the methodological constraints of the research.

2. RESEARCH PARADIGMS

Paradigms refer to the shared set of postulations on the way we perceive the world. A paradigm describes the world to us and assists us to envisage its behaviours (Barker, 1992). Senge (1990, p. 8) refers to paradigms as mental models and in particular depicts them as “...deeply ingrained assumptions and generalizations that influence how people see the world and behave.”

Guba and Lincoln (1994) prefer a more benign sense of paradigm, depicting it as a person’s best perception concerning the world founded on the answer to metaphysical questions. In this sense, a paradigm portends a set of beliefs concerned with first principles. Denzin (1994, p. 107) on his part, fronts a highly integrative view that:

“A paradigm may be viewed as a set of basic beliefs (or metaphysics) that deals with ultimates or first principles. It represents a worldview that defines, for its holder, the nature of the “world,” the individual’s place in it, and the range of possible relationships to that world and its parts, as, for example, cosmologies and theologies do. The beliefs are basic in the sense that they must be accepted simply on faith (however well argued); there is no way to establish their ultimate truthfulness.”

Inquiry paradigms are normally the foundation of research since they define for inquirers what it is that they are about and what falls within and outside the legitimate inquiry (Guba &
Lincoln, 1994). Different modes of investigations permit us to comprehend diverse phenomena and for diverse reasons (Deetz, 1996). Researchers (e.g. Cavaye, 1996; Creswell, 2009) believe that the appropriateness of a methodology depends on what one attempts to achieve, rather than a dedication to a certain paradigm. That is, the methodology embraced ought to be in line with the particular phenomenon of concern. Different situations may well need the employment of different methodologies. By giving attention to the phenomenon under investigation, rather than the methodology per se, makes the selection of appropriate methodologies by researchers for their enquiries easier (Falconer & Mackay, 1999).

Research paradigms cannot be discussed without pointing out certain philosophical dispositions which fall at the centre of worldview discussions: ontology (theory of reality, existence and being), epistemology (theory of knowledge) and methodology (research strategy or strategy of inquiry) (Denzin & Lincoln, 2005; Guba & Lincoln, 1994; Mautner, 2005). A review of literature on research methodology reveals four major paradigms relevant to this study. These are positivism (Denzin & Lincoln 2005), post-positivism, interpretivism (Guba & Lincoln, 1994) and participatory paradigms (Lincoln & Guba, 2000), as indicated in Table 6.1. However, they need not be considered to be independent of one another and research may take place to varying degrees within different paradigms in what Creswell and Plano (2007) describe as a pragmatic paradigm.
Table 6.1

Basic beliefs of alternative inquiry paradigms (Adapted from Guba & Lincoln, 1994, p.109)

<table>
<thead>
<tr>
<th>Item</th>
<th>Positivism</th>
<th>Post-Positivism</th>
<th>Interpretivism</th>
<th>Participatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontology</td>
<td>Naive realism; real “reality” and apprehensible</td>
<td>Critical realism –real “reality” but only imperfectly and probabilistically apprehensible</td>
<td>Relativism; local and specific constructed realities</td>
<td>Historical realism; virtual reality shaped by social, political, cultural, social, economic, ethnic and gender values; crystallized over time</td>
</tr>
<tr>
<td>Epistemology</td>
<td>Dualist/objectivist; findings are true</td>
<td>Modified dualist/objectivist; critical tradition/community; findings probably true</td>
<td>Transactional/subjectivist; created findings</td>
<td>Transactional/subjectivist; value mediated findings</td>
</tr>
<tr>
<td>Methodology</td>
<td>Experimental/manipulative; verification of hypotheses; chiefly quantitative methods</td>
<td>Modified experimental/manipulative; critical multiplism; falsification of hypotheses; may include qualitative methods</td>
<td>Hermeneutical/dialectical</td>
<td>Dialogic/dialectical</td>
</tr>
</tbody>
</table>

2.1. Positivism

Positivism as a paradigm of research owes its origin to the 19th century French philosopher Auguste Comte. Positivism was considered to best describe the worldview of researchers in the natural sciences and is normally based on scientific ‘objectivity’ and observations that are organized in an orderly manner (Babbie, 1993). Attempts were made to use
these methods when investigating social occurrences (Smith, 1993) and assertions were made that social certainty is independent of people and can be investigated objectively by making use of valid and reliable data. Knowledge and truth are issues of correspondence in the positivism paradigm in that they relate to an exterior referent truth (Smith, 1993). This correspondence presumption of truth confers the origin of truth in reality; hence, a statement is confirmed to be true if it concurs with an independently existing reality and is false if it does not (Kim, 2003). However, there have been many issues the supposition of positivism that utter truth exists.

2.2. Post-positivism

Post-positivism as a paradigm was embraced in the 19th century and was a reaction in opposition to the supposition that utter truth exists, particularly in relation to findings regarding humans (Creswell, 2009). Post-positivism is a departure from positivism since it rejects the fundamental principles of positivism (Trochim, 2000). The post-positivists normally take a scientific approach to research (Creswell, 2007) but believe that the researcher and the object of inquiry are not wholly separate or inseparable (Reyes, 2002). However it is a deterministic philosophy since it presupposes that effect possibly is a consequence of cause. Its traditional scientific orientation requires that problems are divided into sub-themes (reductionism) and that the resultant distinct components are tested, for instance by use of hypotheses and research questions. Prominence is also laid on the researcher’s objectivity and the identification of bias (Creswell, 2009).

2.3. Interpretivism/Constructivism

This paradigm postulates that in as much as society is orderly and controlled, it does not achieve a tangible form but rather a product of inter-subjective encounter. In this case, the researcher’s aim is to comprehend the process through which shared reality is made, upheld and
transformed (Smith & Dainty, 1991). However implications of post-positivist world-view for qualitative inquiry have given rise to distinct characteristics unique to itself. Interpretive researchers insist that there ought to be candidness to the understanding of people whom researchers study and reservation in the way researchers employ and hold their comprehension of those being studied (Giorgi, 1997; Husen, 1999; van Manen, 1998). This paradigm advocates for the understanding of the subjective patterns on meanings that are constructed by individuals. Nevertheless, the nature of interpretative research findings (due to contextual and subjective characteristics) is often a significant impediment for researchers who attempt to generalize the results to different environments; what is true in one circumstance may possibly not be true in another (Kim, 2003).

2.4. Advocacy/Participatory

This paradigm developed out of a concern that other paradigms do not touch on social justice concerns, particularly in view of marginalized or disenfranchised individuals in society (Abbott 2002). Researchers also believe that research is highly political and that it has the potential of effect change in society (Huchzermeyer & Karam, 2006). Participatory investigation and putting together an action agenda is hence the emphasis of this paradigm (Creswell, 2007). The purview of partnership with participants ranges from the design of questionnaires to data collection and analysis. Heron and Reason (1997) further assert that specific social issues (domination, oppression, inequity) normally play a pivotal role in framing research questions. Hence the inquest does not only include the aspiration to empower persons but also to make sure that they are not further discriminated against (Majale, 2008). These attributes portend advocacy research as a paradigm that can embrace both the qualitative and quantitative approaches (Creswell, 2009).
2.5. **Pragmatism**

Researchers who hold this worldview pay keen attention to the outcomes of the research, which include: the actions, situations, and consequences of inquiry (Creswell, 2007). There is usually an intricate relationship between design approach and the underlying paradigm stance (Creswell, 2003). For instance a quantitative approach entails maintaining positivist paradigm beliefs while a qualitative approach entails maintaining beliefs linked to an interpretive or constructivist paradigm position. Nevertheless, these relationships are, by no means rigid (Bryman, 2004). The pragmatic paradigm postulates by and large that the approach to research is that of integration of data collection methods and data analysis procedures in the course of the research (Creswell, 2003). The integrated approach embraced by this paradigm is applicable to this study due to the intricacy of investigations embraced. This paradigm allows for the use of multiple methods of data collection to best answer research questions and employs both quantitative and qualitative data collection and analysis criteria (Creswell, 2007).

3. **RESEARCH DESIGN**

The logical argument by Singh and Bojpai (2007) that research design is a choice of an investigator about the components of his project in line with the objectives of the study is very interesting. They maintain that a research design entails mandatory choices made by the researcher as a road map and a set of strategies for collecting evidences, analyzing them and reporting the findings. Mertens (1998) on the other hand cites a research design as the plan and structure of investigation used to obtain evidence to answer research questions. Mertens further asserts that a research design describes the procedures for conducting the study, including when, from whom, and under what conditions the data would be obtained. It (the research design) provides the most valid and accurate steps to obtain answers possible to research questions.
Research design is therefore intentioned to abridge the ambiguity of research evidence as much as possible (Chalmers, 1976). This is because in many cases we can always find evidence consistent with almost any theory. In spite of the relativity of these descriptions about what a research design entails and for the purposes of this study, it can be insinuated with certainty that research design depicts the plan, strategy and structure of investigation conceptualized to obtain answers to research questions on the basis of which this study is advanced. Divergent as these descriptions about research design are, there is some consensus that multiple methods are pivotal to achieving a superior purview of events under investigation (Denzin & Lincoln, 1994). Research designs with inspiration from an array of paradigms allow a more in-depth understanding of possible outcomes and have the potential provide a variety sources and kinds of information (Fraser, 1996).

In social sciences, there is a new school of thought championed by Hall and Howard (2008) and in tow with other mixed methodologists, that cogent consideration of design typologies is central in making research design choices and working in an all-inclusive structure. There are three recognizable design considerations when formulating a research design. The first design consideration considers ‘weight’ (Creswell, 2003; Creswell & Clark, 2007) and priority of each of the approaches employed in the study (Morgan, 1998), determining whether the quantitative or qualitative aspects are of equal importance or if predominance is placed over one or the other. The second design consideration explores the identification of stages in which the qualitative or quantitative approaches are integrated. In some instances, two approaches to design are applied: component design and an integrated design (Caracelli & Greene, 1997). The component design by default allows the quantitative and qualitative methods to remain detached through data collection and analysis while integration takes place during interpretation and
inference. On the contrary, the integrated design permits for the incorporation and conflating throughout the research process. Other methodologist like Teddlie and Tashakkori (2006) offer a design model known as mixed-strands matrix that builds on Caracelli and Greene’s (1997) thoughts to incorporate other forms of design. The mixed strand matrix approach offers additional pragmatic approaches that allow for the use of both qualitative and quantitative strands chronologically. The third and last design consideration aims at ‘sequence decision’ (Morse, 1991) and ‘the aspect of timing decision’ as proposed by Creswell and Plano Clerk (2007) which respond to and order the chronology of stages in which quantitative and qualitative methods are utilized.

3.1. Typologies of mixed methods research

Mixed methodological designs are principally for ‘better understanding’ (Cook, 1986; Greene et al., 1989); mixed methods purposes of complementarity (more complete/comprehensively), triangulation (stronger validity or credibility and less known bias), initiation (insightfully, fresh perspectives, creative concepts and meanings) and understanding with greater consciousness and greater diversity of values, perspectives, and positions. The methodological designs for mixed methods include:

- Triangulation design whereby different methods are used concurrently, with equal priority, to assess same phenomena towards convergence and increased validity.
- Nested or embedded design attributed to Doyle et al. (2009), which provides for the use of two sets of data that play complementary roles to each other, either way. Nested or embedded designs are either embedded experimental or embedded correlational designs.
• Sequential explanatory design which embodies two phases: the initial phase that uses quantitative approach and the final phase that use qualitative approach (Creswell et al., 2003)

• Sequential exploratory design which embraces the use of a qualitative approach in the initial phase and the final phase that use quantitative methodological approach.

• Sequential transformative design that also uses two phases but the differences with the other sequential design typologies is that both qualitative and quantitative methodologies are either equal or dominant.

A summary of these mixed method research typologies are contained in the Table 6.2 adapted from Creswell et al., 2003.

Table 6.2

*Mixed methods design typology (Creswell et al., 2003, p. 224)*

<table>
<thead>
<tr>
<th>Creswell et al. (2003)</th>
<th>Stage of Integration</th>
<th>Implementation</th>
<th>Priority / Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential designs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Sequential explanatory</td>
<td>Interpretation</td>
<td>QUAN $\rightarrow$ qual</td>
<td>Usually QUAN, can be QUAL or equal</td>
</tr>
<tr>
<td>*Sequential exploratory</td>
<td>Interpretation</td>
<td>QUAL $\rightarrow$ quan</td>
<td>Usually QUAL, can be QUAN or equal</td>
</tr>
<tr>
<td>*Sequential transformative</td>
<td>Interpretation</td>
<td>QUAL $\rightarrow$ QUAN QUAN $\rightarrow$ QUAL</td>
<td>Either dominant or both equal</td>
</tr>
<tr>
<td>Concurrent designs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Triangulation</td>
<td>Interpretation or analysis</td>
<td>QUAL + QUAN</td>
<td>Equal</td>
</tr>
<tr>
<td>*Nested/ Embedded</td>
<td>Analysis</td>
<td>qual within QUAN</td>
<td>Either dominant</td>
</tr>
</tbody>
</table>
3.2. Design approaches in this study

This study sought to integrate indigenous values, management strategies and perceptions of the local community on forest resources with current and possible institutional educational arrangements and resources that can be used for environmental education and sustainable management of the Nandi Hills Forests.

As noted earlier, the application and use of both qualitative and quantitative methods in a mixed methods study design uses the strength of both approaches (Creswell, 2009). This study therefore embraced a mixed methodological design approach whereby both qualitative and quantitative methodologies added value and diverse perspectives to this study. The mixed methodological approaches used in this study were the concurrent triangulation and nested/embedded designs. The methods were used concurrently and the mixing of qualitative and quantitative occurred during the analysis and interpretation the data. The approach was to
observe, describe and record dimensions of land use and land cover changes among households, community group and forest management institutions in the study area. The embedded design was applicable in the acquisition and interpretation of satellite data for spatiotemporal variability and change detection procedure. This allowed for correlation of quantitative data with qualitative data to explain land use and land cover changes over a time scale of 20 years. Co-relational and triangulation designs were also used to help gauge community perception about land use, forests and water resources. A four-tier analysis covering the three categories of the population in the study area (namely the households, institutions and community groups) buttressed on the remotely sensed satellite image, was carried out once all the data had been coded and grouped. Descriptive statistics related to the identified variables were calculated using Microsoft Excel and SPSS Computer Packages.

4. **SAMPLE AND SETTING**

The mixed method approach embraced in this study, in terms of the data obtained from human sources, called for a combination of both purposive and probability sampling techniques in order to collect both qualitative and quantitative data. As conferred by Teddlie and Fen (2007), the mixed method sampling techniques amalgamate, or recommend intermediary points of the probability and purposive sampling stances which can be used to best address the research question. Remler and Van Ryzin (2011) hence emphasizes the essentiality of any inquirer ensuring that the sample picked is as representative as possible in order to appropriate generalization to the entire population (Figure 6.1).
The process of sampling normally follows a procedural chronology if at all precision and accuracy is to be achieved. Table 6.3 highlights on some key steps that inform the procedure involved in sampling.

Table 6.3

*Sampling Procedures (Struwig & Stead, 2007, p.110)*

<table>
<thead>
<tr>
<th>Steps</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Definition of the population</td>
<td>The population is defined in terms of elements, units, extent and time</td>
</tr>
<tr>
<td>2. Specification of the sampling frame</td>
<td>The elements of the population are specified</td>
</tr>
<tr>
<td>3. Specification of the sampling unit</td>
<td>The sampling unit is provided e.g. district or division</td>
</tr>
<tr>
<td>4. Specification of the sampling method</td>
<td>The method used to select the sampling element is stated</td>
</tr>
<tr>
<td>5. Determination of sample size</td>
<td>The number of elements in the population that are to be sample is determined</td>
</tr>
<tr>
<td>6. Specification of a sampling plan</td>
<td>The operational procedure for selecting the</td>
</tr>
</tbody>
</table>
7. **Selection of the sample**

List the place and fieldwork necessary for the selection of the sample

---

**4.1. Population, sample frame and sampling units**

Obtaining information from a sample is used when it is not possible or sensible to attempt to obtain the same information from the entire universe or population (Struwig & Stead, 2007). The universal population of the Nandi County according to the 2009 population and housing census stands at 752,965 people (KNBS, 2010). The sample frame of the study is for persons above 18 years in Nandi County and there was heterogeneity in the population in the sample frame due to variety of issues such as: spacio-topographical exposure to the forests, urbanization, intermarriages, migration, education levels and even economic statuses. To alleviate some of these causes of heterogeneity to the closest achievable extent, the sampling units were hence delimitated based on the administrative boundaries (largely per district and finely per division). All the districts (4 districts) in the Nandi County were sampled. Within the four districts, households in eight divisions were sampled with an exception of only one division in the Nandi North District (Kipkaren), which has Kapseret Forest that has since been moved to Uasin-Gishu County (Figure 6.3). Relevant stakeholders (in the management of the Nandi Forests) other than the mainstream local community were also sampled to obtain data.

**4.2. Sampling Techniques**

There are several sampling techniques which however fall in two major categories: probability sampling and non-probability/purposive sampling (Neuman, 2000). The sample units
representing the smallest entity that provided responses in this study were the households, community groups and institutions involved in forest management. The choosing of these sampling units was predicated on the premise that forest management and utilization is directly related to the household size and need for forest resources, and the institutional capabilities and input of the relevant institutions.

4.2.1. **Stratified random sampling**

Stratified sampling was used particularly to enhance homogeneity as much as possible in the strata; in this case a division was regarded as a stratum. Random sampling was then undertaken within each stratum. Stratified sampling was used to identify the administrative divisions of the Nandi County then random sampling was applied to select the samples of respondents in the case of households and community groups. The part of the population within each division chosen for the administration of questionnaires was a product of a random process. Selection of homesteads or households did not follow any prearranged order except for the predetermination of which stratum they belong, and all of them had equal chances of being selected to be respondents. PRA sessions were also conducted in all the districts such that each district was entitled to one PRA. The invitation of the community members for PRA sessions was done through the provincial administration. This also formed an aspect of auto-randomization because not everybody who received the information about the meeting came for the PRA meetings. The attendance of the meetings was based on a personal choice. Conversely the institutions were also stratified into Government Agencies, NGOs and CBOs then sampled within each institutional category stratum.
4.2.2. Convenience sampling

This technique was particularly relevant in backing up the random sampling technique. In each stratum respondents were interviewed to a certain extent at the convenience of the field enumerators (due to distance) and availability/accessibility of the respondents themselves.

4.2.3. Quota sampling

This is a non-probability sampling technique which involves respondents being selected according to their characteristic e.g. age, income, socio-economic status and gender (Struwig & Stead, 2007). In this study, quota sampling took the shape of considering the ages of the population and picking on only those who are above 18 years of age.

4.2.4. Judgemental sampling

This technique takes cognizance expert judgement in choosing what the best sample is for a particular study. I used this technique in identifying the institutions and practitioners involved in the management of the Nandi Hills Forests and sampling them for response. This sampling technique also led to the identification of key community informants with rich information on the cultural practices, indigenous forest management strategies and on-site understanding of land use and land cover change in the study area.
4.3. Sample size determination

The number of households sampled were calculated as the number \( n \) required to estimate population proportions \( \pi \) with 95\% confidence intervals around observed sample proportions \( P \) with an interval no larger than \( P \pm 0.103 \) (Wonnacott & Wonnacott, 1977)

\[
n = \frac{1.96^2 \pi(1-\pi)}{c^2}
\]

\[
n = \frac{1.96^2 \cdot 0.5(1-0.5)}{0.0033^2} = 882
\]

Where 1.96 was the \( z \)-value for a 2-sided 95\% confidence interval, \( c=0.0330 \) is the desired maximal half-width of the confidence interval, and \( \pi=0.5 \) is the population proportion that results in the widest confidence interval for a given sample size (worst-case for a conservative estimate of sample size). Hence 882 households were initially sampled during the administration of the qualitative emphatic questionnaires.

Figure 6.2

*Household sample distribution for qualitative data in Nandi County*
A follow up sampling was undertaken later on with a smaller sample size with some aspects of the qualitative emphatic questionnaires being précised in the quantitative questionnaires. The sample size was consequently obtained using the formula by Fisher et al (1998).

\[
N = \frac{z^2pqD}{d^2}
\]

Where:

- \( N \) = Desired sample size (when population is > 10 000)
- \( z \) = The standard normal derivate set at 1.96 which corresponds to the 95% confidence limit (one tailed).
- \( p \) = Expected Proportion in the target population estimated to have a particular characteristic (0.5 is used where there is no estimate)
- \( q \) = 1 - \( p \) or (1 - 0.5) hence 1.0 - 0.5 = 0.5
- \( d \) = the degree of accuracy usually 0.05
- \( D \) = is equal to 1 where there are no comparisons or replications (design effect)

Thus:

1. When there is no estimate: \( N = \frac{(1.96)^2 (0.5)(0.5)}{0.05^2} = 384 \)

2. When you require a proportion of 25% (the proportion of the population with the desired characteristics)

Where:

\[
N = \frac{1.96^2 \times 0.25(0.75)}{0.0025} = 291.5774
\]

Thus the final sample size; \( N_{\text{final}} \) (to cater for non-responses and abandoned interviews):

\[
N_{\text{final}} = N + 5 \% (N)
\]

=308 households

For purposes of effective distribution of the sample, a total sample size of 306 was used, hence:

\( N_f = 306 \)
The household sample distribution with regard to the administrative attributes of Nandi County is illustrated in Figure 6.2.

![Figure 6.2: Household sample distribution for quantitative data in Nandi County](image)

**4.4. Nature and sources of data**

The study sought to integrate the available and possible resources available for describing what could contribute to effective community environmental education in the Nandi Hills and Nandi forest areas. To attain this goal, two broad sources of data were considered; primary and secondary sources.

Primary data was collected afresh and for the first time and thus were original in character. This data was obtained from direct field observation, focused group discussions,
The primary data was obtained using structured questionnaires (households and institutional), interview schedules for guided Focus Group Discussions (FGDs) and key informant interviews. Ground truthing and direct field observations coupled with real-time photography were also embraced by use of mechanical devices such as GPS and digital cameras.

Secondary data consisted of published and unpublished information about the study area, the subject and the greater Nandi County in general. They included; satellite images, published books, journals, study area-specific reports, strategy papers and development plans, abstracts, and other government documents and related reviews of the above sources.

5. DATA COLLECTION AND DATA COLLECTION INSTRUMENTS

This subsection discusses the instruments used to gather field data and how they were used. A combination several data collection instruments were embraced to gather the information in this study. They included Rapid Rural Appraisal, non-participant observation, questionnaire administration, photography, oral interviews and the use of schedules and checklists. The analysis of forest inventory maps, satellite data (using GIS and Remote Sensing) and the review of already documented information also formed part of this process.

5.1. Rapid rural appraisal

Participatory approaches of data collection were used under the banner of Rapid Rural Appraisal (RRA). Stinson (1979) observes that RRA is done over a relatively shorter period of time (a few days to a few weeks). RRA are semi-structured, multi-disciplinary, and provide room
for flexibility and innovation. Data collection emphasised learning directly from the local inhabitants.

This methodology was used to collect information from stakeholders as to what was the best strategy for participatory forest management. The questions asked in these sessions were open ended to stimulate an argumentative process during the sessions. Webb (2008a) confers that questioning that elicits an argumentative process is critical in order to spur the respondents into justifying their claims, a vital component of deriving meaning from one’s submissions. A series of RRA sessions were undertaken in every sub-location within the Nandi Hills area sampled for by the study for data gathering. The sessions culminated into an all-inclusive stakeholders meeting in the two District Headquarters, Nandi South and Nandi North Districts. The discussions were moderated by the researcher assisted by personnel from the KFS and local Provincial Administration. The views that were generated informed the findings of the study.

5.2. Non-participant observation

This method was used to obtain information on the level of degradation of forest resources, the manifestation of impacts of the current forest utilization practices and the community’s relationship with forest resources. An observation schedule was used for this purpose. This was because observations were anticipated to increase the relevance and reliability of the data gathered during field work (Piel, 1982)

5.3. Oral interview schedule

Oral interview schedules were used to obtain information from the line ministries’ officers and the civil society personnel with interests in forest management in the Nandi Hills
area. Kerlinger (1973) observed that interviews are advantageous because of face to face interpersonal interaction and this formed the basis for this choice. A great deal of information can be obtained through schedules within a short time, adding credence to this choice.

5.4. **Questionnaires**

As noted earlier, the utilization of the forest and its products is driven by the household size and needs. Every community member targeted for environmental education was a member of a household. Two types of household questionnaires were administered namely; qualitative and quantitative data questionnaires. The sample size was 882 for the qualitative household questionnaires, 306 for the quantitative household questionnaires. With the help of the Provincial Administration and opinion leaders within the community, the principal access roads in the villages were identified and used as transects. Simple random sampling was used along the transect line for homesteads and households for interviewing. The heads of the families were interviewed because they are the major decision makers within the households. In the event that the household head was not found, the second available authority within the household was interviewed. The researcher and the research assistants then administered the instruments.

5.5. **Mechanical devices**

Digital cameras were used to capture real-time data on land use, the extent of visible degradation and the other relevant data related to this study.

5.6. **Remote sensing and GIS**

Remote Sensing and GIS data were generated by obtaining Landsat images from the Regional Centre for Mapping of Resources for Development in Nairobi. The acquired maps and satellite imagery were analysed using Erdas Version 8.6 and ArcGIS Version 9.1 software
platform for spatio-temporal variability. This was done to provide the baseline for interpretation and subsequent on-site verification survey. Ground truthing was done by means of field visits, an observation checklist and photographic evidence. After on-site verification, the land use/land cover classes established were geo-referenced and digitized for geospatial analysis. The observation from satellite images enhanced assessment of the extent of spatiotemporal variations in land use and land cover over the period considered.

Satellite images, Landsat TM series of 1990s and ETM of 2000s imagery of the study area were evaluated for land cover change. The remote sensing (satellite) data applied in assessing the land cover changes covered the years of 1994, 1999, 2003 and 2009. Image interpretation was made based on land cover types, supervised land cover classification and the Normalised Difference Vegetation Index (NDVI) computed for images captured at different dates. Standard procedures were followed during image interpretation based on land cover types and visual interpretation of the tonal, textual and structural characteristics renders on images that helped in delineation of land cover classes digitized for various image dates. The various land use and their associated changes were mapped based on the pixel size of the satellite data types. The interpreted data informed on landscape qualities, land cover changes and land use patterns over the study area. The framework that guided the change detection is illustrated in figure 6.3.
Review of documented information also formed part of data gathering methods. The documents reviewed included the National and District Development Plans, Statistical Abstracts, forest inventory maps, remote sensing data, and aerial photographs of the study area for a range of 5-20 years. Others included government documents on environmental education, participatory forest management and scholarly articles on the subject area.
6. DATA ANALYSIS

According to Mouton (2001), data analysis entails the process of disassembling the data into manageable themes, patterns, trends and relationships. Patton (2002, p.108) argues that data analysis “involves reducing the amount of raw information, sifting trivia from significance, identifying significant patterns, and constructing a framework for communicating the essence of what the data reveal.” It appears from these two explanations that data analysis is about making meaning and transforming data into findings.

The data analysis process began as soon as the data had been collected. Qualitative data was transcribed, typed, read and common themes identified as described by Henn, Weinstein and Foard (2006), thus allowing coding and scoring in a master sheet. Quantitative data was on the other hand tabulated, entered into a data base, edited and encoded. This was meant to eliminate errors in the raw data and to place the data into categories to facilitate their tabulation and interpretation (Struwig & Stead, 2007). The tabulation typologies used during data analysis as described by Struwig and Stead (2007, p. 18) included; univariate tabulation – “tabulation of responses to one question at a time one” and bivariate tabulation – “tabulation of responses to two questions simultaneously”. To provide statistical summaries of the data, descriptive statistics were used. This helped in the provision of an overall, coherent and straightforward picture of the data (Struwig & Stead, 2007). Descriptive statistics use in this research were; measures of central tendency (mean or averages), measures of dispersion or variability (standard deviation and variance). Frequencies averages and percentages were calculated for reporting on the findings. Averages were used to analyse land sizes and land use while percentages used to analyse incomes from forest utilization.
The acquired satellite images were analysed and change detection differences computed in tables and the corresponding percentages calculated using MS Excel. The differences were later presented as bar graphs and tables. Statistical package for Social Sciences (SPSS) Version 16 and Microsoft Excel 2007 packages were used.

7. ETHICAL CONSIDERATIONS

The main ethical issues observed and considered in this study are as follows:

- Participants had a right to take part in the study and research or not;
- Participants were provided with adequate information on the research before the interview, and because of the level of literacy, consent obtained was mainly verbal (oral);
- Anonymity and confidentiality of the respondents was ensured by not divulging any sensitive information they gave during the study;
- Scientific accountability was observed as much as possible through proper cross-referencing and by listing all sources used at the end of this thesis; and
- Authority to conduct the research was obtained from Nelson Mandela Metropolitan University Ethics Committee and the Ministry of Education, Science and Technology, Kenya.

8. VALIDITY, RELIABILITY AND TRIANGULATION

Joppe (2000) defines validity as the measure or extent to which the research truly measures what it was intended to determine or how truthful or accurate the research findings are.
Mertens (1998) expands his reference to validity to refer to the trustworthiness or credibility, hence to the extent to which deductions can be drawn from data collection tools that are appropriate and meaningful to the specific study. Validity hence formed a pivotal consideration throughout the process formulating the research, data collection and analysis.

In order to increase the internal validity of the data the following considerations were made during the study: the use of sampling techniques which attempted to ensure the homogeneity of the selected sample through stratification (see sub-section 4.1. Population, Sample Frame and Sampling Units); and blocking of some of the possible intervening or extraneous variables, for instance the demographic characteristics, by including and measuring them. In this study attempts were made to boost external validity by using a large sample improve its representativeness, and comparing and contrasting the findings of the study with other previous and relevant studies highlighted in the literature.

Reliability refers to the accuracy and consistency of data collected in a study and the term is most connected to the methods embraced to measure research variables (Campbell, 1996). In this study, the use of a regulated interview protocol for all respondents augmented the reliability of the information gathered, while triangulation of data from diverse sources was done to shed light on a theme or perspective (Creswell, 2007). Webb (2008b) recommends the need defend one’s findings before an audience, who cross examine the findings, as a way of checking reliability. Triangulation is classically an approach used in enhancing the validity and reliability of the research findings by a particular researcher. Mathison (1988, p. 13) details this by articulating that:
“Triangulation has raised an important methodological issue in naturalistic and qualitative approaches to evaluation [in order to] control bias and establishing valid propositions because traditional scientific techniques are incompatible with this alternate epistemology.”

In this study, different research protocols were utilized at analysis and interpretation levels in order to boost both the quantitative and qualitative aspects of the data for reporting. For instance, information from households on land use practices and land use change was corroborated with quantitative information gleaned from satellite images to depict the extent of spatio-temporal variability. Likewise, trends in land use practices, community perceptions on forest utilization practices were triangulated with information on the same from FGDs and KII.

9. METHODOLOGICAL CONSTRAINTS

Creswell (2007) acknowledges that researchers engaged in studies face difficult issues in the field when gathering data. The following were some of constrains experienced in the course of the study. They included but were not limited to the following:

(a) Access to organization/individuals and groups

Convincing individuals to participate in the study, building trust and credibility at the sites and getting people to respond to the study questions during interview was one of the challenges. Organization and community groups were the hardest to deal with here since they requested for monetary facilitation so as to participate in the study.
(b)  *Topographically related limitations*

The steep slopes, rocky surfaces and lack of access roads for use by vehicles to certain interiors of the river valleys which hampered the mobility of the researchers.

(c)  *Sensitivity of the topic*

Since the topic touches on the delicate issues of land, forest and water resources, which the local community holds dear, may have elicited guarded responses local participants.

(d)  *The community’s perception towards monitoring and evaluation:*

The local communities experiences of monitoring and evaluation has not always been positive and may have also resulted in guarded responses.

All of the above are constraints could threaten the validity and reliability of the findings. However, the type and amount of data generated, and the triangulation that they enabled, suggest that the level of validity and reliability of the data falls within the bounds of ‘believability’ (Creswell, 2009).

10.  **CHAPTER SUMMARY**

This chapter discussed the research methodology and design, the nature and source of data, the population description, sampling methods, data collection techniques, data processing, statistical techniques used in data analysis and presentation. The chapter also discussed constraints to data collection during field work. The next chapter presents the data generated by the study.
CHAPTER SEVEN

RESULTS

1. INTRODUCTION

The data generated in this study are presented in terms of (i) the institutions which contribute to the management of the Nandi Hills forests (ii) land use in the Nandi Hills district as revealed by GIS, remote sensing and ground truthing (iii) interview data which provided information on issues of land ownership, land size occupied by households, as well as householders’ perceptions of forest use, their current status and their potential, and the sources of their knowledge. The mixed methodological approach embraced in this study (see sub-section 3.2 of chapter six) informed the analysis and presentation of results in this chapter. The analyzed satellite images were buttressed on the qualitative and quantitative household questionnaires, FGD and KII data.

2. INSTITUTIONS WHICH CONTRIBUTE TO THE MANAGEMENT OF THE NANDI HILLS FORESTS

A literature search was undertaken to identify institutions that attempt to contribute to the management and conservation of the Nandi Hills Forests, after which field visits were made to the institutions where focus group and key informant interviews were held. The households in the Nandi Hills and Nandi Forest areas (882 qualitative and 306 quantitative household questionnaires) were also interviewed as to their perceptions of the roles, achievements and shortcomings of the institutions involved in the management and conservation of the Nandi Hills Forests. The data indicate that only slightly over two thirds (67%) of the respondents were able
to identify one or more institutions that are involved in the management and conservation of the Nandi Hills Forests, while 33% of those sampled had no idea of the existence of any institutions involved in the management and conservation of the forests (Figure 7.1), suggesting that more needs to be done to increase awareness of such institutions in the Nandi Hills water catchment area.

![Figure 7.1](image)

Figure 7.1

Knowledge of existing institutions that contribute to the management of the Nandi Hills water catchment area (n = 882)

Categorization of the data revealed by the literature search indicated that the institutions that make a contribution to the management of the Nandi Hills Forests fall into three major categories, viz. international organizations, government agencies, and non-governmental/community-based organizations (NGOs/CBOs), as indicated in Table 7.1. The interview data also revealed that the institutions which the interviewees believe are active in the affairs of the forests fall under the same three broad categories and include the same organizations (See Table 7.1).
Table 7.1:

*Institutions involved in the management and conservation of Nandi Forests*

<table>
<thead>
<tr>
<th>Category</th>
<th>Name of Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>International</td>
<td>United Nations Environment Programme (UNEP)</td>
</tr>
<tr>
<td></td>
<td>East Africa Wildlife Society (EAWS)</td>
</tr>
<tr>
<td></td>
<td>CDTF</td>
</tr>
<tr>
<td>Government</td>
<td>Kenya Forest Service (KFS)</td>
</tr>
<tr>
<td></td>
<td>National Environment Management Authority (NEMA)</td>
</tr>
<tr>
<td></td>
<td>Kenya Wildlife Service (KWS)</td>
</tr>
<tr>
<td></td>
<td>Nyayo Tea Zone Development Authority (NTZDA)</td>
</tr>
<tr>
<td></td>
<td>Kenya Forest Research Institute</td>
</tr>
<tr>
<td></td>
<td>Lake Victoria Environment Management Programme (LVEMP)</td>
</tr>
<tr>
<td></td>
<td>Water Resources Management Authority (WRMA)</td>
</tr>
<tr>
<td></td>
<td>Kenya Forest Research Institute (KEFRI)</td>
</tr>
<tr>
<td></td>
<td>National Museums of Kenya (NMK)</td>
</tr>
<tr>
<td></td>
<td>Moi University</td>
</tr>
<tr>
<td></td>
<td>Primary and Secondary Schools</td>
</tr>
<tr>
<td>CBO’s/NGO’s</td>
<td>Nature Kenya</td>
</tr>
<tr>
<td></td>
<td>Kamaenjei Women Group</td>
</tr>
<tr>
<td></td>
<td>Kamarich Youth Group</td>
</tr>
<tr>
<td></td>
<td>South Nandi Biodiversity Group (SONABIG)</td>
</tr>
<tr>
<td></td>
<td>Furaha Nature Group</td>
</tr>
<tr>
<td></td>
<td>Kaptuikong’ Women Group</td>
</tr>
<tr>
<td></td>
<td>Cleopas Group</td>
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<tr>
<td></td>
<td>Langas Group</td>
</tr>
<tr>
<td></td>
<td>Forest Action Network</td>
</tr>
<tr>
<td></td>
<td>Kolonge Group</td>
</tr>
<tr>
<td></td>
<td>Testai Self Help Group</td>
</tr>
<tr>
<td></td>
<td>Umoja Association Group</td>
</tr>
<tr>
<td></td>
<td>Friends of Nandi</td>
</tr>
<tr>
<td></td>
<td>Furaha Conservation Group</td>
</tr>
<tr>
<td></td>
<td>Nandi Environmental Forum (NEF)</td>
</tr>
<tr>
<td></td>
<td>Green Belt Movement (GBM)</td>
</tr>
<tr>
<td></td>
<td>Osach Women Group</td>
</tr>
<tr>
<td></td>
<td>Korosiot Tree Planting Group</td>
</tr>
</tbody>
</table>
2.1. International organizations

Members of CBOs, government agencies and to a small extent, the locals could identify the United Nations Environment Programme (UNEP), the Community Development Trust Fund (CDTF) and the East Africa Wildlife Society (EAWS), without any prompting, as the international organisations which impact on the management of the Nandi Hills Forests. The interviewees were then asked to comment on the roles of these organisations and on issues that they felt were relevant. Most of the responses noted the positive contributions that these institutions made to the management of the Nandi Hills Forests as indicated in Table 7.2.

Table 7.2

<table>
<thead>
<tr>
<th>Institution</th>
<th>Role(s)</th>
<th>Notable remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNEP</td>
<td>• Developing internationally accredited forest management practices to be replicated and/or adopted by national governments to suit their needs;</td>
<td>• Implementation is still not robust especially in Nandi Hills Forests</td>
</tr>
<tr>
<td></td>
<td>• Publishing and disseminating magazines, journals brochures on forest conservation;</td>
<td>• Challenge of access to the publications by locals</td>
</tr>
<tr>
<td></td>
<td>• Organizing seminars and conferences at their headquarters in Nairobi and inviting stakeholder to participate and learn</td>
<td>• Not all stakeholders may be in a position to attend</td>
</tr>
<tr>
<td></td>
<td>• Funding of CFM initiatives by the KFS;</td>
<td>• KFS hasn’t rolled out the programme sufficiently</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Preconditions are sometimes too restrictive for many CBO’s</td>
</tr>
<tr>
<td></td>
<td>• Funding forest conservation initiatives by CBO’s and/or NGO’s e.g. Nature Kenya &amp; NEF;</td>
<td>• Enables effectiveness of the projects &amp; sustainability in their post-exit project life</td>
</tr>
<tr>
<td></td>
<td>• Provide monitoring and evaluation mechanisms for forest conservation projects they fund</td>
<td></td>
</tr>
</tbody>
</table>
### Institution | Role(s) | Notable remark
--- | --- | ---
EAWS | - Publishing and disseminating magazines, journals brochures on forest conservation; 
- Partnering with Nature Kenya in biodiversity conservation initiatives; 
- Conducting research on species dynamics in the Nandi Hills Forests; 
- Organizing seminars and workshops to empower the local CBO’s on effective biodiversity conservation approaches; | - Challenge of access to the publications by locals; 
- Has been successful; 
- A crucial intervention in determining biodiversity index; 
- These have been lauded by the CBO’s to be significant in promoting best practices |

#### 2.2. Government of Kenya

The issues identified by the various stakeholders (local residents and members of CBOs and NGOs) as being the government’s role in the management of the Nandi Hills Forests included:

- Legislation of laws that have led to improved forest management in the Nandi Hills Catchment;
- Enforcement of policies and laws relevant to the management and conservation of Nandi Hills Catchment through the Kenya Police Service, KFS and KWS guards;
- Provision of seedlings for the afforestation and reforestation programme through KEFRI;
- Inclusion of environmental studies in the primary and secondary schools curriculum;
- Developing and offering courses on natural resources management, environment, and forestry at the tertiary colleges and universities;
- Conduction research on forest related disciplines through the various universities and KEFRI;
- Creation of forest buffer zones (Nyayo Tea Zones) through the NTZDA; and
- Profiling the cultures of the Nandi people particularly that have been significant in the sustainable management of the forests through the NMK;

The shortcomings of government in ensuring the sustainable management of the Nandi Hills Forests were identified to be the following:

- There being few forest guards hence hampering law enforcement in the forests;
- Corruption in government which has led to irregular allocation of forest land to individuals and illegal logging and poaching in the forests;
- Lack of a perimeter fence cordonning off the forest reserves in the area; and
- Ineffective implementation of the Kenya Forest Act of 2005 which laid emphasis on community participation in the forest management.

Several government agencies were noted as being involved in the management and conservation of the NHFs, as indicated in Table 7.3.

Table 7.3

*Government ministries involved in the management of the Nandi Forest catchment*

<table>
<thead>
<tr>
<th>Ministry</th>
<th>State Corporation/Parastatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Environment and Mineral Resources</td>
<td>NEMA, LVEMP</td>
</tr>
<tr>
<td>Ministry of Forestry and Wildlife</td>
<td>KFS, KWS, KEFRI</td>
</tr>
<tr>
<td>Ministry of Water and Irrigation</td>
<td>WRMA</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>NALEP</td>
</tr>
<tr>
<td>Ministry of Education</td>
<td>Primary and Secondary Schools</td>
</tr>
<tr>
<td>Ministry of Higher Education</td>
<td>Tertiary Colleges and Universities</td>
</tr>
<tr>
<td>Ministry of Culture and National Heritage</td>
<td>NMK</td>
</tr>
<tr>
<td>Ministry of Regional Development Authorities</td>
<td>NTZDA</td>
</tr>
</tbody>
</table>
2.3. Non-governmental/community-based organisations (NGOs and CBOs)

The organizations that were identified by the household respondents are presented in Table 7.4. Verification of their existence and functionality was done by obtaining the database of the CBOs and NGOs involved in the management and conservation of the Nandi Hills Forests (see Table 7.4), as was the contributions that they wished to make to the management of Nandi Hills Forests.

Table 7.4

Roles of the NGO’s and CBO’s in the management of Nandi Forest catchment area

<table>
<thead>
<tr>
<th>Organizations</th>
<th>Roles</th>
</tr>
</thead>
</table>
| NGO’s         | • Fundraising for and funding of the forest conservation initiatives;  
                • Sensitizing the locals to sustainably manage the forests through workshops, seminars and demonstration forums;  
                • Providing tree seedlings for the locals to assist them increase the forest cover;  
                • Acting as checks and balances for the government on its pledges to sustainability of the forests;  
                • Launching alternative livelihood initiatives for continuity by the CBO’s to avert over-dependence on the forests. |
| CBO’s         | • Enhancing the local population’s perception of ownership of the forests;  
                • Fundraising for the forest conservation initiatives;  
                • Sensitizing the locals to sustainably manage the forests through demonstration forums and campaigns;  
                • Organizing the community to protect sensitive water sources;  
                • Augmenting the government’s forest guards’ roles through the forest scouts initiative;  
                • Improving livelihoods of the community through sustainable alternative livelihood initiatives; |
3. **LAND USE IN THE NANDI HILLS DISTRICT OF KENYA**

A database on land use within the administrative boundaries of the Nandi District was generated via GIS and Remote Sensing (Landsat images of 1994, 1999, 2003 and 2008, thematic layers clipped from Kenya and Nandi District images that include forests and vegetation), ground truthing (observations and photographs taken in the field from 2007 to 2010), questionnaires completed by members of the sample of households, and key informant interviews.

3.1. **Remote sensing and GIS**

Remote Sensing and GIS data were generated by obtaining Landsat images from the Regional Centre for Mapping of Resources for Development in Nairobi. Broad classes of land use/land cover were established and classified images of the land cover prepared following the supervised classification criteria. These included: forest (areas under total forest cover), shrubs (areas with continuous un-interrupted interrupted shrub cover), tea (areas with total tea vegetation cover), grasslands (areas with continuous un-interrupted and interrupted grass cover) and bare ground. The preliminary images interpretation was done in reference to the five land use and/or land cover classes (created following the procedure outlined in figure 6.3). These included land use/land cover typologies from 1994, 1999, 2003 and 2008 from the respective Landsat images. The results of spatiotemporal variability in land use based on false colour composite Landsat images prepared from the clipped bands 2, 3 and 4 of the 1994, 1999, 2003 and 2008 revealed the variation in land cover and land uses within the study sites. PCA was undertaken for the acquired images for purposes of change detection for the five classes of the training area.
Areas for supervised classification were computed using Idrisi Kilimanjaro GIS analysis area computation software. This classification was carried out by prompting the software to run GIS analysis for specific areas in the training site. During the supervised classification of the satellite data for change detection, the analysis software was instructed to adhere to the earlier created land use classes. The preliminary images interpretation was done in reference to the five land use and or land cover classes (created during the initial interpretation). These included land use /land cover typologies from 1994, 1999, 2003 and 2008 from the respective Landsat images (the classes were created based on observers’ own image interpretation skills).

The resultant Landsat images for detection of changes of different land uses and land cover classes in the study area are presented below (processed Landsat satellite images of 1994, 1999, 2003 and 2008 in Figures 7.2, 7.3, 7.4 and 7.5 respectively)
Figure 7.2

Processed Landsat image of the study area (1994)
Figure 7.3

Processed and analyzed Landsat image of the study area (1999)
Figure 7.4

Processed Landsat image of the study area (2003)
Figure 7.5

*Processed Landsat image of the study area (2008)*
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The total area covered by each of the five land use/land cover types in 1994 and 2008 as mapped from the Landsat satellite images, as well as the changes that were calculated by subtracting the sum of the areas of each cover class in 2008 from their corresponding areas in 2003, 1999 and 1994, are summarized in Table 7.5 below.

Table 7.5

<table>
<thead>
<tr>
<th>Land use / Land cover Class</th>
<th>1994 Area (km$^2$)</th>
<th>1999 Area (km$^2$)</th>
<th>2003 Area (km$^2$)</th>
<th>2008 Area (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>51.3477</td>
<td>42.8328</td>
<td>63.9441</td>
<td>42.1317</td>
</tr>
<tr>
<td>Shrubs</td>
<td>26.2089</td>
<td>37.0593</td>
<td>28.8207</td>
<td>31.0905</td>
</tr>
<tr>
<td>Tea</td>
<td>15.7302</td>
<td>32.7798</td>
<td>25.3332</td>
<td>25.4745</td>
</tr>
<tr>
<td>Grassland</td>
<td>23.6512</td>
<td>23.4234</td>
<td>17.4258</td>
<td>29.9916</td>
</tr>
<tr>
<td>Bare ground</td>
<td>31.1589</td>
<td>12.0006</td>
<td>12.5721</td>
<td>19.4085</td>
</tr>
</tbody>
</table>

From the results indicated in the table above it can be seen that the spatiotemporal variation in cover types that occurred in Nandi Hills forest area between 1994 and 2008 were mainly an increase in the areas under shrubs, tea and grasslands areas. Tea cultivation increased by 97.443 km$^2$ (62%) and areas covered by forest cover decreased by 9.219 km$^2$ (18%). Bare ground also decreased by a considerable value of 11.7504 km (38%), while shrubs increased by over 18% (Figure 7.6).
Figure 7.6

The extent of spatiotemporal variation in the study area from 1994 to 2008

The forest cover in the study area is seen to have decreased (from 51.3477 km² in 1994 to 42.1317 km² in 2008) as well as gains in the forest cover (see Table 7.5 above). The area under forest also decreased between 1994 and 1999 by 8.5149 km². However, there were notable gains in forest cover (21.1113 km² between 1999 and 2003). The results of this variation are shown in Figure 7.7 below. The fluctuation in forest cover area denotes spatio-temporal variability in forest cover as a land use.
Variations were also noted on shrubs as a land cover. In 1994 for instance, land cover under shrubs was 26.21 km$^2$ while in 1999 a shrub cover of 37.06 km$^2$ was registered. This was a variation of 10.8504 km$^2$ between these years; 1994 and 1999 (see Figure 7.8).

**Shrubs cover class changes**
Tea farming as a land use registered an upward fluctuation of about 17.05 km² between 1994 and 1999. However there was a decrease in tea cover between 1999 and 2003 as shown in figure 7.10. The subsequent years (2003 and 2004) on the other hand registered a near constant tea cover as shown in Figure 7.9 below.

![Land Use Class: Tea](image)

**Figure 7.9**

*Tea cover class changes*

The area under grassland cover showed a near constant area of about 23 km² between 1994 and 1999. A decrease of about 6 km² was however registered between 1999 and 2003 while an increase of 12.56 km² between 2003 was witnessed (see Figure 7.10).
Figure 7.10

*Grassland cover class changes*

Bare ground as a land cover class registered 31.16 km$^2$ in 1994, 12.00 km$^2$ in 1999, 12.57 km$^2$ in 2003 and 19.41 km$^2$ in 2009 (see Figure 7.11 below).
3.2. Ground truthing and verification

The results presented in this section are informed by on-site inspection, analysis of the responses on the household questionnaires, information from key informant interviews, interpretation of photographs taken in the field, and the researcher’s field notes.

3.2.1. Forests

Preliminary findings from the empirical study based on satellite images shows that more than 10% of forest land has been transformed from primary forests to farm lands between 1994 and 2008 alone. Such changes usually have a serious consequence on both the native forest species of trees and animals. Household data not only supported the visual observation of satellite imagery between 1994 and 2008 which revealed that there was a reduction in the density of trees in the forests, but indicated that this trend emanated from activities undertaken by households like illegal logging, honey harvesting and firewood poaching for fuel wood. The intensification of grazing in the forests, a consequence of climate change (extreme dry weather and unpredictable rainfall), has resulted in the destruction of forest undergrowth with subsequent consequences to biodiversity and environmental aesthetics, such as leaving the forest ground bare and susceptible to soil erosion.

Even when unaccompanied by apparent changes in land cover, similar effects are observed whenever relatively undisturbed forest lands are transformed to more intensive uses, including livestock grazing and selective tree harvest. Ground truthing by on-site inspection confirmed the remote sensing data and revealed that the fragmenting of existing habitat into smaller pieces (habitat fragmentation), which exposes forest edges to external influences, had a negative impact on the core habitat of forests in the study area.
For example, vegetation removal has made the soils near the Cherabus Location, for instance, vulnerable to increased soil erosion by wind and water, especially on steep terrain. A significant loss of plant cover biomass, especially from the closed canopy forest, was documented during the field observations, as was increased intensification of agriculture. A focus group participant in Chepkong’ony Location, Nandi Hills District, put it as follows:

“In the past, we could not see any light in the forest because of the thick undergrowth and overhead canopy cover. Nowadays we could see spaces even a mile ahead. The small land animals and birds have either been hunted for food or scared away by the grazers.”

Observation and key informant interviews revealed that illegal logging, charcoal burning and encroachment for settlement and infrastructural development have been the major drivers of this forest cover change (see Figure 7.12). Data gathered during interviews revealed that wildfires occasioned by honey poachers, mostly during the dry seasons, exacerbated the problem. Not only do changed land-use practices and wildfires degrade soil fertility over time and reduce the suitability of land for future agricultural use, they also have the potential to release quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impacts including increased sedimentation and turbidity.
3.2.2. Soil

The data collected from households indicate the reduction in natural vegetation cover especially forests has reduced the protection of the soil against erosion. Vegetation has thinned out in most areas with the highly affected sites being the Nandi hills. Consequently, the respondents believe that the function of forests and natural vegetation which include protecting soil from erosion; regulating the water balance; maintaining soil fertility by providing organic materials and preventing mineralization of soil humus by excessive exposure to sunlight; and
supplying important products for human and animal nutrition (including medicines) are now impaired and in some instances completely eliminated.

In the course of the field work it was observed that there was a widespread loss of soil surface layer as a result of wind and water erosion with a number of consequences. In some instances land surface has been devegetated and the soil surface, being not permanently protected, has been eroded by wind and running water. Such soils are characterized by an incremental fertility loss (soil nutrient depletion) evidenced in decreasing land productivity over time. The soils have a reduced ability to sustain plant growth thus increasing the encroachment of desert-like conditions. Soil loss through water and wind activity have led to soil surface sealing and encrustation of topsoil reducing water intake resulting in a drier environment; indications of a spiral of edaphic aridity which continues as a self-catalytic effect.

The study site is now characterized by widespread soil degradation caused by deforestation and domestic overexploitation of vegetation. Patches cleared within the forest in anticipation of finding good soils to support agriculture have become bare ground and patches of bare ground and mono-cropping of tea in farm holdings has significantly reduced the ability of water percolation into the soil.

The intensification of agriculture as a land use with emphasis on tea production accompanied by increase in the use of agricultural chemicals, including herbicides and pesticides released to ground and surface waters in some cases have remained as contaminants in the soil. The burning of vegetation biomass to clear agricultural fields (crop residues, weeds and pests) remain a potentially potent contributor to air pollution in the locality.
Increased pressure on the land has accompanied the growing human population, which has forced residents to encroach on marginalized lands such as wetlands and steep slopes. Mudslides, rock falls and flooding of human settlements has now become the norm in many areas.

3.2.3. Water

Qualitative data from key informant reveal that clearance of forested areas has affected the hydrology in Nandi Hills and forests. The surface runoff water has become more intense, and subsurface water is not recharged. The deep regional water table may be unaffected, but the local aquifers have become almost dry. These perched water tables are no longer able to supply enough water for all the livestock on the land.

In periods of droughts or short absence of rainfall, the streams become dry because they are immediately tapped by local aquifers. Natural water courses have water only immediately after a significant rainfall. In the instances whereby streams contain some water for a slightly longer period of time, the water is normally turbid. A high turbidity level of water in the streams was manifested by the brown coloration and the visibility of suspended particulate matter in the soil (see Figure 7.13).
Figure 7.13

*Figure 7.13
A highly turbid stream due to erosion in adjacent farmlands*

4. THE NANDI DISTRICT COMMUNITY

Issues of land ownership, size of land owned by each household, land use practices, perceptions of forest use, status of the forests and their potential, and the sources of community knowledge were investigated via the questionnaire administered to the households (n=306) that were sampled in the Nandi district.

4.1. Land ownership

Most of the sample of residents (285) of Nandi County own land (93.1%) and only 21 (6.9%) own no land within the study sites (see Table 7.6). Further categorization of the size of the land owned by each household (Table 7.6) reveals that most occupy between one to five acres (46%).
Table 7.6

Land ownership by size (n=306)

<table>
<thead>
<tr>
<th>Size of Land</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>21</td>
<td>6.9%</td>
</tr>
<tr>
<td>Less than 1 acre</td>
<td>67</td>
<td>21.9%</td>
</tr>
<tr>
<td>1 – 5 acres</td>
<td>141</td>
<td>46.1%</td>
</tr>
<tr>
<td>6 – 10 acres</td>
<td>68</td>
<td>22.2%</td>
</tr>
<tr>
<td>More than 10 acres</td>
<td>9</td>
<td>2.9%</td>
</tr>
<tr>
<td>Total</td>
<td>306</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

4.2. Land use practices

The land use practices, as revealed by the questionnaires of the residents as outlined in Figure 7.14 indicate that maize farming is the most common land use practice at 48.4%. Biodiversity loss was one of the most evident impacts of land use change within the Nandi Hills forest ecosystems.

![Land use Practices in Nandi County](image)

Figure 7.14

Land use practices in Nandi County
4.3. **Perceptions of forest use**

In part three of the household questionnaires the respondents were asked to indicate if they felt that the forests were useful to them. A total of 271 respondents, representing 89.4% of the valid households (n=306), indicated that forest were indeed useful to them by indicating a ‘Yes’ response on the questionnaire. Thirty two respondents (approximately 10% of households interviewed) said that forest were not useful (see Table 7.9).

Those who had responded that forests were useful to them, when prompted further to list how the forest were useful to them, provided a variety of responses. These included:

- Provide dry season pasture for livestock;
- Increase the aesthetic value of the environment;
- Are water catchments that attract rainfall and store water for rivers;
- Are a source of timber and firewood for domestic and industrial uses;
- Act as purifiers of water and air thus ensuring ecosystems balance;
- Are habitats for an array of biodiversity including plants, birds, reptiles and other wild animals;
- Are tourists’ attraction sites that benefit the government and the local communities through revenues generation

The respondents who indicated forests were not useful to them believed that they are:

- Hideouts for thieves;
- Havens for wild and dangerous animals;
- Only important to the government; and
Chapter Seven: Results

- Are barriers to extension of farmlands - if one destroys them then one is arrested by the government

4.4. Perceptions of the current status of the Nandi Hills Forests and their potential

Results of focus group discussions, key informant and household interviews revealed that a significantly large proportion of the respondents perceived the forest cover in these areas as rapidly declining. The primary drivers of this trend were noted as intensification of agriculture and the need of more land for food production to feed the teeming populations. The majority of households sampled indicated that the forest cover of Nandi Hills Forest has suffered severe deforestation and degradation through heavy exploitation resulting from an escalating demand for timber and fuel wood, land for cropping and grazing. They further purported that the depletion and degradation of the Nandi hills forest are a threat to ecosystem diversity and a fundamental influence on the declining standard of living of many households. The decline in forest resources – and a subsequent decline in land productivity and lack of forage and fodder as well as other tree products and services – was perceived by the farming communities in almost all the locations in the study site.

The forest community indicated that, tea farming, maize production, horticulture farming and livestock rearing are the major agricultural activities in these districts. Consequently, more forest land has been cleared or interfered with to support these activities with a serious loss to biodiversity and ecosystem services provisioning. The community reported that planting of trees for water conservation would prevent the drying up of streams that supply domestic water. A tree called Sesigium in the local language was perceived specifically to help in water purification.
Further it was widely suggested that this tree species be planted along the riparian areas and in wetlands for water conservation.

Culturally forests were perceived to have a religio-cultural significance. Among the Kalenjin groups forest trees and products that were used during circumcision and marriage ceremonies. The forest also acted as a home for initiates during the rites of passage of male members of the community up to the time they fully recovered to rejoin the community.

In terms of livelihood support for the households, forests were perceived to provide dry season grazing relief, honey, wild berries and fruits, wild edible roots and undergrowths that supplemented peoples’ diets. It was also noted that the local Kalenjin Community borrowed a lot of forest conservation practices form the Ogiek, the aboriginal community of Nandi Hills area. A section of the households also reported that the forest modified the climate by attracting rain and creating a micro-climate that favoured the production of tea and other agricultural crops. This was very significant in defining household socioeconomic power.

The study also shows that farmers are very interested in tree planting and are in favour of private ownership of trees and forests (farm and/or plantation forestry). Tree planting and forestry at the household level was seen to have the capacity to supplement household incomes. This could be achieved through planting of fruit trees, fodder trees and beekeeping for small scale commercial purposes. Protection of natural regeneration is also recognized as an important complement to tree planting in the rehabilitation of degraded forest landscapes.

4.5. Sources of community knowledge

The household interviews conducted in the eight divisions revealed that virtually all the respondents were aware of the existence of forests and forest resources around them (98%). Only
2% of the sampled population had no knowledge on the existence of any forest around them (see Figure 7.15). The respondents further reflected that a greater fraction of the community had learnt of the significance of forests around them through informal means; 85% believed that their knowledge on the significance of the forests came from informal sources, 13% said that they had learnt of the forests’ significance formally while 2% said that their knowledge sources had been both formal and informal.

![Comparison of Sources of Information on Significance of Forests](image)

Figure 7.15

*Comparison of the participants’ beliefs of their source of information on the significance of forests (n = 882)*

4.5.1. **Informal sources of knowledge**

The informal sources of information included both theoretical and practical knowledge acquisition mechanisms. The theoretical sources included:

- Propagation of the knowledge by storytelling and folklore by the elderly;
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- Peer information propagation: peers spreading the knowledge during interactions; and

- Presentation of songs.

The practical sources included:

- Proximity knowledge acquisition, which entails learning of the forest existence by virtue of being a forest adjacent resident;

- Default knowledge acquisition on ancestral surrounding by virtue of being born there; and

- Resource destination phenomena: when one accesses the forest as a source for firewood, pasture, medicine, honey and other raw materials.

4.5.2. Formal sources of knowledge

Despite the prolific effect the indigenous knowledge system has had on the local community, there still remain a fraction that obtained knowledge on the forest(s) through formal means. The formal source of the knowledge included:

- Lessons in class;

- Academic visits to the forests as a fulfillment of coursework in school;

- Awareness creation by government agencies such as the KFS, KWS, NTZDA and NEMA;

- Attending seminars and workshops organized by the local CBO’s; and

- Print and electronic media.
4.5.3. Integration of formal knowledge and informal knowledge sources

The data sources of knowledge on forest management and conservation that were gathered through household interviews were placed in categories. After categorization, key informant interviews (KII) were conducted with 18 key informants where they were asked to identify scenarios of integration of formal and informal sources of knowledge that they had experienced. Their responses are presented in Table 7.8.

Inspection of the table suggests that opportunities exist for storytelling, peer information propagation, proximity knowledge acquisition, and default knowledge acquisition in school classrooms. Proximity knowledge acquisition has also taken place during formal seminars and during awareness creation by government. Resource destination learning has taken place during awareness creation by government, while the print and electronic media have only contributed to knowledge acquisition related to resource destination phenomena.
Table 7.7

Scenarios of existing integration of formal and informal knowledge sources on forest significance amongst a sample of key informants

\((n=18)\)

<table>
<thead>
<tr>
<th>Informal sources of knowledge</th>
<th>Storytelling and folklore</th>
<th>Peer information propagation</th>
<th>Presentation of songs</th>
<th>Proximity knowledge acquisition</th>
<th>Default knowledge acquisition</th>
<th>Resource destination phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal sources of knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lessons in class</td>
<td>x</td>
<td>x</td>
<td>0</td>
<td>xxxxx</td>
<td>xxx</td>
<td>0</td>
</tr>
<tr>
<td>Academic visits to the forests</td>
<td>x</td>
<td>0</td>
<td>x</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Attending seminars and workshops</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>xx</td>
<td>0</td>
<td>0</td>
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<td>Awareness creation by government</td>
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<td>Print and electronic media.</td>
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\(x\) – Represents one respondent

\(0\) – Indicates no respondent
5. **CHAPTER SUMMARY**

In this chapter the institutions that impact on the management of the Nandi Hills Forests are documented and their roles in the eyes of local stakeholders are interrogated. The extent of spatiotemporal variability in land use in the forest and its catchment is investigated using GIS, Remote Sensing and ground truthing data. Finally, the local community’s (householders) perceptions of the utilization practices in the forest resources of Nandi Hills and Nandi Forests, their current status and their potential, as well as the formal and informal sources of their knowledge, are considered.
CHAPTER EIGHT

DISCUSSION

1. INTRODUCTION

This chapter discusses the findings of the study in terms of current environmental education and institutional arrangements and policy frameworks in and around the Nandi forests and considers the extent of spatiotemporal variation in land use in the Nandi district, the impact of these changes, and the use of such information in terms of promoting local community environmental education. Community perceptions on utilization of forest resources and their implications are also considered. The research sub-questions in this study guide the discussion. An integrated community environmental education heuristic for sustainable forest management is also presented.

2. ENVIRONMENTAL EDUCATION AND CONSERVATION IN AND AROUND THE NANDI FORESTS

This sub-section interrogates the findings in chapter seven in terms of the formal and informal contributors to environmental education in the Nandi Hills area in an attempt to answer the first research sub-question that is required to be answered when attempting to answer the main research question in this study, viz.:

What are the formal and informal environmental education and management practices that exist that could be meaningfully integrated into the heuristic?
Chapter Eight: Discussion

2.1. Formal education and management practices

The sustainable management of forests, such as those in the Nandi Hills, depends on environmental education, and the institutionalization of environmental education has acted as an interface for the informal environmental education and formal environmental education (Mula & Tilbury, 2011). The results generated from this study reveal that there are a range of institutions and institutional arrangements which aim at influencing the management of the Nandi Forests. These institutions, which mainly include NGOs, local CBOs and the Government of Kenya, play a variety of specific and/or general roles in the day to day management of forests in Nandi County and have had an impact in the area.

In as much as the findings of this study reveals that most of the residents of the Nandi County (67%) are aware of existing relevant institutions in the management of the Nandi Forests, the remaining 33% represent a significant number of people who need to be reached if institutional frameworks geared towards strengthening the knowledge base of forestry in Africa (without which major advancements are prone to bypass the African forest sector) are to benefit the majority of local inhabitants (Matiru, 1999).

While there are a number of forestry-relevant international organisations, government agencies and NGOs which are active in the Nandi County, it is important to note the significant number of CBO’s undertaking various projects in the water catchment area. The existence of these CBOs is an indicator of the involvement of the local community in the management of the forests. Such involvement of the forest adjacent communities in the management and conservation of the forests are an important factor if sustainable management is to be achieved as the literature previously reviewed in this study suggest that the influence of such organisations provide access to conferences, insight into development plans and, in turn, a broad but
sometimes grudging acceptance by the development community of the value of local/indigenous knowledge as part of a shift in addressing the direct concerns of the poor (Warren, 1991, 1992; World Bank, 2000; Shepherd, 2001; Hubbard, 2001).

2.1.1. International organisations

International organizations have been active mainly as partners on issues of sustainable forest management and biodiversity conservation. Apart from playing a funding role, they have played a logistical role or have initiated projects whose implementation rested on the government, CBO’s and/or (see Table 7.3 and 7.4). While emphasizing globally acceptable practices, they have encouraged the localization of these practices to promote relevance and effectiveness.

2.1.2. Government of Kenya

The Government of Kenya is the major institutional player in the management of the Nandi Hills Forests and other forests within the country. The FAO (2006) confirms that government forestry institutions remain the single-most dominant player in the sector and that more than 80% of global forests are under public jurisdiction. The government plays a significant role in protecting its natural resources and protecting its citizens from adverse natural and technological mishaps (World Bank, 2002). In 2008, following a contested presidential election, a coalition government was formed and since then the number of ministries were increased to forty. These ministries have been active in one way or the other in the affairs of the Nandi Hills water catchment zone, and the fact that they were identified by members of local communities (Table 7.5) suggests that they believe that the government has a pivotal role in ensuring the forests are well managed.
2.1.3. **NGOs and CBOs**

A number of NGOs and CBOs are recognised as being actively involved in the Nandi Hills, either working in partnership with communities, or fully constituted by members of the local community. These organizations have increased in number, especially after the passing of the Kenya Forest Act of 2005, which recognized the importance of stakeholders’ involvement in decision-making on matters affecting forests (Government of Kenya, 2005). As outlined in chapter seven, these organizations engage in various activities geared towards the management of the forests and facilitating alternative livelihoods for the Nandi Hills Forest communities. The demand for transparency and good governance by civil society has brought about fundamental changes in Africa (FAO, 2008), and the acceptability of the NGOs and CBOs by the local community has been a plus to the sustainable management of the Nandi Forests. Interview data suggest that there has been a greater degree of collaboration between the NGOs/CBOs and government, including the international organizations, in the recent past.

Environmental education via NGOs and CBOs appears to have enhanced the awareness of the local community on the existence and value of forests in their neighbourhood. Three hundred out of the 306 respondents (98%) interviewed asserted that they are aware of the existence of forests and their resources - a very high level of awareness. They recognize that forests act as water catchment areas, that they are a source of tourist attraction, that they provide fodder for livestock, that they are sources of medicine, and that they are also important religious and cultural sites. These findings, coupled with the fact that environmental education has been elucidated as a driver of awareness, conservation practices, and alternative livelihood systems that have a positive impact on the forests and the community, suggest that environmental
education, if effectively used, could be a key tool in enhancing the sustainable management of Nandi Hills Forests.

2.2. **Informal environmental education**

The high number of respondents who stated that their source of information on forest significance was informal underscores the importance of the preservation and propagation of the local knowledge of the Nandi Hills Forests Communities. This notion is supported by Bicker et al. (2004) who argue that although informal knowledge was inaugurated in communities long before the initiation of formal forest science aspects of it form the basis of several modern forestry practices. Local knowledge among the Nandi Forest Communities is as old as the existence of the *Ogiek* in Nandi Forests and its hinterland (Ng’ang’a, 2005). The *Ogiek* were wholly depended on the forests for their source of livelihood as they were hunters and gatherers and, as such, developed an intrinsic conservation perspective, which was prevalent within all Nandi Forest communities.

Local communities have been reservoirs of vital knowledge that relates to the conservation and sustainable utilization of the forests and the forest resources (Ng’ang’a, 2005), and the various informal knowledge transmission mechanisms (storytelling, folklore, peer relay and proximity knowledge acquisition) noted in this study support this contention. Significance of the local community as local knowledge reservoirs is further adduced by the findings of the study that point out that the sources of information held by local people on forests and their related resources was majorly informal (85%). This understanding is corroborated by Langton and Ma Rhea (2003) who submit that the nature of informal knowledge places custody of the knowledge in humans. The informal education system generates customs, traditions, and norms
handed down to generations both verbally and practically. In the case of the Nandi Hills these practices included, and in some cases still include:

- Circumcision ceremonies which were performed deep inside the forest at specially designated sites which are respected and exclusively preserved. This practice is evidenced by the richness of biodiversity in these circumcision sites within the Nandi Forests;

- Herding of livestock was prohibited in the forest except during dry spells when the locals were allowed to graze selectively at the forest peripheries albeit to a limited extent;

- Hunting and gathering practices, as exemplified by the Ogiek (arguably the aboriginal community of the Nandi Hills Forests and the larger Mau Forest Complex), have survived in these forests. Besides the forests being a source of livelihood for the Ogiek they have had a nostalgic attachment to the forests. The concerns of the Ogiek in preserving and maintaining their traditional knowledge was not only motivated by the desire to conserve 'biodiversity' as an end in itself, but also by the desire to live on their ancestral lands, to preserve their traditional livelihoods, and to safeguard local food security (Langton, 2003). The Ogiek have therefore played an important role as conservationists of the Rift Valley forests, of which the Nandi Hills Forests are a part.

- Members of local communities have continued to undertake traditional marriages, which form significant rites of passage for the young people. These ceremonies, according to Langley (1979), are usually a culmination of several trainings that have been carried out for the bride and groom, which include emphasis on the importance of the forests and their resources;
• The proclamation of superstitious curses and blessings was a preserve of the ‘Orkoiyot’ (the religious head of the Nandi tribe) and were proclaimed as consequences of behaviour or actions. A case in point would be the destruction of the meeting place for the elders, which was normally deep in the forest under a fig tree, hence enhancing the conservation of the forests (explain this – how does it enhance conservation), and;

• The Orkoiyot had the exclusive responsibility of prescribing and in some case administering medicine to the Nandi community. This organized social structure did not allow anyone to harvest or administer the forest resources except by the sanctioning of the Orkoiik.

It appears therefore that the local knowledge system of the Nandi Community emphasized the sustainable utilization of the forest and the forest products. Local community members had acquired sufficient knowledge of plant and animal species and their management and use to enable them to cope with changing abundances of preferred species used for food, medicine, cultural activities (circumcision & rites of passage), and other purposes. However, certain fundamental practices are slowly fading away due to rapid population growth, high urbanization rate and cross-cultural dilution effects (Langley, 1979).

The rapid population growth, standing at 2.9% (Government of Kenya, 2005), has forced the local community to encroach fragile ecosystems such as hill-slopes and to some extent the forest ecosystem including wetlands. Coupled with rapid urbanization, the immigration of foreign communities into the area has diluted the cultural stimulus of the native community, which has provided the driving factor for the effective management of the Nandi Hills Forests.
Nevertheless, formal environmental approaches have attempted to re-energize effective management and these efforts will hopefully bear fruit in the future.

2.3. **Integration of formal knowledge and indigenous knowledge systems**

It appears that formal environmental education has provided a platform for the Nandi Hills Forest communities to interact, not only with their traditional forest conservation practices, but also to appreciate modern day approaches. Matiru (1999) points out that a number of NGOs, CBOs and voluntary organizations are making reliably helpful progress in enlightening the ordinary citizens on laws and their rights in Kenya, and that the escalation of environmental lobby groups has translated into greater awareness by the ordinary citizens on environmental issues that affect them and the community at large. The resolutions of the United Nations Conference on Environment and Development (1992) to advocate for sustainable development through environmental education remains a pivotal issue, internationally, nationally, and in the Nandi Hills Forests. It is this premise that predicates formal environmental education as a crucial tool for effective forest management and conservation and, encouragingly, both the formal and informal systems of environmental education appear to have been embraced at several levels in the Nandi Hills, as evidenced in this study.

The dimensions embraced by the various players in the practice and propagation of formal environmental education may vary in terms of curricula and approach but still remain relevant in content. Depending on the target group, the depth of information investigated in this study varied, such that the higher levels of education and research embraced more technical issues while the lower levels and community-direct levels had simpler content which was often simplified by using local examples in drawing case studies and illustrations. However, findings
of this study suggest that in as much as there is a large portion of the forest communities that is aware of the existence of the forests, information on the reality of their progressive destruction or conservation still remains a vital aspect that requires attention.

Richards (1995) warns that indigenous systems of knowledge and practices are threatened worldwide by socioeconomic and historical pressures. Borrini and Buchan (1997) submit that indigenous knowledge is of increasing interest to forest science as it is ever more acknowledged that indigenous resource management systems can help to improve the framework for sustainable forest management. They also note that limitations of local knowledge by knowledge mortality and lack of codification, which can lead to inter-generational loss of information, can be averted by documentation. These caveats suggests that the integration of formal and informal knowledge systems, which is being undertaken in some instances by the government, NGOs and CBOs, is a crucial aspect that ought to be cemented further in any attempts to design environmental education interventions in the Nandi Hills Forests.

As such, it appears that there is a great potential for sustainable forest management by integrating formal and informal education approaches in order to enhance sustainable management of the Nandi Forests. More than half of the respondents who indicated that they obtained information on the forests and forest resources from both formal and informal sources indicated that they had got their information from lessons learnt in class. Just less than half indicated that they had acquired information on the forests through proximity knowledge acquisition (see Table 7.7). The proximity knowledge acquisition is owed to the fact that most of those living within the Nandi Forests have stayed there for a significantly long time. In turn, the ‘lessons learnt in class’ category of formal knowledge source is owed to the fact that most of the respondents had attained at least some formal education (86.9%). Therefore, integrating both
formal and informal environmental education should provide synergistic opportunities for better management and conservation of the Nandi Hills Forests by local communities.

As noted earlier, two thirds of the forest communities is aware of the existence of the forests and have proximal knowledge of changes to the forest ecosystem, information on the reality of their progressive destruction or conservation still remains a vital aspect that requires attention. It is for this reason that an extensive GIS database was generated in this study and maps were drawn to illustrate spatiotemporal variations in land use in the water catchments regions of Lake Victoria in the Nandi District of western Kenya.

3. **EXTENT OF SPATIOTEMPORAL VARIATION IN LAND USE IN THE NANDI DISTRICT AND THE IMPACT OF THE CHANGES**

This section discusses the findings on spatial temporal variations in land use in the forest and the forest catchment areas of the Nandi district as evidenced by Geographic Information Systems (GIS) and Remote Sensing (RS) observations, photography, and a ground truthing survey, in an attempt to answer the second research sub-question of this study, which is

*What is the extent of spatiotemporal variability in land use in the forest and its catchment?*

3.1. **Spatiotemporal variation**

As noted in chapter seven, a comprehensive GIS database for the Nandi District has been generated in this study. This database comprises of the following GIS layers:

• Thematic layers clipped from the Kenya and Nandi District map that include forests and vegetation.

• Administrative boundary of the Nandi District

• Field photographs

The extent of spatiotemporal variation in land use empirically obtained through triangulation of Remote Sensing (RS), Geographic Information Systems (GIS) data generated from Landsat maps change computations, observation and ground truth survey of the study area, revealed a number of spatiotemporal variations in land use and land cover over the period considered. False colour composite Landsat images prepared from the mosaiced and clipped bands 2, 3 and 4 of the 1994, 1999, 2003 and 2008 provided the resultant Landsat images for detection of changes of different land uses and land cover classes in the study area as presented in the previous chapter (refer to figures 7.2, 7.3, 7.4 and 7.5).

To further understand the extent of spatiotemporal variation in land use, an unsupervised classification of RS data was undertaken. The results indicated the variation that occurred in land cover types such as shrubs, tea and grasslands were positive while there was a reduction in forest cover and bare ground cover, which suggests that there might be serious implications for forests in the Nandi district. On aggregate land areas under shrubs, tea and grasslands areas increased between 1994 and 2008. The nature of the changes in land uses/cover types seem to be in consonance with as the case in other parts of the globe (Geist & Lambin, 2001; Wade et al., 2003), but the data indicates that the spatiotemporal variations are a consequence loss of forest cover and conversion of bare ground to agriculture, and human settlement influx in areas not suitable for agriculture.
One cover type, tea increased by 61.95\% between 1994 and 2008. The greatest registered upward fluctuation of about 17.05 km$^2$ was noted between 1994 and 1999. However there was a decrease in tea cover between 1999 and 2003. The change in tea cover levels are believed to have come from the prevailing fall in tea prices in the global market as at that time. Shrubs increased by 18.62\% between 1994 and 2008. In 1994 for instance, land cover under shrubs was 21.21 km$^2$ while in 1999 a shrub cover of 37.06 km$^2$ was registered. This was a variation of 10.8504 Km$^2$ between these years. Increases in shrubs as a land cover suggests either a continuous loss of forest cover or encroachment of aridity from loss of forests. The area under grassland cover showed a near constant area of about 23 km$^2$ between 1994 and 1999. A decrease of about 6 km$^2$ was however registered between 1999 and 2003 while an increase of 12.56 km$^2$ between 2003 and 2008 just like shrubs basically exhibiting similar trends.

Results from the GIS data indicated a decrease in forest cover of 9.219 km$^2$ (17.95\%). This is an implication of changing land use practices from forests to human settlements and agriculture as emergent land uses/land practices. The fluctuations in forest cover area denote spatiotemporal variability in forest cover as a land use and the data, based on the predetermined classes, clearly showed variations in land use and land cover over time and that the forest cover in Nandi Forests is under considerable threat.

3.2. Impacts of land use change

The data under discussion are informed by the analysis of the coded entries from the household questionnaires, observation notes, information from key informant interviews, photographic interpretation and GIS and RS data, as well as selected literature on the topic. It is broadly recognized that land cover transformation has the potential to cause soil erosion, biodiversity losses, amplified surface run off and flooding, climate change effects, and an
increase in carbon dioxide concentration in the atmosphere (Lambin et al., 2003). Another school of thought suggests that land cover variation contributes to land degradation in all its forms including earth-atmosphere exchanges and loss in biodiversity with potential to demean sustainable development (Turner et al., 2004). Changes in land use are related to land ownership (or not) and the resultant land use practices, which have an effect on biodiversity, forest cover, soil resources, and hydrology are factors which contribute to the impact they have on the environment. Each of the above are discussed below.

3.2.1. Land ownership

The study data reveals that most of the residents of Nandi County own land (93.1%) and only about 6.9% own no land within the study site. Out of those who own land, a significant proportion (68%), own land less than five acres in extent and, as a result, one of the major impacts of land use change is land fragmentation. An increasing population has exerted pressure on the limited land resources, thus accelerating land fragmentation in the Nandi district, and settlements were observed on marginal lands such as slopes and hillsides (Figure 7.12).

3.2.2. Land use practices

Agriculture’s contributions to GDP vary across countries, but assessments suggest an average contribution of 21% internationally, ranging from 10% to 70% (Mendelsohn et al., 2000). In Africa, the agricultural sector is a critical mainstay of local livelihoods and national GDP in most countries. According to Kenya London News (2011), Kenya’s agriculture sector contributes 25% of GDP and at least 50% of exports, including tea and horticulture. In order to maintain this level of GDP, Vision 2030 envisages that Kenya will raise income from agriculture by processing and thereby adding value to her products before they reach the market. Kenya’s
vision is to do so in a manner that enables her producers to compete with the best in other parts of the world.

Findings in this study, and other sources used in the research appear, to substantiate that agriculture in all its forms is the leading land use activity within the study site. However, of all the agricultural activities noted during the study, maize farming was the most dominant. Perhaps this is as a consequence of the fact that maize is Kenya’s staple food for most of her population. The increasing human population exerts pressure on the agricultural land available to produce more food even, if it means clearance of forest as seen in Nandi hills forests area. Cumulatively, all evidence points to agriculture being the major driver of land use change within the study site.

3.2.3. Biodiversity loss

The degree and type of land use has a direct bearing on floral and faunal resources and their habitats, and impacts biodiversity at both the local and global levels. Anthropogenic modification of landscapes from natural vegetation (e.g. wilderness) to any other use typically results in habitat loss, degradation, and fragmentation, all of which can have devastating effects on biodiversity, and land conversion is the single greatest cause of extinction of terrestrial species (Bierregaard et al., 2001).

Field observation and photographic evidence revealed cases where deforestation from logging or burning is followed by the conversion of the land to agriculture or other land uses. This is a typical case of biodiversity loss as a consequence of land use change within the study sites. Even in instances whereby some forests are left standing, the ensuing fragmentised landscape typically fails to support many species that previously existed there. The habitat suitability of forests have been impacted by the fragmenting of existing habitat into smaller
pieces (habitat fragmentation) which exposes forest edges to external influences and decreases core habitat area that subsequently negates on the ability of forests to optimally perform their functions.

Preliminary findings based on satellite images shows that more than 10% of forest land was transformed from primary forests to farm lands between 1994 and 2008 alone. This has had a serious consequence on the native forest species of tree and animals through habitat deprivation and losses. Even when unaccompanied by apparent changes in land cover, similar effects were observed whenever relatively undisturbed forest lands were transformed to more intensive uses, including livestock grazing and selective tree harvest.

Observations suggest that changes in land use and land cover, especially land clearing for agriculture and the harvest of trees and other biomass, has impacted all aspects of the environment detrimentally. The practice has made the soils in the study site vulnerable to massive increases in soil erosion by wind and water, especially on steep terrain. Wild fires occasioned by honey poachers, more so during the dry seasons, releases pollutants to the atmosphere, with a number of possible consequent human effects. The overall scenario in the Nandi Hills appears to be not only degraded soil fertility over time and reduced suitability of land for future agricultural use, but also the release of quantities of phosphorus, nitrogen, and sediments to streams and other aquatic ecosystems, causing a variety of negative impacts on the Nyando and Yala Rivers, which source their water from this catchment area and feed water to Lake Victoria (Verchot et al., 2008).
3.2.4. Forest cover

The impact of land use change on natural ecosystems is also measured by plant cover and biomass production and by the disruption of food production systems or the functioning of the natural environment. The results of this study indicated a significant loss of plant cover biomass especially from the closed canopy forest. This loss, as documented from the field observations, reveal that the intensification of agriculture, illegal logging, charcoal burning and encroachment for settlement and infrastructural development have been the major drivers of this forest cover change. However, the analysis of satellite images indicates an increase in forest cover between the 1999 and 2003, which may be partly attributed to the reduction of shrub cover in the same period. What were observed as shrubs in 1999 would have grown into trees by 2003. Another explanation could be that after the passage of the Kenya Forest Policy in 1994 several state and non-state sectors were enabled to work with communities adjacent to the Nandi Forests in terms of promoting agroforestry (Kohler, 2004).

Deforestation (the overall and effectively permanent reduction in the extent of tree cover) has emerged as one of the major impacts of land use change in the study area. Visual observation of satellite imagery of between 2003 and 2008 reveal that there was a reduction in the density of trees in the forests. Even though interventions were introduced by the government which were backed by robust legislative provisions in the Kenya Forest Act 2005 (Government of Kenya, 2005), encroachment of hillsides due to increased population pressure was a major contributer to the rapid decline of forest cover during this period (Adhola et al., 2009). Also, the lawlessness that accompanied the 2008 post-election violence resulted in the burning of a large chunk of the Nandi South Forest near Koyo in the Kaptumo Division. Household data support that the trend emanated from activities undertaken by households like illegal logging, honey harvesting and
firewood poaching for fuel wood. The intensification of grazing in the forests, a consequence of climate change (extreme dry weather and unpredictable rainfall), has resulted in the destruction of forest undergrowth with consequence for biodiversity and environmental aesthetics. This has left the forest ground bare and susceptible to soil erosion.

3.2.5. Soil resources

The data collected from households indicate the reduction in natural vegetation cover, especially forests, has reduced the protection of the soil against erosion. Vegetation has thinned out in most areas in the Nandi hills. Consequently, the function of forests and natural vegetation which include protecting soil from erosion; regulating the water balance; maintaining soil fertility by providing organic materials and preventing mineralization of soil humus by excessive exposure to sunlight; and supplying important products for human and animal nutrition (including medicines) are now impaired, and in some instances completely eliminated.

Field observations revealed that there was widespread loss of the soil surface layer as a result of wind and water erosion with a number of consequences. Land surface having been devegetated and as the soil surface is not permanently protected it is seasonally eroded by wind and running water. Such soils are characterized by an incremental fertility loss (soil nutrient depletion) evidenced in decreasing land productivity over time. The soils have a reduced ability to sustain plant growth thus increasing the encroachment of desert-like conditions. Soil loss through water and wind activity have led to soil surface sealing and encrustation of topsoil reducing water intake resulting in a drier environment; a whole spiral of edaphic aridity is thus triggered, which continues as a self-catalytic effect.
The study site is now characterized by widespread soil degradation caused by deforestation and domestic overexploitation of vegetation. Patches cleared within the forest in anticipation of finding good soils to support agriculture have become bare ground because the places had underground rocks.

The intensification of agriculture as a land use, with emphasis on tea production accompanied by increase in the use of agricultural chemicals including herbicides and pesticides released to ground and surface waters, could lead to ground and surface water pollution. The burning of vegetation biomass to clear agricultural fields (crop residues, weeds and pests) remained a potent contributor to air pollution in the locality.

3.2.6. Hydrology

Qualitative data from key informants reveal that clearance of forested areas has affected the hydrology in Nandi Hills and forests. The surface runoff water has become more intense, and subsurface water is not recharged. The deep regional water table may be unaffected, but the local aquifers have become almost dry and these perched water tables cannot supply enough water for all the livestock. In periods of droughts or short absence of rainfall, the streams become dry because they merely tap the local aquifer. Natural water courses have water only immediately after a significant rainfall. In the instances whereby streams contain some water for a slightly longer period of time, the water is normally turbid. A high turbidity level of water in the streams was manifested by the brown coloration and the visibility of suspended particulate matter in the soil (see Figure 7.13).

All of the issues discussed above have direct impact on the residents of the Nandi Hills, and their incorporation in any attempt to design an environmental education intervention in the
area would benefit from making this issues and findings explicit (and in visual form where possible).

4. **COMMUNITY PERCEPTIONS ON UTILIZATION OF FOREST RESOURCES**

This sub-section interrogates the findings of the study on the perceptions of the local community on the state of and the forest utilization practices that they are undertaking, based on the research question:

*What knowledge and perceptions do community members have in terms of the current utilization practices in the forest resources of Nandi Hills and Nandi Forests?*

The people’s perception that forests are critical to their livelihoods is vital if they are to become involved in fighting for the conservation of their habitat. Many households were able to link forests with values such as water conservation, income generation, flood control, rainfall, food and medicine, grazing lands during the dry season, tourism development and biodiversity conservation. Their awareness on these aspects corroborates the assertions of White and Martin (2002) who have postulated that if indigenous and other local communities have been increasingly acknowledged for being important stewards of forest estates, they would ensure that forest utilities and environmentally crucial resources are exploited sustainably.

4.1. **Perceptions on forests’ significance**

The findings of the study indicate that a significant portion of the local community (89.4%) believe that forests and forest resources are useful to them. These data, and the fact that the Kenya Forest Act of 2005 (Government of Kenya, 2005) empowers local communities in forest management through the Community Forest Management mechanism; suggest that there is hope for the sustainable management of the Nandi Forests.
As pointed out by the respondents, the forests are crucial since they act as water catchments, are a source of timber and firewood, are habitats for an array of floral and faunal biodiversity and are major tourist attraction sites that benefit the government and the local communities through revenues generation. The few (10.6%) who did not see the significance of these forests were not able to build a strong case. Their reservations were informed by issues such as: the forests being hideouts for thieves, havens for wild and dangerous animals and barriers to extension of farmlands.

4.2. Perception of the forest status

The submission by Enger et al. (1992) that whenever a resource is exploited, the two major interests that are always in conflict are environmental and economic has been buttressed by the strong perception by the locals that the forest cover in the area had rapidly declined and suffered severe deforestation and degradation due to human exploitation. Farmers’ responses suggested that the forest and wetlands under the jurisdiction of the government had been more severely deforested and degraded compared to community and private owned ones. This is because the forests and wetlands were perceived as government property of some sort. The perception was evidenced with great extremity during the post election violence in Kenya after the 2007 general elections, when the locals torched sections of forests to express their displeasure with the government. They also used some wetlands as burying sites for victims of the violence. The most affected areas were found around Koyo wetland and Kimondi forest in Nandi South District.

However, the keen interest and involvement of farmers in tree planting and particularly agroforestry and plantation forestry is a sign of hope in boosting the general forest cover of the area. The willingness by the local community to play a part in enhancing the natural regeneration
of the indigenous forests is based on the perception, amongst others, that further irresponsible forest exploitation would result in little or no rainfall in the area. Albeit most of them not understanding the push and pull factors of that determine precipitation in the Nandi County, their appreciation of the forests’ role in the hydrological cycle is valuable.

Data generated from the local community indicated that, tea farming, maize production, horticulture farming and livestock rearing are the major agricultural activities in these districts. Consequently, more forest land has been cleared or interfered with to support these activities, with a serious loss of biodiversity and ecosystem services provisioning. Community members stated that planting of trees for water conservation would prevent the drying up of streams that supply domestic water. A tree called *Sesigium* in the local language was perceived specifically to help in water purification. Further it was widely suggested that this tree species be planted along the riparian areas and in wetlands for water conservation. Tree planting and forestry at the household level was seen to have the capacity to supplement household incomes. This could be achieved through planting of fruit trees, fodder trees and beekeeping for small scale commercial purposes.

The data reveals that there is also strong religious and cultural significance of forests. This is pegged on the perception that the forest is more of a sacred place compared to other areas that are dominated by other land uses. For instance, the use of ‘*Sinendet*’ (*Periploca linearifolia*), a creeper, as a symbolic plant during ‘*Tuluap Ng’etik*’ (a place for circumcision ceremony) to signify successful completion of the circumcision process is an important ritual. The choice of the ‘*Sinendet*’ by the community as the plant for this purpose is based on its fast regeneration. Albeit being able to regenerate fast, ‘*Sinendet*’ is a forest interior specie that has been conserved as it is only harvested once a year during circumcision ceremonies.
As noted earlier, if indigenous and other local communities are acknowledged for being important stewards of forest estates, they would better ensure that forest utilities and environmentally crucial resources are exploited sustainably (White & Martin, 2002). Part of the acknowledgement process is acknowledgement of their knowledge, perceptions and beliefs and, as such, any community environmental education intervention would probably be enhanced by making explicit and bringing into focus via discussion the issues that have been noted above.

5. INTEGRATED COMMUNITY ENVIRONMENTAL EDUCATION HEURISTIC FOR SUSTAINABLE FOREST MANAGEMENT

In view of the findings of this study, the following heuristic is offered for consideration when developing and implementing community environmental education based on what is available in the area (institutional arrangements, policy frameworks, formal and informal education approaches), evidence that can be gleaned from the local population, and data that can be generated from technological sources (GIS, remote sensing, mapping of land use changes), as was done in this study. The proposed heuristic is illustrated in Figure 8.1.
The data generated in this study suggest that a combination of these four aspects should result in an integrated approach to community environmental education. The GIS and RS data corroborate the assertions of the local community on the land cover, and local knowledge and formal environmental education have been key drivers of awareness creation and sustainable forest management. Well documented GIS and RS data could be disseminated through both formal and informal educational practices to create environmental awareness, and the current legal and institutional frameworks provide means of advancing environmental education and sustainable practices in the area.

As highlighted in chapter three, by the conceptual framework for SWCAM (figure 3.3), sustainable management of forests is anchored on accurate acquisition and dissemination of data. This accuracy is highly dependent on application of appropriate technologies, such as GIS and remote sensing which complement local knowledge pools and institutionalized mechanism for forest management. The heuristic (figure 8.1) generated from this study portends a great potential for an integrated community environmental education approach as a viable mechanism for enhancing the sustainable management of the Nandi Forests. Raising awareness of community benefits and the impact of local practices (governmental, NGO, business and individual) on forest resources, and issues of community ownership, and challenges to sustainably manage the forests as if they were their own, enhances the probability of all
concerned coming to greater consensus on sustainable management of the local natural resources. Increased awareness of locals and wider implications, such as sustainable income generation and water provision to Lake Victoria (which has implications for both Kenyans and other African nations fed water by the Nile), also improves attitudes to forest preservation possibilities of embracing more sustainable alternative livelihoods. Once better understandings of local issues are developed, further opportunities such as the potential of the community to benefit from compensations drawn from carbon trading under the Afforestation and Reforestation Clean Development Mechanism envisaged by the Kyoto Protocol, can be better argued and understood.

6. CHAPTER SUMMARY

This chapter brings out the discussions drawn from the findings of the study. It begins by discussing on environmental education and conservation in and around the Nandi Forests, then expounds on the findings on the extent of spatiotemporal variation in land use in the Nandi County and the impact of the changes. The perception of the community on forests and forest resources is also discussed in this chapter and the chapter ends by drawing up an integrated community environmental education heuristic for sustainable forest management.
1. INTRODUCTION

Institutions play a pivotal role in enhancing sustainable resource management besides being conduits necessary for integrating various environmental management approaches for effective resource use (FAO, 2009). As pointed out by the FAO (2006), the existence and extent of specific forest types are important since they form the basis for conservation efforts that reduce deforestation, restore and rehabilitate degraded forest landscapes. Significantly, the indigenous and/or local communities that may be well equipped with information on best practices and management approaches can contribute to the sustainable management of forests.

This closing chapter reflects upon the key finding of the study highlighting on the place of institutional environmental and educational arrangements and practices which are pertinent to the sustainable management of the Nandi Hills Forests. The limitations of the study are also presented, coupled with recommendations for further research.

2. MAIN FINDINGS

The results of this study reveal that the already existing institutions in the Nandi Hills area are reservoirs of important information and are vehicles of awareness creation. While the findings of this study indicate that most of the residents of the Nandi County (67%) are aware of existing relevant institutions in the management of the Nandi Forests, the remaining 33%
represent a significant number of people who ought to be empowered with knowledge on the existence and significance of these institutions.

The passage of the Kenya Forest Act (2005) was a major milestone in enhancing the involvement of the Nandi Forests adjacent communities in the management of the forest. The anchoring of community forestry principles in law that gave way to the formation of Community Forest Associations (CFAs) has seen the progressive increment of participation of the local community in the management of the Nandi Forests, exemplified by the already several existing CBOs in the area. This in return has contributed to the increased awareness and consciousness of the local community on the need and importance of conserving the forests not just to them but for the future generations.

The majority of households sampled indicated that the forest cover of Nandi Forest has suffered severe deforestation and degradation through heavy exploitation resulting from an escalating demand for timber and fuel wood, land for cropping and grazing. They further noted that the depletion and degradation of the Nandi Forest are a threat to ecosystem diversity and a fundamental influence on the declining standard of living of many households.

The decline in indigenous forest resources and a subsequent decline in land productivity and lack of forage and fodder as well as other tree products and services were perceived as threats by the farming communities in almost all the locations in the study site. Several changes have been noted with the most significant being: increased area of tea plantations, cropping, rural residential development, and both increased and decreased dairying in different parts of the region. Changes in how cropping and dairying are undertaken, increased farm amalgamation and
changes in water availability and use, were also noted as being significant threats to sustainability.

It is also noteworthy that the uptake of on-farm forestry, exemplified by the involvement of the locals in agroforestry, has significantly improved in the last 15 years. This has also eased the pressure on the indigenous forests and enhanced the timber and fuel wood supply for the community for domestic and commercial purposes. More farmers are currently involved in agroforestry and are able to generate revenue from on-farm forestry and at the same time aid in increasing tree cover and pressure on forests. This is an indication that once a community is empowered with the necessary knowledge on what benefits them and what they stand to benefit from, they shall definitely embrace it and make it part of their societal orientation.

There has been a great degree of spatiotemporal variation (land use change) within the study site. Land-use change is arguably the most predominant socioeconomic force driving changes and degradation of the Nandi Forest ecosystem. Deforestation, agriculture, and other human activities have substantially altered the landscape of Nandi Forests. Such disturbance of the land has affected important ecosystem processes and services, the implication of which have had wide ranging consequences such as irregular rainfall regimes, increased river turbidity, increased erosion and the cessation of forest interior species.

An integrated approach to community environmental education possesses a profound potential in the quest to sustainably manage the Nandi Forests, since it incorporating variously crucial conservation and benefit-based considerations. The heuristic developed from this study, which underscores community environmental education, asserts the essentials of SFM, while
incorporating a community-driven approach that is informed by knowledge, technology and institutional frameworks.

3. LIMITATIONS OF THE STUDY

The findings of this study need to be considered with the following limitations. While random sampling would have been the desired methodology, certain circumstances in the field called for adoption of non-probability sampling criteria. For instance convenience sampling was embraced especially in areas that had rugged terrains and homesteads were scattered far and wide. The households to be interviewed were conveniently picked from those that were at least 5km from the main access roads. It should also be noted that the membership of the FGD sessions that were conducted among the local community was dominated by the elderly males. The perspectives drawn from the FGDs could have harboured some biases that might have not been representative of the females and younger men in the community. Satellite images for analysis to quantify land use change could only be obtained from the year 1994 to 2008, therefore the information obtained from the respondents that dated earlier years or after 2008 could not be verified from the satellite images. However the trend observed from the Landsat images analyzed in this study suggested an acceptable degree of validity and reliability.

4. SUGGESTIONS FOR FURTHER RESEARCH

This study has explored the various synergistic, possible relationships that exist between the local knowledge systems of the Nandi Forests Community, formal environmental education and GIS/Remote Sensing with a view of enhancing sustainable management of these forests.
However, it is imperative to point out relevant and related areas of study for further research. The study consequently recommends the following, based on its findings:

- The data suggests that more emphasis needs to be taken in order to not just increase the awareness of the local population about these institutions, but to empower them with relevant forest management and conservation initiatives and skills in order to secure the future of the forests and the forest-adjacent communities. Therefore further research needs to be undertaken to explore the possibilities of strengthening concepts of community forest management, driven by the local population.

- It is also important in future to consider how merging the myriad of CBOs into fewer CFAs which would probably have a stronger impact on the conservation of the forests. Currently there is duplicity of roles by CBOs and efficient dissemination of best practices is hampered by the uncoordinated approach and piecemeal conservation initiatives by the various groups.

- A detailed study on climate change adaptation-mitigation synergies framed within the findings of this study, which highlight the significance of community and institutional use and management of forest resources, could provide deeper understanding and significance for all concerned with the process.

- The GIS files generated in this study are flexible and can always be updated as a way of checking future state of land use and land cover in the area as well as the future trend of land use and land cover changes. Therefore further studies should be undertaken with an aim of frequently updating the LULC change and disseminating the change detection patterns to the local community.
• In recent times ICTs, especially mobile phones and computers, have been instrumental in disseminating information, capacity building local communities and even enhancing resource use efficiency. Therefore the uptake of ICTs need to be interrogated and proper action taken, especially in illuminating best practices on SFM to the local communities around the Nandi Forests.

• It is important to explore both the observable and perceived impacts of land use change; how both perceived and observable impacts differ across different types of socio economic classes and proximity to forest ecosystems and the reasons views may differ across groups on the utilization practices of forest resources. This will help in further disaggregating the awareness creation mechanisms relevant to the various cohorts or socioeconomic classes of the community.

5. CONCLUSION

This study has brought to light the essence of environmental education that is incorporative of the community through formal and informal approaches in forest knowledge acquisition and management in the Nandi County. The heuristic developed in this study encapsulates an integrated community environmental education approach that is anchored in institutional and policy frameworks, local forest knowledge, formal environmental education, and GIS/remote sensing. The heuristic (figure 8.1) enables the adoption of strategies using readily accessible, though loosely applicable, information for problem solving in developing and implementing community environmental education practices for effective forest management and conservation practices that are responsive to the needs of the Nandi Forest Community. Such environmental education has the potential to best reveal to the local community the accruable
benefits they stand to reap by sustainably managing the Nandi Forest, which are dependent, to a great extent, on the level of awareness of the local community of the significance of sustainable forest management and what their actions and/or inactions mean to the forests.

Although the heuristic developed in this study has the potential to assist in the facilitation of community environmental education for the sustainable management of forests, this goal will not be attained if the findings of the study is not effectively disseminated. Possible avenues for dissemination are (i) to run a series of workshops and seminars for the Nandi Forest Stakeholders via the local university (Moi University) and the NEF, and (ii) to publish the findings of the study in both academic journals and popular media (magazines, newspapers, local radio stations, etc.) in order to make the findings accessible to both policy makers and implementers at the highest level and local stakeholders in the area.
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APPENDICES

Appendix A: Promoter’s letter

Centre for Research, Technology and Innovation
Faculty of Education
Tel: +27 6041 504 42565
Paul.webb@nmmu.ac.za
27 April 2010

TO WHOM IT MAY CONCERN

I am writing to confirm that Mr Julius Gordon Tanui is a registered PhD student in the Faculty of Education at the Nelson Mandela Metropolitan University, Port Elizabeth, South Africa. His student number is 210117133 and the title of his research is “Community environmental education with GIS and remote sensing for sustainable management of Lake Victoria catchment area: A case of Nandi Hills and Nandi Forest, western Kenya”.

I am his study promoter and would be most grateful for any assistance that you may be able to provide in terms of the data collection process that he is undertaking.

Please feel free to contact me should you require any further information.

Yours faithfully

[Signature]

PROFESSOR PAUL WEBB
DIRECTOR: CENTRE FOR EDUCATIONAL RESEARCH, TECHNOLOGY AND INNOVATION
Appendix B: Letter to the respondents

Nelson Mandela Metropolitan University
Faculty of Education
P.O. Box 77000
Port Elizabeth- 6031
SOUTH AFRICA.

Dear respondent,


I kindly request for your assistance in my research work by filling in the attached questionnaire honestly and objectively. Your unreserved responses will be treated with utmost confidentiality and will be exclusively used for the purposes of this study.

Thank you.

Yours faithfully,

Julius Gordon Tanui
Student No. 210117133
Appendix C: Qualitative household questionnaire

Nelson Mandela Metropolitan University

Faculty of Education

<table>
<thead>
<tr>
<th>Interviewer’s Name</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Contacts:</td>
<td></td>
</tr>
</tbody>
</table>

Part I: Formal and informal environmental education

1. a) Are you aware of any forest(s) around here? (Nandi North/South)

   [ ] Yes  [ ] No

   b) If yes what is the name of the forest(s)?

   _________________  _________________
   _________________  _________________

   c) How did you come to know about the forest(s) in 1b above? (Explain)

   ________________________________________________________________
   ________________________________________________________________

2. a) How has your knowledge of forests in 1c above impacted your interaction with forests and forest resources?

   ________________________________________________________________
   ________________________________________________________________

   b) What forest management and conservation practices are you aware of? (List and briefly discuss)

   ________________________________________________________________
   ________________________________________________________________

   c) What is the source(s) of your knowledge in the practices in 2b above?
d) Has this knowledge been useful in the conservation and management of the forest(s)?

[ ] Yes [ ] No

(i) If yes in 2d above, how? (Explain)

(ii) If no in 2d above, why? (Explain)

Part II: Spatiotemporal variability in land use

3. a) What changes have you seen within forest(s) and the forest catchments?

b) What are the evidences of the changes in 3(a) above? (Explain briefly)

(a) What have been the possible drivers of the forest cover and land use change over the years?
Part III: Impacts of land use change and perceptions on forest utilization

4. a) What are the impacts of land use change on the;
   (i) Forest and Surrounding?

   ____________________________________________________________
   ____________________________________________________________

   (ii) Socio-Economic Environment?

   ____________________________________________________________
   ____________________________________________________________

Part IV: Usefulness of forests

5. a) Are forests useful to you?
   [  ] Yes  [  ] No

   b) If yes in 5a above, in what ways are they useful?

   ____________________________________________________________
   ____________________________________________________________

   c) If no, what do you think about them and why?

   ____________________________________________________________
   ____________________________________________________________

Part V: Awareness on institutions concerned with forest management

6. a) Are you aware of any group(s) or institutions concerned with the management of forest resource?
   [  ] Yes  [  ] No

   b) If yes, list them;

   ____________________________________________________________
   ____________________________________________________________

   a) How is the community organized in utilization of forest resources?
b) How effective have the arrangement in (c) above succeeded in sustainable forest management (Briefly Explain)

7. In your view, what do you think can be done to enhance sustainable forest management;

   a) By the Government?

   b) By the local community?

   c) N.G.Os?

   d) Educational Institutions?

   Thank You!
Appendix D: Quantitative household questionnaire

Nelson Mandela Metropolitan University

Faculty of Education

General Information

<table>
<thead>
<tr>
<th>S/No.</th>
<th>District</th>
<th>Division</th>
<th>Location</th>
<th>Sub-location</th>
<th>Village</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

PART I: Socio-economic background

1. Sex of the respondent
   Male [ ] 1
   Female [ ] 2

2. What is your age in years_________________________________ 

3. What is your highest level of education?
   - No formal education [ ] 1
   - Primary school [ ] 2
   - Secondary school [ ] 3
   - College [ ] 4
   - University [ ] 5

4. What is the size of the family?
   [1] 1 to 3
   [2] 4 to 6
   [3] 7 and above

5. For how long have you lived in this area?
   [1] 0 to 5 years
   [2] 6 to 10 years
   [3] 11 to 15 years
   [4] 16 to 20 years

6. What is your total monthly income in Kenya shillings (circle only one choice)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Less than 2000</td>
<td>1</td>
</tr>
<tr>
<td>2 000 – 5 000</td>
<td>2</td>
</tr>
<tr>
<td>5000-10,000</td>
<td>3</td>
</tr>
<tr>
<td>More than 10000</td>
<td>4</td>
</tr>
</tbody>
</table>
Part II: Land use and land use change

7. Do you own any land?
   1 = Yes  2 = No

8. If yes, what is the size of your land?

9. What is the size of your farm land?

10. On average what percentage of your land is covered by trees?

11. What acreage of land did you cultivate in the last season?

12. What is the major land use practice you are involved in? (tick only one)

13. Has the size of land under the land use identified in Q12 above changed in the last 20 years?

14. If Yes in Q13, how has it changed?

15. Has the forest cover changed in the last 20 years?  [1] Yes  [2] No

16. How has the forest cover changed in the last 20 years?

17. What has been the main driver of the forest cover change? (tick only one)
18. What are some of the impacts of land use/land cover change in the area?
   a) Increased forest encroachment Yes [ ]1 No [ ]2
   b) Variability in weather conditions Yes [ ]1 No [ ]2
   c) Enhanced water availability Yes [ ]1 No [ ]2
   d) Reduced water availability Yes [ ]1 No [ ]2
   e) Increased soil fertility Yes [ ]1 No [ ]2
   f) Decreased soil fertility Yes [ ]1 No [ ]2
   g) Employment creation Yes [ ]1 No [ ]2
   h) Food security enhancement Yes [ ]1 No [ ]2
   i) Loss of indigenous forests Yes [ ]1 No [ ]2

**Part III: Perceptions on forest**

19. Are the Nandi Forests important to you?

20. What are some of the benefits of forests to you?
   a) Source of firewood Yes [ ]1 No [ ]2
   b) Causes rainfall Yes [ ]1 No [ ]2
   c) Source of Medicine Yes [ ]1 No [ ]2
   d) Creates employment Yes [ ]1 No [ ]2
   e) Source of industrial raw materials Yes [ ]1 No [ ]2
f) Aesthetic value  
   Yes [ ] 1  
   No [ ] 2

g) Generates tourism revenue  
   Yes [ ] 1  
   No [ ] 2

h) Water resources conservation  
   Yes [ ] 1  
   No [ ] 2

i) Source of grass for livestock  
   Yes [ ] 1  
   No [ ] 2

j) Source of honey, wild fruits and berries  
   Yes [ ] 1  
   No [ ] 2

k) Cultural Significance (rites, worship, etc.)  
   Yes [ ] 1  
   No [ ] 2

l) Fertile land for agriculture  
   Yes [ ] 1  
   No [ ] 2

21. What is the **most** important benefit of forests to you?

   Source of firewood  [ ] 1
   Causes rainfall  [ ] 2
   Source of Medicine  [ ] 3
   Creates employment  [ ] 4
   Source of industrial raw materials  [ ] 5
   Aesthetic value  [ ] 6
   Generates tourism revenue  [ ] 7
   Water resources conservation  [ ] 8
   Source of grass for livestock  [ ] 9
   Source of wild fruits and berries  [ ] 10

22. Do you think that the Nandi forests are being managed well?

   [1] Yes [ ]  
   [2] No

23. If No in Q19 above, what are some of the management practices you would propose to improve the management of the Nandi forests?

   a) Public community education on importance of forest  Yes [ ]  
      No [ ]
b) Community Forest Management  
   Yes [ ]  No [ ]

c) Agro-forestry  
   Yes [ ]  No [ ]

d) Regulated logging  
   Yes [ ]  No [ ]

e) Statutory regulation/Full government control  
   Yes [ ]  No [ ]

f) Fencing  
   Yes [ ]  No [ ]

g) Conservation by NGOs e.g. Nature Kenya  
   Yes [ ]  No [ ]

Thank You!
Appendix E: Key informant interview schedule

Nelson Mandela Metropolitan University

Faculty of Education

<table>
<thead>
<tr>
<th>Name of the enumerator:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the Institution:</td>
</tr>
<tr>
<td>Designation of the officer:</td>
</tr>
</tbody>
</table>

1. What are the formal or informal environmental practices that have influence management of Nandi Forest and Nandi Hills within the community?
__________________________________________________________________________
__________________________________________________________________________

2. What role does your organization play in management and conservation of Nandi Forests and Nandi Hills?
__________________________________________________________________________
__________________________________________________________________________

3. What are some of the changes in land use in the forest and forest catchments that you have noted?
__________________________________________________________________________
__________________________________________________________________________

4. What are the possible impacts of land use change in Nandi Forest and Nandi Hills?
__________________________________________________________________________
__________________________________________________________________________

5. In your view, how does the local community perceive forest and forest resources?
6. What are the existing institutional arrangement for the management and conservation of Nandi Hills and Nandi Forest?
   At the:
   • Community level (Village, sub location level)
   • Division level
   • District level
   • National Level

7. What is the effectiveness of these arrangements of these arrangements in the management and conservation of Nandi Hills and Nandi Forest? (Answer as per the levels above)
   • Community level
   • District level
   • National level
8. What are some of the opportunities that you think have been explored for sustainable management of Nandi Hills and Nandi Forests?

9. In your opinion, how should Nandi Hills and Nandi Forest be managed and Conserved in view of the concepts of community Environmental education?

Thank You!
Appendix F: Observation checklist on forest utilization

Nelson Mandela Metropolitan University
Faculty of Education

General Information

<table>
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<th>Name of the observer:</th>
<th>Brief site description:</th>
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</thead>
<tbody>
<tr>
<td>Site Name:</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td></td>
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</table>

Forest utilization Practices

1. Timber/Wooded walled houses or fencing ( ) Yes ( ) No.
   
   How many cases? ______
   
   Likely source of building material:

2. Charcoal/ fuel wood used in the homestead for cooking ( ) Yes ( ) No.
   
   How many households? _____
   
   Likely source of charcoal or firewood:

3. a) Any evidence of harvesting of forest resources

   ( ) Yes ( ) No

   b) Specify the exact activity for which the product is intended/utilized for:
Forest Ecosystem Change Drivers

- a) Any damage or destruction to the forest? ( ) Yes ( ) No

  b) Name exact location where damage has been done:

  c) Describe the activity that has caused the damage:

  d) Quantify the extent of the damage (intensity)

     ______ Low
     ______ Moderate
     ______ High
     ______ Severe
     ______ Very severe

- a) Any evidence of indiscriminate logging or grazing? ( ) Yes ( ) No

  b) Describe the extent:

     ______ Low
     ______ Moderate
     ______ High
     ______ Severe
     ______ Very severe

  c) Describe the likely cause and rationale for the conclusion:

Conclusion
Describe the general health of the forest ecosystem
Appendix G: Focus group discussion guide

Nelson Mandela Metropolitan University
Faculty of Education

1. a) Have there been any changes, and what changes have you seen within forest(s) and the forest catchments in Nandi County?

b) What are the evidences of the changes in 1(a) above? (Explain briefly)

2. In your opinion, what have been the possible drivers of the forest cover and land use change over the years in Nandi County?

3. What are some of the cultural and indigenous practices among the local community that have an impact on the Nandi Forests (whether positive or negative)

4. a) Are you aware of any initiatives by the state and non-state actors geared towards conserving the Nandi Forests? (Please list them)
b) How effective have these initiatives in 4(a) above succeeded in sustainably managing the Nandi Forests (Briefly Explain)

c) In your view, what do you think can be done to ensure that the Nandi Forests are sustainably managed?

Thank You!
Appendix H: List of FGD participants in Chemomi Location, Nandi Hills Division  
Nelson Mandela Metropolitan University  
Faculty of Education

<table>
<thead>
<tr>
<th>Name</th>
<th>Phone No</th>
<th>Signature</th>
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<tbody>
<tr>
<td>Benjumin Katani</td>
<td>0770852307</td>
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<tr>
<td>Philemon Kogo</td>
<td>0710164359</td>
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<tr>
<td>Millicent Jepketch</td>
<td>0729273883</td>
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<tr>
<td>David Malakwen</td>
<td>0772301059</td>
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<td>Hezron Muge</td>
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<tr>
<td>Victor Maru</td>
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<tr>
<td>Salina Muge</td>
<td>0713484654</td>
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<tr>
<td>Hellen Chepkwin</td>
<td>0727206614</td>
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<tr>
<td>Eunice Muge</td>
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<tr>
<td>Elizabeth Mutai</td>
<td>0732266053</td>
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</tr>
<tr>
<td>Lydia Jerottich Muge</td>
<td>0727062727</td>
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</table>
Appendix I: List of FGD participants in Chepkong’ony Location, Kaptumo Division

Nelson Mandela Metropolitan University
Faculty of Education

<table>
<thead>
<tr>
<th>Name</th>
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<td>JACKSON KIRWA KEMBOI</td>
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<tr>
<td>DAVID NGETICH</td>
<td>0726600835</td>
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<tr>
<td>CHARLES K. ROTICH</td>
<td>0729058634</td>
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<td>STEPHEN K. BII</td>
<td>0716757665</td>
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<td>EUNICE TANUI</td>
<td>0725920408</td>
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<td>DIANA CHERUIJOT</td>
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<td>RAEL CHIRCHIR</td>
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<td>RACHEL RONO</td>
<td>0728402632</td>
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<tr>
<td>GEDION K. NGENY</td>
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<tr>
<td>PAUL ROP</td>
<td>—</td>
<td></td>
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<tr>
<td>SANBAYI MARUS</td>
<td>—</td>
<td></td>
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<td>AGIRI KOECH</td>
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<td>CHARLES TANUI</td>
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<td>DORCAS C. KIPONGO</td>
<td>0727775502</td>
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Appendix J: Research authorisation letter

REPUBLIC OF KENYA

NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Telegram: "SCIENCE&TECH", Nairobi
Telephone: 254-020-241349, 2213102
254-020-310871, 2213123.
Fax: 254-020-2213215, 318245, 318249
When replying please quote

Our Ref: NCST/RCD/17/012/03

Julius Gordon Tanui
Nelson Mandela Metropolitan University
South Africa.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on
“Community environmental education with GIS and remote sensing for
sustainable management of Lake Victoria catchment area: A case of
Nandi Hills and Nandi Forests, Western Kenya,” I am pleased to inform
you that you have been authorized to undertake research in Nandi
District for a period ending 30th June 2012.

You are advised to report to The District Commissioner, the District
Education Officer and the District Forest Officer, Nandi District
before embarking on the research project.

On completion of the research, you are expected to submit two hard
copies and one soft copy in pdf of the research report/thesis to our office.

DR. M. K. RUGUTT, PhD
DEPUTY COUNCIL SECRETARY

Copy to:
The District Commissioner
The District Education Officer
The District Forest Officer
Nandi District.
Appendix K: Research clearance permit

THIS IS TO CERTIFY THAT:
Prof./Dr./Mr./Mrs./Miss/Institution
Julius Gordon Tanui
of (Address) Nelson Mandela Metropolitan University, South Africa.
has been permitted to conduct research in

Location
Nandi
District
Rift Valley
Province

on the topic: Community environmental education with GIS and Remote sensing for sustainable management of Lake Victoria catchment area: A case of Nandi Hills and Nandi Forests, Western Kenya.

for a period ending: 30th June 2012.

CONDITIONS

1. You must report to the District Commissioner and the District Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit.
2. Government Officers will not be interviewed without prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two (2)/four (4) bound copies of your final report for Kenyans and non-Kenyans respectively.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

Research Permit No. NCST/RCD/17/012/03
Date of issue 14th March 2012
Fee received KSH.2,000

applicant's
signature

secretary

National Council for Science & Technology

Republic of Kenya

Research Clearance Permit

(COND paradise, see back page)
Appendix L: Classified image of Nandi Forests in 1990
Appendix M: Classified Image of Nandi Forests in 2000
Appendix N: Classified Image of Nandi Forests in 2010

CLASSIFIED IMAGE OF NANDI FOREST 2010

Legend:
- Unclassified
- Natural forest
- Tea plantation
- Bare ground/logged
- Mixed cropland
- Nandi County

SOURCE: LANDSAT ETM 2010