An Investigation of Forest Ecosystem Health in Relation to Anthropogenic Disturbance in the Southwestern Mau Forest Reserve, Kenya

A dissertation for the Award of the Degree of
Doctor of Natural Sciences (Dr. rer. nat.)
Faculty of Chemistry and Biology
University of Bremen

Presented by
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Date of conferrment 18th September, 2007

Gilbert Obwoyere. Obati

Declaration

Statement according to §6 Final Examination Regulation of the University of Bremen for the Degree of Dr of Natural Science (Dr. rer. nat.).

I herewith declare and confirm that I have elaborated my dissertation titled

An Investigation of Forest Ecosystem Health in Relation to Anthropogenic Disturbance in the South-western Mau Forest Reserve, Kenya

Single-handed and without using other sources other than those mentioned herein.

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Abstract

The dissertation describes investigations carried out from September 2005 to August 2006 to assess forest ecosystem health in relation to human disturbance in the Southwestern Mau forest reserve Kenya. The study involved the determination and comparison of tree species composition and structure, regeneration potential and capacity, litter production and nutrient fluxes between disturbed and undisturbed sites. A socioeconomic appraisal of the inhabitants was also carried out. Forest cover change analysis of the greater Mau forest was done for the period between 1984 and 2003 using Landsat satellite images.

A total of 24 families, 34 genera and 37 woody species comprising mainly trees were enumerated. There were 20 families in the undisturbed sites while 21 were present in the disturbed sites. In undisturbed sites, 30 species belonging to 29 genera were recorded while 29 species from 27 genera were tallied in the disturbed sites. The mean species richness was higher in the disturbed sites. Undisturbed sites had a lower proportion of shrubs and under storey trees with a higher frequency of over storey trees. Both sites had high number of seedlings and wildings.

Regarding survival and recruitment from seasonal seed rain, disturbed sites had significantly higher mean species richness. Germinations from seasonal seed rain indicated higher mean seedling species richness in disturbed plots while seedling density was significantly higher in undisturbed plots. No significant mean differences in species composition were recorded from the seed bank trials.

A higher amount of fine litter was collected in disturbed plots with insignificant mean differences with regard to K, C and N content between the sites. There were no significant mean differences in the C: P, ratios whereas undisturbed plots had significantly lower mean C: N ratios. Within stand mean nutrient use efficiency for C, N, P, K, and Ca were lower in the undisturbed plots.

Survey results indicated that several tree species that were once common or dominant in the area were increasingly becoming rare. Increase in human population, firewood collection, agricultural expansion, land subdivision among others were ranked as important causes of forest degradation. Positive significant correlations were reported between the definition of provision of services, forest condition, provision of goods, the adequacy of goods provided and ecosystem health. However, a significant negative correlation was reported for the values attached to the current land use. The presence of disturbance indicator species like *Neoboutonia macrocalyx*, *Croton megalocarpus* and *Vernonia auriculifera* in the vegetation community indicates considerable levels of human disturbance in the reserve representing retrogression in the vegetation succession.

The vertical stratification of the forest reserve depicts secondary growth in the reserve. The potential for natural regeneration of trees after natural or anthropogenic disturbance exists despite a poor soil seed bank. High litter annual turn over in disturbed sites, coupled with lower nutrient content and nutrient use efficiency as well as higher fine litter C: N and C: P ratios defines them as poorer sites. A chronological degradation in the condition of the forest over time is apparent with current land uses having negative significant effects. Thematic change and image difference analysis indicated a significant change in closed canopy forest.

Gilbert Obwoyere. Obati

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Dedicated to

My Late Mother
Jessicah Vihenda Obati

and my Family

Rodah Afandi Obwoyere, Faith Vihenda Obwoyere

and Anne Neema Obwoyere

Table of contents

List of tables

List of figures

List of symbols and acronyms

Cap	Chapter
CBD	Convention on the Conservation of Biodiversity
CFAN	CIDA Forestry Advisors Network
CIDA	Canadian International Development Agency
CIFOR	Centre for International Forestry Research
CITES	Convention on International Trade in Endangered Species
cm	Centimetre
dbh	Diameter at breast height
FD	Forest Department
GDP	Gross Domestic Product
GIS	Geographical Information System
GNP	Gross National Product
GoK	Government of Kenya
GPS	Global Positioning Systems
ha	Hectares
IAD	Itare A Disturbed,
IAU	Itare A Undisturbed,
IBD	Itare B Disturbed,
IBU	Itare B Undisturbed
IUCN	International Union for the Conservation of Nature
KFS	Kenya Forest Service
KIFCON	Kenya Indigenous Forest Conservation Programme
Km^2	Square kilometres
KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LSD	Least significant difference
MAU	Mara A Undisturbed,
MAD	Mara A Disturbed,
MBD	Mara B Disturbed,
MBU	Mara B Undisturbed,
m^2	Square metres

MEA	Millennium Ecosystem Assessment
MENR	Ministry of Environment and Natural Resources
MoU	Memorandum of understanding
N	Total number of individuals in all species
NEMA	National Environmental Management Authority
NMK	National Museums of Kenya
NRC	Non-Resident Cultivator
NTFP	Non Timber Forest Products
PFTs	Plant Functional Types
RIL	Reduced Impact Logging
S	Total number of species present
Sig	Significance
SUMAWA CRSP	Sustainable Management of Watersheds Collaborative Research Support project
UNCBD	United Nations Convention on Biological Diversity
UNEP	United Nations Environmental Programme
US$	United States of America Dollar
WHCBC	World Heritage Convention and Biodiversity Conservation
WRCF	World Remaining Closed Forests
WWF	Worldwide Fund for Nature

1. INTRODUCTION

Historically, the nature and value of earth's life support systems have largely been ignored until their disruption or loss highlighted their importance (Daily et al. 1997a). For example, deforestation has belatedly revealed critical role forests serve in regulating the water cycle, mitigating floods, drought, the erosive forces of wind and rain, and silting of dams and irrigation canals. Human societies derive essential goods, including food, game animals, fodder, fuel wood, timber, and pharmaceutical products and services such as pollination of crops, flood control, water purification soil erosion control etc. from natural ecosystems. Soils provide important interrelated services (Daily et al. 1997b). Soil shelters seed and provide physical support as they sprout and mature into adult plants. Soil also retains and supplies nutrients to plants including, playing a central role in the decomposition of dead organic matter and wastes. Similarly, soils play a key role in regulating geochemical cycles (Jenny 1980; Vitousek et al.1986; Schlesinger 1991; Pimentel et al. 1995; Vitousek et al. 1997).

These ecosystem goods and services represent an important and familiar component of human economy. Recently, it has been recognised that natural ecosystems[1] also perform fundamental life-support services essential to human civilization (MEA 2005a; MEA 2005b; MEA 2005c). This array of services is generated by a complex interplay of natural cycles powered by solar energy and operating across a wide range of spatial and temporal scales (Holdren and Ehrlich 1974; Ehrlich and Ehrlich 1981).

In the recent past, economic and cultural development has focused heavily upon human-engineered and exotic sources of fulfilment of human needs and diverted attention from the local biological underpinnings (ecosystem services[2]) that are essential to economic prosperity (Daily 1997). Many of these services are performed seemingly for free yet are worth trillions of dollars (Costanza et

[1] **Ecosystem.** A dynamic complex of plant, animal communities and the non-living environment interacting as a functional unit (CBD 1992).

[2] **Ecosystem services**- a wide range of goods and services rendered to man by ecosystems as a result of interactions between the biotic and abiotic components e.g. Food, water, shore protection, cultural values, regulation of climate, flood control etc (MEA 2005a).

al. 1997). The infinite value put on the value of ecosystem services often translates to zero in the equations that guide land use policy decisions. Hence, practitioners in the juvenile field of ecological economics strive to deliver more concrete numbers to help nations avoid unsustainable economic choices that degrade both their natural resources and the vital services that healthy ecosystems generate (Costanza et al. 1997; Sagoff 1997).

Daily et al. (1997b) suggest with certainty that ecosystem services are essential to civilization. These operate on a grand scale and in intricate and little-explored ways that most cannot be replaced by technology, and that anthropogenic activities[3] are already impairing their flow. It is apparent that if current trends continue, humanity will alter virtually all of earth's remaining natural ecosystems. In addition, many of the human activities that modify or destroy natural ecosystems also cause deterioration of ecological services, which may result in adverse long-term effects on human welfare.

Some of these adverse effects due to impairment of natural ecosystems include the current debate on global climate change. It is postulated that this will have immense implication on forest ecosystems in developing world. For example, in meeting obligations of climate change, it is largely expected that more land including forest[4] ecosystems will be required for the cultivation of genetically optimized crops for the manufacture of bio fuels to substitute fossil fuels. This is particularly worrying for countries like Kenya where forest cover is already dwindling and current governments are poised not to miss on this opportunity "green revolution" of the current time by moving the states towards modern industrialized countries through modern agribusiness activities. Similarly, other developing countries for example Indonesia, Malaysia, Argentina, Uganda and Mexico where vast forest areas have been cleared to pave way for agricultural intensification.

The importance of these wild areas cannot be overemphasized. This can be seen in the various international organisations (UNEP, WHCBC, IUCN, WWF),

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[3] **Anthropogenic activities** – An array of planned or unplanned manipulations of the environment by humans in order to meet their subsistence and/or commercial needs.

[4] **Forest** FAO in their assessment of tropical forests defined forests as vegetation types where trees cover more than 10% of the land area (Rietbergen 1993).

conventions (CBD) and treaties (CITES) that have been ratified over the past few years to specifically oversee issues related to environment and sustainable development. The designation of protected areas as Ramsar sites, areas of world heritage have had some significant contribution to their conservation and management. However, despite the importance of forests like the other resources there is no global convention or treaty on forests. Hence no global forestry policy is in place.

According to UNEP 2001, the extent of the Worlds remaining closed forests (WRCF) in 1995 was estimated at approximately 2.87 billion hectares, occupying about 21.4% of land area of the world. Fifty-four countries have over 30% of their land area under closed forests. About 80.6% of the WRCF are concentrated in fifteen countries; ranked in the highest to lowest order are Russia, Canada, Brazil, the United States of America, Democratic Republic of Congo, China, Indonesia, Mexico, Peru, Bolivia, Venezuela, India, Australia and Papua New Guinea. Three countries, Russia, Canada and Brazil contain about 49% of the WRCF. An estimated 83.6% of the WRCF have low, 11.3% medium and 5.1% high population densities in and around closed forests. Many of these forest areas with low population densities offer significant opportunities for conservation if appropriate steps are taken by national governments and international community. The UNEP outlines policy options for the protection of the WRCF should include strong protection measures, education and alternatives to forest exploitation or intermediate use.

Forests offer a variety of socioeconomic and ecological goods and services. During the past few decades forests have attracted unprecedented global attention. Numerous international conferences, conventions and agreements including the Forestry Principles agreed upon during the Earth Summit in 1992 and the Convention on Biological Diversity (CBD 1992) have called for the protection of global forests (UNEP 2001).

However, forest resources around the world are increasingly under threat due to conversion of forestlands to other land uses and overexploitation of forests for timber. With the current trends, the Earth's remaining closed canopy forests and associated biodiversity are destined to disappear in the coming decades. The protection of all forests is impractical; hence conservation efforts and priorities should focus on those target areas that offer the best prospects for continued existence. Hence it is critical to assess and determine status of ecosystem health in view of anthropogenic activities in these forested areas using the latest scientific methods.

Over the past twenty years, Kenya has experienced intense deforestation. It is estimated that about 19000 Ha of forest cover are felled or converted each year (Wamukoya and Juma 2000). Forest cover in Kenya has continued to decline and now stands at less than 2% of the total arable land (Okowa-Bennun and Mwangi 1996; Wamukoya and Juma 2000; UNEP 2001). This falls far below the internationally accepted minimum of 10% (IUCN 1995).

1.1 STATEMENT OF THE PROBLEM

Kenya is endowed with important priceless natural areas including natural closed canopy forests[5] , which serve as important habitats for plant and animal species of global importance including wildlife and birds of migratory importance within the region (Whitemore 1997; Bennun and Njoroge 1999; Brooks et al. 1999; Birdlife International 2003). The forest ecosystems of Kenya serve as abodes of rare, endemic as well as endangered species. They are therefore an important element in the national as well as regional economy. For example, the annual turnover from tourism, which is almost completely dependent on natural areas amount to the highest to the national economy contributing over 14.9% of the country's GDP (KNBS 2007a).

The forests also serve to provide sustenance of local livelihoods through the use of forest products and services including food, timber, firewood, water, medicines etc (Bleher et al. 2006). However, owing to the increased pressure and observed rampant degradation of forest ecosystem in the country which has led to adverse impacts on the ecosystems' ability to provide goods and services (Mutanga 1996; Bleher et al. 2006). There is therefore, an urgent need to provide baseline information concerning the current state of the forests in terms of vegetation composition, structure, regeneration capacities and potentials as well as community values as a basis to estimate forest ecosystem health in order to provide further management interventions.

[5] **Natural closed canopy forests**. Natural forests with over 40% canopy cover.

In most forested areas in Kenya including the Mau forest reserve clearing activities have transformed land use changes to the effect that forest products and services are in short supply (Mutanga 1996; Mitchell 2004; Bleher et al. 2006). Socioeconomic development of native populations in particular and that of the entire nation in general is threatened by these activities (Odubho and Ojwang 2000). The Mau was selected for this study for its unique attributes including but not limited to its national and regional importance as an important water tower, its relative importance to other reserves in terms of species diversity and endemism, conflict of interest between the government and forest dwelling communities as well as other stakeholders. It is also the largest near continuous block of montane forests in East Africa.

This study aimed at bridging the gap between the dependencies of previous studies on either biophysical or socioeconomic attributes in defining the status of ecosystems in view of human degradation. An integrated approach to defining the health of the ecosystem at the local level was attempted. Assessment and documentation of the status of ecosystem health and analysis of the effects of human induced changes on a Kenyan montane natural forest, characterized by a human dominated landscape, were done. The study purposed analyzed and determined the effects of human activities on forest cover dynamics, vegetation composition and structure including regeneration capacity and potential from in situ and seed bank as well as fine litter budgets as a basis to estimate and define ecosystem health.

1.2 CONCEPTUAL FRAMEWORK

The causes of declining biodiversity and land degradation are often multiple and complex and usually involve a combination of human and natural factors (MEA 2003; MEA 2005b; Bohensky and Lynam 2005). Their impacts are also multiple and affect a range of natural and socio-economic considerations. Direct and indirect relationships occur between the state of natural resources (soil, vegetation, water, ecosystem), and the biological diversity[6] at species level

[6] **Biodiversity** the variability among living organisms from all sources including, interalia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part, this includes diversity within species, between species and of ecosystems (CBD 1992 Art. 2).

(animal, plant and microbial species) and ecosystem level (habitats, interactions, functions) and their management (Bohensky and Lynam 2005).

Management practices directly or indirectly affect the capacity of land users to conserve and sustain resources and provide goods and ecological services (Nelson et al. 2006; Butler and Oluoch-Kosura 2006). The assessment and monitoring of biodiversity and associated ecosystem processes, therefore, requires an integrated suite of biophysical and socio-economic indicators (Brunson 1996).

The hierarchical, multiscalar paradigm proposes that a healthy forest ecosystem is one that maintains its complexity, structure and resilience (Kolb et al. 1994; Kimmins 1996; Kimmins 1997). The maintenance of complexity structure and resilience (ecosystem integrity[7]) proposes a no use or preservation management style. This then tends to preclude utilization of the forest ecosystem by man.

Resource management thus operates within the constraints indicated by ecological understanding that define the context of annual management decisions. This theory may apply suitably for the management of service rather than consumptive uses of the forest (Costanza et al.1992).

Definitions of ecosystem health[8] have included health as homeostasis, absence of disease, diversity or complexity, stability or resilience vigour or scope of growth or a balance between system components. All these represent pieces of the puzzle but none is comprehensive. In defining ecosystem health a systematic approach to the preventative, diagnostic, and prognostic aspects of ecosystem management, and to the understanding of relationships between ecosystem health and human health have been sought. It seeks to understand and optimize the intrinsic capacity of an ecosystem for self-renewal while

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[7] **Ecosystem integrity**-This is the maintenance of natural structure, function and complexity supporting and maintaining a balanced integrated adaptive community of organisms having a species composition diversity and functional organization comparable to that of a natural habitat of the region (Jorgensen and Müller 2000).

[8] **Ecosystem health.** The state of an ecosystem in terms of structure and function over time in the face external stress (resilience). It determines the quality and quantity of goods and services (Ecosystem services) derived from ecosystems. An ecosystem is thus considered healthy if it is stable, resilient to stress and continuously provides a set of services. In this study stability was measured using species richness and structural complexity, resilience the regeneration potential and capacity while the provisions of services was derived from the perceptions and opinions of the inhabitants.

meeting reasonable human goals. It encompasses the role of societal values, attitudes and goals in shaping our conception of health at human and ecosystem scales. Therefore, health is a measure of the overall performance of a complex system that is built up from the behaviour of its parts. The assessment of the relative importance values range from subjective qualitative to objective and quantitative about the system under study.

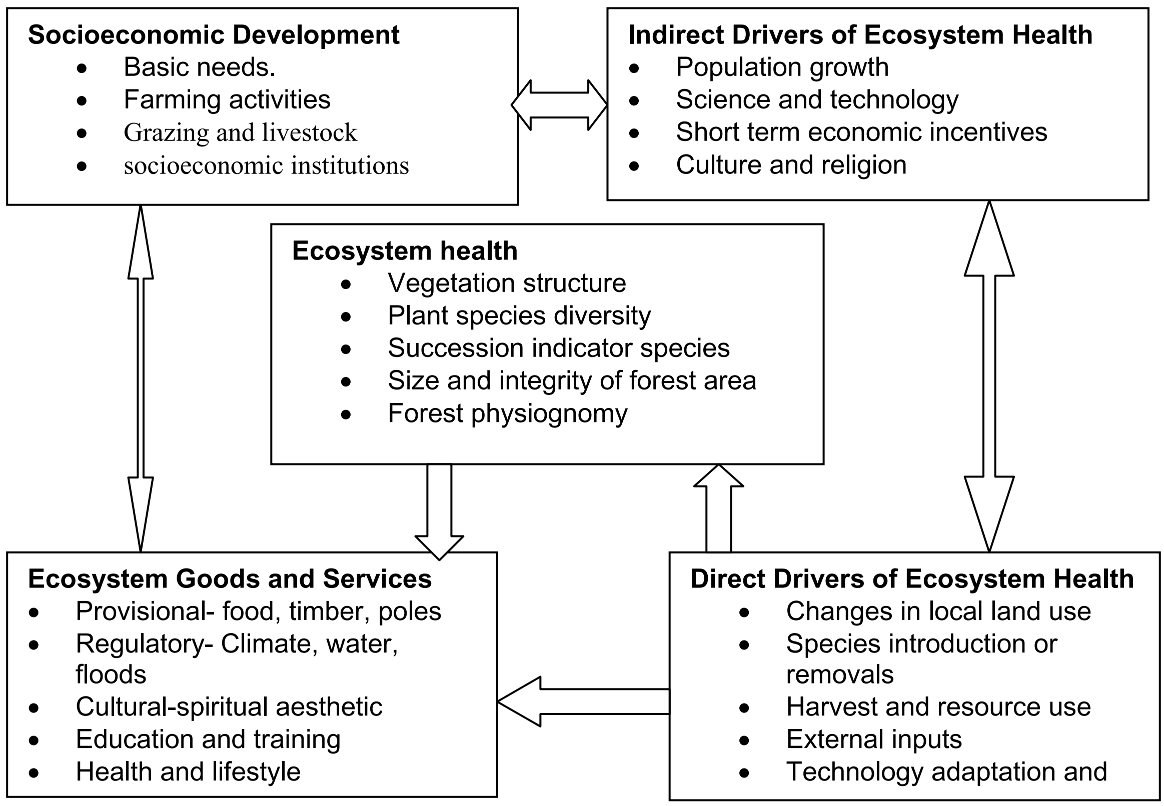
Forest health is therefore difficult to measure unambiguously (Kimmins 1996; Kimmins 1997) although past advances have been made in examining and providing case studies (Rapport et al. 1998;). In order to have a compromise between the utilitarian and ecologist theories about ecosystem health it is important to provide a link between the ecologist and the non-ecologist in their quest for particular values in forest ecosystems (Rapport et al. 1998).

The missing link in the emerging theory and practice of integrated environmental management is an approach to scale that will link theories of ecosystem management with easily observable indicators of ecosystem health.

In view of the above a conceptual framework providing an ecosystem approach to environmental management with strong basis for ecosystem health and socioeconomic development was used as a guide during the study (MEA 2003).

Consequently, important elements on the health of ecosystems would provide insights as to whether ecosystems have the capacity to continue providing the required goods and services to humanity. These will then serve as important pathways to the understanding of the drivers of ecosystem health impairment within the investigated forest reserve[9].

[9] **Forest reserve** an area declared to be a forest area under section 4 of the Forest Act (CAP 385). Both consumptive and non consumptive utilization are permitted under license.



Source, MEA 2003

Fig. 1.6.1 Ecosystem health conceptual framework

The figure shows the inter relationships between the socioeconomic environment (socioeconomic development), ecosystem goods and services and ecosystem health and its drivers.

This will form a basis for informed management interventions as well as strategic decision-making processes. The context of evaluating forest species composition and structure, land use change, litter production and nutrient budgets as well as regeneration capacity and potential, consumptive and non-consumptive uses of the forest would serve as benchmark, which will provide an integrated perspective on ecosystem health. This will aid in analysing the possible future trends for the nearby forest inhabitants, who solely depend on the forest for sustenance. It is presumed that a healthy state of the forest could be used as a possible indicator of the state of livelihoods of the local people who depend on the ecosystem.

It has been shown the world over that natural resource degradation and poverty are all a part of a vicious cycle (MEA 2005a). The contribution being made through this study is that, such issues being raised have never been investigated and documented within the Kenyan context in montane forest reserve. Therefore, this would serve to contribute to current knowledge on the same issues with the generation of capacity in handling similar and emerging issues in the field of renewable natural resource management.

1.3 RESEARCH OBJECTIVES

This study was guided by a broad objective, a set of specific objectives, hypotheses and research questions.

1.3.1 Broad objective

The broad objective of the study was to determine the status of ecosystem health in view of anthropogenic activities in the Southwestern Mau forest reserve, Kenya.

1.3.2 Specific objectives

The specific objectives of the study were to:

1) Assess vegetation structure (based on diameter, height and basal area) and composition as defined by species richness and diversity) in disturbed and relatively undisturbed forest sites in the SW Mau forest reserve.
2) Assess and compare fine litter turnover and quality in disturbed and relatively undisturbed forest sites.
3) Assess the regeneration capacity and potential (seedling germinations and recruitment from seasonal seed rain as well as the seed bank) in the disturbed and undisturbed forest sites.
4) Determine and rank the principal socioeconomic causes of forest degradation through the assessment of the perceptions and attitudes of the inhabitants about the importance, status and causes of degradation in the Mau forest reserve.
5) Evaluate the perceptions and attitudes of the inhabitants regarding supply of ecosystem goods and services.
6) Analyze forest cover dynamics by execution of a spatial-temporal analysis over the last three decades using remote sensing and GIS to show the extent of human related disturbance in the Mau forest reserve.

1.3.3 Hypotheses

The study attempted to test the following hypotheses:

i. Forest cover in the Mau forest reserve has decreased significantly over the past two decades (1984 to 2003).
ii. Tree species richness is higher in the undisturbed plots than in the disturbed plots.
iii. Shannon Wiener diversity index is higher in the undisturbed plots than in the disturbed.
iv. The structural complexity (Holdridge's HC) is higher in the undisturbed plots than in the disturbed plots.
v. Within stand fine litter annual production is significantly higher in the undisturbed plots than in the disturbed plots.
vi. Within stand nutrient input is higher in the undisturbed plots than in the disturbed plots.
vii. Fine litter quality is higher in the undisturbed plots than in the disturbed plots.
viii. Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from annual seed rain.
ix. Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from seasonal annual seed rain
x. Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from the seed bank.
xi. Tree species in the undisturbed plots were significantly higher than that in disturbed plots.
xii. Human population increase, land use change, domestic energy requirements (firewood and charcoal), infrastructural development logging are the main drivers of forest degradation in the SW Mau forest reserve.
xiii. The supply of goods and services from the Mau forest reserve adequately meets the needs of the inhabiting human population.

A reconnaissance survey was carried out in the Southwestern Mau forest reserve to select appropriate sites for the study. A visit to the Bureti district forest offices and contact with the central government administration to introduce and explain the goal of the study was done. With the help of the foresters in charge of Mara Mara and Itare forest stations study sites were selected based on a set criteria i.e. they were to be in the neighbourhood of a settlement not more than 5 kilometres away.

Two sites were designated for the study in Mara Mara and Itare each having a representation of disturbed and undisturbed areas of the Southwestern Mau forest reserve base on the following criteria.

a) Disturbed sites: areas cleared for settlement, grazing points, forest edges and numerous foot paths, firewood collection, post and poles making and cattle grazing trails, abandoned pit latrines and fruit trees.

b) Undisturbed sites: represented by three complete storeys minimal human disturbance were also evident such as stem debarking, footpaths, firewood collection, post and poles making and cattle grazing trails.

Study plots were laid out as detailed in the methods section for enumeration of the study parameters.

2. BACKGROUND TO THE STUDY AREA

2.1 THE EAST AFRICAN MONTANE FOREST ECOREGION

The East Africa, montane forests ecoregion is found as moderate to high altitude patches along a chain of isolated mountain ranges along the Rift Valley, from southern Sudan through Kenya and Uganda to northern Tanzania (Sayer et al.1992; Newmark 2002). The ecoregion consists of more than 25 montane forest patches of various sizes. The eco-region is found at altitudes between 1000 to 3500 metres above sea level.

Climate is relatively temperate and seasonal in this region due to the high altitude. Temperatures fall, below 10^0C during the cold season. Frost is possible at higher altitudes. Precipitation in the region varies between 1200-2000mm per annum. Climatic conditions vary by region and are modified by local conditions.

Geologically the region has been influenced by the rifting of the African plate system. Associated with this rifting was the development of several active volcanoes in the area, for example, Mount Kenya, Kilimanjaro and Meru (Lovett and Wasser 1993). Associated with these high mountains are mountain ranges such as Ngong Hills, Aberdare ranges and the Mau ranges in Kenya. The soils in this region are typically complex with differences arising from climatic and altitudinal variations. However, most of the region has a volcanic base rock, giving rise to typically fertile soils highly suitable for forestry and agriculture.

2.1.1 Vegetation and biome type

The eco-region is dominated by sub-montane and montane forests, giving rise to tropical and subtropical moist broadleaf biome type (Meadows and Linder 1993). At high altitudes the eco-region grades into the afromontane[10] heathland/moorland and afro-alpine vegetation. According to White (1983), phytogeographically the area is regarded as part of the Afromontane Archipelago[11]-like regional centre of endemism.

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[10] **Afro-montane** is a term used to describe the plant and animal species common to the mountains of Africa and the southern Arabian Peninsula. The afromontane regions of Africa are discontinuous, separated from each other by lowlands. Afromontane forests are generally cooler and more humid than the surrounding lowlands.

[11] **The Afromontane archipelago** mostly follows the Great Rift Valley from the Red Sea to Zimbabwe, with the largest areas in the Ethiopian Highlands, the Albertine Rift of Uganda, Rwanda, Burundi, Democratic Republic of the Congo, and Tanzania, and

The vegetation formerly consisted of various kinds of forest, with bamboo and heath land/grassland at higher altitude. The forest is most highly developed on the windward sides of the mountains and mountain ranges. Much of the original habitats have been lost where they are not protected (Lind and Morrison 1974; White 1983; Newmark 1991; Meadows and Linder 1993; Lovett and Wasser 1993; Wass 1995; Young 1996; Lovett and Friis 1996; Chapman and Chapman 1996).

The region contains moderate levels of species richness and relatively low rates of endemism in comparison to other tropical eco-regions around the equatorial belt of Africa. Conversely, it contains endemic species and the mix of plants and animals is of interest in defining and interpreting the regions biogeographical history. A number of narrow centres of plant endemism exist in the eco-region (WWF and IUCN, 1994) concentrated in the heath land eco-region being of lower relative importance for the conservation of endemic plants.

On the other hand, avifaunal (Burgess et al. 1998; Stattersfield et al. 1998) endemism is quite moderate, while mammal endemism is more pronounced. However there are no endemic large mammals. The rates of endemism in the East African eco-region are lower than those in some of the other East African forested blocks (e.g. the Albertine Rift, East Arc Mountain forests and the Zanzibar-Inhambane coastal forest mosaic) (Bennun et al. 1995; Wass 1995; Burgess and Clarke 2000).

2.1.2 Biogeographical history

Species distributional patterns in the East African Mountains define some of their biogeographical history. Some of the mammalian and plant species suggest that these forests may be impoverished outliers of the Guineo-Congolian[12] block (Lovett and Wasser 1993). For example, the presence of the antelope “bongo” in Kakamega and Mau forests in western Kenya illustrates a strong link with the forests of West and Central Africa (Birdlife International 2003). Other elements of the fauna indicate linkages with the surrounding more

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the Eastern Arc highlands of Kenya and Tanzania. Other Afromontane regions include the Drakensberg range of southern Africa, the Cameroon Highlands, and the Cameroon Line volcanoes, including Mount Cameroon, Bioko, and São Tomé.

[12] **Guineo-Congolian** Humid tropical forests predominantly of mixed broadleaved trees includes humid closed forests and Savannas separated into several types according to their humidity and characteristic species.

arid habitats. The presence of single mountain endemics illustrates that the evolution of novel species has proceeded in this region independent of other areas (Lovett and Wasser 1993).

The eco-regions biogeographical history is also reflected in the bryophyte flora. According to Pócs 1998, the East African Arc[13] Mountains contain many endemics but of more importance is the occurrence of 45 species of bryophytes, which are also found in Madagascar. Conversely, the younger forests of the East African Mountains have fewer bryophyte endemics, but significant is the absence of the Madagascan species, providing convincing evidence that these mountains have a different biogeographical history.

The East African Mountains region was historically a mosaic of forest, bamboo and grasslands throughout its higher elevations, grading into extensive areas of savannah, woodlands and other habitats at lower altitudes while at higher altitudes it graded into heathland/moorland habitats. Although history points to the habitats of this eco-region as having been always fragmented by their presence on different isolated mountains, over time and through the activities of man, the habitat has increasingly become more fragmented (Newmark 2002; Pócs 1998; Lovett and Wasser 1993).

2.1.3 Current status

In the recent past, a number of remaining blocks of forest and forest mosaic habitats are found within national parks and forest reserves. Grasslands and savannah-woodlands are also found within these protected areas. In most cases, the natural habitats currently stop at the borders of the protected areas. Most of the forest and montane habitats outside protected areas have been converted to agricultural or other human use (Goldammer 1992). Examples of such conversion are observed around Mt Kenya National Park (Gathaara 1999) being typical of the situation elsewhere in the region.

At lower altitudes, tracts of forest and forest mosaic have been converted to tea and coffee plantations and likewise to subsistence agriculture and conifer plantations. The major loss of habitat to large-scale agriculture and conifer

[13] **The East African Arc** ecoregion extends in elevational patches along a chain of isolated mountain ranges, from the Taita Hills, close to the Kenyan border with Tanzania, down through eastern Tanzania to the gap between the Udzungwa Mountains and Mt. Rungwe.

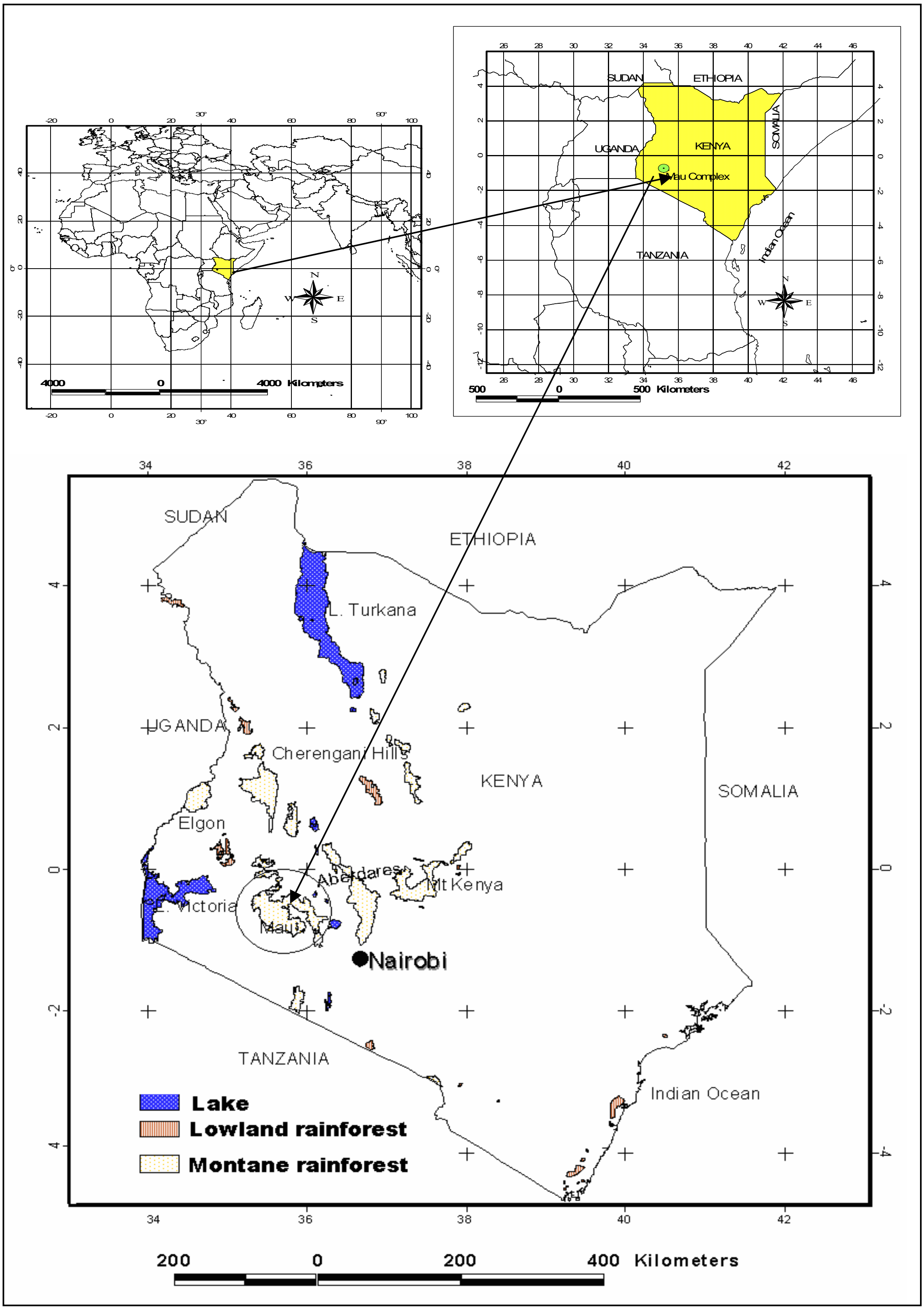
plantations occurred during the British colonial period in the early and middle of the 19th Century. A rapidly increasing population in independent Kenya has exacerbated the pressure on habitats leading to further losses. Even lower altitude areas of grassland have not been spared either (Newmark 1991; Jackson and McCarter 1994; Young 1996; Gathaara 1999; Matiru 2000).

A rapidly increasing human population characterizes the region. For example population densities of 200-300 persons per square kilometre have been reported in many areas (Jackson and McCarter 1994; Gathaara 1999; Matiru 2000). Such densities remain worrying especially when the people live right up to the boundaries of protected areas and in some instances encroachment extends within the borders of the reserves (Gathaara 1999).

2.1.4. Montane forest cover in kenya

Kenyan montane forests are found in the central and western highlands and on higher hills and mountains along the southern border. Most of these mountain blocks are of recent volcanic origin and are relatively species poor. The volcanic mountains contain sub-montane forests: evergreen seasonal forests and evergreen forests. Deciduous tree species e.g. *Calodendrum capense* and *Ekebrgia capensis* and the association of the *Cassipourea malosana–Setaria plicatilis* are common in the evergreen seasonal forests. Evergreen forests are characterized by *Cassipourea malosana-Podocarpus latifolius* and the *Cassipourea malosana-Olea hochstetteri* communities (Niemelä and Pellikka 2004; Dale and Greenway 1961; Noad and Birnie 1990).

The Aberdare ranges are located on the eastern side of the Gregory Rift Valley. The annual rainfall ranges from 940 to 3220mm with the maximum to the southeast. Low clouds and mist provide additional moisture (Goldammer 1992). The Elgon mountain forests are characterized by *Rapanea rhododendroides, Hagenia abyssinica* and *Olea welwistchii*. Mount Kenya forests contain *Hypericum keniense* and *Hypericum revolutum* (Dale and Greenway 1961; Noad and Birnie 1990; Virtanen 1991; Niemeliä and Pellikka 2004)). The Mau is the largest single block of montane forest in East Africa (Sayer et al. 1992).



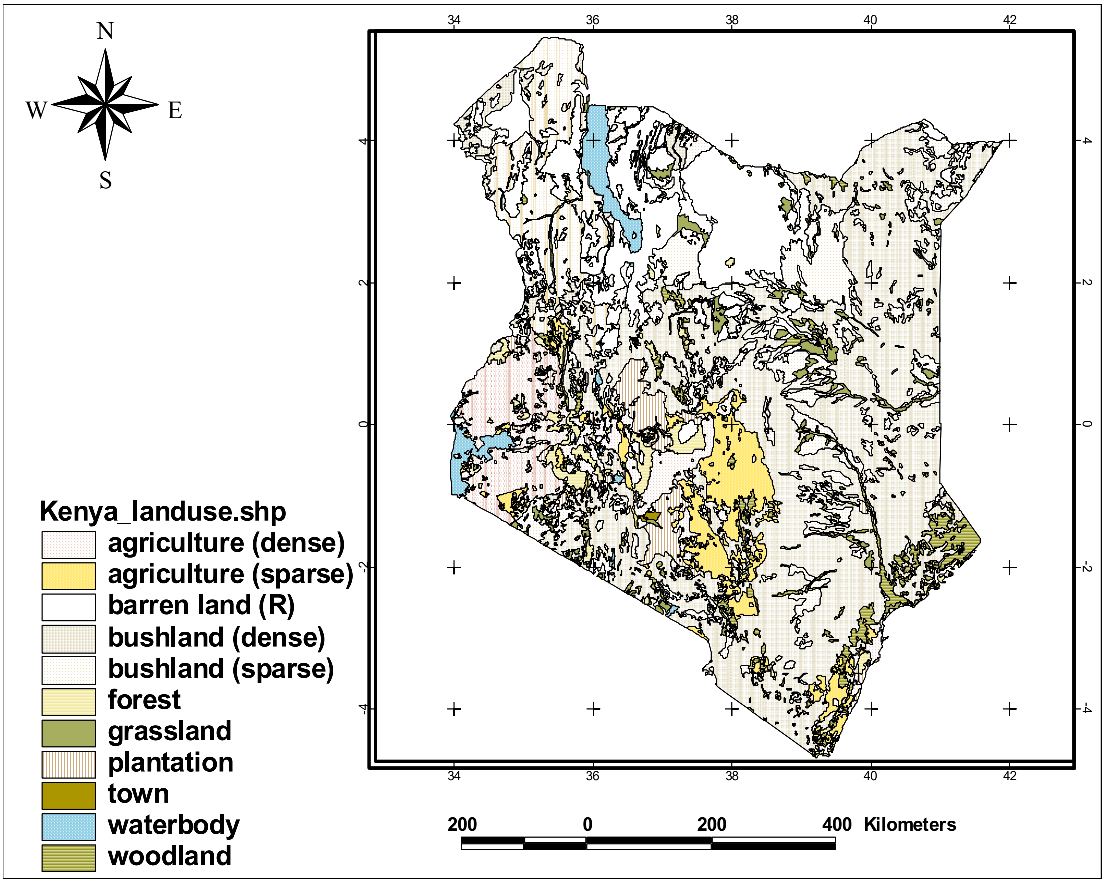
Source SUMAWA CRSP 2004

Fig. 2.1.1 Distribution of montane forests in Kenya

Most of the forested areas in Kenya are in or around mountains. This emphasizes the importance of these montane forests as watershed and important biodiversity areas.

2.2 LAND USE AND VEGETATION COVER IN KENYA

Kenya has a total land area of about 582,645 km^2 or about 5.8 million ha including 2.6 million ha of forest on both government land (56%) and trust land (44%). Population densities have grown over time, rising from 15 persons per km^2 of land in the 1960s to 27 and 37 in the 1980s and 1990s respectively. The country's population density is estimated at 50 persons per km^2 for the 2000s. This increase in population density has taken place against a shortage of good agricultural land that is only about 1.9 million ha which represents only a third of the total land area. This scenario translates to corresponding Figures for arable land per capital of 2.2 ha in the 1960s, 1.24 ha in the 1980s, 0.89 ha in the 1990s and 0.66 ha estimate for the 2000s. By the year 2020, arable land per inhabitant is projected to be 0.48 ha.



Source SUMAWA CRSP 2004

Fig. 2.2.1 Land use categories in Kenya

The map shows the different land use types in Kenya. The land area under forests is very small in proportion to the land area. The small area under forests is threatened by conversion into other land uses.

2.2.1 Extent and distribution of indigenous natural forests

Kenya presents the most diverse forests in East Africa, though they are also the most highly fragmented. (Ahmed and Mlay 1998). Kenya's vegetation cover includes natural and plantation forests, private owned forests and mangrove forests. Other forms of vegetation and land use in Kenya include wood/bush land, wooded grasslands, grassland, farmland and urban development.

Kenya's closed canopy forests are estimated to cover less than 2 % of the country (Wass 1995; UNEP 2001). Over 88% (representing 1.24 million hectares) of Kenya's forest cover is made up of indigenous forests[14] (Wass 1995; IUCN 1999) while 11.43% representing 1.06 million hectares is covered with plantation forests.

The latest inventory done in 1994 by Kenya Indigenous Forest Conservation Programme (KIFCON) came up with a differentiation between two types of forest cover. The total indigenous forest cover in gazetted forest areas[15] was estimated by KIFCON (Wass 1994), to be 1.06 million ha (excluding the mangrove forests along the coastline), while the area of indigenous closed canopy forest outside the gazetted forests was estimated to be 180,000 ha (0.18 million ha). Besides the gazetted forests, the country has a total of about 37.6 million ha of natural woody vegetation consisting of 2.1 million ha of woodlands, 24.8 million ha of bush-lands and 10.7 million ha of wooded grasslands. These forests are further geographically restricted to the highlands and climatically to regions of the country with average annual rainfall of over 1000mm.

Most of the closed canopy forests are concentrated in the high and medium potential zones of Kenya where, incidentally, the human population and agricultural production are also concentrated; hence there is potential conflict between closed canopy forest and agriculture. Within the arid and semi-arid zones, closed forests are fewer and are found concentrated mainly on isolated mountain ranges and along river courses, both permanent and seasonal, with

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[14] **Indigenous forests** These are forests with species native to a specific area not introduced, opposite of exotic.

[15] **Gazetted forest area** An area of land set aside through relevant and competent ministry by the government through a gazette notice as forest.

the rest of this zone being composed of woodlands, bush-lands and wooded grasslands (FAO 2003).

An extensive cover of mangrove forests are found along the coastline, which is estimated to total 54,355 ha (0.54 million ha.), a figure which was not included in the national forest cover estimated by KIFCON (Wass 1994; IUCN 1999).

2.3 FOREST MANAGEMENT IN KENYA POLICY FRAMEWORK

The Environmental Management and Co-ordination Act (1999) is the umbrella legislation governing the management of natural resources in the country. The Act specifically addresses issues relating to the protection of forests, reforestation and afforestation, energy conservation, the planting of trees or woodlots, and the conservation of biological diversity. An independent authority, National Environmental Management Authority (NEMA) has been established to implement the provisions of the Act providing public involvement in any major development decisions that have a bearing on the environment.

The Act also recognizes the value of environmental conservation by indigenous peoples and provides for the protection of the traditional interests of local communities customarily resident in such areas.

The Kenya Forest Master plan was developed between 1991 and 1994, to provide a development framework for a period of 25 years. However, the implementation of the plan has been slow blamed on lack of political goodwill and funding. In view of the above Kenya has recently undertaken a major review of forest policy and legislation. The resulting forest policy provides for far-reaching changes in the management of forest resources in the country

The new policy emphasizes the significance of Kenya's forests to the national economy and recognizes that sustainable forest management as integral component of national development. It addresses farm forestry, dry land forestry, private sector involvement and community participation in forest management. Specifically, the new policy emphasizes the potential of forests for commercial production, and embraces the preservation of religious and cultural sites, traditional medicinal sources, water catchments, and habitats for endemic and threatened species of flora and fauna. The main objectives of the policy include: increase the forest and tree cover, conserve and preserve forests, their inherent biodiversity and natural habitats; contribute to sustainable land use, contribute to poverty reduction, manage the forest resources efficiently for maximum sustainable benefits, recognize and maximize benefits of viable and efficient forest-based industry for national development; and promote national interests in relation to international environmental and forest-related conventions and principles.

The changes have led to the establishment of the Kenya Forest Service (KFS) as a corporate body to oversee the management of forests in Kenya. Kenya Forest Service's mandate has now been expanded to manage forests including those under local authorities, privately owned, provisional and state forests. To date, funding of forestry activities has come mainly from the central government (Treasury) and from development partners. This has been inadequate for the efficient management and conservation of the country's forest resource, and with the establishment of the Kenya Forest Service the intention is to broaden the funding base.

Legislation on specifically protected areas, which through gazettement by the government are, designates as protected by law. Applicable statutes are the Forest Act Cap 385, under the Forest Act, the Minister of Environment and Natural Resources may from time to time declare unalienated Government land to be a forest area or part thereof to be a "nature reserve" whereby strict preservation of flora and fauna are undertaken. The following statues cover land use activities with direct impact on the environment: the Agriculture Act (Cap. 318 of the Laws of Kenya); the Land Control Act (Cap. 302); the Chief's Authority Act (Cap 128); the Mining Act (Cap 306); the Local Government Act (Cap 268) the Trust Lands Act (Cap 288) the Land Planning Act (Cap. 303); Governments Land Act (Cap 280); the Physical Planning Act of 1996, the Registered Land Act (Cap 300) the Irrigation Act (Cap 347); the Crop Production and Livestock Act (Cap 321).

The management of the natural forests and that of the forest resource in general is governed by the national forest policy, which is implemented mainly by the Forest Department, since most forestland falls under its jurisdiction as gazetted forest reserve. The Kenya Wildlife Service (KWS) has management responsibility for all indigenous forests falling within national parks, national reserves and game sanctuaries. These two organisations recently signed a Memorandum of Understanding (MoU) for joint management of selected indigenous forests of particular importance. In addition to the above-gazetted categories of forests, other natural forests are found falling under trust lands, lands held in trust for the local people under the jurisdiction of the local authorities commonly known as County Councils. These forests are managed by the local county councils and in some cases with assistance of the Forest Service and Kenya Wildlife Service (KWS). Forests falling within gazetted national monuments are managed by the National Museums of Kenya (NMK).

Following a presidential decree in 1985 that banned commercial exploitation of natural forests, there is no formal indigenous forest management in Kenya to date. In the recent past however, other forms of non-traditional forest management are emerging based on non-extractive uses. The current policy initiative has also proposed participatory forest management strategies based on benefit sharing, with the forest adjacent communities.

In general terms, the national parks and reserves enjoy stronger political support in conservation than gazetted forest reserves where management is low keyed. The Kenya Forest Service at the moment lacks adequate funding and other resources for effective management of the forest resources. Hence, most of the natural forests are currently facing a lot of threat from human activity that include illegal encroachment, excisions, charcoal burning, poaching of timber and other forest products and forest fires originating from adjacent farmlands. If this trend persists it is expected that the total area under national forest will decline substantially to give way to agricultural activities. This portends a catastrophe in view of this limited resource and its direct/indirect linkage with agricultural activities.

2.4 THE MAU FOREST COMPLEX

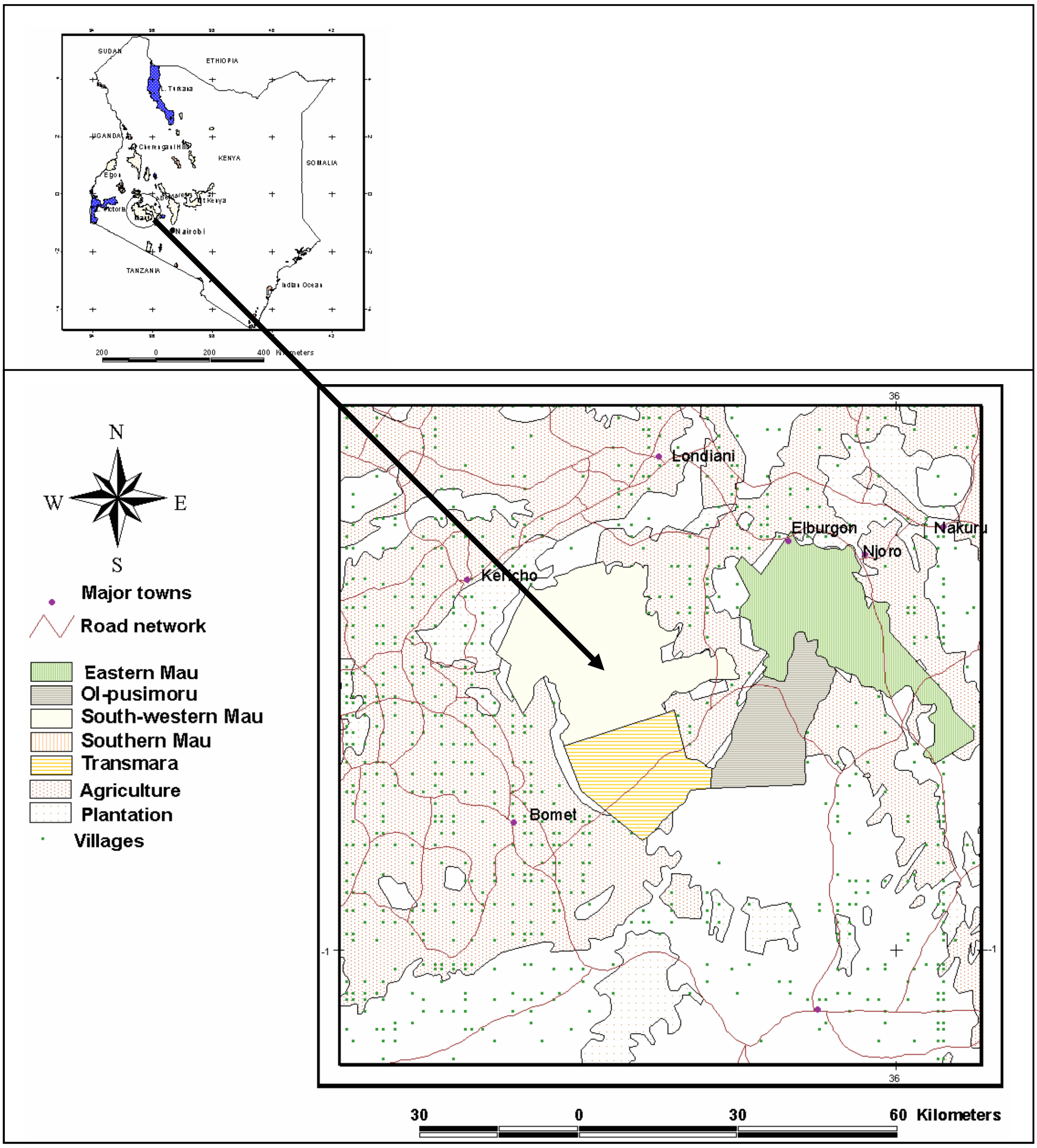
Mau forest complex is located in the Rift Valley province, about 200 km to the northwest of Nairobi (Fig 2.1.1). It lies in the montane rain forest region with high potential for closed-canopy forest growth.

2.4.1 Position and size

The forest complex lies on longitude 35°.33’ and Latitude –0°.5’. (Fig.2.1.1). It covers an approximate area of 270,000 hectares (Wass 1995). The forest reserve spans across five administrative districts: Narok, Nakuru, Bureti, Bomet and Kericho. The altitude is between 1800-3000m above sea level.

There are five main forest reserves; Eastern, Western and Southwestern Mau, approximately 66,000, 22,700 and 84,000 hectares respectively, Trans-Mara 34,400 ha and Ol Pusimoru (17,200 ha). A sixth large block, the Maasai Mau approximately 46000 ha is as yet ungazzeted (Fig. 2.4.1). In early 2001, 59,134 ha (35,301 in eastern Mau, 22,797 ha in the Southwestern Mau, 713 ha in Western Mau and 103ha was designated for degazzetment.

The forest contains the largest remaining block of tropical moist broadleaf forest (Wass, 1995). The Kenya forestry Master plan (MENR, 1994) put the Mau forest catchments protection value at Kenya shillings 806 million per year being the highest in comparison with other watersheds in the country.



Source SUMAWA CRSP 2004

Fig. 2.4.1 The Mau Forest Complex

There are five main forest reserves Eastern, Western and Southwestern Mau, Trans-Mara, Ol Pusimoru the Maasai Mau. The study was carried out in the SW Mau.

2.4.2 Human habitation of the Mau complex

Expansion in human population coupled with increased demand for forestland overstretched the forest department allocation scheme for plantation establishment leading to discontinuation of the practice in 1986. The discontinuation was also in addition to illegal activities by the resident cultivators and their families. The discontinuation of the shamba system[16] poised an

[16] **Shamba system** A system of forest plantation establishment, initially common in South America (Taungya system) where native residents are assigned forest land to cultivate there crops with mutual agreement to tend forest trees planted

additional problem since communities around the forest margins took advantage moved in and settled in areas that had been cleared. This in itself presented a higher degree of threat to forest protection as these people claimed rights to ownership of the land on which they settled. In the 1990s, the forest department introduced “the Non Resident Cultivation[17]” (NRC) system for plantation establishment, attempting to reduce the risk of cultivators claiming squatter rights on forestland.

In 1986, through a presidential order and later 1988 an act of parliament so the creation of the Nyayo tea zone[18] cooperation which was assigned forest land to grow tea while providing a buffer zone between agricultural land and designated forest reserve. No definite dimensions were provided but rather a general 100 m width into the forest was nominally accepted. This was then subjected to abuse leading to destruction of forests. For example out of a possible 2152 ha cleared in the Mau only a paltry 542 ha were planted with tea leading to extensive forest loss and degradation.

The Mau complex has not been left out when it comes to carving out forests for the sole purpose of settling the “landless”. In postcolonial Kenya, each successive government has been very keen to settle people along the forest boundaries or within the clear felled forest plantations. It is estimated that 28% of forest cover in the reserve was lost between 1967 and 1989 through such excisions (Matiru 2000). Unfortunately, a number of recent excisions have also targeted the western part, which contains the most valuable, and intact tracts of closed canopy forests (Bird Life International 2003; Matiru 2000). Such excisions into the study area confounded by human activities affects the livelihood of millions of people living within and outside the reserves including those across international boundaries (KIFCON 1993).

2.5.3 Environmental factors

Annual precipitation ranges from 1000 mm in the east with a bimodal regime to 2000 mm in the west where it is more or less continuous throughout the year.

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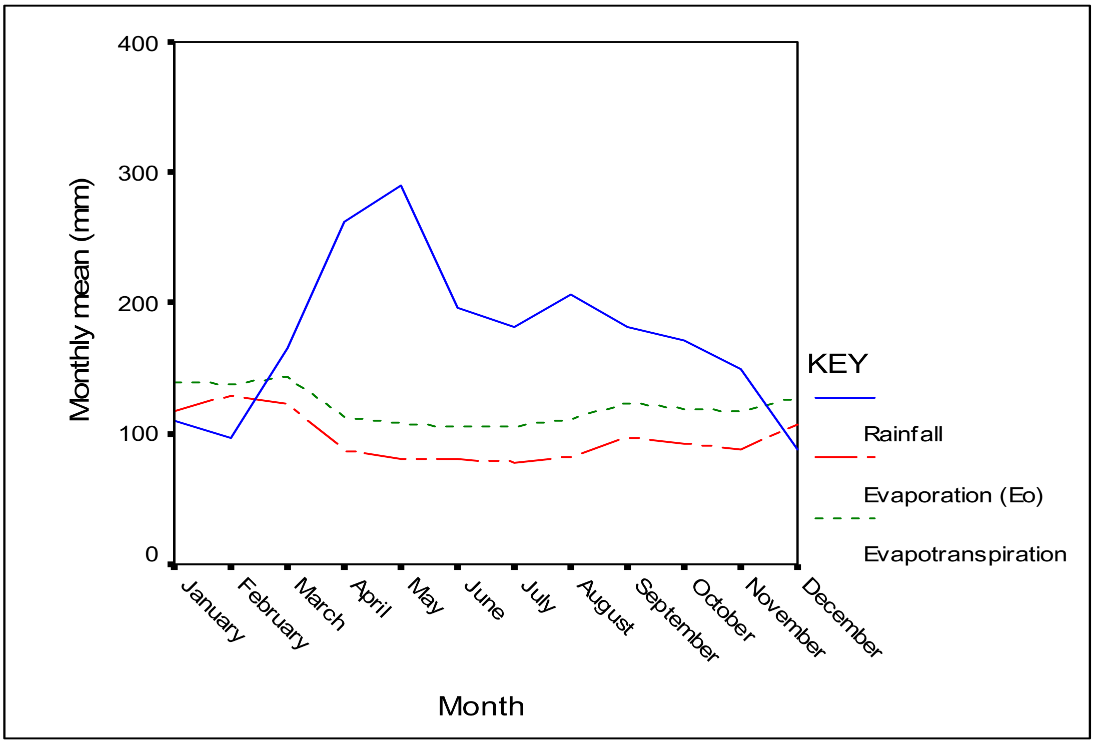
by the forest department for a specified period of time (until the crops cannot compete with the trees).

[17] **Non Resident Cultivation** Variation of the shamba system where the cultivators are not allowed to live on the forest land

[18] **Nyayo tea zone** a buffer zone created between forests and agricultural fields to check on illegal encroachment onto forest land.

Mean temperatures are in the range of 12-16°C with the greatest diurnal variation during the dry season. Potential evapotranspiration varies between 1400mm in the higher and wetter parts to 1800mm in the lower, drier zones (Jackson and McCarter 1994).

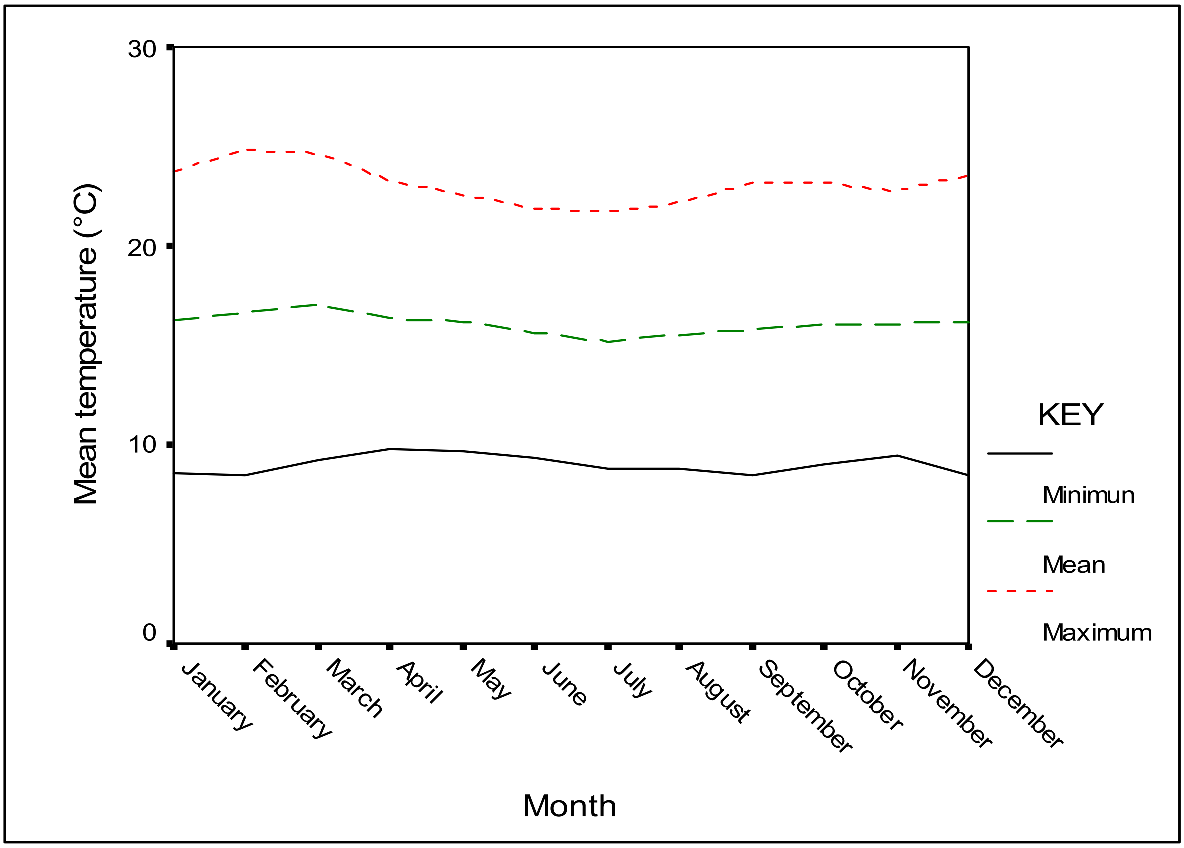
Meteorological data from 1986-2005 indicates a bimodal rainfall pattern (TRF 2005). The long rains set in March and end in June, while the short rains start in July and end in November. Mean monthly potential evaporation and evapotranspiration lag behind precipitation all the year round except in January, February and December, which represent the hottest and driest months of the year in the area.



Source, TRF 2005

Fig. 2.4.2 Monthly variations in rainfall evaporation and evapotranspiration
Twenty year mean monthly potential evaporation and evapotranspiration lag behind precipitation all the year round.

Mean monthly rainfall is highest in May and lowest in February (Fig. 2.4.1). The mean monthly temperatures seem to be almost uniform without extremely high peaks and lows (Fig.2.4.2).

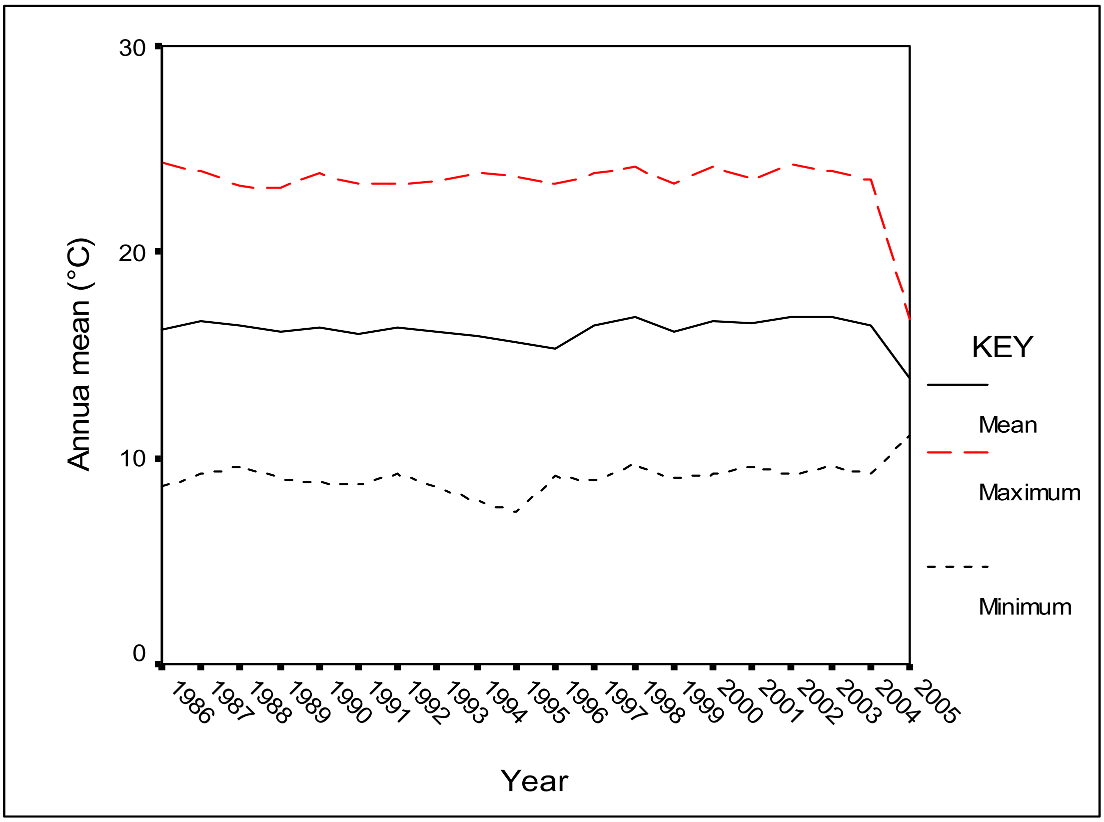


Source, TRF 2005

Fig. 2.4.3 Monthly variations in temperature regime

Mean monthly temperature regime remained stable with mean monthly minimum, maximum and mean temperatures being stable being suitable for broad-leafed evergreen montane vegetation and arable agriculture.

However, the temperature regime remained stable with mean monthly minimum, maximum and mean temperatures being stable over the period under review (Fig. 2.4.3).



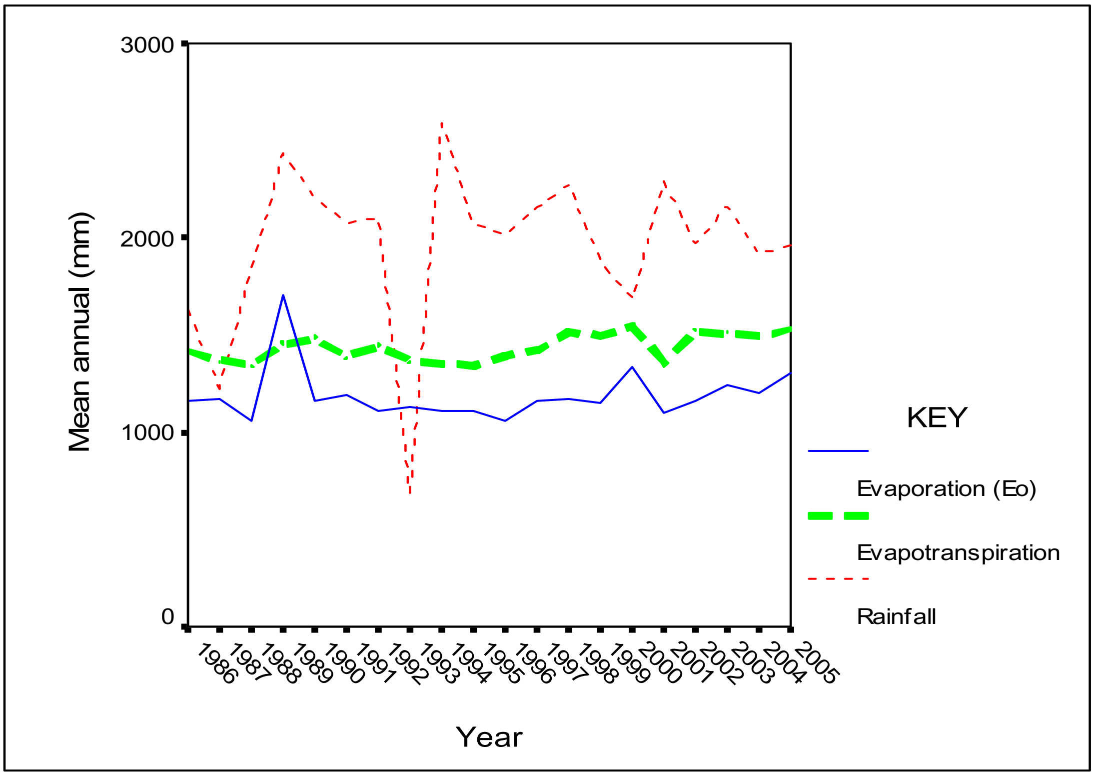
Source, TRF 2005

Fig. 2.4.4 Annual variations in temperature regime

Temperature regime remained stable with mean monthly minimum, maximum and mean temperatures being stable being suitable for broad-leafed evergreen montane vegetation and arable agriculture.

From these data, it is observed that mean monthly rainfall has been greater than the potential evaporation except in 1993 when mean monthly rainfall hit a less than 100 mm. In 1987 mean monthly rainfall lagged behind evapotranspiration. This presents a scenario where soil moisture deficits can be expected.

Comparisons for mean monthly rainfall, potential evaporation and evapotranspiration were compared over the twenty-year period indicate that evapotranspiration and potential evaporation lagged behind rainfall for the entire period except in 1993. However, in 1987 mean monthly precipitation totals lagged behind evapotranspiration. Mean monthly totals for potential evaporation were also higher than those for evapotranspiration in 1989 (Fig. 2.4.4).



Source TRF 2005

Fig. 2.4.5 Evaporation, evapotranspiration and rainfall regime

Comparisons for mean monthly rainfall, potential evaporation and evapotranspiration were compared over the twenty-year period indicated that evapotranspiration and potential evaporation lagged behind rainfall showing that there is hardly any soil moisture deficit in the area.

Given that environmental data could not be acquired for 2006 (due to logistical constraints), during which a greater part of the data collection was made, a focus on major trends of the long term environmental variability from previous years, provides an insight on the general weather conditions within the forest reserve.

2.5.4 Drainage soils, vegetation and fauna

Numerous streams drain the forests west of the escarpment, forming part of the Sondu and Mara River system, which flow into Lake Victoria, and the southern Ewaso Ngiro system, which flows into Lake Natron. The Mau has deep, fertile, volcanic soils.

Vegetation patterns of the Mau are diverse, but there is a broad altitudinal zonation from West to the East, lower montane forest below 2300 m giving way to thickets of Bamboo *Arundinaria alpina* mixed with forest and grassland, and finally to montane sclerophyllous forest near the escarpment crest.

The lower montane forest is in best condition in the Southwestern Mau Nature Reserve, characteristic tree species include *Aningeria adolfi-friedericii and Strombosia scheffleri.* Elsewhere this zone has been destructively and heavily logged, most recently for plywood from *Polyscias kikuyuensis*. Logged-over areas are dominated by pioneer species such as *Tabernaemontana stapfiana, Syzigium guineense* and *Neoboutonia macrocalyx*.

Pockets of less-disturbed forest hold *Olea capensis*, *Prunus africana, Albizia gummifera* and *Podocarpus latifolius.* Substantial parts of the high *Juniperus-Podocarpus-Olea* forest have been encroached and cleared, although sections remain in good condition. Large areas of both the Eastern and Western Mau have been converted to plantation forest with pine and cypress species.

2.5.5 Land use and socioeconomic environment

The population density around the Mau varies. Tegat sub location, Bomet District on the western side had an estimated 325 persons' km^{-2}, while Amalo sub location[19] Nakuru district eastern side had 136 persons Km^{-2} and Sogoo sub location on the southern boundary had only 37 persons' km^{-2} (KIFCON 1993).

These forest adjacent communities are mainly involved in intensive smallholder agriculture, in the Southwestern side characterized by growing proportion of cash crops (tea) and zero grazing[20] stock. In the drier areas more mixed agro pastoral land uses are found (Jackson and McCarter 1994).

It is estimated that some 11000 households are living within two kilometres of the Southwestern Mau and Transmara forests. Three quarters of these people use the forests for basic subsistence needs, including firewood, poles, forest fibres, honey collection, game meat, plant food and medicinal plants (KIFCON 1993).

The Mau forest complex reserve is not an exception to the main conservation problems facing many Kenyan forests: increasing pressure on the productive land from an expanding population. Immigration of other ethnic groups has

[19] **Sub location** The smallest central government administrative unit.

[20] **Zero grazing** A grazing method in high population density areas where high-grade dairy animals are confined and fed from housing units.

added and increased pressure on the forest resources (Bird Life International 2003).

Current use of the forest by local people includes illegal hunting, honey gathering, fuel wood collection and grazing by domestic stocks. These activities are unregulated and cause further degradation and prevent degraded areas from recovering. Infrastructure development (schools, churches, and market centres roads) is another aspect that is contributing to the loss in forest cover in this area (Matiru 2000).

3. METHODS

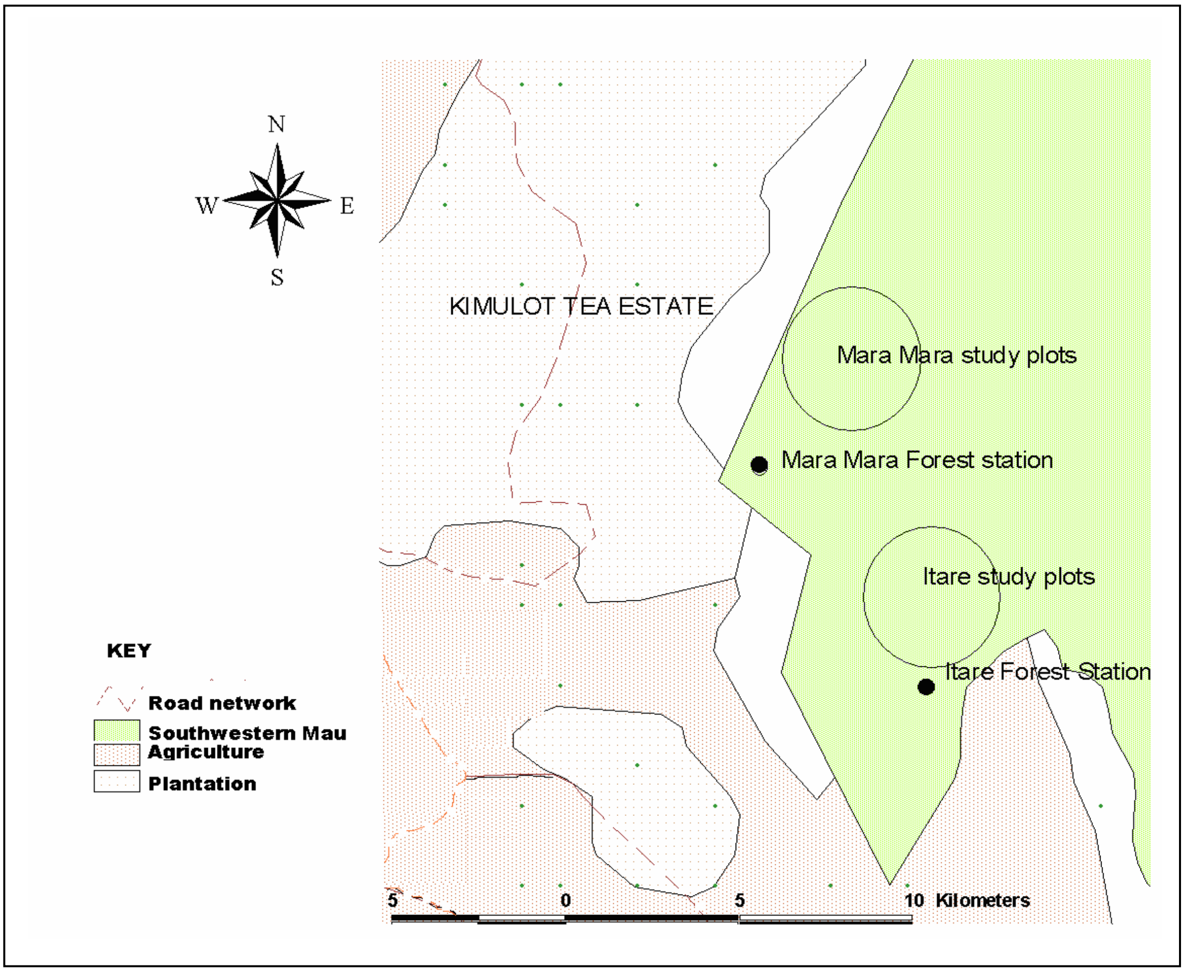
The chapter presents methods used in data collection during the study. The field investigations were carried out between October 2005 and September 2006. Two research assistants (see acknowlegdements) were recruited to assist in the data collection and field activities. They were selected based on their vast understanding of the forest reserve, since they are staff of the Kenya forest department (Mara Mara Forest Station). Their capacity in addressing the needs. of the study was evaluated before selection. Two more were recruited for the purpose of carrying out the socioeconomic survey. The study was carried out in two forest reserves (Mara Mara and Itare). An overview of the study sites is given followed by details of methods used to collect data as guided by the objectives of the study.

An assessment of vegetation structure (based on diameter, height and basal area) and composition (as defined by species richness and diversity), fine litter production, nutrient inputs, litter quality and nutrient use efficiency was done. Regeneration potential was assessed by evaluating the recruitment and germinations from seasonal seed rain as well as the seed bank. A socioeconomic assessment of the perceptions and attitudes of the inhabitants about the importance, status and causes of degradation was carried out. The provisional capacity of the reserve for goods and services was also evaluated.

A spatial-temporal analysis of vegetation cover dynamics in the reserve over the last three decades was done using remote sensing and GIS to show the extent of human related disturbance. This provided a complementary overview on the state of forest cover dynamics and land use changes in the reserve. In turn this was valuable for the pre-determination of emerging scenarios and extrapolation of the forest cover dynamics. It was intended that data and information on the impacts of anthropogenic activities on the forest reserve will help to provide informed decisions for interventions on ecosystem health and address emerging issues related to utilization efficiency by local inhabitants.

3.1 THE STUDY AREA

This study focused on the Southwestern Mau reserve. Literature shows (Matiru 2000) that it has been affected most by excision since independence as compared to the other blocks. Secondly, the forest block has households living in close proximity. Thirdly, it is the largest of the blocks and somehow has what can be termed remnants of the natural forest and finally its conservation status is critical and endangered as rated by WWF (2001). Hence forms a good study site for the determination and comparison of the effects of human activities on ecosystem health.



Source SUMAWA CRSP 2004

Fig. 3.1.1 The study sites

The figure shows the study sites Mara Mara and Itare. The plots for the enumeration of vegetation parameters as well as the areas in which the household survey was carried out are shown.

3.1 1 Field plot layout

A plot measuring (100 X 50) m was demarcated randomly in an area close to a settlement with evidence of household accessibility and use, a second was demarcated at least one kilometre from the first towards the interior of the forest reserve. The procedure was repeated three times to obtain eight plots namely Mara A disturbed (MAD) Mara A undisturbed (MAU), Mara B disturbed (MBD), Mara B undisturbed (MBU), Itare A disturbed (IAD), Itare A undisturbed (IAU), Itare B disturbed (IBD) and Itare B undisturbed (IBU). The assumption was proximity results in higher accessibility and use levels, hence more disturbances. The above plots were used in the evaluation of vegetation composition and structure, nutrient cycling, in situ regeneration and seed bank analysis. Vegetation composition, structure, regeneration studies and fine litter assessments were measured in a nested design (Bullock 1996; Hughes et al. 2000) (see Fig. 3.1.2).

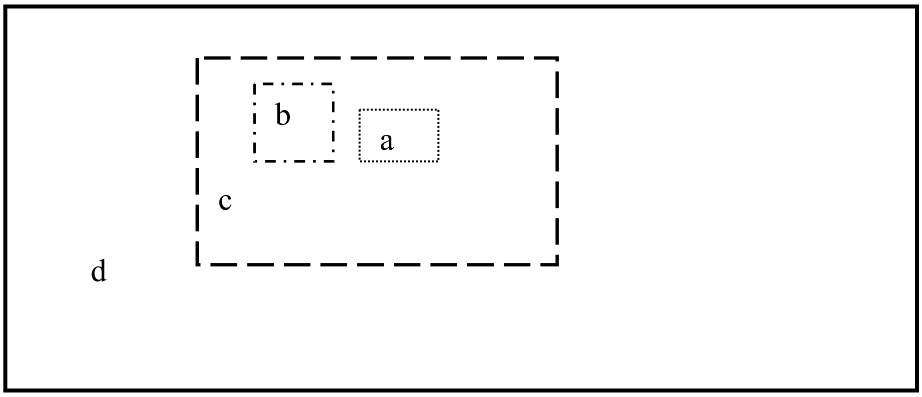


Fig. 3.1.2 Field plot design

(a) 25x25 cm micro plots for seed bank soil sampling eight (25x25) per 10X10 m plot (n = 120). (b) 50x50 cm for seedling counts 8(50x50) cm per 10x10 plot (n = 120). (c) 10x10 m plot for enumeration of shrubs and trees with dbh 10-30 cm and also trees with height > 1.3m but dbh < 10cm per 100x50 plot n = 60 (d) 100x50 m main plot for enumeration of trees with dbh 30 cm and 15 litter baskets were randomly paced in this plot.

3.2 TREE PHYTOSOCIOLOGICAL PARAMETERS

Parameters related to forest tree structural complexity (height, diameter at breast height (dbh) and basal area) and species composition and diversity were evaluated.

3.2.1 Methods

Stratified random sampling according to Islam et al 2000 was used to measure phytosociological parameters at three stand height levels within the plot: (1) the over storey, (2) the under storey and (3) the ground layers. All variables related to trees with diameter greater than 30 cm at breast height (dbh[21]) were measured in the (50 x 100) m plot (d). Diameter and height were measured using large diameter callipers (Haglöf Aluminium calliper (65 cm for small trees

[21] **Diameter at breast height** (dbh) A measure at breast height (4.5 feet), over bark, of the tree bole, perpendicular to the tree bole.

and 127cm for large trees) and a clinometer (Haglöf Electronic Clinometer) respectively.

Parameters related to trees with dbh 10-30 cm were measured in 15 (10x 10) m plot nested within the larger plot. Sub canopy trees (more than 1.3 m in height but less than 10cm dbh was measured in 15 (10x10) m plots. Parameters related to plants less than 1.3 m high (tree seedlings) were measured in eight (50x 50) cm (n = 120) micro plots established in each of the 10x10 subplots. All tree seedlings were counted per species. The above procedures were repeated in eight plots equally representing the disturbed and undisturbed sites.

All individuals larger than 3 cm over bark diameter at breast height (dbh) were enumerated and their heights recorded. The over storey forest species were classified into tree and sapling categories. A tree in this context was defined as a woody plant with minimum dbh of 10cm while a sapling was regarded as a woody species with dbh of 3-10 cm.

The under storey represented the seedling and shrub layer which included all individual woody species less than 3 cm dbh and having height greater than 30 cm. Species characterized by short stature, with irregular boles were classified as shrubs.

Tree species diversity was expressed as the number of species present (S). This was used as the first pass estimate of diversity. This is largely a descriptive factor and does not reflect relative abundance. In order to have an effective measure of diversity and account for both richness and the abundance a proportional abundance index the Shannon-Wiener diversity index (H´) was used with the assumptions that randomness in sampling was achieved (Shannon and Wiener, 1963).

The index combines two quantifiable measures, 1) the species richness S (the number of species in the community) 2). abundance N (is the total number of individuals in the sample). The index is termed H’ with higher values indicating increased diversity. Evenness J is equal to the H’ divided by maximum possible diversity (In of S). The values for evenness range from zero to one where a sample of equal numbers of individuals of the same species has a value of one.

Shannon Wiener diversity index

$$H' = -\sum_i^n (pi)(\ln pi)$$

……………………………… (1)

Evenness J = $H' / \ln S$

… ………………………… (2)

where

H' = Information content of sample, Index of species diversity, or *degree of uncertainty*,
p_i = Proportion of total sample belonging to **i**th species
lnpi = natural logarithm of the proportion
S= Number of species

This was done within the assumption that all species are represented in the sample (Magurran 1988; Roth et.al. 1994; Rosenzweig 1995; Begon, et.al. 1996).

The enumerated trees were further classified into seedlings/wildings, shrubs, under storey trees and over storey trees using diameter and height. The criteria for classification were as follows:

Table 3.2.1 Criteria for diameter and height classification
This was in order to delineate the proportionate contribution of each class to the architectural structure of the forest

Measurement level	Diameter (cm)	Height (m)
Seedlings/wildings	0.00 –3.00	0.00 – 1.30
Shrubs	3.10 – 9.99	1.31 – 10.00
Under storey trees	10.00 – 29.99	10.01 – 19.99
Over storey trees	30.00 – 100.00	20.00 - 60.00

Source Adapted from Kuchler 1949

Trees with diameter more than 10cm were used in the evaluation of the structural complexity. For quantification of forest structure for trees over 10 cm dbh a complexity index was used (Holdridge et al. 1971). The index was calculated from the following equation

HC = (A x d x n x h) / 1500 m^2……………………………………………..(3)

Where

HC = Holdridge's complexity index,
A = basal area ($m^{2)}$ d = tree density i.e. the of trees/1500m^2,
n = number of species/1500m^2,
h = mean tree height in metres.

3.2.2 Data analysis

Distribution of the parameters was given for the general study area and also comparisons made for the disturbed and undisturbed plots. Descriptive statistics especially the mean and measures of spread (standard deviation) were also given. Data was analysed using SPSS for Windows Version 12 (SPSS 2003).

Test hypotheses were:

- Species richness is higher in the undisturbed plots than in the disturbed plots.
- Shannon Wiener diversity index is higher in the undisturbed plots than in the disturbed.
- The structural complexity (Holdriedge's HC) is higher in the undisturbed plots than in the disturbed plots.

These were falsified if the mean values for the variables in disturbed plots were significantly higher than those in the undisturbed plots.

Test for equality of means in the sampling plots was done using one way ANOVA after 95% confidence intervals of the mean indicated such differences (Bohrnstedt and Knoke 1994). In order to determine the exact plots that exhibited differences in the means of the above phytosociological parameters Levene test was used to ascertain the homogeneity of variances. Where the variances were unequal the Welch test was used to test the equality of means. Multiple comparisons using LSD were carried out to delineate the exact significant differences among the study plots. Independent samples T-test was used to compare pooled means across disturbed and undisturbed plots. A general linear model using univariate analysis of variance was used to determine the sources and significance of variation in species richness, distribution of diameters and heights between forest sites, study plots and state of the study plots in terms of disturbance. (Bohrnstedt and Knoke 1994; Sheskin, 1997; Lomax 2001).

3.3 VEGETATION REGENERATION CAPACITY AND POTENTIAL

Three possible regeneration pathways were assessed and their potential evaluated in the study plots. The study evaluated 1). the potential of in situ regeneration from seed rain over time, 2). the capacity of the seed rain through the assessment of seasonal germination and 3). the value and potential of the seed bank. All the above were assessed in the disturbed and undisturbed study plots.

3.3.1 Methods

Seedling recruitment from annual seed rain was measured in (10x10) m plots nested in the 50x100 m. Tree seedlings with h < 1.3 metres were tallied in 8 (50X50) cm (n = 120) micro plots nested in the 10x10 m plots. Seedling counts and height measurements were made for the dry and wet season. Seedling tallies including densities, names of species and their respective families for the disturbed and undisturbed sites were recorded. Germination from seasonal seed rain was measured after the onset of rains. Seedlings from this germination were enumerated in 15 (50x50) cm subplots (n = 120) randomly located in the (100X50) m plots.

In the 10x10 plots eight (25x25) cm micro plots were nested (n = 120). Soil samples were scooped up to 15cm depth for seed bank assay. This was done for both the disturbed and undisturbed sites. The soil samples were well mixed to derive a composite sample for each of the 10x10m plot. Fifteen sub samples were drawn from the composite sample and treated to regular ample watering regime in the nursery. A control of sterile vermiculite was placed together with the treatments to check any contaminations from the nursery environment.

Germination and subsequent identification of tree and shrub species was monitored for a period of six months. Seedling tallies for the disturbed and undisturbed sites were recorded. The layout in the nursery is illustrated below.

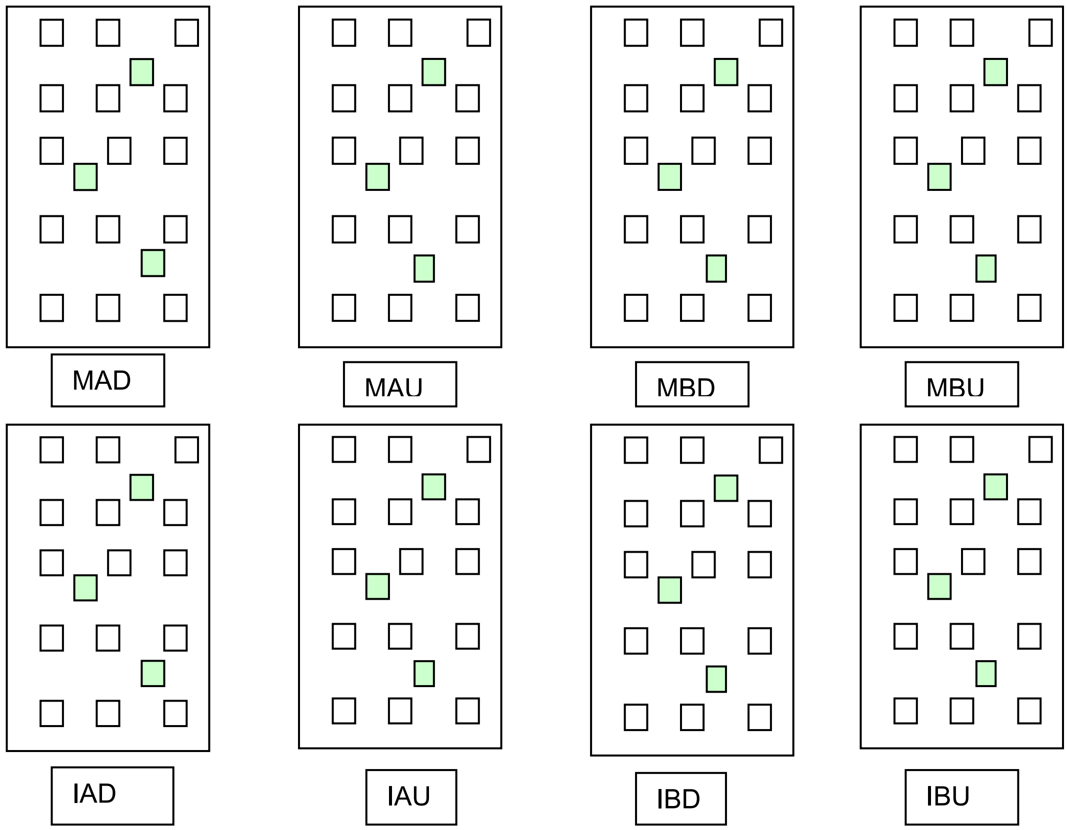


Fig. 3.1.3 Seed bank assay experimental layout
Fifteen soil bank samples were drawn for each sampling plot. Three control samples (per plot) of sterilized vermiculite (green) were used to check for contamination from the nursery conditions.

3.3.2 Data analysis

Data was analysed using SPSS for Windows Version 12 (SPSS 2003). The test hypotheses were

- Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from annual seed rain.
- Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from seasonal annual seed rain.
- Undisturbed sites had a significantly higher regeneration capacity and potential than the disturbed sites from the seed bank.
- Species richness in the undisturbed plots were significantly higher than that in disturbed plots.

These were falsified if the means of the variables in the disturbed plots were significantly higher than those in the undisturbed plots.

In order to determine whether there were any significant differences in species richness as well as their seedling densities in the sampling plots for seedlings germinating from the seed rain of the previous season; 95% confidence intervals of the mean and one-way analysis of variance were used where homogeneity of variances was achieved. Otherwise, the Welch test which is more conservative and powerful. Independent samples T-test was used to compare pooled means across disturbed and undisturbed plots (Bohrnstedt and Knoke 1994; Sheskin 1997; Lomax 2001).was used. Multiple comparisons using LSD were further used to delineate the plots that had significant mean differences.

For seed bank data differences in representation of the mean number of families, genera and species in the assessment plots, 95% confidence intervals of the mean number were used (Bohrnstedt and Knoke 1994).

A general linear model using univariate analysis of variance was used to determine the sources and significance of variation in seedling species richness, among forest sites, study plots and state of the study plots in terms of disturbance.

3.4 FINE LITTER PRODUCTION; NUTRIENT FLUX AND USE EFFICIENCY

This study investigated the influences of human activities on forest reserve productivity and nutrient cycling in the fine litter compartment. The overall objective was to understand the effects of human disturbances on site litter quantity (annual litter production) and quality (C: N and C: P ratios). Stand nutrient cycling and nutrient use efficiency in the same compartment were also evaluated. The specific objectives were to investigate if and how annual litter quantity and quality varies between disturbed and undisturbed sites in the forest reserve.

3.4.1 Methods

Fifteen litter baskets ($0.5m^2$) were randomly placed at positions at least one metre above the ground in each of the 8 (50x100)m plots (n = 120). They were constructed of stainless wire ring and fine mesh screen bottom. Collections from these baskets were made every 28 days. The harvested material was placed in paper bags labelled and taken to the laboratory, refrigerated and dried at 65 ^{o}C and weighed to the nearest 0.01g. The oven dry weight of the litter was used to estimate the fine litter production of the sites.

A composite sample of the oven-dried litter was drawn for analysis of nitrogen (N), phosphorus (P) potassium (K) magnesium (Mg), calcium (Ca) and carbon (C). The litter was ground to pass through a 0.5mm mesh screen. In determining the dry weight of the samples, 5 grammes of the fine ground litter was weighed in porcelain crucibles and dried overnight at 105°C. The samples were then cooled to room temperature in desiccators and reweighed. The crucibles were emptied and cleaned thoroughly dried overnight and reweighed the next day. The water content of the samples were determined by subtracting the oven dry weight of sample from the wet weight of sample.

Extractions for the determination of litter phosphorus potassium calcium and magnesium concentrations in the samples were done. The litter samples were weighed and ashed overnight at 550°C. They were then cooled to room temperature in desiccators. The ash was then inserted on a sand-bath and 10 ml 3 mol HCl (Hydrochloric acid) added and evaporated. This was repeated once with evaporation for at least 90 minutes. After cooling, the samples were conveyed with 12.5 ml 10 mol HCl and hot water into 250 ml volumetric flask. On cooling to room temperature the new samples were adjusted to the 250 ml mark and filtered into PE bottles using a fluted filter.

Litter phosphorus concentrations were determined using the “flow injection-method” and a colorimetric method with ammonium molybdate on a Tecator Sampler 5027 and Analyser 5012. Potassium, calcium and magnesium were measured with a Philips Atomic Absorption Spectrophotometer PU9100. Values of P, K, Ca and Mg were given milligram’s P(or K, Ca and Mg) per litre extract. Element content in milligram’s (P, K, Ca and Mg) per 100g dry litter weight was calculated as follows:

(P, K, Ca and Mg) per 100g = (A/B)x10) x Water factor ………………………..(4)

Where

A = P(or K Ca and Mg)/l Extract

B = litter air dry weight

Water factor = 100/(100-Water content in %).

An estimate of total %C and %N concentration was determined from the combustion of random samples using gas chromatography on a EuroEA3000 Element Analyzer. Measurements of litter C content was used to calculate mass based C: N and C: P ratios that were in turn used to define site quality for the study sites.

Total fine litter nutrient inputs (Kg ha^{-1} yr^{-1}) to the sites were calculated by multiplying monthly litter production values for each sampling site by nutrient concentration for the same site and month and adding them over the entire year (Read and Lawrence 2003). These annual nutrient input values were used to calculate within stand nutrient use efficiency (NUE) defined as kilograms of dry litter mass per kilogram of nutrient content (Vitousek 1982; Vitousek 1984). This was used to assess and define stand nutrient cycling (Vitousek 1982; Vitousek 1984; Vitousek and Silver 1994).

3.4.2 Data analysis

Data was analysed using SPSS for Windows Version 12 (SPSS 2003). The test hypotheses were

- ❖ Within stand fine litter annual production is significantly higher in the undisturbed plots than in the disturbed plots.
- ❖ Within stand nutrient input is higher in the undisturbed plots than in the disturbed plots.
- ❖ Fine litter quality is higher in the undisturbed plots than in the disturbed plots.

These hypotheses were falsified when the annual production, nutrient input, litter quality and nutrient use efficiency values in the disturbed plots were significantly higher in the disturbed plots.

Monthly and annual fine litter means in Kg/ha for the sites was recorded. Site monthly mean differences were tested using ANOVA. Annual mean nutrient inputs were recorded in Kg ha^{-1} yr^{-1}. A test for homogeneity of variances was done using the Levene statistic (Bohrnstedt and Knoke 1994; Sheskin 1997; Lomax 2001). Site patterns in mean annual litter concentrations and nutrient use efficiency (NUE) was analysed using simple ANOVA where variance homogeneity was achieved and the Welch test where homogeneity of variances was not achieved. Independent samples T-test was used to compare pooled means across disturbed and undisturbed plots (Bohrnstedt and Knoke 1994; Sheskin 1997; Lomax 2001).

A general linear model using univariate analysis of variance was used to determine the sources and significance of variation in annual fine litter inputs and litter quality among forest sites, study plots and state of the study plots in terms of disturbance.

3.5 SOCIOECONOMIC AND ECOLOGICAL CHARACTERIZATION

In order to assess individual local actions at the household level and their effects on the overall health dynamics in the forest reserve, information about the direct and indirect drivers of forest degradation at the forest reserve level was sought. The perceptions and attitudes of the inhabitants regarding supply of ecosystem goods and services at the forest reserve scale were evaluated. This was executed using a household survey.

3.4.1 Socioeconomic survey

Qualitative data was collected through focus group discussions as suggested by Harvey and Macdonald (1993). Enumerators (see acknowledgements) were trained for 2 days. Questionnaires (Appendix 8.5) were administered to 150 rural households selected at random from the study area. Single visit personal interviews were conducted to collect quantitative data. The head of the household was interviewed and responses recorded. Other members of the household were encouraged to participate whenever the head of the household were required to recall events. The questionnaire was pre-tested before commencement of the study and appropriate adjustments made. Personal observations were made by the interviewer in order to verify some of the information given. Interview schedules were used to guide these discussions (Appendix 8.6).

The unit of analysis was the household while the total number of households in the study areas constituted the sampling frame. The choice of the household was rationalized as follows:

a) Many research efforts on the subject of ecosystem health have largely been macro in approach to the extent that they have ignored the household.

b) The household provides an important matrix, which facilitates an analysis of ecosystem services supply and demand issues.

c) The household is also an important decision making organ with potential to influence regional and even landscape scenario.

d) It is the unit that is directly affected by the impacts of degradation of ecosystem health.

The sampling design was purposive random sampling (Harvey and Macdonald 1993; Bohrnstedt and Knoke 1994). The sampling units were selected within five kilometres of the forest reserve boundary. A household was selected alternately at a distance at least one kilometre from the previous. The operationalisation of the study variables is shown in Table3.4.1.

Table 3.4.1 Operationalisation of study variables

The table shows the description of the measurement levels of the variables. household socio-ecological wellbeing and household wellbeing

Variable	Descriptors
Ecosystem health	Adequacy of supplied goods/services
Importance of goods/services,	Access to goods and services socioeconomic welfare,
	shortage of goods, forest condition, number of species storeys
	population of wild animals and dominant tree species
Threats to ecosystem services.	Changes in land use
	Growth in population size
	Resource utilization
	Introduction or removal of species
	Infrastructural changes
Consumption of vegetation resources	Firewood
	Timber
	Thatching grass
	Herbal medicine
	Fodder/pasture
Household socioeconomic wellbeing	Household size
	Marital status
	Income
	Accessibility to health services
	Housing
	Land tenure arrangements
Time and period of occupancy	Year of settlement
	Number of years settled
	Distance from forest boundary

In order to define an index for the health of the forest reserve selected variables were redefined and weighted in order to calculate the indices (Harvey and MacDonald 1993; Bohrnstedt and Knoke 1994)). It was considered for example, that the more important goods were ranked by the community the more they were used or obtained from the reserve and hence the health was considered impaired.

Similarly, the more accessible the reserve is the more the disturbance and hence less value. Adequacy of the goods and services was also considered and it is argued that the higher the adequacy the less the competition and hence higher health levels. Shortage of resources was also considered an important measure of the health of the reserve with shortages representing poor health while no shortages showing good health. Scores were then assigned to the various levels of the variables as shown in Table 3.4.2.

Table 3.4.2 Criteria for assigning scores to selected variables

Assignment of scores to variables included in the index describing household-socioecological health.

Variable	Value labels	Score	Variable	Value labels	Score
Importance of goods and services	Very important	0	Marital status	Married	4
	Important	1		Single	3
	Moderate	2		Widowed	2
	Not important	3		Divorced	1
	Not at all	4	Size of house	Several	3
Adequacy of goods and services	Very adequate	3		Large	2
	Adequate	2		Medium	1
	Inadequate	1		Small	0
	Very inadequate	0	Occupation	Civil servant	4
Access to goods and services	Accessible	0		Teacher	3
	Inaccessible	1		Business	2
Resource shortage	In short supply	0		Farmer	1
	No shortages	1	Housing type	Permanent	3
Household income (Ksh)	0-624000	1		Iron sheet roof	2
	624001–1248000	2		Grass thatched	1
	1248001–1560000	3		Temporary	0
	1-4	4	Land tenure	Title deed	4
	5-8	3		No title deed	3
	9-12	2		Hired/rented	2
Household size	13-16	1		Communal	1
Health facilities	Very satisfied	3		Squatter	0
	Satisfied	2	Household socio-ecological health	Sum total of the above scores	
	Moderately satisfied	1			
	Not satisfied	0			

Using the above criteria the following indices were constructed for the definition of household socio-ecological health. (Table 3.4.3).

Table 3.4.3 Descriptors of household socio-ecological health

Resultant range of scores of variables included in the indices for definition and description of household socio-ecological well-being and household socioeconomic well-being.

Variable	Description	Range of Score
Importance value of the reserve in providing services (IFS)	Very important	0-7
	Important	8-15
	Moderately important	16-23
	Not important	24-30
Importance value of the forest in providing goods (IFG)	Very important	0-3
	Important	4-7
	Moderately important	8-11
	Not important	12-15
Adequacy value for goods derived from the reserve (AG)	Very adequate	21-27
	Adequate	14-20
	Moderate adequacy	7-13
	Inadequate	0-6
Shortage value of goods obtained from the reserve (SG)	Acute shortage.	0.0-2.5
	High shortage	3.0-5.5
	Moderate shortage	6.0-8.5
	No shortage	9.0-11.5
Accessibility to goods and services (AFR)	High accessibility	0
	No access	1
Current land use value (CLU)	Farmland,	0
	Pasture	1
	Forests	3
Household socioeconomic wellbeing values (HHW)	Very good	21.0-23.5
	Good	18.0-23.5
	Satisfactory	15.0-17.5
	Fair	12.0-14.5
Household socio-ecological health values (HSEH)	Very healthy.	71.0-83.5
	Healthy	58.0-70.5
	Moderately healthy	43.0-57.5
	Not healthy	30.0-42.5

3.4.2 Data analysis

Data was analysed using SPSS for Windows Version 12 (SPSS 2003). Frequency distributions for the descriptor variables were done. Descriptive and inferential statistics were also used. An attempt was made to determine the relationship between the calculated predictors and household socio-ecological health. Pearson product moment correlation coefficient was used.

3.5 GIS BASED DETECTION OF FOREST COVER DYNAMICS

Determination of the state of forest cover between 1984 and 2003 was done. This was facilitated by use of remote sensed data LANDSAT (TM) satellite image for 1984 (Landsat 5TM 1 July 1984 Path 169 Row 060 and Landsat 7ETM 4th.February 2003. Path 169 Row 060 Vegetation cover was determined by the colour tone, the distribution form and texture of plant covered areas. Forest cover change was determined by comparing the two images.

3.5.1 Image processing

The Landsat multispectral data sets were obtained in separate files. In order to consolidate the different bands into one single file layer stack function in Image analysis for ArcGIS (Leica Geoosystems) was used (Booth-Lamirand 2003). The greyscale single bands 4,3, and 2 were combined together to obtain a multiband multispectral data set.

Image classification was performed with six target classes (Closed canopy forest, bare ground, settlements, agricultural fields, scattered trees and secondary vegetation or re-growth). The purpose was to provide a framework for organising and categorizing information that could be extracted from the data (Jensen et al.1996). The classification scheme included classes that were both important to the study and discernible from the data at hand. This was designed to be hierarchical in structure providing an avenue to describe the study area in several levels of detail. Unsupervised classification was used since the ground truthing data was collected in 2006 yet the images data were of later years hence could increase errors in identification and assignment of training samples for supervised classification. Furthermore supervised approach is subjective in the sense that the analyst tries to classify information categories, which are often composed of several spectral classes whereas spectrally distinguishable classes were revealed by the unsupervised approach hence greatly reduce ground data collection requirements (Kumar 2004).

The classification was based on the Iterative Self Organising Data Analysis Technique (ISODATA) (Tou and Gonzalez 1974) a clustering method that uses spectral distance as in the sequential method, but iteratively classifies pixels, redefines the criteria for each class and repeats the classification, so that the spectral distance pattern in the data gradually emerge. The method utilizes minimum spectral distance to assign a cluster for each candidate pixel. The process begins with a specified number of arbitrary cluster means or the means of existing signatures, and then processes repetitively, so that those means shift to the mean of the clusters in the data.(Booth-Lamirand 2003; Kumar 2004)

Resulting classes from the unsupervised classification were compared and confirmed from 1: 50000 topographic map of the study area from the Survey of Kenya. However, since the map were relatively old most of the confirmations relied on the vast knowledge of the area gained during the fieldwork.

3.5.2 Forest cover change detection

Change detection involved the comparison of 2003 image with that of 1984. The Image difference function of Image Analysis for ArcGIS has the ability to conveniently perform change detection by comparing two images of the same place from different times. It is particularly useful in plotting environmental changes such as urban sprawl, deforestation or damage caused by wild fires or tree diseases (Booth-Lamirand 2003). In image difference one is able to highlight specific areas of change at a predetermined level. Image difference resulted in two images, a greyscale continuous image and a five class thematic image.

The first image generated represented the difference created by subtracting the Before image from the After image. Change was calculated in brightness values over time, implying that brighter areas have increased in reflectance. This was interpreted to mean an area has lost vegetation cover over time. Similarly, dark areas have decreased reflectance and hence have become more vegetated.

The second image represented the highlight difference image. The thematic image was divided into five change categories; decreased, some decreased, unchanged, some increased and increased. The decreased class represented areas of negative (darker) change greater than the set threshold for change and is the red colour (15%). The increased class represented areas of positive (brighter) change greater than the threshold set at (15%) and shown in green colour. Other areas of positive and negative change less than the threshold and areas of no change were shown as transparent.

The algorithm used was based on subtraction of two images on a pixel-by-pixel basis executed as follows

1) the before image was subtracted from the after image,
2) the resulting decrease percent was converted into a value,
3) the resulting increase percent was converted into a value,
4) If the difference was less than the decrease value assign the pixel to class 1 (Decreased) and
5) If the difference was greater than the increase value assign the pixel to class 5 (Increased).

Thematic change analysis (1984-2003) for the Mau forest complex was done using Image Analysis for ArGIS 9.2 (Leica Geosystems). This was done in order to identify areas that had undergone change over time. It was performed after classification of the data.

Thematic change creates an output image from two raster files. The class values of the two input files were organised into a matrix. The first input file specifies the columns of the matrix and the second one specified the rows. Zero was not treated in any special way. The number of classes in the output file was the product of the number from the two input files.

Using the categorizations of the before and after themes the type of changes over time was identified. Of importance to this study was the change from closed canopy forest to other land use categories over time. A thematic image with all possible combinations of the change was produced.

4. RESULTS

This section presents the results of the study based on the various themes, which have been addressed. Descriptive statistics are given followed by inferential statistics to test hypotheses. Multiple comparisons are used to determine significant differences in the study variables across the study plots.

4.1 VEGETATION COMPOSITION AND STRUCTURE

An account of the distribution of families, genera and species in the study plots is given. Comparisons between disturbed and undisturbed sites are illustrated for families, genera and species alike; species diversity index for the two sites also are also illustrated. The distribution of diameters and heights in the study sites is recorded and illustrated as measures of structure. Holdridge's index of complexity of the two sites is then provided.

4.1.1 Vegetation floristic composition

A total of 1415 individuals belonging to 24 families, 34 genera and 37 species of woody species comprising mainly trees were enumerated (see Table 4.1.1).

Table 4.1.1 Tree floristic composition in the study area

A list of all the species of trees enumerated in the study plots distinguished in their respective families and genera.

Family	Freq(%)	Genus	Freq(%)	Species	Freq
Alariaceae	30(2.1)	*Polycias*	30(2.1)	*P. fulva*	30
Alangiaceae	5(.4)	*Alangium*	5(0.4)	*A. chinense*	5
Apocynaceae	129(9.1)	*Tabernaemontana*	129(9.1)	*T. stapfiana*	129
Asteraceae	83(5.9)	*Vernonia*	83(5.9)	*V. auriculifera*	83
Bignoniaceae	22(1.6)	*Spathodea*	22(1.6)	*S. campanulata*	22
Caricaceae	2(0.1)	*Cylicomorpha*	2(0.1)	*C. perviflora*	2
Ebenaceae	46(3.3)	*Diospyros*	46(3.3)	*D. abyssinica*	46
Euphorbiaceae	379(26.8)	*Neoboutonia*	327(23.1)	*N. macrocalyx*	327
		Macaranga	14(1.0)	*M. kilimandscharica*	14
		Bridelia	10(0.7)	*B. micrantha*	10
		Strombosia	1(0.1)	*S. schefferi*	1
		Croton	27(1.9)	*C. macrostachyus*	26
				C. megalocarpus	1
Flacourtiaceae	9(0.6)	*Dovyalis*	9(0.6)	*D. macrocalyx*	1
				D. lucida	8
Lobeliaceae	6(0.4)	*Lobelia*	6(0.4)	*L. giberroa*	6
Meliaceae	29(2.0)	*Ekebergia*	29(2.0)	*E. capensis*	29
Mimosaceae	90(6.4)	*Albizia*	90(6.4)	*A. gummifera*	90
Monimiaceae	6(0.4)	*Xymalos*	6(.4)	*X. monospora*	6
Myrtaceae	148(10.5)	*Syzigium*	148(10.5)	*S. guineense*	148
Rizophoraceae	16(1.1)	*Cassipourea*	16(1.1)	*C. malosana*	16
Rubiaceae	137(9.7)	*Lasianthus*	8(.6)	*L. kilimandscharicus*	8
		Psychotria	113(8.0)	*P. mahonii*	113
		Galiniera	11(0.8)	*G. coffeiodes*	11
		Vangueria	4(0.3)	*V. infausta*	4
		Rothmannia	1(0.1)	*R. urcelliformis*	1
Rutaceae	57(4.0)	*Zanthoxylum*	51(3.6)	*Z. gilletii*	51
		Teclea	6(.4)	*T. nobilis*	6
Rosaceae	101(7.1)	*Hagenia*	10(0.7)	*H. abyssinica*	10
		Prunus	91(6.4)	*P. africana*	91
Sapindaceae	18(1.3)	*Allophylus*	18(1.3)	*A. abyssinicus*	18
Samydaceae	33(2.3)	*Casearia*	33(2.3)	*C. battiscombei*	33
Sapotaceae	2(0.1)	*Aningeria*	2(0.1)	*A. adolfi-friederieri*	2
Sterculiaceae	14(1.0)	*Dombeya*	14(1.0)	*D. torrida*	13
				D. goetzenii	1
Ulmaceae	16(1.1)	*Celtis*	16(1.1)	*C. africana*	16
Verbenaceae	37(2.6)	*Clerodendrum*	37(2.6)	*C. myricoides*	37
24	**1415(100)**	**34**	**1415(100)**	**37**	**1415**

Among the 24 families encountered, 20 were represented in the undisturbed sites while 21 were present in the disturbed sites (see Table 4.1.2).

Table 4.1.2 Tree floristic composition by sampling sites

A list of all the species of trees enumerated in the study plots distinguished in their respective families and genera. Figures in bold show tree species enumerated in undisturbed plots while the others represent the disturbed sites.

Family	Freq (%)	Genus	Freq (%)	Species	Freq (%)
Alariaceae	16(2.2) **14(2.0)**	*Polycias*	16(2.2) **14(2.0)**	*P. fulva*	16(2.2) **14(2.0)**
Apocynaceae	23(3.1) **106(15.5)**	*Tabernaemontana*	23(3.1) **106(15.5)**	*T. stapfiana*	23(3.1) **106(15.5)**
Alangiaceae	**5(0.7)**	*Alangium*	**5(0.7)**	*A. chinense*	**5(0.7)**
Asteraceae	75(10.2) **8(1.2)**	*Vernonia*	75(10.2) **8(1.2)**	*V. auriculifera*	75(10.2) **8(1.2)**
Bignoniaceae	9(1.2) **13(1.9)**	*Spathodea*	9(1.2) **13(1.9)**	*S. campanulata*	9(1.2) **13(1.9)**
Caricaceae	2(0.3)	*Cylicomorpha*	2(0.3)	*C. perviflora*	2(0.3)
Ebenaceae	**46(6.7)**	*Diospyros*	**46(6.7)**	*D. abyssinicaa*	**46(6.7)**
Euphorbiaceae	200(27.3) **179(26.2)**	*Neoboutonia*	167(22.8) **160(23.4)**	*N. macrocalyx*	167(22.8) **160(23.4)**
		Macaranga	9(1.2) **5(0.7)**	*M. kilimandscharica*	9(1.2)**5(.7)**
		Bridelia	3(0.4) **7(1.0)**	*B. micrantha*	3(0.4)**7(1.0)**
		Croton	22(3.0) **5(0.7)**	*C. macrostachyus*	21(2.9)**5(0.7)**
				C. megalocarpus	1(0.1)
		Strombosia	**1(0.1)**	*S. schefferi*	**1(0.1)**
Flacourtiaceae	2(0.3) **7(1.0)**	*Dovyalis*	2(0.3) **7(1.0)**	*D. macrocalyx*	**1(0.1)**
				D. lucida	2(0.3) **6(0.9)**
Lobeliaceae	6(0.8)	*Lobelia*	6(0.8)	*L. giberroa*	6(0.8)
Meliaceae	5(0.7) **24(3.5)**	*Ekebergia*	5(0.7) **24(3.5)**	*E. capensis*	5(0.7) **24(3.5)**
Mimosaceae	29(4.0) **61(8.9)**	*Albizia*	29(4.0) **61(8.9)**	*A. gummifera*	29(4.0) **61(8.9)**
Monimiaceae	**6(0.9)**	*Xymalos*	**6(0.9)**	*X. monospora*	**6(0.9)**
Myrtaceae	76(10.4) **72(10.5)**	*Syzigium*	76(10.4) **72(10.5)**	*S. guineense*	76(10.4) **72(10.5)**
Rizophoraceae	2(0.3) **14(2.0)**	*Cassipourea*	2(0.3) **14(2.0)**	*C. malosana*	2(0.3) **14(2.0)**
Rubiaceae	97(13.3) **40(5.9)**	*Galiniera*	5(0.7) **6(0.9)**	*G. coffeiodes*	5(0.7)**6(0.9)**
		Psychotria	88(12.0) **25(3.7)**	*P. mahonii*	88(12.0) **25(3.7)**
		Lasianthus	**8(1.2)**	*L. kilimandscharicus*	**8(1.2)**
		Vangueria	4(0.4)	*V. infausta*	4(0.5)
		Rothmannia	**1(0.1)**	*R. urcelliformis*	**1(0.1)**
Rutaceae	30(4.1) **27(4.0)**	*Zanthoxylum*	28(3.8) **23(3.4)**	*Z. gilletii*	28(3.8) **23(3.4)**
		Teclea	2(0.3) **4(0.6)**	*T. nobilis*	2(0.3)**4(0.6)**
Rosaceae	92(12.6) **9(1.3)**	*Prunus*	82(11.2) **9(1.3)**	*P. africana*	82(11.2) **9(1.3)**
		Hagenia	10(1.4)	*H. abyssinica*	10(1.4)
Sapindaceae	14(1.9) **4(0.6)**	*Allophylus*	14(1.9) **4(0.6)**	*A. abyssinicus*	14(1.9) **4(0.6)**
Samydaceae	17(2.3) **16(2.3)**	*Casearia*	17(2.3) **6(2.3)**	*C. battiscombei*	17(2.3) **16(2.3)**
Sapotaceae	**2(0.3)**	*Aningeria*	**2(0.3)**	*A. adolfi-friederieri*	**2(0.3)**
Sterculiaceae	14(1.9)	*Dombeya*	14(1.9)	*D. torrida*	13(1.8)
				D. goetzenii	1(0.1)
Ulmaceae	15(2.0) **1(0.1)**	*Celtis*	15(2.0) **1(0.1)**	*C. africana*	15(2.0) **1(0.1)**
Verbenaceae	7(1.0) **30(4.4)**	*Clerodendrum*	7(1.0) **30(4.4)**	*C. myricoides*	7(1.0) **30(4.4)**
21 **(20)**	732 (100) **683(100)**	27 **(29)**	732 (100) **683(100)**	29 **(30)**	732 (100) **683(100)**

In undisturbed plots 30 species belonging to 29 genera were recorded while 29 species from 27 genera were tallied in the disturbed plots. However, among the sampling plots the mean species richness was higher in the disturbed plots than in the undisturbed (see Fig. 4.1.1).

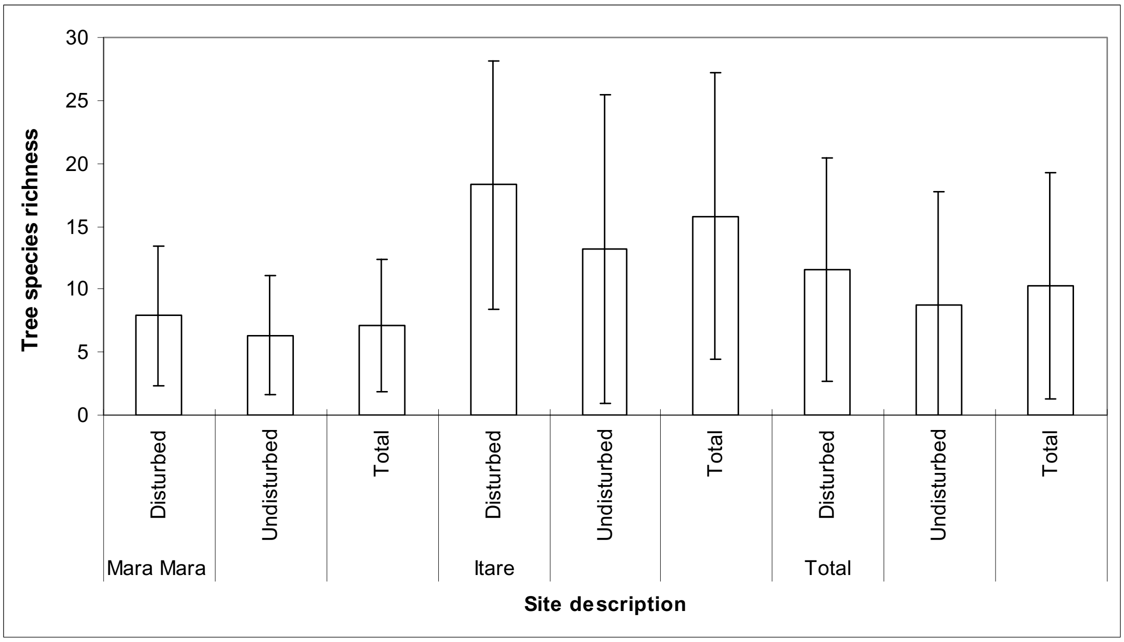


Fig. 4.1.1 Tree species richness in the sampling plots
The figure shows the mean tree species richness in the sampling plots in SW Mau forest reserve. Comparison between the forest sites and the state of the sites are illustrated.

Testing for equality of means between disturbed and undisturbed for the number of families, genera and species results (see Table 4.1.3). indicated significant differences in the mean number of families, genera and species. Independent sample t test for pooled means for disturbed and undisturbed sites indicated significant mean differences in number of families, genera and species with higher means being indicated for disturbed sites (see Table 4.1.3). Multiple comparisons Least significant difference (LSD) indicated higher mean numbers in the disturbed plots (see Appendix 8.1.2).

Table 4.1.3 Tests for diversity and evenness in tree species richness

The table shows the Levene statistic for homogeneity of variances, the Welch Test for mean differences, independent samples t test for pooled means for disturbed and undisturbed sites in the SW Mau forest reserve. The Shannon Wiener diversity index for the study plots is also given.

Test for equality of mean number of families', genera and species

Variable	Test	Statistic	df1	df2	Sig.
Family	Levene	105.55	7	1407	0.000
	Welch-Test	52.12[a]	7	485.19	0.000
Genera	Levene	143.82	7	1407	0.000
	Welch-Test	67.14[a]	7	482.41	0.000
Species	Levene	145.23	7	1407	0.000
	Welch-Test	670.05[a]	7	482.23	0.000

[a] Asymptotically F-distributed

Independent samples t-test for families, genera and species

	Site description	N	Mean	Sd	T	Sig
Family	Undisturbed	683	7.13	6.26	-5.913	0.000
	Disturbed	732	9.13	6.49		
Genera	Undisturbed	683	8.77	8.81	-5.849	0.000
	Disturbed	732	11.51	8.78		
Species	Undisturbed	683	8.81	8.91	-5.806	0.000
	Disturbed	732	11.55	8.87		

Species diversity and evenness

Sampling plot statistics	N	S	Shannon Wiener H	H_E
Total area	1415	37	1.82	0.50
Disturbed	732	29	1.98	0.59
Undisturbed	683	27	1.97	0.60
Mara A Disturbed	208	17	2.45	0.87
Mara A Undisturbed	248	20	2.42	0.81
Mara B Disturbed	267	19	2.62	0.89
Mara B Undisturbed	190	17	2.47	0.87
Itare A Disturbed	102	17	2.18	0.77
Itare A Undisturbed	92	19	2.09	0.71
Itare B Disturbed	155	19	2.54	0.86
Itare B Undisturbed	153	13	2.54	0.99

The mean species richness by forest sites, study plots and site description are shown in Appendix 8.1.1. Univariate analysis of variation using test of between-subjects effects showed that the variation in tree species richness was significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). The variation was significantly contributed by the forest site, state of site, the interaction between forest site and state of site and forest site, state of site and the sampling plots (see Table 4.1.4)

Table 4.1.4 Variation in species richness.

The table shows the sources of variation and their interaction in influencing tree species composition in the SW Mau forest reserve. The strength of the effects of the sources of variation is given by Eta squared.

Source	SS Type III	df	MSS	F	Sig	Eta
Corrected Model	30209.027(a)	7	4315.58	72.15	0.000	0.264
Intercept	164221.18	1	164221.18	2745.65	0.000	0.664
Plot	151.65	1	151.65	2.54	0.112	0.002
Site	22084.19	1	22084.19	369.23	0.000	0.208
Site description	3457.46	1	3457.46	57.81	0.000	0.039
Plot * site	355.89	1	355.89	5.95	0.015	0.004
Plot * site description	194.39	1	194.39	3.25	0.072	0.002
Site * site description	767.93	1	767.93	12.84	0.000	0.009
Plot * site * site description	816.91	1	816.91	13.66	0.000	0.010

a R-Square = 0.264 (Corrected R-square = 0.260)

4.1.2 Tree species diversity and evenness

Generally there seemed to be higher tree species diversity in the disturbed sites. Mara B disturbed had the highest diversity (see Table 4.1.3 and Fig. 4.1.2).

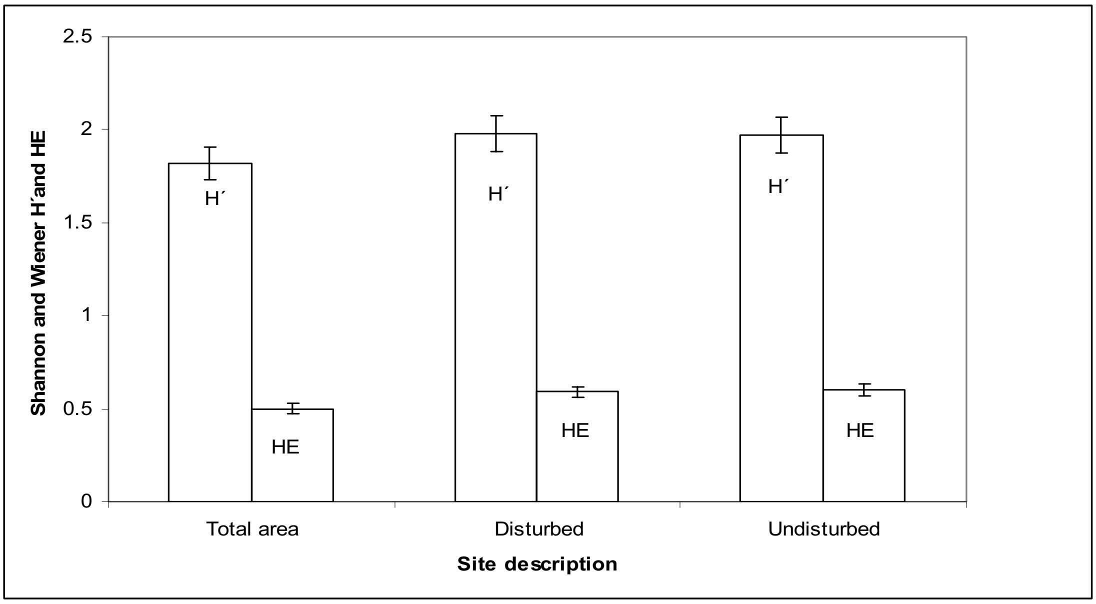


Fig. 4.1.2 Species diversity and evenness among study plots

The figure shows the value of Shannon Wiener diversity index H´ and the evenness of distribution of species in the study sites. A comparison is made for the entire area sampled (Total area) and pooled values for the disturbed and undisturbed sites in the SW Mau forest reserve.

4.1.3 Forest structure and complexity

According to the results (see Table 4.1.5 and Fig. 4.1.3), trees with diameter between 3-10cm (shrub layer) were the most represented followed by under storey trees when classification was based on diameter at breast height (dbh).

There were fewer over storey trees compared to the other categories. Seedlings were abundantly present.

Table 4.1.5 Forest structure

The table shows the structural composition based on diameter and height classes in the SW Mau forest reserve.

Distribution of DBH and height classes in study plots								
	Disturbed				Undisturbed			
	Diameter (cm)		Height (m)		Diameter(cm)		Height(m)	
Measurement level	Freq	%	Freq	%	Freq	%	Freq	%
Seedlings/wildings	432	59.0	334	45.6	387	56.7	332	48.6
Shrubs	166	22.7	315	43.0	115	16.8	225	32.9
Under storey trees	119	16.3	67	9.2	113	16.5	76	11.1
Over storey trees	15	2.0	16	2.2	68	10.0	50	7.3
Total	732	100.0	732	100.0	683	100.0	683	100.0

When the classification was based on height (see Table 4.1.5 and Fig. 4.1.3), majority were found to be seedlings. Approximately 40% belonged to the shrub layer with the under storey and over storey components individually contributing less than 10%.

Vegetation sampled had a low proportion of over storey trees. Undisturbed sites had a lower percentage of shrubs and under storey individuals than the disturbed. However the undisturbed sites had a higher frequency of over storey trees than the disturbed. Both sites had high number of seedlings and wildings. This was similar when both height and diameter were considered (see Table 4.1.5 and Fig. 4.1.3).

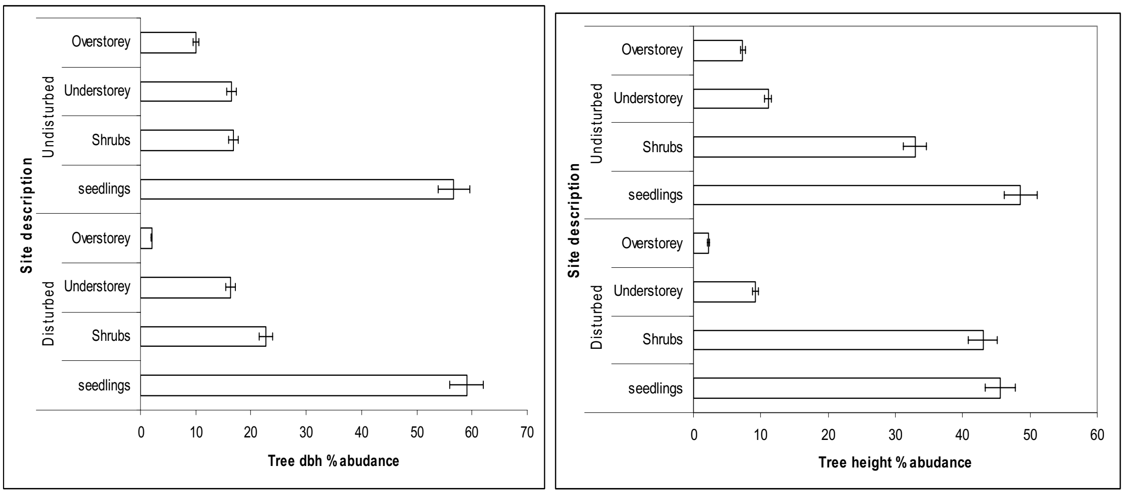


Fig. 4.1.3 Forest structure based on height and diameter

The figure shows the proportional contribution of seedlings shrubs under storey trees and over storey trees based on diameter and height classes to the physiognomic appearance of the forest in disturbed and undisturbed sites assuming 5% measurement error in the SW Mau forest reserve.

Differences in the mean diameter, height and basal area between forest sites and the respective disturbed and undisturbed plots are shown in Fig. 4.1.4a,b and c respectively. The mean tree diameter at breast height total tree height and basal area by forest sites, study plots and site description are shown in Appendices 8.1.4, 8.15 and 8.1.6 respectively.

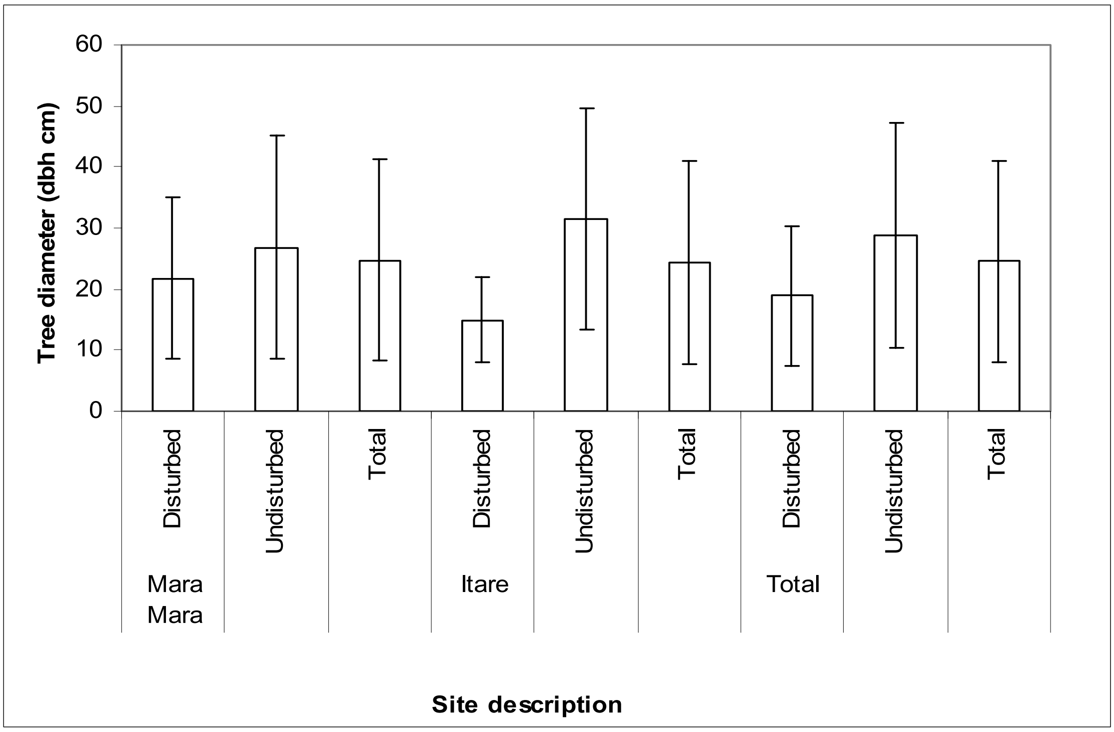


Fig. 4.1.4a Distribution of tree diameter

Figure shows the distribution tree diameters based on trees >10 cm diameter in the sampling pots in the SW Mau forest reserve. Comparisons between forest sites and description of disturbance state are illustrated.

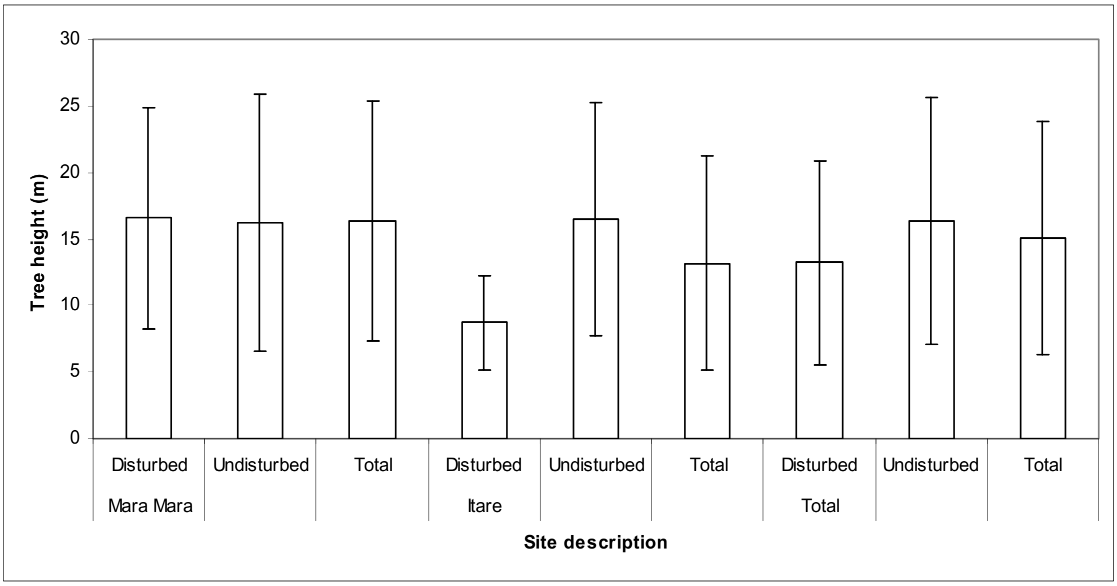


Fig. 4.1.4b Distribution of total tree height

Figure shows the distribution trees height to the general physiognomic appearance of the forest. This is based on trees >10cm diameter in the sampling pots in the SW Mau forest reserve. Comparisons between forest sites and description of disturbance state are illustrated.

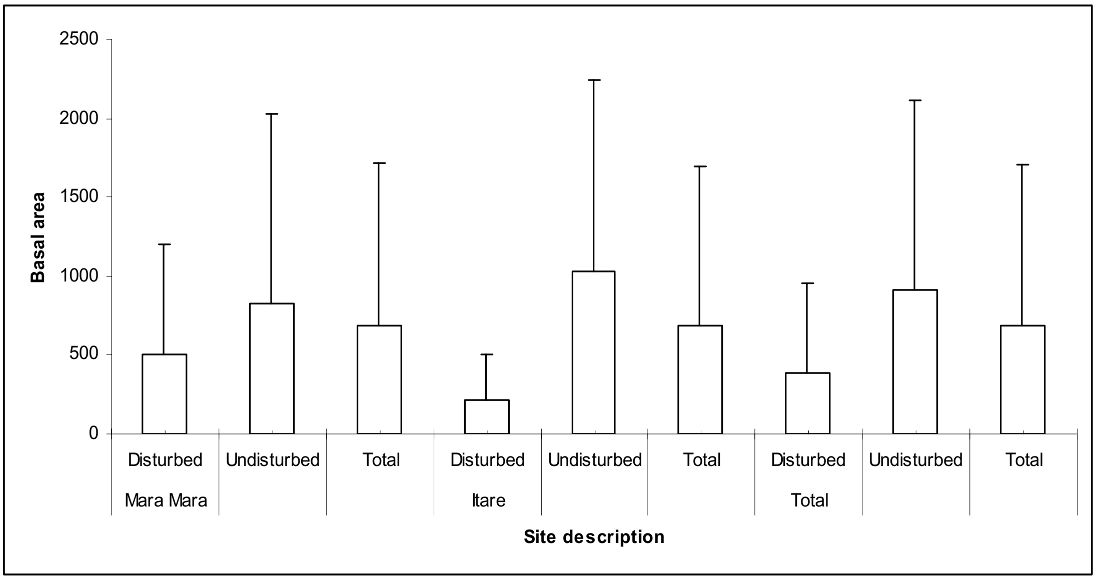


Fig. 4.1.4c Distribution of tree basal area

Figure shows the distribution tree basal area ($m^{-2}ha^{-1}$) based on trees >10 cm diameter in the sampling plots in the SW Mau forest reserve. Comparisons between forest sites and description of disturbance state are illustrated.

The mean dbh was similarly higher in undisturbed sites both in the under storey and over storey vegetation. The variation about the mean indicates less difference in the distribution of diameters in the under storey between the disturbed and undisturbed sites. However a marked difference was shown in the over storey with undisturbed sites having higher dbh classes that are more uniformly distributed. Holdridge's complexity index (Table 4.1.6) was higher in the undisturbed plots (Fig. 4.1.5)

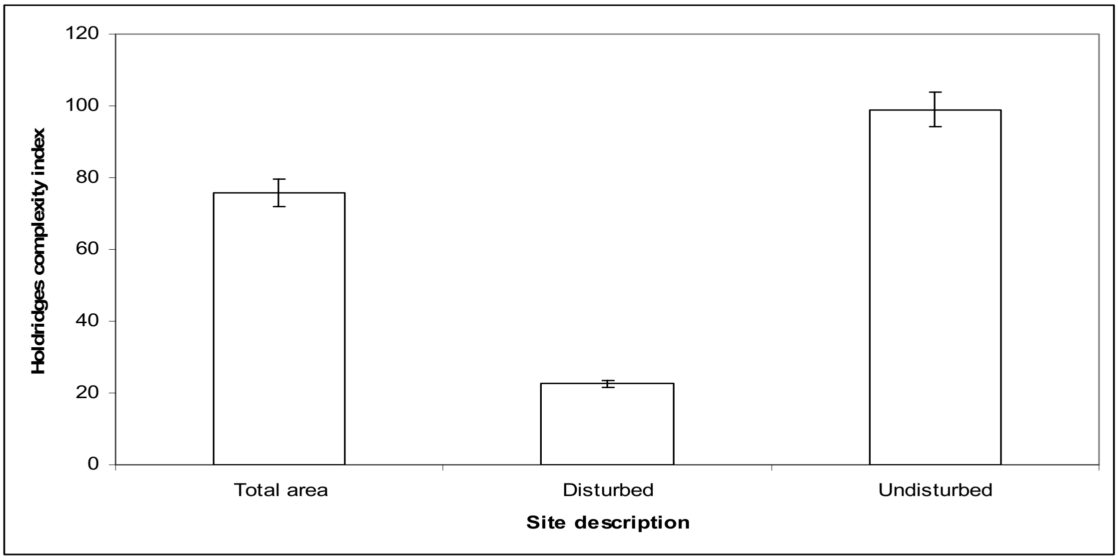


Fig. 4.1.5 Holdridge's complexity index in the sampling plots

The figure shows Holdridge's complexity (HC) index based on tree basal area, tree density, species richness and mean tree height in the SW Mau forest reserve.

Multiple comparison results show high complexity of structure in the undisturbed sites than the disturbed (Appendix 8.1.7). Independent sample t test for pooled means for disturbed and undisturbed sites indicated significant mean differences in diameter, height and basal area with higher means being indicated for undisturbed sites (see Table 4.1.6).

Table 4.1.6 Equality of means for height, diameter and basal area

The table shows test for mean differences for height and dbh between disturbed and undisturbed sites and Holdridge's complexity index (H) and multiple comparisons between disturbed and undisturbed sites in the SW Mau forest reserve.

Variable	Test	Statistic	df1	df2	Sig.
Height (m)	Levene	18.94	7	1407	0.000
	Welch-Test	7.25 [a]	7	516.99	0.000
Diameter (cm)	Levene	250.05	7	754	0.000
	Welch-Test	15.28 [a]	7	285.68	0.000
Basal area (m^2/ha)	Levene	13.75	7	307	0.000
	Welch-Test	13.71 [a]	7	118.91	0.000

[a] Asymptotically F-distributed0

Independent samples t-test for structure

	Site description	N	Mean	SD	T	Sig
DBH (cm)	Disturbed	134	18.91	11.38	-5.889	0.000
	Undisturbed	181	28.80	18.317		
Height (m)	Disturbed	134	13.22	7.70	-3.258	0.001
	Undisturbed	181	16.34	9.26		
Basal area (m^2/ha)	Disturbed	134	381.70	575.16	-5.190	0.000
	Undisturbed	181	913.07	1204.27		

Holdridge's structural complexity index

Plot	BA (m^2)	Density	N	Height (m)	HC
Total area	6.87	315	28	15.02	75.84
Disturbed	3.82	134	20	13.2	22.52
Undisturbed	9.13	181	22	16.34	99.00
Mara A Disturbed	2.72	28	11	20.67	11.56
Mara A undisturbed	3.98	53	7	15.19	14.98
Mara B disturbed	1.357	50	10	14.2	6.38
Mara B undisturbed	4.60	51	11	17.35	29.87
Itare A Disturbed	0.89	44	14	11.11	4.06
Itare A undisturbed	5.54	27	11	23.3	25.54
Itare B disturbed	0.71	35	8	8.23	1.08
Itare B undisturbed	1.85	27	8	12.78	3.40

Univariate analysis of variation using test of between-subjects effects showed that the variation in tree diameter at breast height (dbh) was significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). The variation was significantly contributed by the state of site, sampling plots, the interaction between forest site and state of site forest site, state of site and the sampling plots (see Table 4.1.7a).

Table 4.1.7a Variation in tree diameter
The table shows the sources of variation and their interaction in influencing dbh distributions in the SW Mau forest reserve.

Source	SS Type III	Df	MSS	F	Sig	Eta
Corrected Model	13873.423(a)	7	1981.92	8.54	0.000	0.163
Constant Term	162289.35	1	162289.35	698.93	0.000	0.695
Forest site	475.22	1	475.22	20.05	0.154	0.007
Site description	6053.34	1	6053.34	26.07	0.000	0.078
Sampling plot	1225.43	1	1225.43	5.28	0.022	0.017
Forest site * state of site	2535.25	1	2535.25	10.92	0.001	0.034
Forest site * sampling plot	0.27	1	0.27	0.001	0.973	0.000
State of site * sampling plot	350.94	1	350.94	1.51	0.220	0.005
Forest site * state of site * sampling plot	2222.31	1	2222.31	9.57	0.002	0.030

a R-Square = 0.163 (Corrected R-Square = 0.144)

The mean tree height by forest sites, study plots and site description are shown in Appendix 8.1.5. Univariate analysis of variation using test of between-subjects effects showed that the variation in total tree height was significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). The variation was mainly contributed by the location of the site, state of site, sampling plots, the interaction between forest site and state of site and the effects of the interaction between forest site, state of site and the sampling plots (see Table 4.1.7b).

Table 4.1.7b Variation in total tree height
The table shows the sources of variation and their interaction in influencing total tree height distributions in the SW Mau forest reserve.

Source	SS Type III	df	MSS	F	Sig	Eta
Corrected Model	4243.78(a)	7	606.25	9.39	0.000	0.176
Intercept	60048.02	1	60048.02	929.68	0.000	0.752
Forest site	1529.98	1	1529.98	23.69	0.000	0.072
Site description	525.96	1	525.96	8.14	0.005	0.026
Sampling plot	586.10	1	586.10	9.07	0.003	0.029
Forest site * state of site	1131.42	1	1131.42	17.52	0.000	0.054
Forest site * sampling plot	27.02	1	27.02	0.42	0.518	0.001
State of site * sampling plot	88.89	1	88.89	1.38	0.242	0.004
Forest site * state of site * sampling plot	771.17	1	771.17	11.94	0.001	0.037

a R-Square = 0.176 (Corrected R-Square = 0.158)

Univariate analysis of variation using test of between-subjects effects showed that the variation in basal area was significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). The variation was significantly contributed by the state of the site, sampling plots, the interaction between forest site and state of site and the effects of the interactions between forest site, state of site and the sampling plots (see Table 4.1.7c).

Table 4.1.7c Variation in basal area

The table shows the sources of variation and their interaction in influencing basal area distributions in the SW Mau forest reserve.

Source	SS Type III	df	MSS	F	Sig	Eta
Corrected Model	40119210.86a	7	5731315.84	6.14	0.000	0.123
Constant Term	119523906.68	1	119523906.68	128.00	0.000	0.294
Forest site	1279904.49	1	1279904.49	1.37	0.243	0.004
Site description	16095703.44	1	16095703.44	17.24	0.000	0.054
Sampling plot	5218800.46	1	5218800.46	5.59	0.019	0.018
Forest site * state of site	4725433.02	1	4725433.02	5.06	0.025	0.016
Forest site * plot	4760.95	1	4760.95	0.01	0.943	0.000
State of site * sampling plot	452603.98	1	452603.98	0.49	0.487	0.002
Forest site * state of site * plot	7891593.72	1	7891593.72	8.45	0.004	0.027

a R-Square = 0.123 (Corrected R-Square = 0.103)

4.2 SEEDLING SURVIVAL AND RECRUITMENT FROM ANNUAL SEED RAIN

An account of the species composition of the seedling strata in the study plots is given. Comparisons between disturbed and undisturbed sites are illustrated for families, genera and species.

4.2.1 Tree seedling floristic composition

From the sampled plots (see Table 4.2.1) a total of 20 families, 20 genera and 25 species were recorded with a total of 653 individuals being enumerated. Majority of the individuals recorded belonged to the family Apocynaceae, Euphorbiaceae Mimosaceae, Myrtaceae, Rosaceae and Rubiaceae each having at least over 10% representation. Frequent genera included *Syzigium, Prunus, Psychotria* and *Neoboutonia*. Some of the sampled species included *Syzigium guineense*, *Albizia gummifera, Neoboutonia macrocalyx, Psychotria mahonii, Tabernaemontana stapfiana, Prunus africana* and *Solanum terminale*. Some species, for example *Croton megalocarpus, Aningeria adolfi-friederieri* and *Hagenia abyssinica* had only one individual represented (see Table 4.2.1).

Table 4.2.1 Tree seedling floristic composition in the study sites

A list of all the species of tree seedlings enumerated in the study plots distinguished in their respective families and genera in the SW Mau forest reserve.

Family	Freq(%)	Genus	Freq(%)	Species
Alariaceae	22 (3.4)	*Polycias*	22 (3.4)	*P. fulva*
Apocynaceae	59 (9.0)	*Tabernaemontana*	59 (9.0)	*T. stapfiana*
Alangiaceae	2 (0.3)	*Alangium*	2 (0.3)	*A. chinense*
Asteraceae	10 (1.5)	*Vernonia*	10 (1.5)	*V. auriculifera*
Bignoniaceae	4 (0.6)	*Spathodea*	4 (0.6)	*S campanulata*
Ebenaceae	33 (5.1)	*Diospyros*	33 (5.1)	*D. abyssinica*
Euphorbiaceae	76 (11.6)	*Neoboutonia*	72 (11.0)	*N. macrocalyx*
		Bridelia	3 (0.5)	*B. micrantha*
		Croton	1 (0.2)	*C. megalocarpus*
Flacourtiaceae	6 (1.1)	*Dovyalis*	6 (1.1)	*D. lucida*
Meliaceae	2 (0.3)	*Ekebergia*	2 (0.3)	*E. capensis*
Mimosaceae	76 (11.6)	*Albizia*	76 (11.6)	*A. gummifera*
Myrtaceae	117 (17.9)	*Syzigium*	117 (17.9)	*S. guineense*
Rizophoraceae	7 (1.1)	*Cassipourea*	7 (1.1)	*C. malosana*
Rubiaceae	91 (13.9)	*Psychotria*	85 (13.0)	*P. mahonii*
		Galiniera	6 (0.9)	*G. coffeiodes*
Rutaceae	15 (2.3)	*Zanthoxylum*	9 (1.4)	*Z. gilletii*
		Teclea	6 (0.9)	*T. nobilis*
Rosaceae	90 (13.8)	*Prunus*	89 (13.6)	*P. Africana*
		Hagenia	1 (0.2)	*H. abyssinica*
Sapindaceae	8 (1.1)	*Allophyllus*	8 (1.1)	*A. abyssinicus*
Samydaceae	17(2.6)	*Casearia*	17 (2.6)	*C. battiscombei*
Sapotaceae	1 (0.2)	*Aningeria*	1 (0.2)	*A. adolfi-friederieri*
Ulmaceae	15 (2.3)	*Celtis*	15 (2.3)	*C. Africana*
Verbenaceae	2 (0.3)	*Clerodendrum*	2 (0.3)	*C. myricoides*
20	**653(100)**	**25**	**653(100)**	**25**

Sixteen families were recorded in the disturbed and 20 in the undisturbed sites (see Table 4.2.2). The distribution of genera in the study sites followed a similar pattern as their respective families. In undisturbed sites, representation from *Syzigium* and *Albizia* were highest. *Prunus africana* dominated in the disturbed sites. A total of 328 individuals belonging to 22 species were enumerated in undisturbed sites (see Table 4.2.2). The most frequent species was *S. guineense*.

4.2.2 Tree seedling species richness and densities

The distribution (Fig. 4.2.2) from the sampling plots indicated higher number of families, genera and species in the disturbed plots than the undisturbed plots.

Table 4.2.2 Tree seedling floristic composition in study plots

A list of all the species of trees enumerated in the study plots distinguished in their respective families and genera in the SW Mau forest reserve. Figures in bold show tree species enumerated in undisturbed plots while the others represent the disturbed sites.

Family	Freq (%)	Genera	Freq (%)	Species	Freq (%)
Alariaceae	12(3.7)	*Polycias*	12(3.7)	*P. fulva*	12(3.7)
	10(3.0)		**10(3.0)**		**10(3.0)**
Apocynaceae	16(4.9)	*Tabernaemontana*	16(4.9)	*T. stapfiana*	16(4.9)
	43(13.1)		**43(13.1)**		**43(13.1)**
Alangiaceae	2(0.6)	*Alangium*	2(0.6)	*A. chinense*	2(0.6)
Asteraceae	2(0.6)	*Vernonia*	2(0.6)	*V. auriculifera.*	2(0.6)
	8(2.4)		**8(2.4)**		**8(2.4)**
Bignoniaceae	3(0.9)	*Spathodea*	3(0.9)	*S. campanulata*	3(0.9)
	1(0.3)		**1(0.3)**		**1(0.3)**
Ebenaceae	**33(10.1)**	*Diospyros*	**33(10.1)**	*D. abyssinica*	**33(10.1)**
Euphorbiaceae		*Neoboutonia*	30(9.2)	*N. macrocalyx*	30(9.2)
			42(12.8)		**42(12.8**)
	32(9.8)	*Croton*	1(0.3)	*C. megalocarpus*	1(0.3)
	44(13.4)		**2(0.6)**		**2(0.6)**
		Bridelia	1(0.3)	*B. micrantha*	1(0.3)
			2(0.6)		**2(0.6)**
Flacourticeae	6(1.8)	*Dovyalis*	6(1.8)	*D. lucida*	6(1.8)
Meliaceae	1(0.3)	*Ekebergia*	1(0.3)	*E. capensis*	1(0.3)
	1(0.3)		**1(0.3)**		**1(0.3)**
Mimosaceae	21(6.5)	*Albizia*	21(6.5)	*A. gummifera*	21(6.5)
	55(16.8)		55(16.8)		55(16.8)
Myrtaceae	48(14.8)	*Syzigium*	48(14.8)	*S. guineense*	48(14.8)
	69(21.0)		69(21.0)		69(21.0)
Rizophoraceae	1(.3)	*Cassipourea*	1(0.3)	*C. malosana*	1(0.3)
	6(1.8)		**6(1.8)**		**6(1.8)**
Rubiaceae	71(21.8)	*Galiniera*	2(0.6)	*G. coffeiodes*	2(0.6)
			4(1.2)		**4(1.2)**
	20(6.1)	*Psychotria*	69(21.2)	*P. mahonii*	69(21.2)
			16(4.9)		16(4.9)
Rutaceae		*Zanthoxylum*	6(1.2)	*Z. gilletii*	6(1.2)
	8(2.5)		**3(0.9)**		**3(0.9)**
	7(2.1)	*Teclea*	2(0.6)	*T. nobilis*	2(0.6)
			4(1.2)		**4(1.2)**
Rosaceae	82(25.2)	*Prunus*	81(24.9)	*P. africana*	81(24.9)
			8(2.4)		8(2.4)
	8(2.4)	*Hagenia*	1(0.3)	*H. abyssinica*	1(0.3)
Sapindaceae	5(1.5)	*Allophylus*	5(1.5)	*A. abyssinicus*	5(1.5)
	3(0.9)		**3(0.9)**		**3(0.9)**
Samydaceae	7(2.2)	*Casearia*	7(2.2)	*C. battiscombei*	7(2.2)
	10(3.0)		10(3.0)		10(3.0)
Sapotaceae	**1(0.3)**	*Aningeria*	**1(0.3)**	*A. adolfi-friederieri*	**1(0.3)**
Ulmaceae	14(4.3)	*Celtis*	14(4.3)	*C. africana*	14(4.3)
	1(0.3)		1(0.3)		**1(0.3)**
Verbenaceae	2(0.6)	*Clerodendrum*	2(0.6)	*C. myricoides*	2(0.6)
16(20)	325 **(328)**	21(22)	325**(328)**	21(22)	325**(328)**

The above distribution was similarly shown by the mean tree species richness as shown in the Figure 4.2.1 below.

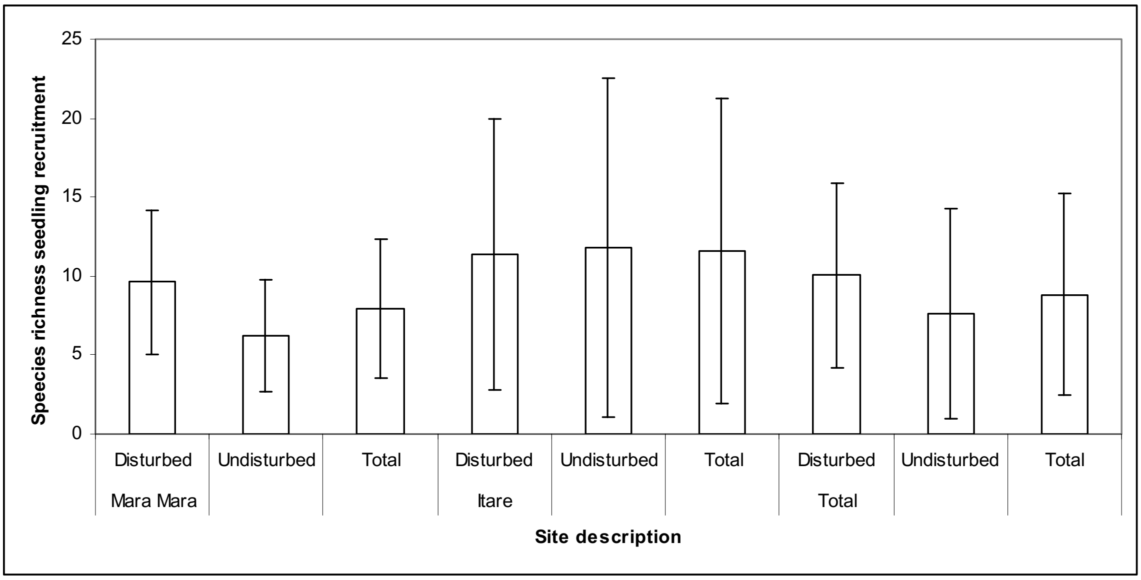


Fig. 4.2.1 Tree seedling species richness among study plots

The figure shows the mean number of tree species seedlings recruited from germinations of the previous year seed rain in the SW Mau forest reserve. Differences between Mara Mara and Itare are illustrated as well as those between disturbed and undisturbed plots.

Tests for equality of means indicated significant differences in the sampling plots regarding the mean number of families, genera and species (see Table 4.2.3, Fig. 4.2.2). Independent sample t test for pooled means for disturbed and undisturbed sites indicated significant mean differences in the number of families, genera and species with higher means being indicated for disturbed sites (Family $t = 5.992$ $p < 0.001$, Genera $t = 5.213$, $p < 0.001$ and species $t = 4.969$, $p < 0.001$).

Multiple comparisons (see Appendix 8.2.2) further revealed differences between individual sampling plots with regard to the two variables. Emphasis was drawn mainly to significant mean differences between disturbed and undisturbed plots.

Table 4.2.3 Differences in tree seedling floristic composition

The table shows the Levene statistic for homogeneity of variances, the Welch Test for mean differences, for disturbed and undisturbed sites in tree floristic composition in the SW Mau forest reserve ([a] Asymptotically F-distributed)

Tests for equality of mean number of families, genera and species					
Variable	Test	Statistic	Df1	df2	Sig.
	Levene	46.946	7	645	0.000
Family	Welch-Test	54.774 [a]	7	168.957	0.000
Genus	Levene	59.137		645	0.000
	Welch-Test	55.580 [a]	7	167.705	0.000
Species	Levene	61.648		645	0.000
	Welch-Test	55.671 [a]	7	167.613	0.000

The mean tree seedling species richness for recruitment from previous season germination by forest sites, study plots and site description are shown in Appendix 8.2.1. Univariate analysis of variation using test of between-subjects effects showed that the variation in seedling tree species composition can be significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). The variation was significantly contributed by the location of the site (i.e. the Mara Mara and Itare forests) and the state of the site. The interaction effects between forest site and state of the sites, forest sites and sampling plots and state of site and sampling plots were also significant sources of variation (see Table 4.2.4).

Table 4.2.4 Variation in tree seedling species richness

The table shows the sources of variation and their interaction in influencing tree seedling species composition as a measure of recruitment from germinations of the previous season seed rain in the SW Mau forest reserve.

Source	SS Type III	df	MSS	F	Sig	Eta
Corrected Model	5804.656(a)	7	829.24	26.03	0.000	0.220
Constant Term	40020.77	1	40020.77	1256.20	0.000	0.661
Forest site	1199.37	1	1199.37	37.65	0.000	0.055
State of site	456.61	1	456.61	14.33	0.000	0.022
Sampling plots	28.84	1	28.84	0.91	0.342	0.001
Forest site * state of site	203.55	1	203.55	6.39	0.012	0.010
Forest site * sampling plot	1789.52	1	1789.52	56.17	0.000	0.080
State of site * Sampling plot	537.88	1	537.88	16.88	0.000	0.026
Forest site * state of site * sampling plot	52.09	1	52.09	1.63	0.201	0.003

a R-Square = 0.220 (Corrected R-Square = 0.212)

4.3 GERMINATION FROM ANNUAL SEASONAL SEED RAIN

Results of the germinations from the previous season's seed rain are presented. Distribution of the families and species encountered given, and comparisons between disturbed and undisturbed sites illustrated.

4.3.1 Tree seedling floristic composition

Results (see Table 4.3.1) indicate that 12 families 18 genera and 18 species were recorded in the sampling plots. Majority of the seedlings belonged to Euphorbiaceae. Mimosaceae, Meliaceae, Rosaceae, Rutaceae and Rubiaceae. Notable genera included *Neoboutonia*, *Albizia*, *Macaranga*, *Zanthoxylum*, *Prunus*, *Psychotria*, *Ekebergia Syzigium*, *Croton* and *Tabernaemontana*. *Neoboutonia macrocalyx* was the most dominant species. *A gummifera*, *Ekebergia capensis, P. africana, P. mahonii, S. guineense* and *T. stapfiana* were also recorded.

Euphorbiaceae had the majority of individuals counted among the 11 families enumerated in the disturbed plots. Among the undisturbed plots 10 families were enumerated (see Table 4.3.1).

Table 4.3.1 Floristic composition, germination from seasonal seed rain
A summary list of the tree seedling floristic composition in the study plots after the onset of rains representing germination from the previous season's seed rain distinguished in their respective families and genera in the SW Mau forest reserve.

Seedling species composition in the study sites				
Family	**Freq (%)**	**Genera**	**Freq (%)**	**Species**
Alariaceae	1(0.7)	*Polycias*	1(0.7)	*P. fulva*
Apocynaceae	9(6.3)	*Tabernaemontana*	9(6.3)	*T. stapfiana*
Euphorbiaceae	59(41.0)	*Neoboutonia*	40(27.8)	*N. macrocalyx*
		Macaranga	12(8.3)	*M. kilimandscharica*
		Bridelia	1(0.7)	*B. micrantha*
		Croton	6(4.2)	*C. macrostachyus*
Meliaceae	8(5.6)	*Ekebergia*	8(5.6)	*E. capensis*
Mimosaceae	23(16.0)	*Albizia*	23(16.0)	*A. gummifera*
Monimiaceae	2(1.4)	*Xymalos*	2(1.4)	*X. monospora*
Myrtaceae	11(7.6)	*Syzigium*	11(7.6)	*S. guineense*
Rizophoraceae	1(0.7)	*Cassipourea*	1(0.7)	*C. malosana*
Rosaceae	12(8.3)	*Prunus*	11(7.6)	*P. Africana*
		Hagenia	1(0.7)	*H. abyssinica*
Rubiaceae	9(6.3)	*Galiniera*	1(0.7)	*G. coffeiodes*
		Psychotria	8(5.6)	*P. mahonii*
Rutaceae	7(4.9)	*Zanthoxylum*	6(4.2)	*Z. gilletii*
		Teclea	1((0.7)	*T. nobilis*
Samydaceae	2(1.4)	*Casearia*	2(1.4)	*C. battiscombei*
12	**144(100)**	**18**	**144(100)**	**18**

In the disturbed plots 14 genera were recorded. *Neoboutonia* had the highest representation. In the undisturbed sampling plots 15 genera were recorded with *Neoboutonia* having the highest representation followed by *Albizia*. Among the 144 individuals sampled 67 belonging to some 14 species were recorded in disturbed plots. Seventy-seven individuals belonging to 15 species were recorded in the 60 randomly selected undisturbed sampling plots (see Table 4.3.2).

Table 4.3.2 Tree seedling floristic composition in sampling plots

A summary list of all the species of trees enumerated in the study plots distinguished in their respective families and genera in the SW Mau forest reserve. Figures in bold show tree species enumerated in undisturbed plots while the others represent the disturbed sites.

Family	Freq (%)	Genera	Freq (%)	Species	Freq (%)
Alariaceae	1(1.5)	*Polycias*	1(1.5)	*P. fulva*	1(1.5)
Apocynaceae	2(3.0) **7(9.1)**	*Tabernaemontana*	2(3.0) **7(9.1)**	*T. stapfiana*	2(3.0) **7(9.1)**
Euphorbiaceae	22(32.8) **37(49.4)**	*Neoboutonia*	16(23.9) **24(31.2)**	*N. macrocalyx*	16(23.9) **24(31.2)**
		Croton	1(1.5) **5(6.5)**	*C. macrostachyus*	1(1.5) **5(6.5)**
		Bridelia	**1(1.3)**	*B. micrantha*	**1(1.3)**
		Macaranga	5(7.5) **7(9.1)**	*M. kilimandscharica*	5(7.5) **7(9.1)**
Meliaceae	6(9.0) **2(2.6)**	*Ekebergia*	6(9.0) **2(2.6)**	*E. capensis*	6(9.0) **2(2.6)**
Mimosaceae	9(13.4) **14(18.2)**	*Albizia*	9(13.4) **14(18.2)**	*A. gummifera*	9(13.4) **14(18.2)**
Monimiaceae	1(1.5) **1(1.3)**	*Xymalos*	1(1.5) **1(1.3)**	*X. monospora*	1(1.5) **1(1.3)**
Myrtaceae	5(7.5) **6(7.8)**	*Syzigium*	5(7.5) **6(7.8)**	*S. guineense*	5(7.5) **6(7.8)**
Rizophoraceae	**1(1.3)**	*Cassipourea*	**1(1.3)**	*C. malosana*	**1(1.3)**
Rosaceae	8(11.9) **4(5.2)**	*Prunus*	7(10.4) **4(5.2)**	*P. Africana*	7(10.4) **4(5.2)**
		Hagenia	1(1.5)	*H. abyssinica*	1(1.5)
Rubiaceae	7(10.4) **2(2.6)**	*Psychotria*	7(10.4) **1(1.3)**	*P. mahonii*	7(10.4) **1(1.3)**
		Galiniera	**1(1.3)**	*G. coffeiodes*	**1(1.3)**
Rutaceae	4(6.0) **3(3.9)**	*Zanthoxylum*	4(6.0) **2(2.6)**	*Z. gilletii*	4(6.0) **2(2.6)**
		Teclea	**1(1.3)**	*T. nobilis*	**1(1.3)**
Samydaceae	2(3.0)	*Casearia*	2(3.0)	*C. battiscombei*	2(3.0)
11**(10)**	67(100) **77(100)**	14**(15)**	67(100) **77(100)**	14**(15)**	67(100) **77(100)**

4.3.2 Tree species densities and richness

Tree species seedling richness varied among the forest sites and the description of the sites (see Fig. 4.2.2).

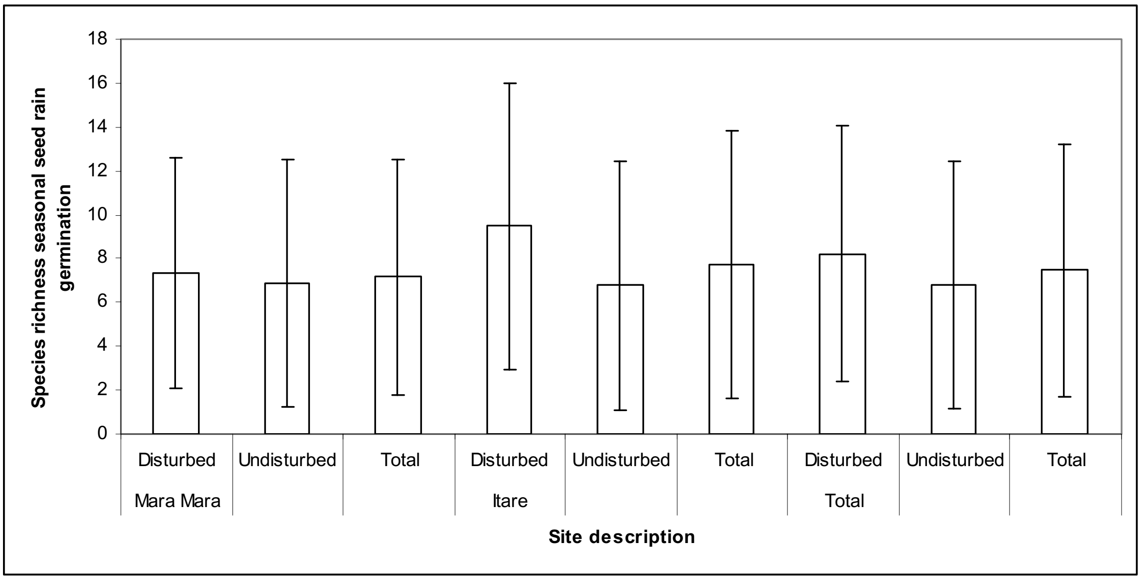


Fig. 4.2.2 Tree seedling species richness among study plots

The figure shows the mean number of tree species seedlings germinations of the previous season seed rain in the SW Mau forest reserve. Differences between Mara Mara and Itare are illustrated as well as those between disturbed and undisturbed plots.

The variances regarding seedling densities in sampling plots were significantly different. However, no significant differences were reported for species richness by the test. Hence, ANOVA indicated significant differences in the mean number of species. Likewise, significant differences occurred in the distribution of mean number of seedlings (see Appendix 8.2.4).

Table 4.3.3 Differences in species richness and density

The table shows tests for mean differences in species richness and density in the SW Mau forest reserve, for disturbed and undisturbed sites.

Variable	Test	Statistic(a)	df1	Df2	Sig.
Species richness	Levene	1.51	7	136	0.168
Seedling density	Levene	2.84	7	136	0.009
	Welch-Test [a]	2.39 [a]	7	50.900	0.034

[a] Asymptotically F-distributed *

ANOVA

Variable	Source	SS	df	MSS	F	Sig
Species richness	Between groups	574.41	7	82.06	2.67	0.013
	Within groups	4175.48	136	30.70		
	Total	4749.89	143			

Independent sample t test for pooled means for disturbed and undisturbed sites indicated significant mean differences in the number of families (t = 3.064) with higher means being indicated for disturbed sites. The mean differences were however insignificant for genera (t = 1.111 p > 0.05) and species (t = 1.461 p > 0.05)

Least significant difference test (see Appendix 8.2.4) further revealed higher mean species richness in disturbed plots than in the undisturbed. However, the seedling density was significantly higher in undisturbed plots.

The mean tree seedling species richness for germination from previous season seed rain by forest sites, study plots and site description are shown in Appendix 8.2.3. Univariate analysis of variation using test of between-subjects effects showed that the variation in tree species composition can be significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). Significant variation was mainly contributed by the interaction between locations of the site; sampling plots and the state of the site (see Table 4.3.4).

Table 4.3.4 Variation in species richness of germinating tree seedlings

The table shows the sources of variation, their interaction and estimated strength in influencing tree seedling species richness from germinants of the previous season's seed rain in the SW Mau forest reserve.

Source	SS Type III	Df	MSS	F	Sig	Eta squared
Corrected Model	574.41(a)	7	82.06	2.67	0.013	0.121
Constant Term	7578.86	1	7578.86	246.85	0.000	0.645
Forest site	35.90	1	35.90	1.17	0.281	0.009
State of site	103.09	1	103.09	3.36	0.069	0.024
Sampling plots	13.47	1	13.47	0.44	0.509	0.003
Forest site * state of site	49.91	1	49.91	1.63	0.204	0.012
Forest site * sampling plot	231.33	1	231.33	7.54	0.007	0.052
State of site * Sampling plot	11.79	1	11.79	0.38	0.537	0.003
Forest site * state of site * sampling plot	127.63	1	127.63	4.16	0.043	0.030

a R-Square = 0.121 (Corrected R-Square = 0.076)

4.4 GERMINATION FROM THE SEED BANK RESERVES

Results of the germinations from the soil seed bank assays are presented. Most of the germinations occurred during the first three months of the trial. Distribution of the families and species encountered are given and comparisons between disturbed and undisturbed sites are illustrated.

4.4.1 Seed bank tree floristic composition

Seven families, 12 genera and 12 species were recorded from all the composite soil samples collected for the analysis of seed bank reserves (see Table 4.4.1). Solanaceae had the highest representation followed by Euphorbiaceae. Least occurrence was represented by Apocenaceae, Caricaceae and Sterculiaceae.

Table 4.4.1 Seed bank tree seedling floristic composition

A list of all the species of tree seedling enumerated from the seed bank nursery germination trials distinguished in their respective families and genera in the SW Mau forest reserve.

Family	Freq (%)	Genus	Freq (%)	Species
Apocynaceae	1 (0.5)	*Tabernaemontana*	1 (0.5)	*T. stapfiana*
Caricaceae	1 (.5)	*Cylicomorpha*	1(1.5)	*C. perviflora*
Euphorbiaceae	38 (18.4)	*Neoboutonia*	34 (16.4)	*N. macrocalyx*
		Macaranga	1 (0.5)	*M. kilimandscharica*
		Croton	3 (1.5)	*C. macrostachyus*
Lobeliaceae	6 (3.2)	*Lobelia*	6(3.2)	*L. giberroa*
Mimosaceae	2 (1.1)	*Albizia*	2(1.1)	*A. gummifera*
Olearaceae	1 (0.5)	*Olea*	1(0.5)	*O. europea var. africana*
Rutaceae	2 (1.1)	*Zanthoxylum*	2(1.1)	*Z. gilletii*
Solanaceae	116 (61.1)	*Solanum*	116 (61.1)	*S. terminale*
Sterculiaceae	1(0.5)	*Dombeya*	1(0.5)	*D. goetzenii*
Ulmaceae	24 (12.6)	*Celtis*	24(12.6)	*C. africana*
Total 10	190(100)	12	190 (100)	12

All the seven families, seven genera and seven species were recorded in the disturbed sites. Over half of the tallies encountered belonging to the family Solanaceae. However, a substantial number of the individuals belonged to Euphorbiaceae and Ulmaceae. In the undisturbed sites, three families, and three genera with five species were encountered. (see Table 4.4.2).

Table 4.4.2 Seed bank tree seedling floristic composition

A list of all the species of tree seedlings enumerated from the seed bank nursery germination trials distinguished in their respective families and genera in the SW Mau forest reserve. Figures in bold show seedlings enumerated from undisturbed plots.

Family	Freq (%)	Genus	Freq (%)	Species
Apocynaceae	1(0.9)	*Tabernaemontana*	1 (0.9)	*T. stapfiana*
Caricaceae	1 (0.9)	*Cylicomorpha*	1 (0.9)	*C. perviflora*
Euphorbiaceae	21 (18.9) **19 (21.3)**	*Neoboutonia*	20 (18.0) **14 (17.7)**	*N. macrocalyx*
		Macaranga	1 (0.9) 2 (2.5)	*M. kilimandscharica*
		Croton	3 (3.8)	*C. macrostachyus*
Lobeliaceae	6 (5.4)	*Lobelia*	6 (5.4)	*L. gibberoa*
Mimosaceae	2 (2.5)	*Albizia*	2 (2.5)	*A. gummifera*
Oleariaceae	1 (0.9)	*Olea*	1 (0.9)	*O. europea var. africana*
Rutaceae	2 (2.5)	*Zanthoxylum*	2 (2.5)	*Z. gilletii*
Solanaceae	62 (55.9) **52 (65.8)**	*Solanum*	62 (55.9) **52 (65.8)**	*S. terminale*
Sterculiaceae	1 (0.9)	*Dombeya*	1 (0.9)	*D. goetzenii*
Ulmaceae	18 (16.2) **6 (7.6)**	*Celtis*	18 (16.2) **6 (7.6)**	*C. africana*
Total	111 **(79)**	7 **(3)**	111 **(79)**	12 **(5)**

4.4.2 Seed bank potential and capacity

No significant differences in the Mara A and B assessment plots were reported. Nevertheless, significant differences were envisaged in the Itare plots. It is worthy reporting that no seedlings germinated from samples collected from Itare B undisturbed plots. The mean species richness from the nursery seed bank germination trials are illustrated in the Figure 4.2.3.

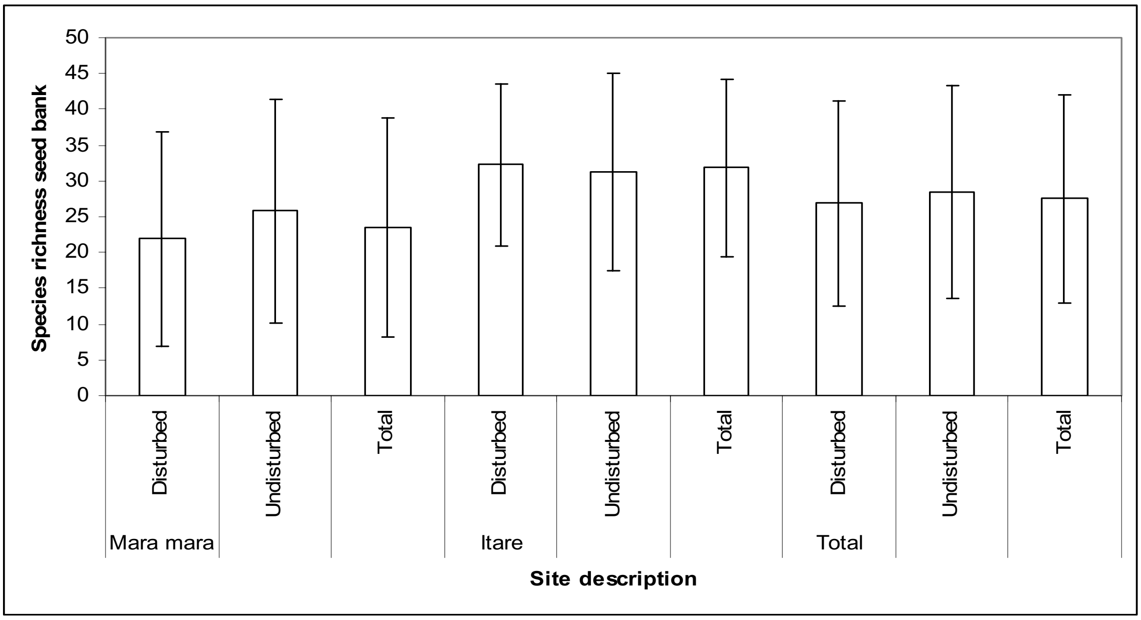


Fig. 4.2.3 Tree seedling species richness among study plots
The figure shows the mean number of tree seedlings species richness from the germinations from the seed bank. Differences between Mara Mara and Itare are illustrated as well as those between disturbed and undisturbed plots in the SW Mau forest reserve.

One-way analysis of variance result indicated significant differences in the mean number of families, genera, and species (see Table 4.4.3). Independent sample t test for pooled means for disturbed and undisturbed sites indicated no significant mean differences in the number of families ($t = 0.523$ $p > 0.05$), genera ($t = -0.691$ $p > 0.05$) and species ($t = -0.726$ $p > 0.05$). Dunned-T test indicated significant mean differences in a few of the plots with undisturbed plots having higher means (see Appendix 8.2.6).

Table 4.4.3 Differences in tree seedling species richness and density

The table shows differences in seedling floristic composition and density, for disturbed and undisturbed sites for germinations from the seed bank nursery trials in the SW Mau forest reserve.

ANOVA						
Variable	Source	SS	Df	MS	F	Sig
Family	Between groups	1071.82	6	178.64	4.30	0.000
	Within groups	7609.56	183	41.58		
	Total	8681.37	189			
Genus	Between groups	3913.62	6	652.27	3.83	0.001
	Within groups	31195.09	183	170.47		
	Total	35108.75	189			
Species	Between groups	4490.37	6	748.39	3.87	0.001
	Within groups	35405.09	183	193.47		
	Total	39895.45	189			
Seedling density	Between groups	2012.82	6	335.47	.83	0.547
	Within groups	73478.94	182	403.73		
	Total	75491.757	188			

The mean tree seedling species richness from seed bank germinations by forest sites, study plots and site description are shown in Appendix 8.2.5. Univariate analysis of variance using test of between-subjects effects showed that the variation in tree seedling species richness in the seed bank was significantly explained by the combined effects of forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed). Individually, variation due to forest site was significant (i.e. Mara Mara and Itare) see Table 4.4.4.

Table 4.4.4 Variation in seed bank species richness

The table shows the sources of variation and their interaction in influencing seed bank tree seedling species richness in the SW Mau forest reserve.

Source	SS Type III	df	MSS	F	Sig	Eta
Corrected Model	4481.64(a)	7	640.23	3.29	0.003	0.112
Constant Term	1259420.05	1	1259420.05	647.25	0.000	0.781
Forest site	2808.80	1	2808.80	14.44	0.000	0.730
State of site	216.42	1	216.42	1.11	0.293	0.006
Sampling plots	602.64	1	602.64	3.10	0.080	0.017
Forest site * state of site	19.88	1	19.88	0.10	0.750	0.001
Forest site * sampling plot	118.74	1	118.74	0.61	0.436	0.003
State of site * Sampling plot	24.71	1	24.70	0.13	0.722	0.001
Forest site * state of site * sampling plot	226.36	1	226.36	1.16	0.282	0.006

[a] R-Square = 0.112 (Corrected R-Square = 0.078)

4.5 FINE LITTER PRODUCTION IN THE SW MAU FOREST RESERVE

A description of the litter production in the study plots is given. Monthly litter yields are also given and comparisons between disturbed and undisturbed sites illustrated.

4.5.1 Site fine litter production

Litter was collected between September 2005 and August 2006. A higher amount of fine litter was collected in disturbed plots than in undisturbed ones. The highest cumulative amount of fine litter was collected during the month of January, while the lowest collection was made in the month of June in both disturbed and undisturbed sites. The mean minimum litter collected was recorded in June 2006 while the maximum was recorded in January 2006 (see Appendix 8.3.2). Results showed higher mean monthly litter inputs in the undisturbed plots than in the disturbed (see Appendix 8.3.4 and Fig. 4.5.1).

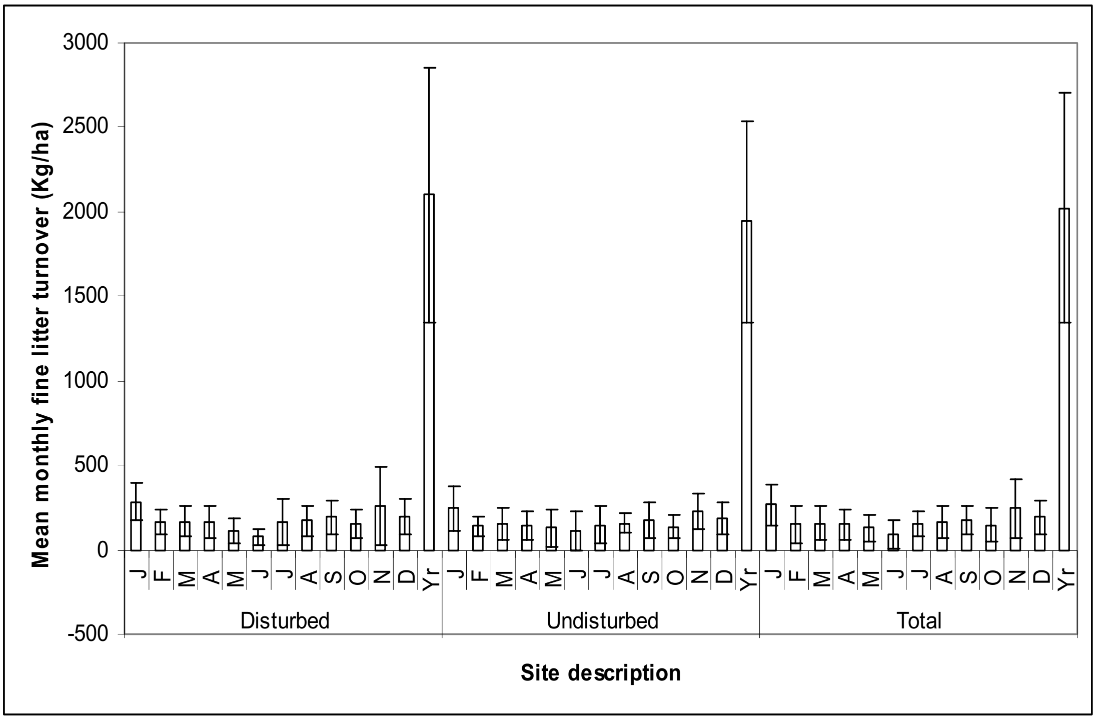


Fig. 4.5.1 Variation in fine litter inputs in the sampling plots
The figure shows the mean monthly fine litter turnover in Kg/ha, in the SW Mau Forest reserve turnover values in disturbed and undisturbed sites are compared.

The mean total annual fine litter input in Kg/ha/yr by forest sites, study plots and site description are shown in Appendix 8.3.3. The mean annual litter output from disturbed sites was relatively higher when compared to undisturbed plots (see Figure 4.5.2).

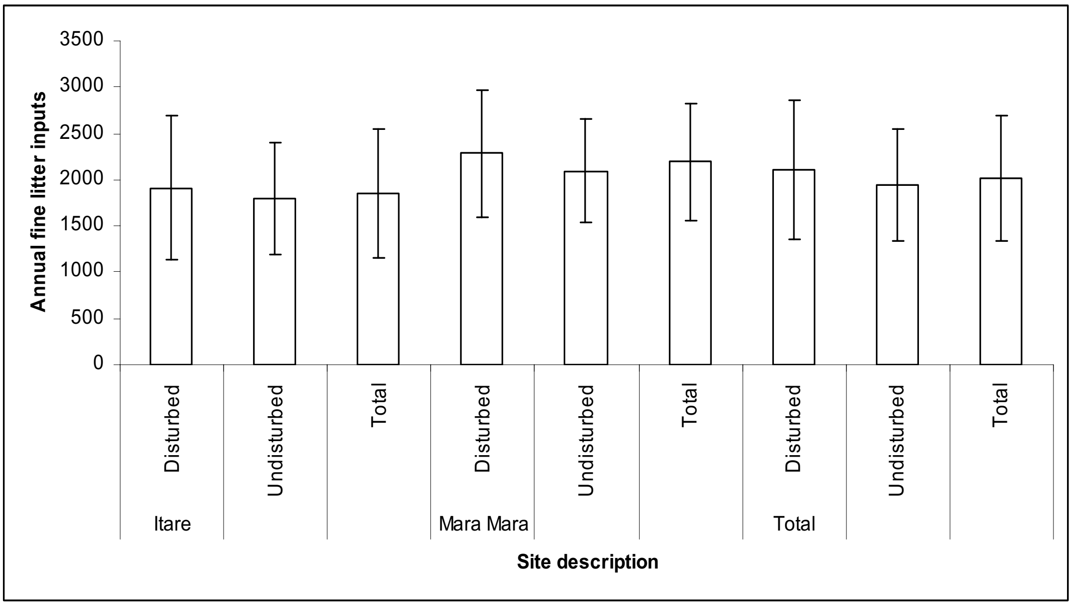


Fig. 4.5.2 Variation in fine litter inputs in the sampling plots

The figure shows the mean site fine litter turnover in Kg/ha in the SW Mau forest reserve. Turnover values in disturbed and undisturbed sites are compared as well as between the forest sites.

Univariate analysis of variation using test of between-subjects effects showed that the variation in fine litter inputs was not significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed. The variation was however, significantly contributed by the location of the site (i.e. the Mara Mara and Itare). The interaction effects did not significantly influence the variation in litter inputs (see Table 4.5.1).

Table 4.5.1 Variation in total annual fine litter input

The table shows the sources of variation and their interaction in influencing annual fine litter production in the SW Mau forest reserve.

Source	SS Type III	df	MSS	F	Sig	Eta-
Corrected model	6210771.23(a)	7	887253.033	2.03	0.057	0.113
Intercept	490104626.41	1	490104626.41	1121.18	0.000	0.909
Forest site	3492182.01	1	3492182.01	7.99	0.006	0.067
State of site	733734.96	1	733734.96	1.68	0.198	0.015
Plot	421623.08	1	421623.08	0.97	0.328	0.009
Forest site * State of site	34131.39	1	34131.39	0.08	0.780	0.001
Forest site * Plot	152724.68	1	152724.68	0.35	0.556	0.003
State of site * Plot	159476.04	1	159476.04	0.37	0.547	0.003
Forest site * State of site * Plot	1216899.08	1	1216899.08	2.78	0.098	0.024

[a] R-Square = 0.113 (Corrected R-Square = 0.057)

4.5.2 Fine litter nutrient content

From the results (Appendix 8.3.5 and. Fig. 4.5.3a), litter samples from the undisturbed plots had similar percentage carbon content as the general area sampled.

However, differences were recorded for the carbon content from disturbed plots. Variations occurred in the content of P, K, Mg and Ca among the sampling plots (and Fig. 4.5.3b).

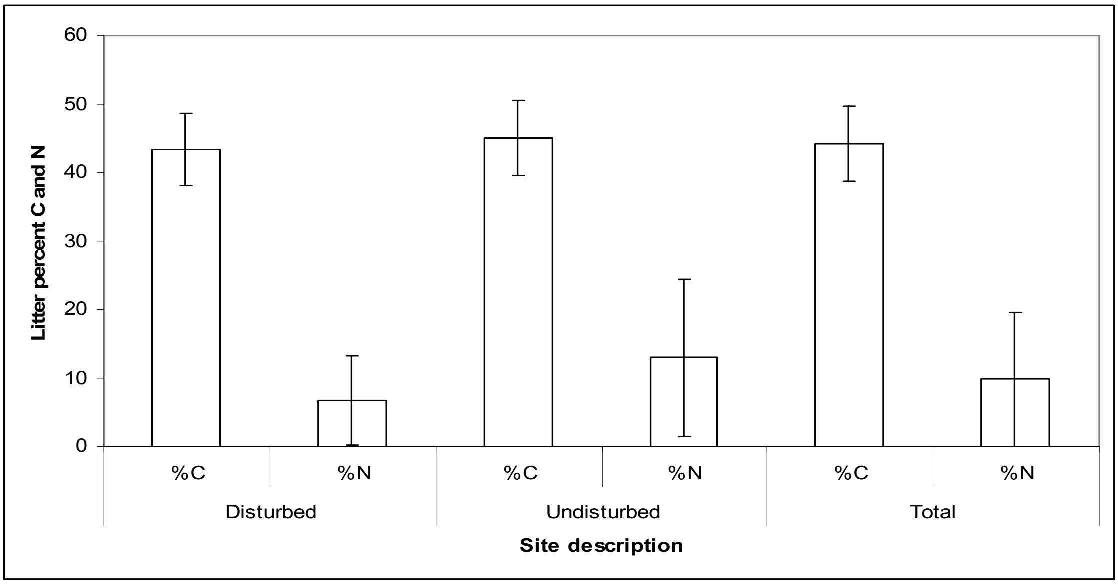


Fig. 4.5.2a Litter percent carbon and nitrogen content
Differences in mean fine litter content (C and N) across disturbed and undisturbed plots in the SW Mau forest reserve.

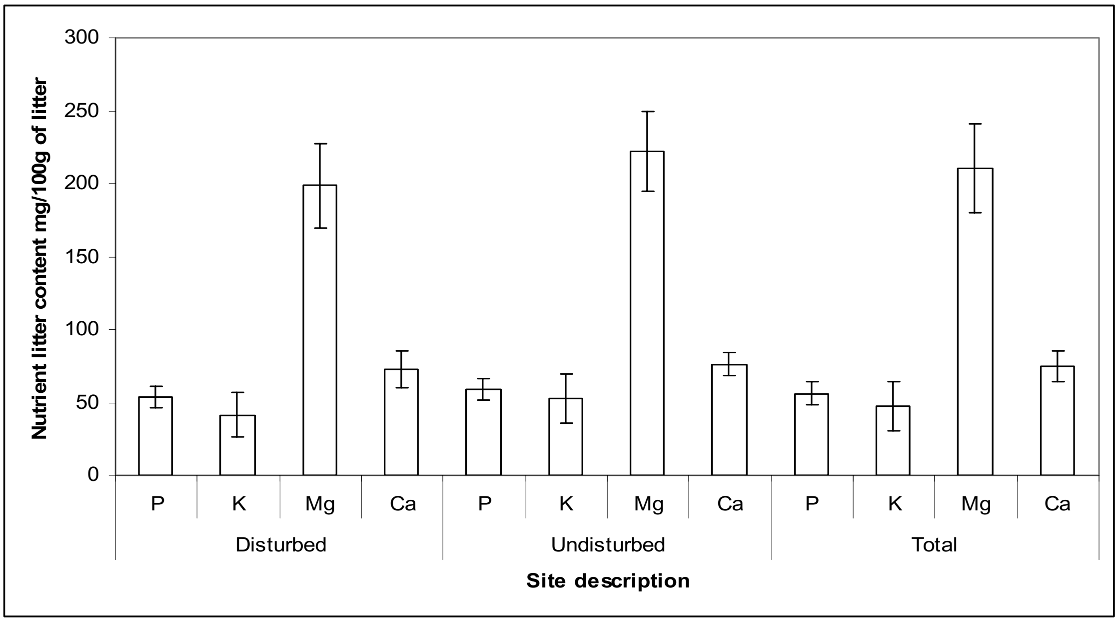


Fig. 4.5.3b Mean litter nutrient content
Differences in mean fine litter content (P, K, Mg and Ca) across disturbed and undisturbed plots in the Mau forest reserve.

One-way ANOVA indicated no significant mean differences between the sampling plots with regard to K, C and N. Significant mean differences were however reported for, Mg and Ca, (see Table 4.5.2). Multiple comparisons LSD (see Appendix 8.3.6) indicated that litter from undisturbed plots had higher means for P and, Mg, while the contrary was recorded for Ca.

Table 4.5.2 Test for equality of means for fine litter nutrient content
Analysis of variance between sampling plots for fine litter nutrient content in the Mau forest reserve.

		ANOVA				
	Source	SS	df	MSS	F	Sig
Phosphorus	Between groups	558.62	3	186.21	4.205	0.013
	Within groups	1417.08	32	44.28		
	Total	1975.69	35			
Potassium	Between groups	1441.39	3	480.46	1.776	0.172
	Within groups	8656.40	32	270.51		
	Total	10097.79	35			
Magnesium	Between groups	10545.42	3	3515.14	5.257	0.005
	Within groups	21395.90	32	668.62		
	Total	31941.32	35			
Calcium	Between groups	2007.47	3	669.16	11.574	0.000
	Within groups	1850.08	32	57.82		
	Total	3857.55	35			
Carbon	Between groups	41.71	3	13.90	0.457	0.714
	Within groups	973.02	32	30.41		
	Total	1014.73	35			
Nitrogen	Between groups	374.46	3	124.82	1.343	0.278
	Within groups	2973.42	32	92.92		
	Total	3347.89	35			

4.5.3 Site fine litter quality.

The C: N ratios were higher in the disturbed plots than the undisturbed (Appendix 8.3.7). The disturbed and undisturbed plots had equal means for the C: P ratio (see Appendix 8.3.8) Statistical mean differences were shown between the disturbed and undisturbed sampling plots (see Fig. 4.5.4a and b, Table 4.5.3).

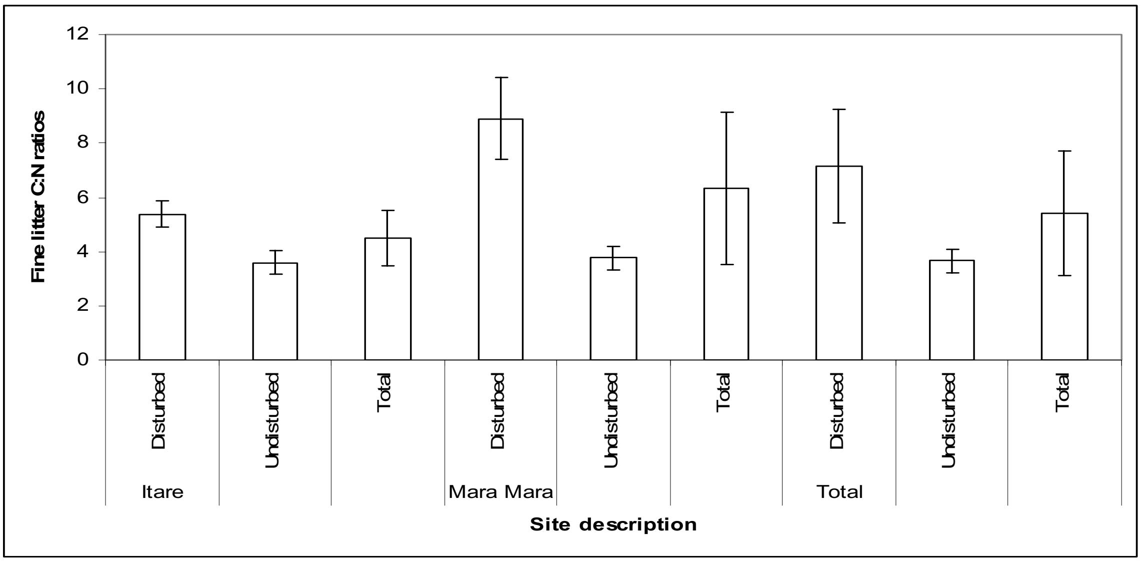


Fig. 4.5.4a Fine litter quality (C: N) in the sampling sites
The figure illustrates the differences in C: N fine litter ratios in the disturbed and disturbed sampling sites in the SW Mau forest reserve. Variations between Mara Mara and Itare forest sites are also illustrated.

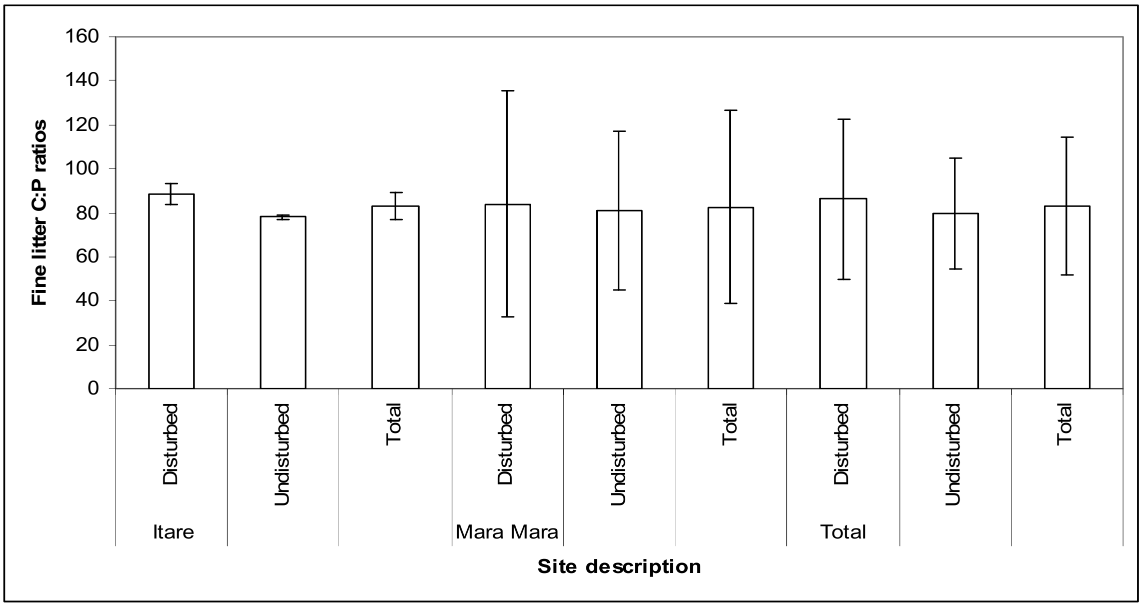


Fig. 4.5.4b Fine litter quality (C: P) in the sampling sites
The figure illustrates the differences in C: P fine litter ratios in the disturbed and disturbed sampling sites in the SW Mau forest reserve. Variations between Mara Mara and Itare forest sites are also illustrated.

Independent sample t test for pooled means for disturbed and undisturbed sites indicated no significant mean differences in the C: P, ratios. However, C: N had significant mean differences with undisturbed plots having lower mean ratios (see Table 4.5.3). Multiple comparisons among the study plots are shown in Appendix 8.3.9.

Table 4.5.3 Test for mean differences in site litter quality

The table shows tests for equality of means for C: N and C: P ratios between the study plots in the SW Mau forest reserve.

Test for equality of means

Variables	Test	Statistic	df1	Df2	Sig.
C: N	Levene	5.62	7	112	0.000
	Welch-Test	90.74[a]	7	47.50	0.000
C: P	Levene	4.54	7	112	0.000
	Welch-Test	22.40 [a]	7	45.43	0.000

[a] Asymptotically F-distributed

Independent samples t-Test for mean for C: N and C: P ratios

	State of site	N	Mean	SD	T	Sig
C: N	Undisturbed	60	3.67	.439	-12.620	0.000
	Disturbed	60	7.14	2.09		
C: P	Undisturbed	60	79.52	25.20	-1.178	0.242
	Disturbed	60	86.23	36.23		

The mean fine litter C: N ratio by forest sites, study plots and site description are shown in Appendix 8.3.7. Univariate analysis of variation using test of between-subjects effects showed that the variation in fine litter C: N ratio was significantly explained by forest sites (Itare and Mara Mara) sampling plots (A and B) as well the description of the sites (disturbed or undisturbed. The variation was mainly contributed by the location of the site (i.e. the Mara Mara and Itare) and the state of the site. The interaction effects were strongest between forest site and the state of the site (see Table 4.5.4a).

Table 4.5.4a Variation in fine litter quality in the SW Mau forest reserve

The table shows the sources of variation and their interaction in influencing site fine litter quality (C: N ratios) in the SW Mau forest reserve.

Source	SS Type III	Df	MSS	F	Sig	Eta
Corrected Model	553.73(a)	7	79.11	116.39	0.000	0.879
Intercept	3508.24	1	3508.24	5161.66	0.000	0.979
Forest site	102.16	1	102.16	150.30	0.000	0.573
State of site	361.79	1	361.79	532.30	0.000	0.826
Sampling plot	1.91	1	1.91	2.81	0.097	0.024
Forest site * State of site	84.27	1	84.27	123.98	0.000	0.525
Forest site * sampling plot	1.09	1	1.09	1.60	0.209	0.014
State of site * sampling plot	0.13	1	0.13	0.19	0.664	0.020
Forest site * State of site * sampling plot	2.40	1	2.40	3.53	0.063	0.031

[a] R-Square = 0.879 (Corrected R-Square = 0.872)

The mean fine litter C: P by forest sites, study plots and site description are shown in Appendix 8.3.8. The carbon phosphorus ratio was not significantly explained by forest sites (Itare and Mara Mara) sampling plots (A an B) as well the description of the sites (disturbed or undisturbed (see Table 4.5.4b).

Table 4.5.4b Variation in fine litter quality

The table shows the sources of variation and their interaction in influencing site fine litter quality (C: P ratios) in the SW Mau forest reserve.

Source	SS Type III	Df	MSS	F	Sig	Eta
Corrected Model	5784.99(a)	7	826.43	0.84	0.558	0.050
Intercept	824155.53	1	824155.53	835.57	0.000	0.882
Forest site	16.91	1	16.91	0.02	0.896	0.000
State of site	1351.00	1	1351.00	1.37	0.244	0.012
Sampling plot	51.18	1	51.18	0.05	0.820	0.000
Forest site * State of site	424.61	1	424.61	0.43	0.513	0.004
Forest site * sampling plot	53.82	1	53.82	0.06	0.816	0.000
State of site * sampling plot	2268.78	1	2268.78	2.30	0.132	0.020
Forest site * State of site * sampling plot	1618.70	1	1618.70	1.64	0.203	0.014

[a] R-Square = 0.050 (Corrected R-Square = 0.010)

4.5.4 Fine litter nutrient inputs and stand nutrient use efficiency

Annual inputs of carbon, magnesium and calcium were higher in the disturbed sites than in the undisturbed. Conversely, higher inputs for nitrogen, phosphorus and potassium were recorded in undisturbed sites (Appendix 8.3.10). Significant differences for the mean values for P, K, Mg, and Ca were reported. Mean values for C were however, not significantly different between the disturbed and the undisturbed sites (Fig. 4.5.5).

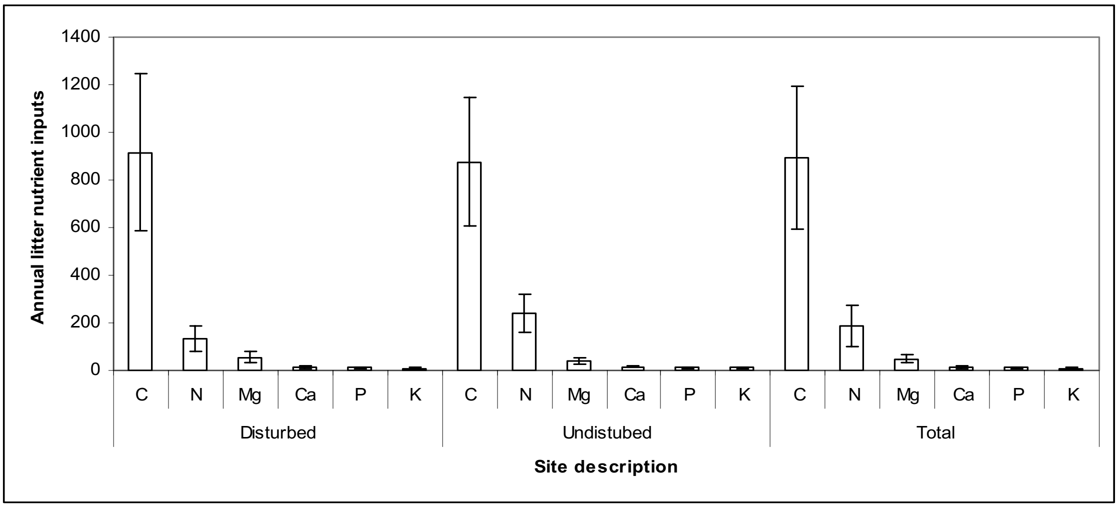


Fig. 4.5.5 Annual fine litter nutrient inputs

Differences in mean fine litter annual nutrient (C, N, Mg, Ca, P and K) inputs in Kg ha^{-1} yr^{-1}across disturbed and undisturbed plots in the SW Mau forest reserve. Total fine litter nutrient inputs (Kg ha^{-1} yr^{-1}) to the sites were calculated by multiplying monthly litter production values for each sampling site by nutrient concentration for the same site and month and adding them over the entire year.

Significant differences in the mean for inputs of N were also significantly different across the study plots. Independent sample t test for pooled means for disturbed and undisturbed sites indicated no significant mean differences in the annual inputs of C, P, and Ca. However, the N, K and Mg had significant mean differences with undisturbed plots having higher means (see Table 4.5.5). Multiple comparisons (see Appendix 8.3.11) using LSD revealed significantly higher values of N, P, K and Ca input in undisturbed plots when compared to the disturbed. However, mean values for Mg were significantly higher in the disturbed plots.

Table 4.5.5. Differences in mean annual fine litter nutrient inputs

Comparisons between mean annual nutrient inputs in $Kgha^{-1}yr^{-1}$ in the SW Mau forest reserve.

Test for homogeneity of variances

Element	Levene-Statistic	df1	df2	Sig
Carbon	1.61	7	112	0.139
Nitrogen	2.17	7	112	0.043
Phosphorus	1.29	7	112	0.261
Potassium	1.54	7	112	0.161
Magnesium input	1.84	7	112	0.086
Calcium	1.49	7	112	0.177

Test for equality of means ANOVA

Element	Source	SS	Df	MSS	F	Sig
Carbon	Between groups	1082633.90	7	154661.99	1.81	0.093
	Within groups	9590980.01	112	85633.75		
	Total	10673613.91	119			
Phosphorus	Between groups	362.57	7	51.806	3.89	0.001
	Within groups	1491.78	112	13.32		
	Total	1854.34	119			
Potassium	Between groups	276.86	7	39.55	3.12	0.005
	Within groups	1419.43	112	12.67		
	Total	1696.28	119			
Magnesium	Between groups	12800.47	7	1828.64	6.73	0.000
	Within groups	30432.49	112	271.72		
	Total	43232.96	119			
Calcium	Between groups	1006.46	7	143.78	6.07	0.000
	Within groups	2653.44	112	23.69		
	Total	3659.89	119			

Independent samples t-test

Nutrient	State of site	N	Mean	SD	T	Sig
C	Undisturbed	60	876.49	267.30	-0.67	0.494
	Disturbed	60	914.08	329.76		
N	Undisturbed	60	241.51	80.83	8.47	0.000
	Disturbed	60	135.01	54.27		
P	Undisturbed	60	11.50	3.59	0.24	0.810
	Disturbed	60	11.33	4.31		
K	Undisturbed	60	10.66	3.92	2.68	0.008
	Disturbed	60	8.86	3.43		
Mg	Undisturbed	60	42.90	13.37	-4.21	0.000
	Disturbed	60	56.61	21.41		
Ca	Undisturbed	60	14.74	4.67	-0.61	0.540
	Disturbed	60	15.37	6.33		

Within stand mean nutrient use efficiency for C, N, P, K, and Ca were lower in the undisturbed plots than in the disturbed. However, values for magnesium were higher in the undisturbed plots (see Appendix 8.3.12). The within stand mean nutrient use efficiency for C, N, P, K, and Ca in the undisturbed disturbed sites are illustrated in Fig. 4.5.6.

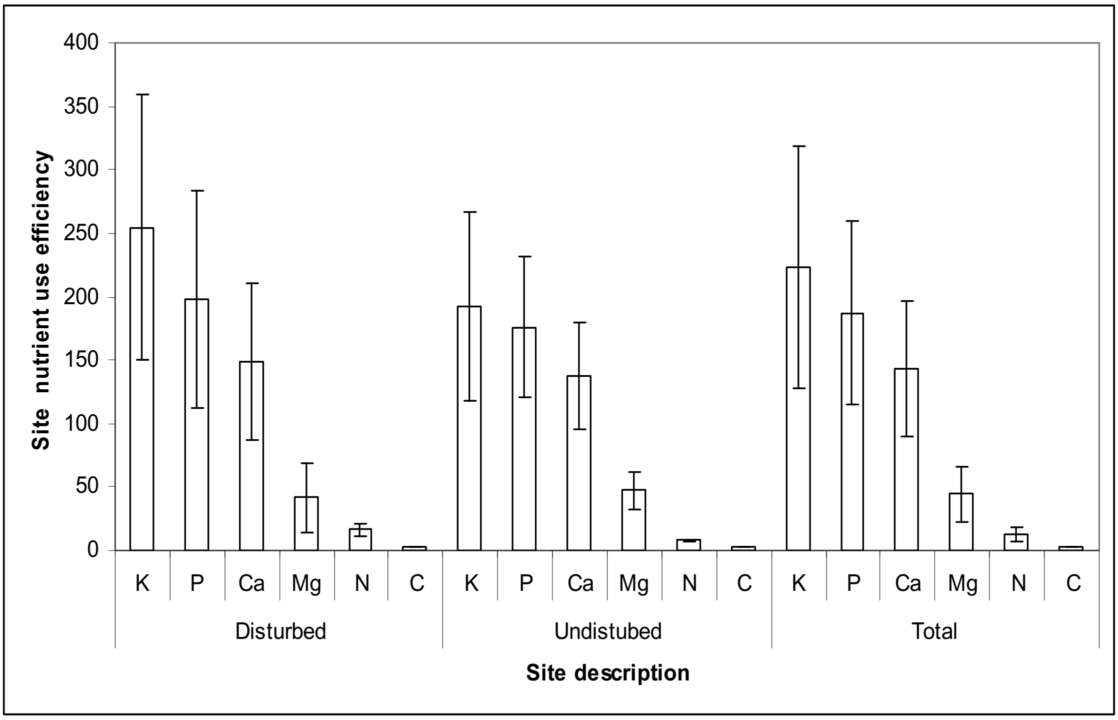


Fig. 4.5.6. Within stand nutrient use efficiencies in the sampling sites

The figure shows within stand nutrient use efficiency (NUE) defined as kilograms of dry litter mass per kilogram of nutrient content for K, P, Ca, Mg, N and C. in the SW Mau forest reserve.

Test for equality of means indicated significant differences between the plots for the nutrient use efficiency mean values for C, N, P, K, Mg and Ca (see Table 4.5.6).Independent sample t test for pooled means for disturbed and undisturbed sites indicated no significant mean differences in the nutrient use efficiency of P, Mg and Ca. However, N and K had significant mean differences with undisturbed plots having lower mean use efficiencies (see Table 4.5.6).

Table 4.5.6. Differences in mean nutrient use efficiency
Comparisons between mean within stand nutrient use efficiencies in the sampling plots in the SW Mau forest reserve.

Test for equality of means

Element	Test	Statistic[a]	Df1	Df2	Sig.
Carbon	Welch-Test	6.52 [a]	7	47.09	0.000
Nitrogen	Welch-Test	110.93 [a]	7	47.45	0.000
Phosphorus	Welch-Test	361.82 [a]	7	45.77	0.000
Potassium	Welch-Test	87.16 [a]	7	47.06	0.000
Magnesium	Welch-Test	32.56 [a]	7	44.55	0.000
Calcium	Welch-Test	473.49 [a]	7	46.93	0.000

[a] Asymptotically F-distributed

Independent samples t-Test

NUE	State of site	N	Mean	Sd	T	Sig
C	Undisturbed	60	2.22	0.04	-5.67	0.000
	Disturbed	60	2.30	0.11		
N	Undisturbed	60	8.13	1.00	-13.25	0.000
	Disturbed	60	16.39	4.73		
P	Undisturbed	60	176.13	54.94	-1.68	0.096
	Disturbed	60	198.23	85.89		
K	Undisturbed	60	192.78	74.44	-3.73	0.000
	Disturbed	60	254.46	104.47		
Mg	Undisturbed	60	47.15	14.91	1.38	0.171
	Disturbed	60	41.62	27.23		
Ca	Undisturbed	60	137.50	42.17	-1.16	0.249
	Disturbed	60	148.77	62.38		

4.6 SOCIOECONOMIC AND ECOLOGICAL CHARACTERIZATION

A description of the community demographic profile is given, settlement history and land use changes outlined as well as perceptions about status of biodiversity and forest condition. The importance and adequacy of forest goods and services to the community are evaluated. The overall relationship between socioeconomic well being and forest health is illustrated. Efforts towards conservation are solicited.

4.6.1 Community demographic profile

The age range for the household heads was 21 - 82 years. The number of males and females in the households was 0 - 13 and 0 - 7 respectively. Household size ranged between 1 and 16 members while time of occupancy or settlement ranged between 2 - 86 years. For the sampled households the distance from the homestead to the forest reserve boundary ranged from 0 - 4 km at time of settlement but currently stands at 0.05 - 4km (see Table 4.6.1).

Table 4.6.1 Household demographic profile

The table shows the household structure based on gender age, size, and residence with respect to forest boundary in the SW Mau forest reserve.

Personal socioeconomic descriptors					
Variable	N	Min	Max	Mean	SD
Age of household head	149	21.00	82.00	48.87	12.76
Household size (male)	144	0.00	13.00	3.71	1.85
Household size (female)	144	0.00	7.00	3.22	1.42
Total household size	146	1.00	16.00	6.90	2.51
Number of years settled in the area	149	2.00	86.00	36.24	16.03
Distance to forest reserve boundary (Km)	145	0.05	4.00	1.48	1.01
Distance at time of settlement (Km)	145	0.00	4.00	1.13	0.87

The major sources of income were listed as sales from tea and sale of livestock and livestock products. Other sources of income in the sampling area include business, formal employment; remittances, casual labour, and sale of firewood and honey (see Table 4.6.2).

Household expenditure on firewood was the highest among other forest-based goods. The expenditure on pasture and fodder was nearly half that on firewood and nearly the sum of charcoal and honey.

Table 4.6.2 Household income source and expenditure

The table shows the sores of household income among household living near the SW Mau forest reserve. The main stay of the households is tea farming, which contributes the highest to household cash inflows. The mean monthly household incomes and expenditure are shown.

Household sources of income

Source	No of respondents(N = 150)	% of respondents (N = 150)
Cash crops (Tea)	127	84.7
Livestock	33	22.0
Business	28	18.7
Employment	18	12.0
Casual labour	16	10.7
Firewood	6	4.0
Remittances	4	2.7
Honey	4	2.7

Monthly and annual household incomes

Source of income	Monthly(N = 150)				Annual(N = 150)			
	Mean	SD	Total Ksh	US $	Mean	SD	Total Ksh	US $
Cash crops	759727.00	13763.11	972450	13892	90203.14	165305.5	11546002	164943
Employment	4361.11	6698.65	235500	3364	52333.33	80383.75	2826000	40371
Business	2450.00	6868.5	151900	2170	29400	82422.02	1822800	26040
Livestock	961.03	1725.5	65350	934	11525	20708.82	783700	11196
Casual labour	750.00	1241.25	33000	471	9000	14894.98	396000	5657
Honey	163.41	793.65	6700	96	2100	9660.39	84000	1200
Remittances	151.16	562.04	6500	93	1902.44	6898.57	78000	1114
Firewood	143.9	383.44	5900	84	1726.83	4601.25	70800	1011
Total			1477300	21104			17607302	251533

Household expenditures on forest based resources

Variable	Monthly (N = 150)				Annual (N = 150)	
	Mean	SD	Ksh	US$	Ksh	US$
Firewood	60.00	90.25	8344	119	100128	1430.40
Fodder/Pasture	33.43	72.4	4580	65	54960	785.14
Honey	19.38	109.74	2500	35	30000	428.57
Charcoal	13.28	106.01	1700	24	20400	291.43
Total			17124	244	205488	2935.54

Majority of the household sampled were headed by men. Similarly, most of the household heads were married (see Fig. 4.6.1).

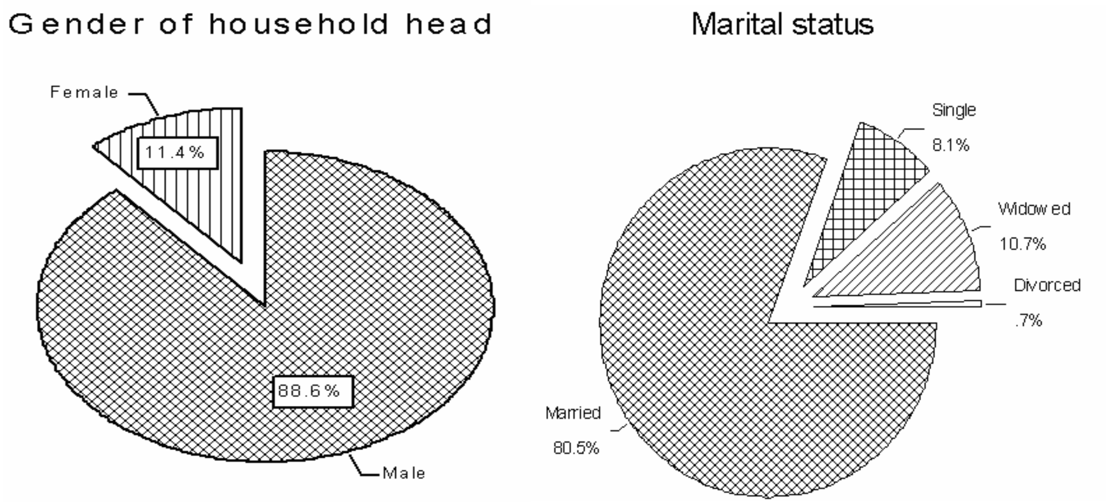


Fig. 4.6.1 Household gender and marital status

The households in the study area have a patriarchal family structure. Hence most if not all households are headed by men. Cases of female-headed households arise only in cases of death of the husband, single parenthood, separation or divorce. Marriage is an important social institution and divorce is highly discouraged.

Housing units in the study area were mainly semi-permanent, though some were permanent constructed of raw stalls. Some of the respondents however, lived in temporary structures (see Fig. 4.6.2).

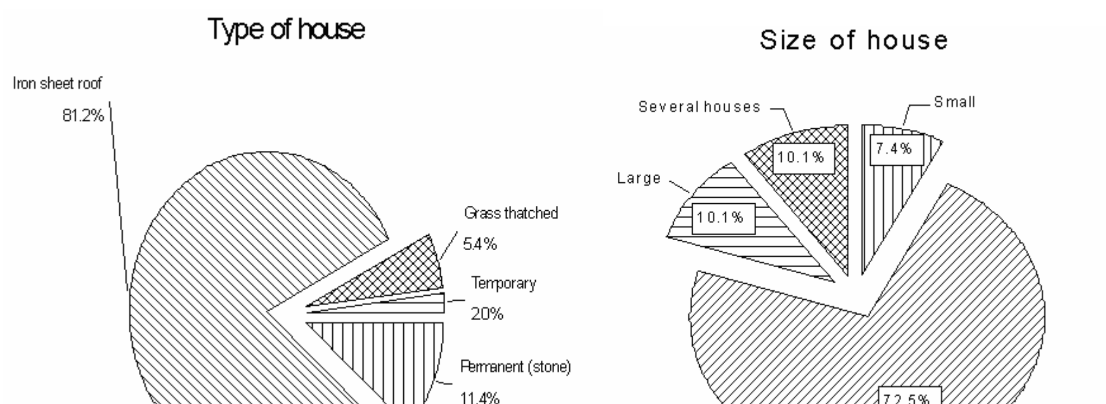


Fig. 4.6.2 Housing type and size

Most of the houses were constructed of wood with mud walls and iron sheet roof, permanent houses were constructed of raw stone, brick or sand and cement blocks with iron sheet roof. Grass thatched houses were made of wood and mud walls with a grass-thatched roof repaired after several seasons while temporary structures were makeshift structures used by illegal settlers and squatters. The size of the houses varied from large which consisted of 3 - 4 bedrooms and other spacious rooms housing all the household members, medium sized houses comprised 2 - 3 bedrooms with a living room while small houses had only one bedroom. Several houses arose especially in large households where the boys had a separate house for themselves in addition to other houses in case of polygamy.

Health care in the study area was obtained mainly from the divisional health centre. However, some of the respondents indicated reliance on herbalists and individual use of herbs for medicine obtained from the forest reserve. Majority of the respondents were satisfied with the health care afforded (see Fig. 4.6.3).

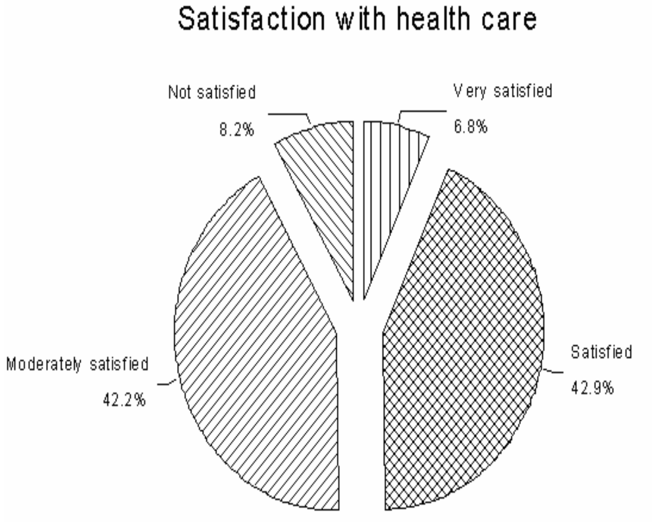


Fig. 4.6.3 Household level of satisfaction with the health care

The level of satisfaction with health care was determined by evaluating the distance to the nearest health care facility, type of health facility as well the service provided. Very satisfied means the distance to the health facility is less than 5 kilometres, it is a district or private hospital and most services are available. A variation from this yielded the other levels of satisfaction.

Based on the above variables the socioeconomic status of households was defined in terms of social stratification (see Fig. 4.6.4).

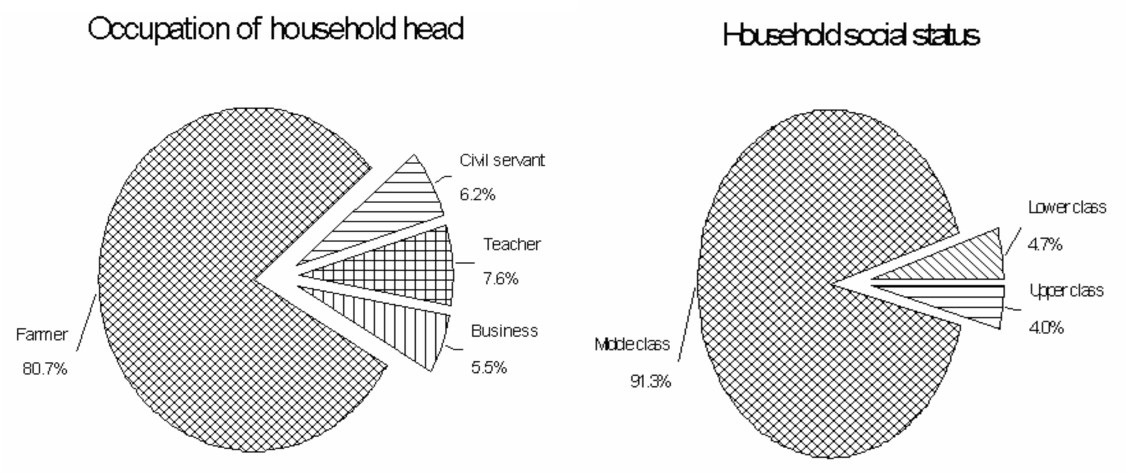


Fig. 4.6.4 Household occupation and social stratification

The households sampled had a similar lifestyle and belong to one ethnic group. Their social stratification is mainly based on tea growing which is almost practised by all households. This is the reason why almost all belong to the middle class interpreted to mean they can afford basic needs food, shelter and clothing. The stratification is based on their socioeconomic profile. Those belonging to upper class have mainly diversified their income sources by engaging in business or being employed in the civil service.

4.6.2 Livestock sub sector

Livestock keeping is an integral part of the lifestyle of the people living in the study area. Grazing animals both cattle, sheep and goats are a familiar part of the landscape in the reserve. The type of livestock kept range from indigenous native types, pedigree to crosses between the two types herein referred to as improved (see Table 4.6.2). Majority of the respondents have set aside part of their land for grazing, while some graze their animals solely in the forest reserve. A few graze their stocks along the roadsides. Others, complement the set aside land with forest grazing while at the same time graze the stocks both along the roadsides and in the forest.

Photo Fieldwork 2006

Fig. 4.6.5 Livestock grazing in the SW Mau reserve

Livestock grazing is a phenomenal aspect in the SW Mau forest reserve. It is responsible for considerable disturbance in the form of browsing, grazing trampling and trailing in the reserve. In cases of overgrazing soil erosion may result.

The main methods of grazing as indicated by the respondents (see Table 4.6.3) include free range in the forest, tethering and padlocking. Zero grazing an intensive practice where the livestock are fed from shelters in the homestead is not popular.

Table 4.6.3 Livestock statistics grazing area and methods

Household involvement in livestock keeping as a source of livelihood is illustrated. Grazing types and areas are also given to illustrate the relative importance of the SW Mau forest reserve.

Livestock statistics					
Livestock type	Range	Mean per household	SD	SE	Total
Improved cattle	0.00-25	2.93	3.81	0.34	378
Indigenous sheep	0.00-35	1.91	4.72	0.42	244
Indigenous cattle	0.00-14	1.61	2.61	0.23	206
Indigenous goats	0.00-50	1.27	5.08	0.45	163
Improved sheep	0.00-30	0.67	2.99	0.67	82
Improved goats	0.00-40	0.44	3.67	0.33	54

Grazing area and methods

Grazing area	**% of respondents**	Grazing method	**% of respondents**
Part of the farm	52.7	Tethering	28.0
Forest	23.3	Forest grazing	28.7
Forest/ part of the farm	6.0	Paddocking	22.7
Roadside	4.7	Tethering/forest grazing	6.7
Forest / roadside	3.3	Zero grazing	4.0

4.6.3 Settlement history and land use changes

Survey results (Fig. 4.6.5) indicated that human settlement in the study area started in the early 1920s and has been ongoing with the latest immigrants having arrived in 2004. Land ownership according to the household survey (see Fig. 4.6.5) ranged from land with title deeds, land without titles, and either hired or rented land to squatter status. According to information gathered from sampled households that land at time of settlement was primarily forest, and or pasture, however, current land use among the respondents was farmland with a minority having forest and pasture patches (see Fig. 4.6.6).

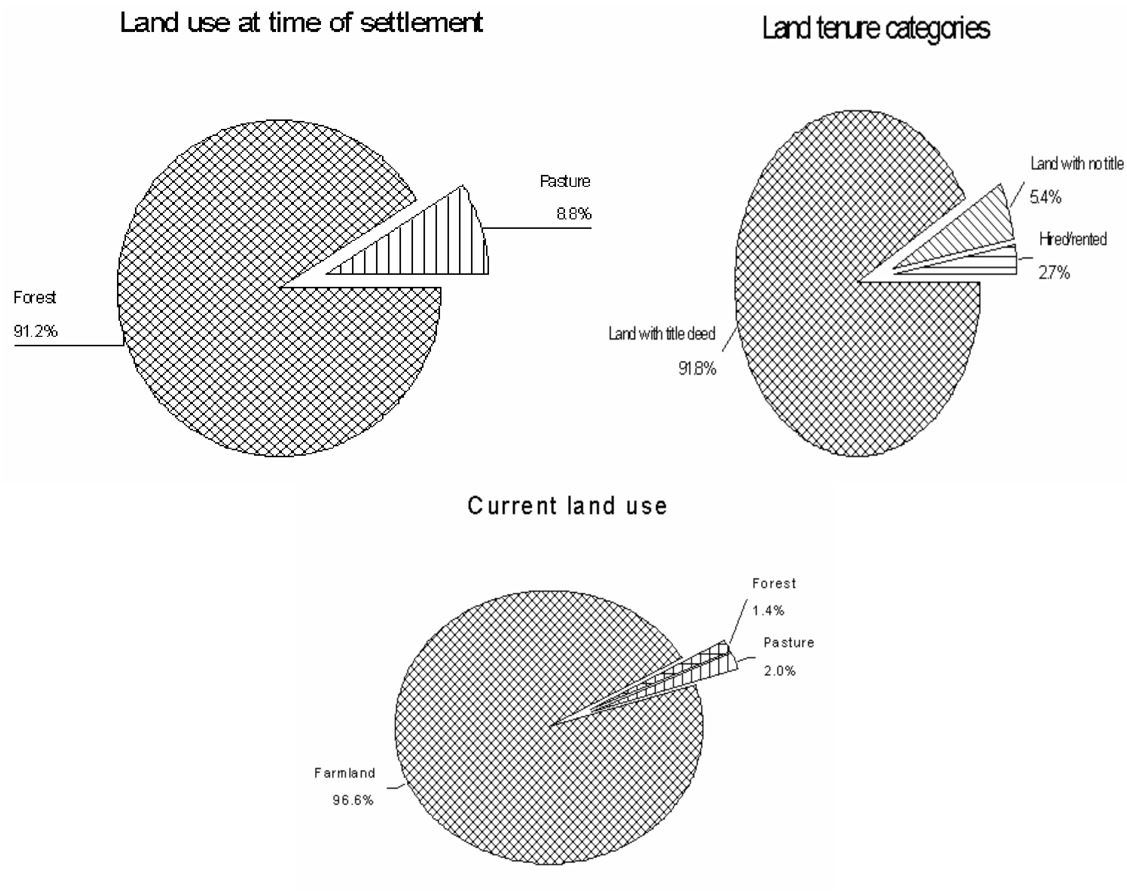


Fig. 4.6.6 Land tenure and land use change

From the household survey, it emerged that at time of settlement the occupied land was mainly forest. The early settlers (formal) (1920) settled on forested land, later settlers bought or inherited land that was mainly pasture. Current evaluation shows that over 90% of the households have there land as farmland. Preserved forests patches on individually owned land are rare. Most of the land is owned privately with title deeds, which provides incentives for long time investments in tea farming.

4.6.4 Biodiversity and forest condition

At the time of settlement the following tree species (see Table 4.6.4a) were identified by the respondents as having dominated the forest landscape; *Zanthoxylum gilletii*, *Prunus africana, Hagenia abyssinica, Albizia gummifera, Croton macrostachyus, Syzigium guineense* and *Ekebergia capensis.*

Table 4.6.4a Dominant tree species at time of settlement

The table shows the dominant tree species that were encountered by the respondents at the time of settlement on the fringes of SW Mau forest reserve

	Dominant tree species at time of settlement	
Tree species	No of respondents(N =150)	% of respondents(N =150)
Z. gilletii	72	48.0
P. Africana	64	42.7
P. fulva	44	29.3
H. abyssinica	32	21.3
A. gummifera	27	18.0
C. macrostachyus	23	15.3
S. guineense	7	4.7
E. capensis	7	4.7

Survey results (see Table 4.6.4b) revealed that majority of the respondents at time of settlement encountered a three-storey forest; many tree species, the presence of large sized trees and many and varied wildlife species.

Table 4.6.4b Description of forest physiognomy

The table shows respondents description of the physical appearance of the forest at time of settlement and the current state including the size of trees, relative number of species, storeys and population and variety of wildlife in the SW Mau forest reserve.

Respondents perceptions about forest physiognomy		
Variable	Condition at Settlement (%)	Present Condition (%)
Number of storeys		
One	1.3	4.7
Two	18.7	66.7
Three	73.3	16.0
Number of species		
Few	0.0	8.0
Several	4.7	16.0
Many	93.3	72.7
Size of trees		
Small	0.0	1.3
Medium	2.0	11.3
Big	89.3	82.7
Very big	7.3	0.7
Population and variety of wildlife		
Few	10.7	90.7
Many	85.3	6.0
Very many	2.7	0.7

The physical appearance of the forest at settlement time was also described as having two storeys with few species of medium sized trees and few wildlife species. There were also isolated cases where only one storey layering of the forest was seen at time of settlement.

Photo Fieldwork 2006

Fig. 4.6.7 Undisturbed site in the SW Mau reserve

The photograph shows a typical undisturbed site in the SW Mau reserve. The presence a multi storey layering lianas and climbers. A high frequency of lichens orchids and mosses on tree trunks was common.

Among the households sampled, over half were of the opinion that the changes observed in forest physiognomy could be attributed to growth in human population, clearing for the "nyayo tea zone[22]", tree felling for household use, charcoal conversion, overgrazing by domestic animals and illegal logging in and around the reserve (see Table 4.6.4c).

Table 4.6.4c Causes for change in forest physiognomy

The table shows the perceptions of the respondents as to the causes of the changes in forest appearance between time of settlement and the current state in the SW Mau forest reserve.

Reasons for change in forest physiognomy			
Reason	% respondents(N = 150)	Reason	% respondents N = 150
Population growth	57.3	Road construction	25.3
Nyayo tea zone	42.7	Energy alternatives	8.0
Tree felling	30.7	Wind throw	6.7
Illegal logging	28.7	Climate change	5.3
Overgrazing	28.7	Stem debarking	4.7
Charcoal	31.3	Corruption	0.7

[22] **Nyayo tea zone** . A zone of tea plantation around forest reserves mend to to a barrier between private land and the forest reserve

Photo Fieldwork 2006

Fig. 4.6.8 Livestock and road development

Effects of livestock grazing and road construction (picture foreground) in the SW Mau forest reserve has led to site degradation. Overgrazing, trampling and tracking by livestock were common. Loss of forest cover during road construction and the opening of the area for exploitation were evident during the survey.

Photo Fieldwork 2006

Fig. 4.6.9 Extraction of posts in the SW Mau forest reserve

The extraction of posts and poles in the reserve is done both at commercial and subsistence level. Posts are used for construction of farm structures. Specific species are sought hence can lead to decimation of individual species for example *Juniperus procera*, *Bridelia microphylla.*

Photo Fieldwork 2006

Fig. 4.6.10 Firewood collection from the SW Mau forest reserve

This could be for sale or for domestic energy needs. Households rated firewood collection as one of the most important direct drivers of forest degradation. Members of the community suggested that it is important to seek alternative energy sources for domestic use if conservation efforts are to bare any fruits in the area.

Photo Fieldwork 2006

Fig. 4.6.11 Collection of withies for building in the SW Mau reserve

This is a bundle of young trees that have been harvested from the reserve for purposes of domestic construction. They are used to construct houses, grain stores, livestock pens and fences.

Infrastructural development especially road construction was also singled out as a factor that contributed to the changes. Other factors reported as causes of the changes include absence of alternatives to fuel wood as a source of domestic energy; stem debarking for medicines, changes in climatic patterns and wind throw (see Table 4.6.4).

Photo Fieldwork 2006

Fig. 4.6.12 Debarking of trees for medicine

The most common species that have been affected in the SW Mau are *Zanthoxylum gilletii* (seen in this plate), and *Prunus africana.* The method of extracting the bark is unsustainable as it leads to death of the affected trees.

Respondents reported a number of animals and trees to have reduced in numbers in the reserve. According to the survey results, (see Table 4.6.5) the population of antelopes, wild pigs, elephants, hyenas and various monkeys was on a rapid decrease.

Table 4.6.5 Threatened animals and trees and perceived threats

The table shows the animals and tree species perceived threatened as well as the perceived threats for both trees and animals in the SW Mau forest reserve (N = 149)**.**

Threatened animals and tree species			
Animals	% respondents	Trees	% of respondents
Antelopes	34.7	*Hagenia abyssinica*	13.3
Wild pigs	34.7	*Ekebergia capensis*	4.7
Elephants	15.3	*Prunus africana*	2.0
Hyenas	12.0	*Podocarpus Spp.*	1.3
Monkeys	2.0	*Albizia gummifera*	0.7

Perceived threats			
Animals	% respondents	Trees	% respondents
Hunting	40.7	Population and settlements	36.0
Population and settlements	36.0	Change in land use	24.7
Destruction of habitats	26.7	Debarking for medicines	8.0
Changes in land use	24.7	Animal damage	12.7
Overgrazing	12.7	Illegal logging	6.7
Pathological causes	4.7	Pathological causes	4.7
Poverty	2.0	Poverty	2.0
Laxity by conservation agents	2.0	No regeneration	1.3

Survey results indicate that several tree species that were once common or dominant in the area are increasingly becoming rare (see Table 4.6.5). Listed species were occasionally encountered especially on fringes of the forest reserve.

Several reasons (see Table 4.6.6) for the diminishing presence of animal species in the reserve were given. Similarly, threats to once dominant tree species in the landscape were listed. According to the respondents, human population increase in areas around the reserve was the major single factor with multifaceted ways of influencing forest degradation. Increase in human population was ranked as a very important cause of forest degradation, followed by firewood collection. The other listed causes are also human related activities (see Table 4.6.6).

Table 4.6.6 Causes and threats to animals and trees in the reserve

The table lists causes or drivers to loss of animals and trees in the reserve. Rankings of the given threats in the SW Mau forest reserve by the respondents are also recorded.

Causes of forest degradation			
Causes	% respondents	Causes	% respondents
Population increase	88.7	Logging	48.7
Firewood collection	87.3	Land use change	44.7
Agriculture	69.3	Land subdivision	42.7
Overgrazing	56.7	Infrastructure	38.7
Exotic species	50.0	Timber	34.7
Charcoal	49.3	Wild fires	27.3

Ranking of the causes					
Ranking	Very Important	Important	Moderately Important	Not important	Not important at all
Causes	Percent	Percent	Percent	Percent	Percent
Population increase	56.0	32.7	0.0	0.0	3.3
Firewood collection	30.0	32.0	22.0	3.3	3.3
Logging	9.3	13.3	4.0	14.7	36.7
Infrastructure	5.3	5.3	21.3	5.3	41.3
Land subdivision	4.7	27.3	8.0	2.0	43.3
Land use change	3.3	25.3	12.7	2.7	37.3
Agriculture	3.3	46.0	16.0	3.3	18.0
Overgrazing	2.0	18.7	28.7	2.7	29.3
Exotic species	2.0	20.7	27.3	1.3	32.0
Charcoal	1.3	11.3	14.7	20.0	31.3
Timber	0.7	5.3	6.0	8.7	54.7
Wild fires	0.0	1.3	1.3	5.3	65.3

4.6.5 Forest products use, importance and adequacy

Over 80% of households sampled indicated that the reserve was moderately important to important in providing goods. The proportion that considered it very important and not important was 8.7% and 10.7% respectively (Table 4.6.5 and Fig. 4.6.7).

Slightly over half of the respondents' considered the reserve moderately important in providing forest services. Among those interviewed over 30% indicated the reserve as not important in the provision of services. Slightly over

10% perceived the reserve as important to very important for this role (see Table 4.6.7 and Fig. 4.6.7).

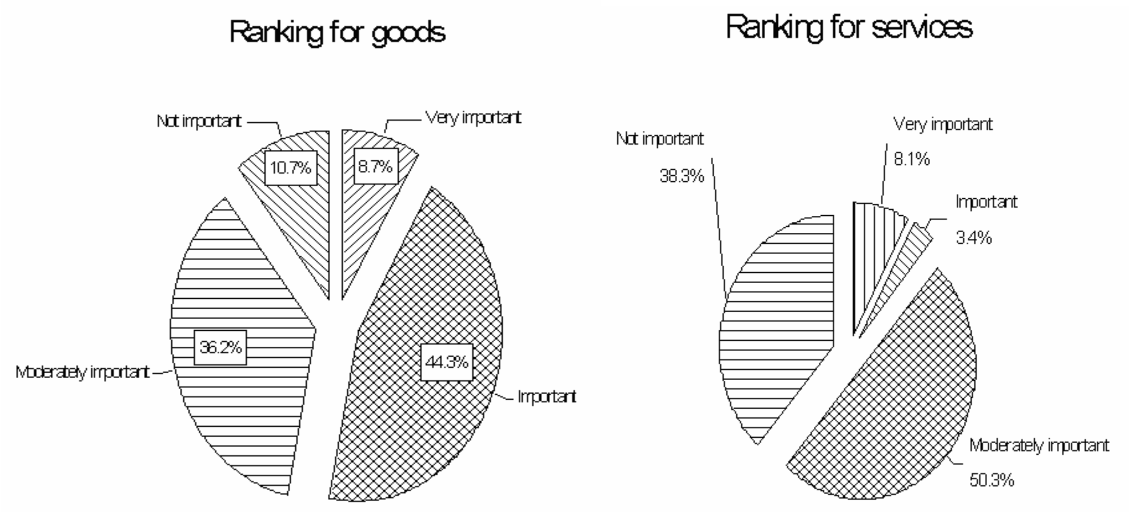


Fig. 4.6.6 Perceived importance ranking forest goods and services

The goods that were ranked from the reserve represent timber and non-timber forest products (NTFP); food, fruits, leaves roots and nuts, firewood, charcoal, honey, pasture and fodder, medicinal plants thatching grass, and tannins, resins and gums. Services evaluated included water catchments, aesthetic value, wildlife sanctuary, and soil conservation and erosion control ceremonial and ritual sites.

Majority of the respondents indicated during the survey that they lacked free access to goods and services from the forest reserve (see Table 4.6.7). Top on the list of barriers to access goods and services was the forest policy. Second, to blame was long distances in search of the goods or services. Bureaucracies' including obtaining of licenses was also viewed as a direct barrier to accessing the provisions from the reserve. Unavailability of goods and services due to exhaustion was also pointed out as a limiting factor to obtaining the goods and services. Poverty among the inhabitants although majority were classified as middle class, pockets of individuals who solely depend on the forest was present. Loss of forest area "forest degradation" and corruption among forest officers were also categorised as barriers (see Table 4.6.7).

Table 4.6.7 Perceptions and attitudes towards resource availability

The table shows the perceptions of household heads regarding shortage of vital goods obtained from the reserve and barriers to accessing these goods in the SW Mau forest reserve.

Resource shortages	% of respondents	Barriers to access	% of respondents
Charcoal	88.7	Forest policy	90.7
Timber	86.7	Long distances	20.7
Tannins resins and gums	84.0	Licenses	20.0
Thatching grass	78.7	Goods exhausted	5.3
Wild fruits	60.0	Poverty	4.7
Building poles/posts	43.3	Corruption	2.0
Honey	43.3	Forest degradation	1.3
Pasture/fodder	36.0		
Medicines	28.7		
Firewood	4.2		

Respondents indicated that the reserve did not satisfy their needs for the identified goods. Majority ranked the reserve as an inadequate source of goods. However, a few indicated that goods sourced from the reserve were very adequate. Results show that the respondents experienced acute, high, moderate and no shortages of goods (see Table 4.6.7 and Fig. 4.6.7).

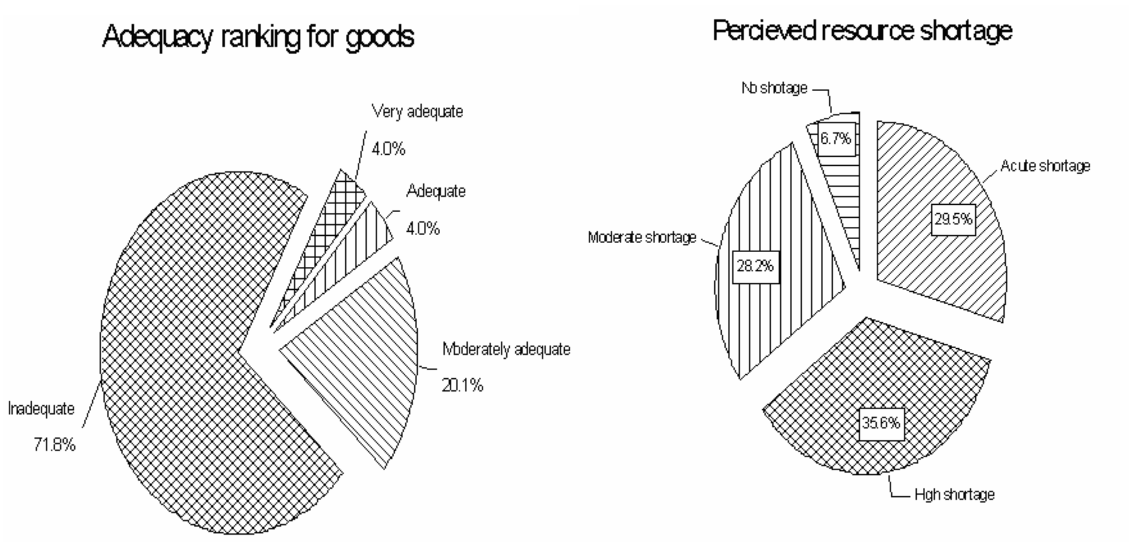


Fig. 4.6.7 Perceived adequacy and shortage of goods.

Perceived adequacy and shortage of timber and non timber forest products (NTFP); food, fruits, leaves roots and nuts, firewood, charcoal, honey, pasture and fodder, medicinal plants thatching grass, and tannins, resins and gums was evaluated. Very adequate and inadequate represented absolute adequacy inadequacy in meeting the needs of the respondents respectively. On the other hand, no and acute shortage represented absolute abundance and unavailability respectively.

4.6.6 Household socio-ecological well being

According to a self-evaluation, using selected indicators socioeconomic wellbeing was rated by the minority of the respondents as very good. Over half considered their status as satisfactory. Half of those who considered their status good rated their fate as only fair (see Table 4.6.8). On the other hand, their socio-ecological characterization considered the forest reserve as healthy, moderately healthy, very healthy and not healthy (see Table 4.6.8 and Fig. 4.6.8).

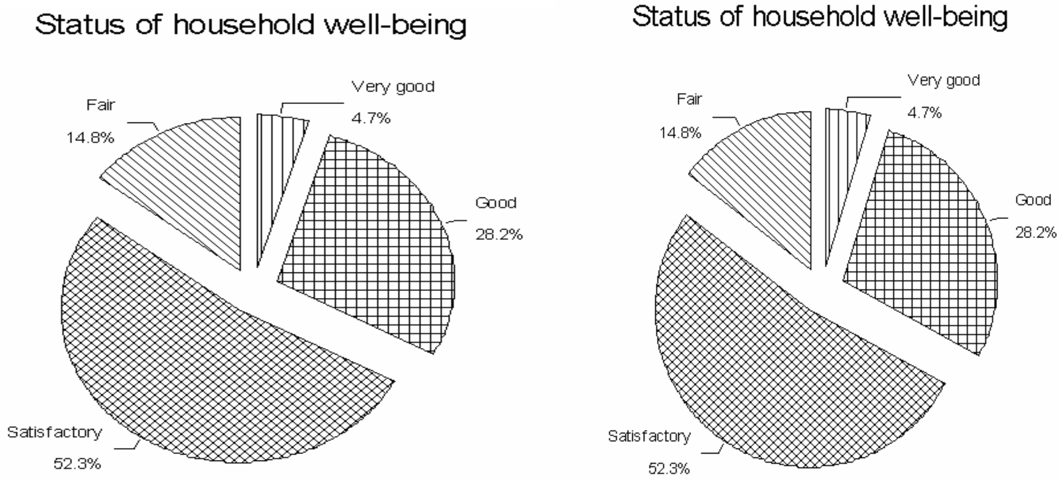


Fig. 4.6.8 Household and socio-ecological wellbeing

Household well being was based on household income, household size, marital status, type and size of housing, occupation of household head and land tenure. The above were combined to generate an index of household well being ranging from very good to fair. Household wellbeing then was combined with parameters related to supply of goods and services including importance adequacy, access and shortage of goods and services from the SW Mau forest reserve to generate an index defining household socio-ecological well being ranging from very healthy to not healthy.

Table 4.6.8 Household socio-ecological wellbeing

The table shows how households perceive the different descriptors of household-socio-ecological well being defined as an index of satisfaction of the household with the goods and services obtained from the reserve and household socioeconomic wellbeing.

Category	Freq	%	Cum%	Category	Freq	%	Cum %
Household wellbeing (HHW)				Shortage of goods (SG)			
Fair	22	14.8	14.8	Acute shortage	44	29.5	29.5
Satisfactory	78	52.3	67.1	High shortage	53	35.6	65.1
Good	42	28.2	95.3	Moderate shortage	42	28.2	93.3
Very good	7	4.7	100.0	No shortage	10	6.7	100.0
Adequacy of goods (AG)				Household Socio-ecological health (HSEH)			
Very adequate	6	4.0	4.0	Very healthy	17	11.4	11.4
Adequate	6	4.0	8.1	Healthy	91	61.1	72.5
Moderately adequate	30	20.1	28.2	Moderately healthy	33	22.1	94.6
Inadequate	107	71.8	100.0	Not healthy	8	5.4	100.0
Importance of forest for services (IFS)				Importance of forest for goods (IFG)			
Very important	32	21.5	21.5	Very important	40	26.8	26.8
Important	71	47.7	69.1	Important	78	52.3	79.2
Moderately important	43	28.9	98.0	Moderately important	30	20.1	99.3
Not important	3	2.0	100.0	Not important	1	0.7	100.0
Current land use (CLU)				Access to forest reserve (AFR)			
Farmland	144	96.6	96.6	High accessibility	4	2.7	2.7
Pasture	3	2.0	98.7	No accessibility	145	97.3	100.0
Forest	2	1.3	100.0				

4.6.7 Forest protection and conservation

The survey results (see Table 4.6.9) indicated activities the government through its respective relevant departments could do to arrest further degradation in the reserve. Activities that could be carried out by the community were also given.

Table 4.6.9 Efforts towards conservation

The table enlists some of the activities and interventions that can be undertaken by the government as a custodian of all forest and the community as beneficiaries to conserve the SW Mau forest reserve.

Government	%respondents	Community	%respondents
Involve community	82.00	Plant indigenous trees	60.0
Provide seedlings	36.7	Legal entry to reserve	64.7
Provide health care	8.7	Energy saving strategies	18.0
Train and provide equipment	4.7	Plant more trees on farms	59.3
Employ officers	15.3	Education and awareness	73.3
Substitutes for timber/posts	7.3	Individual/group nurseries	4.7

Results (see Table 4.6.9) indicate positive significant correlations with the value attached to the provision of services, forest condition, provision of goods, the

adequacy of goods provided. However, a significant negative correlation was reported for the values attached to the current land use. On the other hand, no significant relationship was reported between household socio-ecological wellbeing and household wellbeing and accessibility to forest goods and services.

Table 4.6.9 Household socioe-cological well being and its descriptor variables. **The table shows the Pearson correlation coefficients between household socio-ecological well being and descriptor indices of the relative importance of the SW Mau forest reserve in providing goods and services current land use and household socioeconomic status, correlation significant * p < 0.05. ** p < 0.01.**

		IFS	IFG	AG	SG	AFR	CLU	HHW
IFS	r	1.000						
	Sig	.						
IFG	r	0.179*	1.000					
	Sig	0.029	.					
AG	r	0.089	-0.249*	1.000				
	Sig	0.279	0.002	.				
SG	r	-0.048	0.113	-0.109	1.000			
	Sig	0.561	0.172	0.186	.			
AFR	r	0.069	-0.056	0.101	-0.106	1.000		
	Sig	0.400	0.496	0.222	0.197	.		
CLU	r	-0.227*	-0.028	-0.302**	0.053	0.027	1.000	
	Sig	0.005	0.739	0.000	0.523	0.743	.	
HHW	r	-0.178*	0.023	-0.085	0.050	-0.173*	-0.085	1.000
	Sig	0.030	0.780	0.304	0.544	0.035	0.301	.
HSEH	r	0.745*	0.286**	0.511**	0.238**	0.038	-0.315**	0.105
	Sig	0.000	0.000	0.000	0.003	0.645	0.000	0.203

4.6.8 Household socio-ecological wellbeing and ecosystem health

Figure 4.6.10 shows the relationship between the socio-ecological environment and ecosystem health, and from the study, it is apparent that they are interdependent. It has been demonstrated that the definitions of ecosystem health and socio-ecological wellbeing of communities residing near such ecosystems are interdependent. For example in defining ecosystem health, species composition and tree diversity, structural complexity and physiognomy, site quality, regeneration potential and nutrient input parameters were considered. However, the comparison of these parameters between disturbed and undisturbed sites suggested that, the effects of human activities resulted in significant reductions in the above parameters.

Similarly in defining household socio-ecological well being the results indicated that there was a positive significant relationship between importance of the forest in providing goods and services, accessibility of the reserve as well as shortage of goods and the socio-ecological well being of the households. On the other hand, current land uses had a negative significant relationship with the socio-ecological well being of the households (see Table 4.6.9). Consequently, it is important to note that the parameters defining household socio-ecological well being is directly dependent on the health status of the forest reserve. Eventually any conservation efforts will be driven by the health status of both the households and the ecosystem. In principle therefore, a community that has a high socio-ecological state will tend to live within an ecologically stable ecosystem.

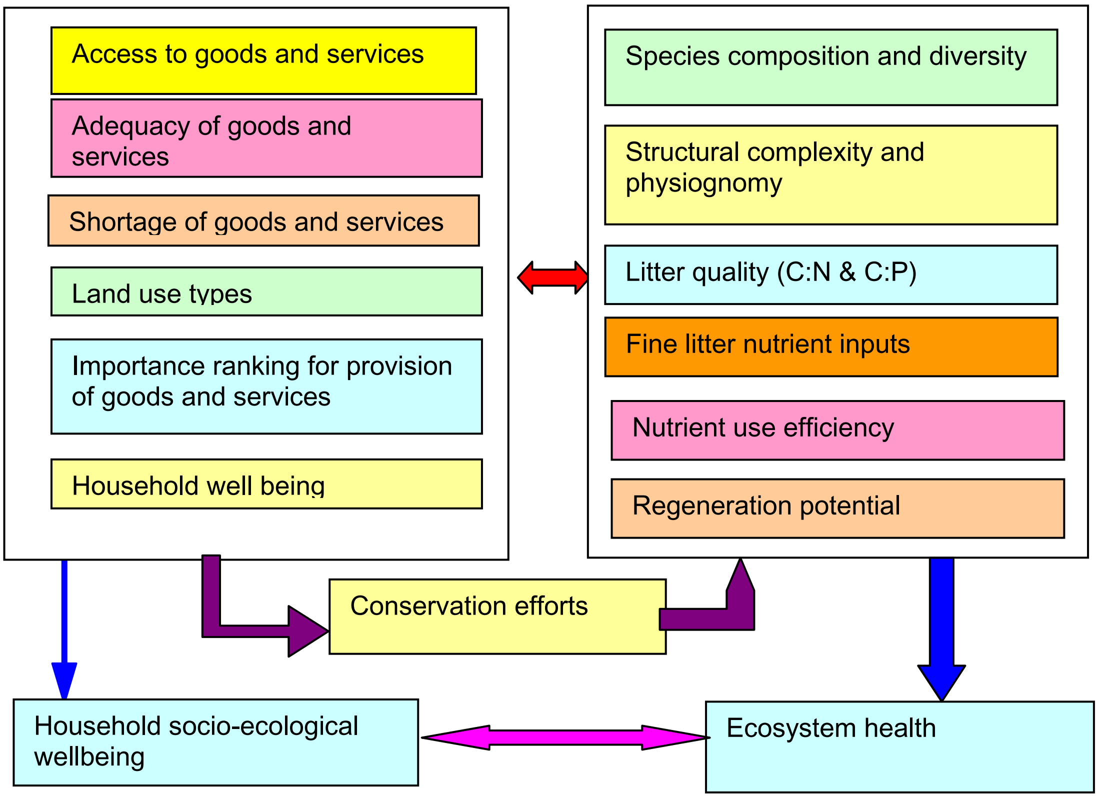


Fig. 4.6.9 Household socio-ecological well being and ecosystem health
The interdependencies between socio-ecological well being and ecosystem health in the SW Mau forest reserve; it is important to note that both systems are linked and conservation efforts must address both in order to achieve equilibrium for sustainability of both.

4.7 GIS BASED DETECTION OF FOREST COVER DYNAMICS

4.7.1 Forest cover status 1984 1995 and 2003

From the unsupervised classification of Landsat 5TM band 432 images for 1 July 1984, 21st January 1995 and Landsat 7ETM for 4th February 2003, six land cover categories (closed canopy forest, bare ground, settlements, secondary regrowth, agricultural fields and scattered trees) in the landscape were recognized and evaluated. From the relative pixel values and counts of the various categories it was evident that the area under closed canopy was highest in 2003 in the Mau forest complex however there was a significant decrease between 1984 and 1995. Area under bare ground was least in 2003 and highest in 1984. However, the area under settlement has continued to increase over the study period. Areas under regenerating vegetation have also considerably increased over the study period. Cover category belonging to scattered trees reduced between 1984 and 2003. The various land cover categories are shown and illustrated below (Fig. 4.7.1 a, b, and c).

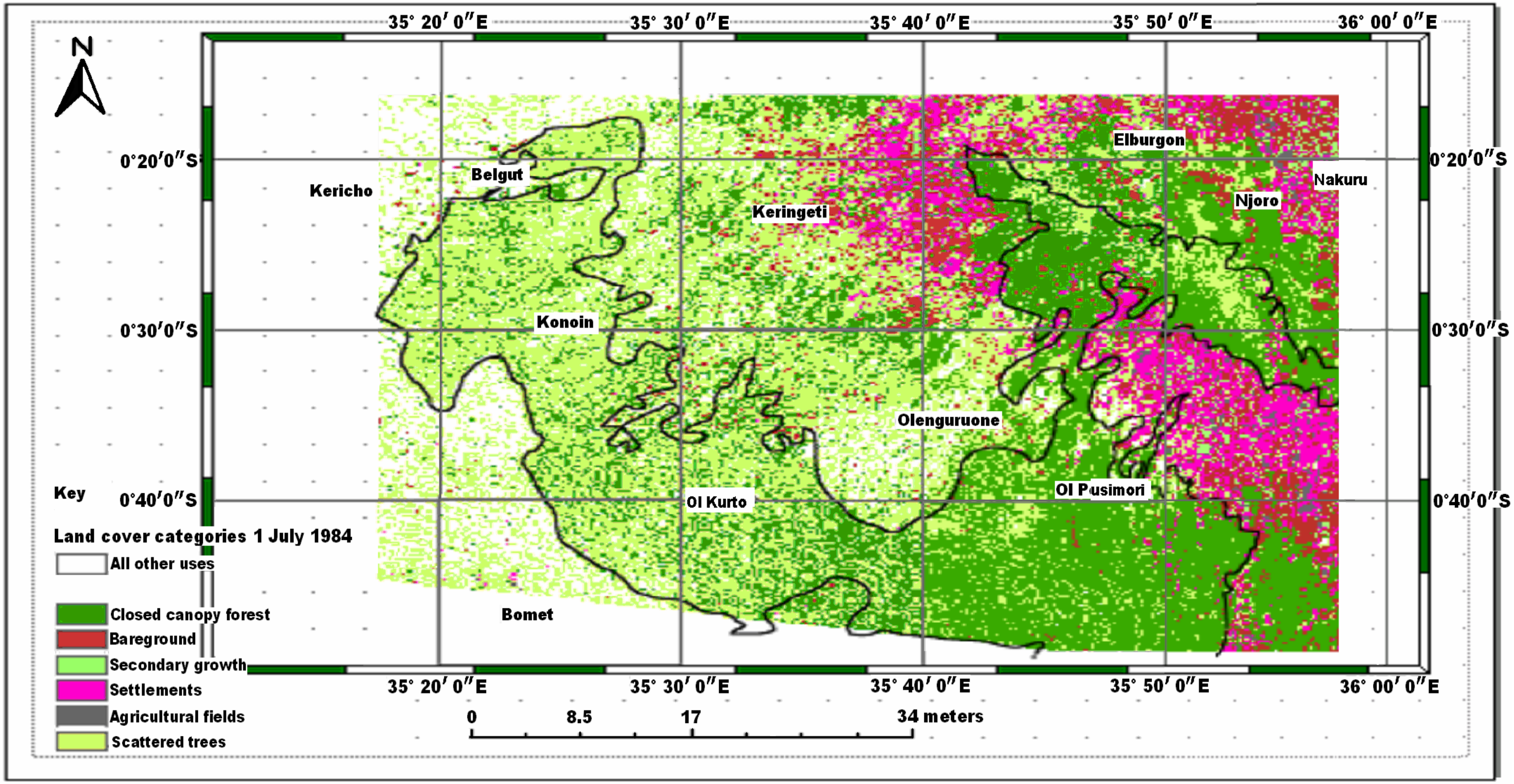


Fig. 4.7.1a Unsupervised classification 1 July.1984

Relatively few settlements and agricultural fields could be masked by agricultural crops that are at a mature stage during this time of the year and hence classified in another category.

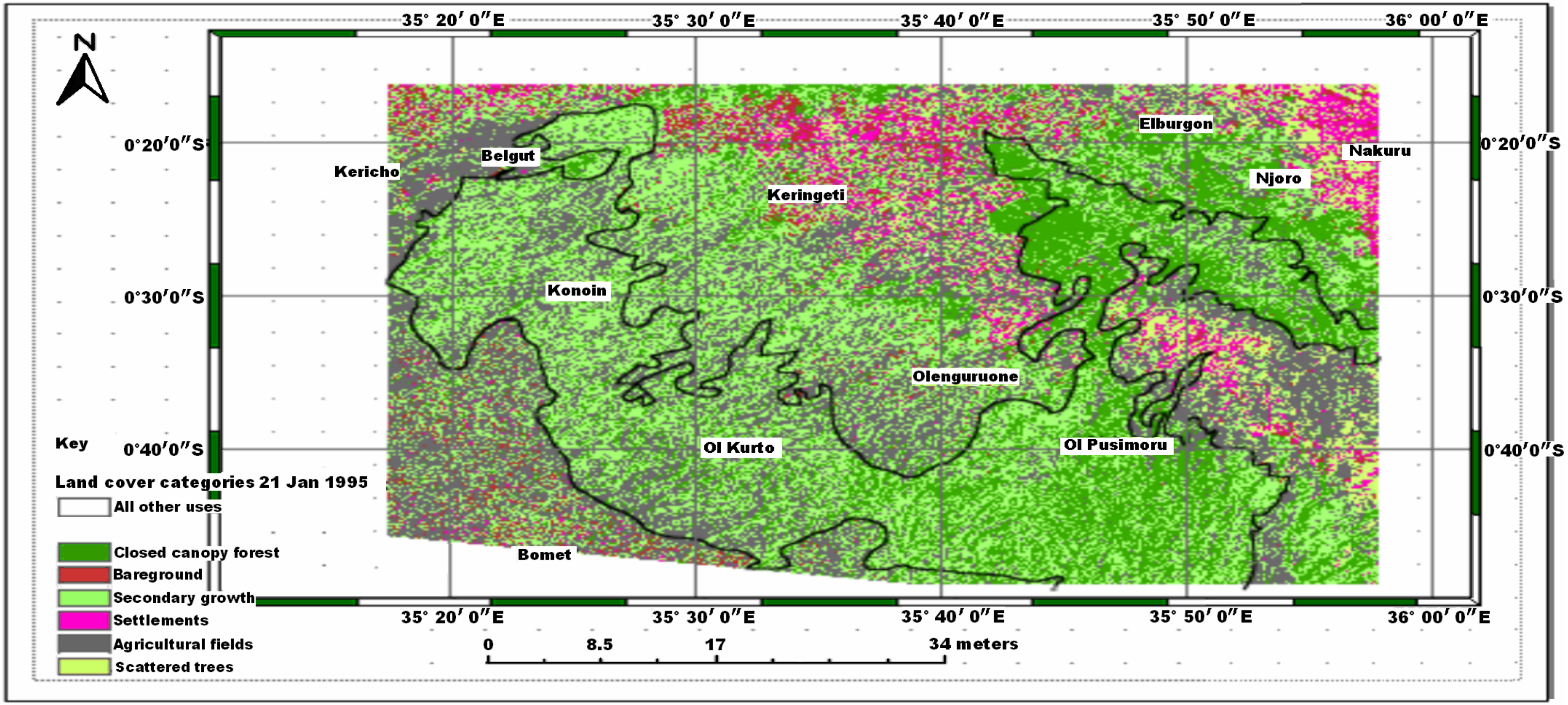


Fig. 4.7.1b Unsupervised classification 21st January.1995

Relatively more settlements than in 1984, presence of agricultural fields within forest reserve boundary visible.

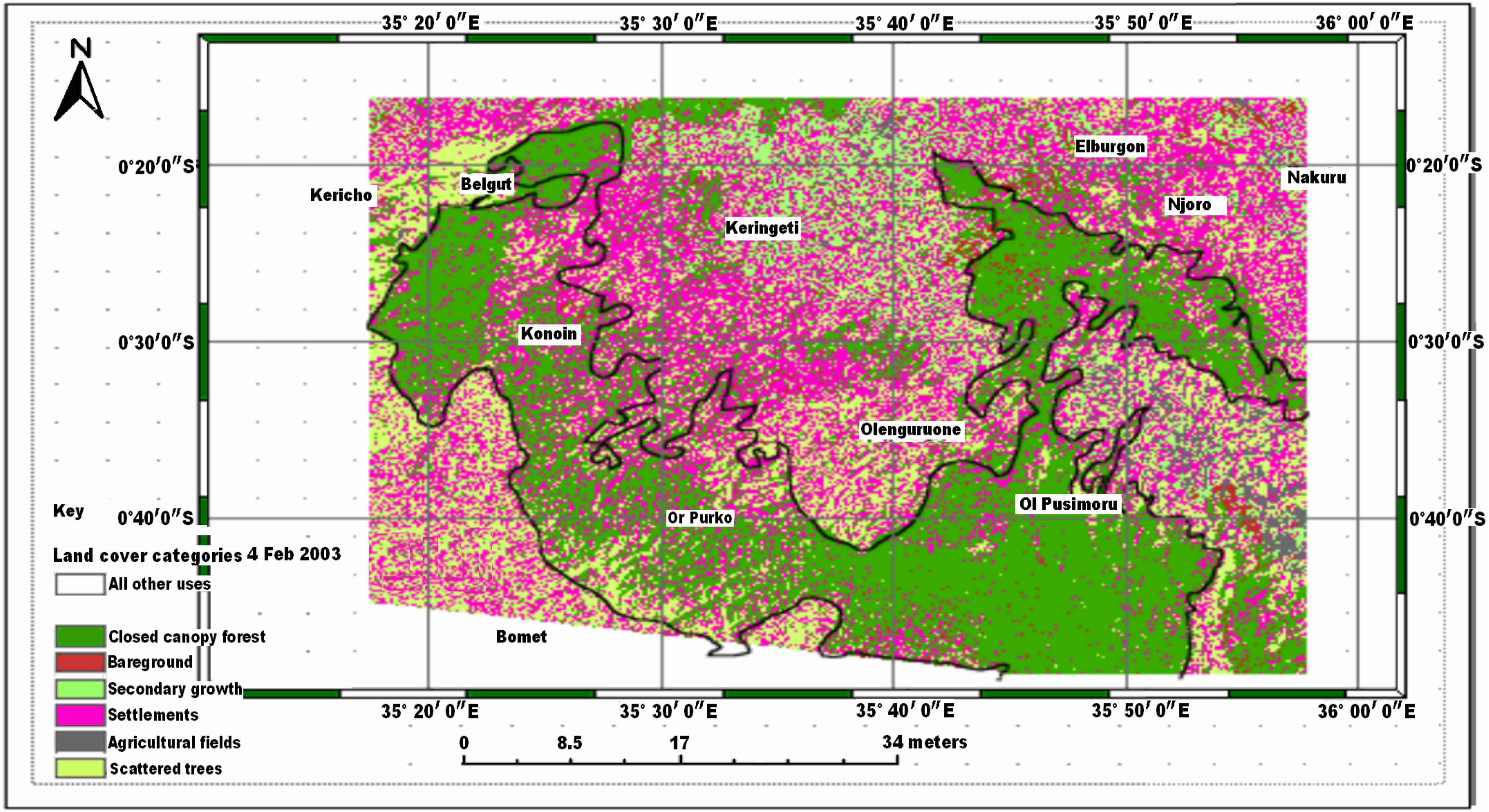


Fig. 4.7.1c Unsupervised classification 4th February 2003

Higher densities of settlements, high closed canopy vegetation restricted to the forest reserve with scattered trees on agricultural fields.

4.7.2 Forest cover change 1984-2003

Image difference was useful in identifying forest cover change over time. From the greyscale image it was evident that a cumulative image difference value of 226.82 in the range (-223 - 3.82) representing 47% negative difference in the reflectance values between 1984 image and 2003 image. This was interpreted as decreased reflectance indicating increased vegetation cover over the study period. On the other hand, a cumulative image difference value of 252.18 accounting for 52% positive difference in the reflectance values was recoreded. This was interepreted as increased reflectance an indication of decreased vegetation cover (see Table 4.7.1 and Fig. 4.7.2).

Table 4.7.1 Image difference (1984-2003) reflectance value

The table represents the difference in reflectance values of the individual pixels from the two images (1984 and 2003) indicating decrease or increase in vegetation where more reflectance represents reduction in vegetation and vise versa.

Class	Image difference range	Reflectance value	% total value	Interpretation
1	-223- -26.18	196.82	41.17	Vegetation increased
2	-26.18- 3.82	30.00	6.28	Vegetation increased
3	3.82- 16.94	13.12	2.74	Vegetation decreased
4	16.94-138.78	121.84	25.49	Vegetation decreased
5	138.78-255.00	117.22	24.52	Vegetation decreased

On the other hand, the image difference highlight resulted in five categories with values ranging between zero and four. Vegetation cover in the study area increased with more than 15% or less while in others it reduced by more or less than the same magnitude while in others it remained the same ((see Table 4.7.2 and Fig. 4.7.5).

Table 4.7.2 Image difference (1984-2003) highlight values

In the Figure a value of zero represents areas where vegetation decreased by more than 15%, 0 - 1 increased by >15%, 1 - 2 decreased by <15% 2 - 3 increased by < 15% and 3 - 4 remained unchanged between 1984 and 2003. The circled areas showed increased vegetation cover.

Class	Highlight value	Description
1	0	Decreased >15 percent
2	0 – 1	Increased >15 percent
3	1.01 – 2.0	Some decreased < 15 percent
4	2.01 – 3.0	Some increased < 15 percent
5	3.01 – 4	Remained unchanged

4.7.3 Thematic change analysis 1984-2003

The resultant theme showed all possible combinations of change between closed canopy forest and other land uses over the period 1984-2003. The analysis shows that change from closed canopy high forests to settlements was the most frequent form of change. There is evidence also for closed canopy forests being converted to agricultural fields during the analysis period. Some areas have also experienced drastic changes from closed canopy to bare ground within the short period of analysis. It is also worthy noting that considerable areas have young re-growth coming up in otherwise devegetated areas (see Fig. 4.7.4).

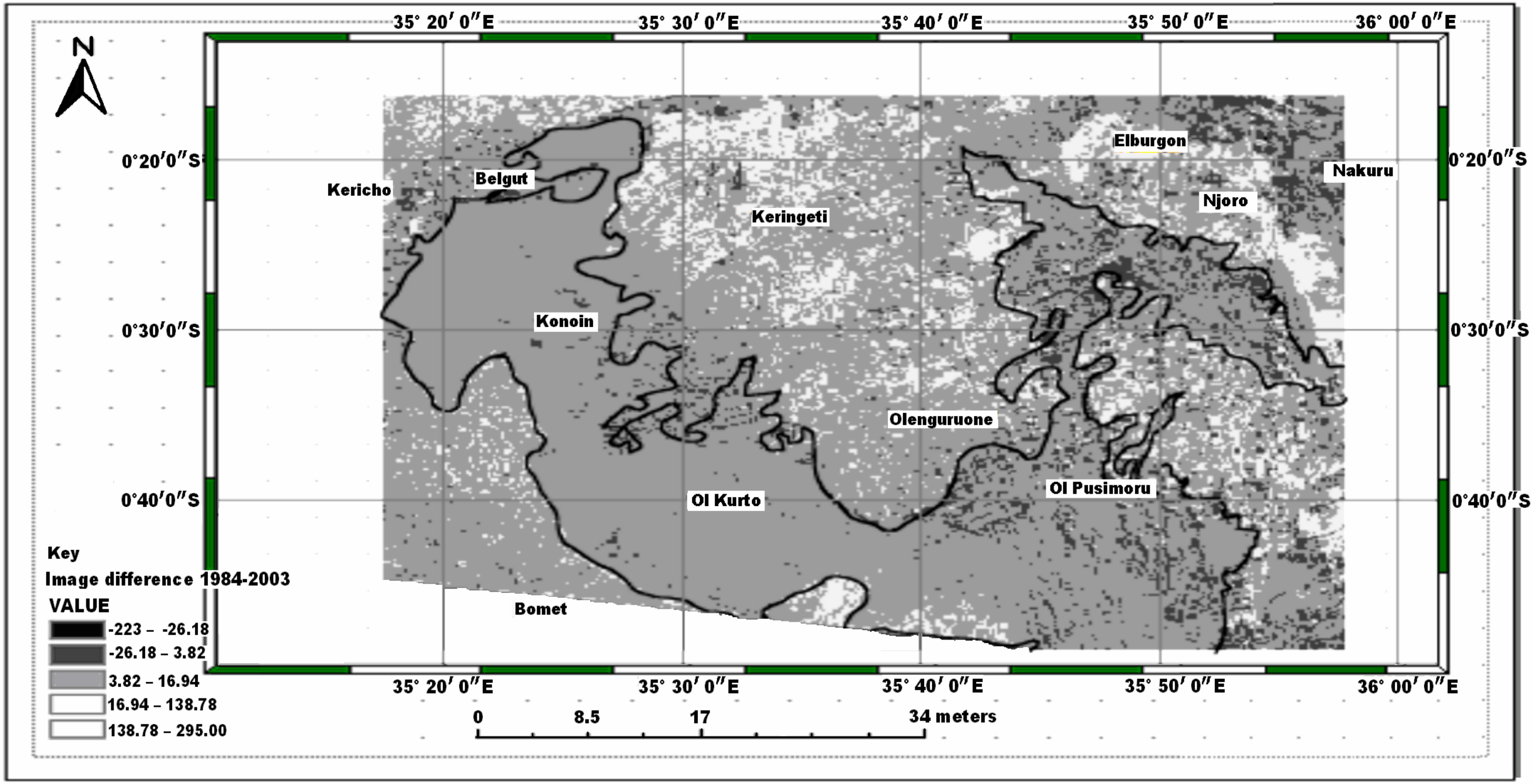


Fig. 4.7.2 Image difference (1984-2003) values

The Figure represents the difference in reflectance values of the individual pixels from the two images (1984 and 2003) indicating decrease or increase in vegetation where more reflectance represents reduction in vegetation and vise versa.

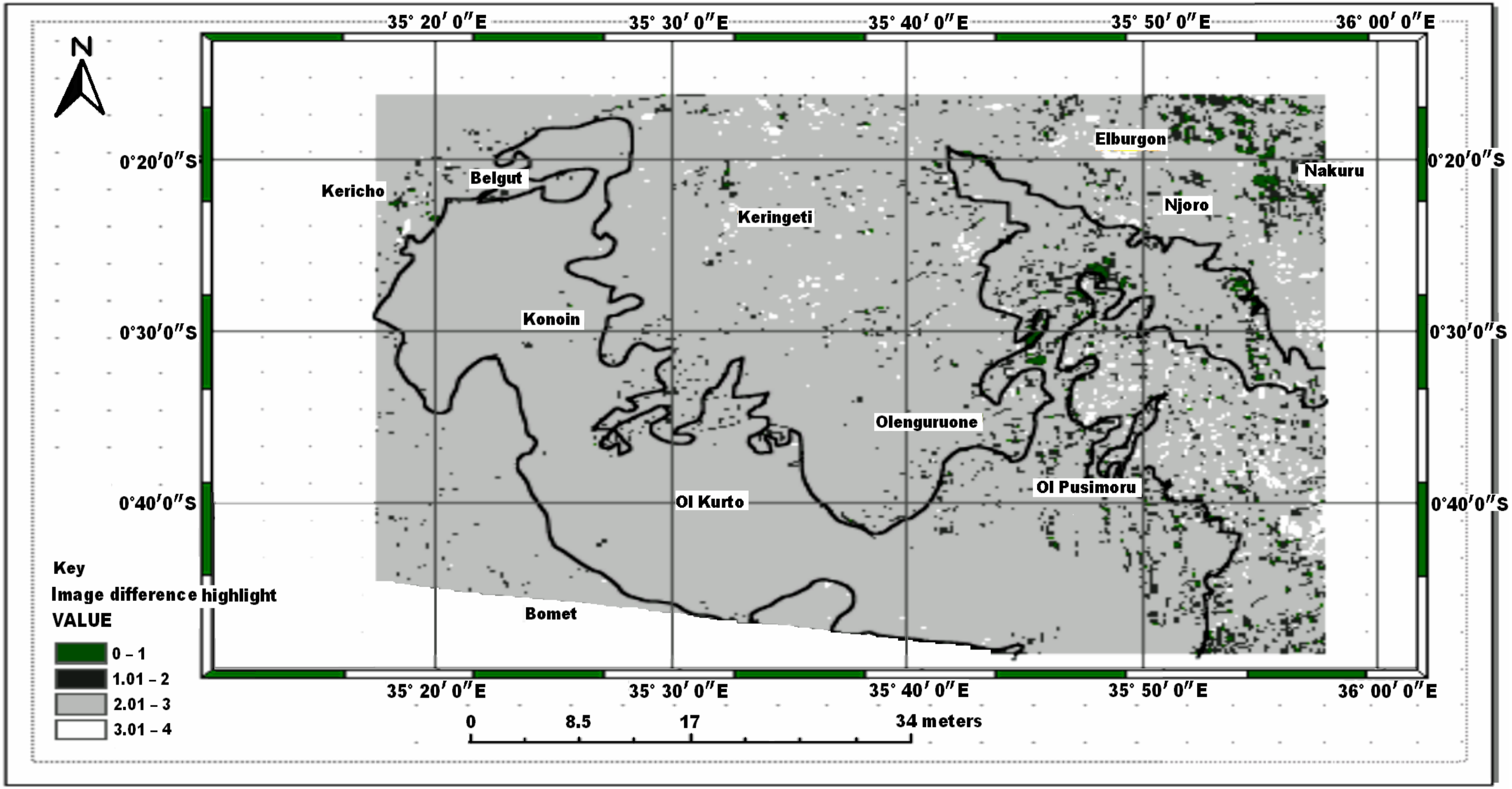


Fig. 4.7.3 Image difference (1984-2003) highlight values

In the figure a value of 0-1 represents areas where vegetation increased by >15%, 1 - 2 decreased by < 15% 2 - 3 increased by < 15% and 3 - 4 remained unchanged between 1984 and 2003.

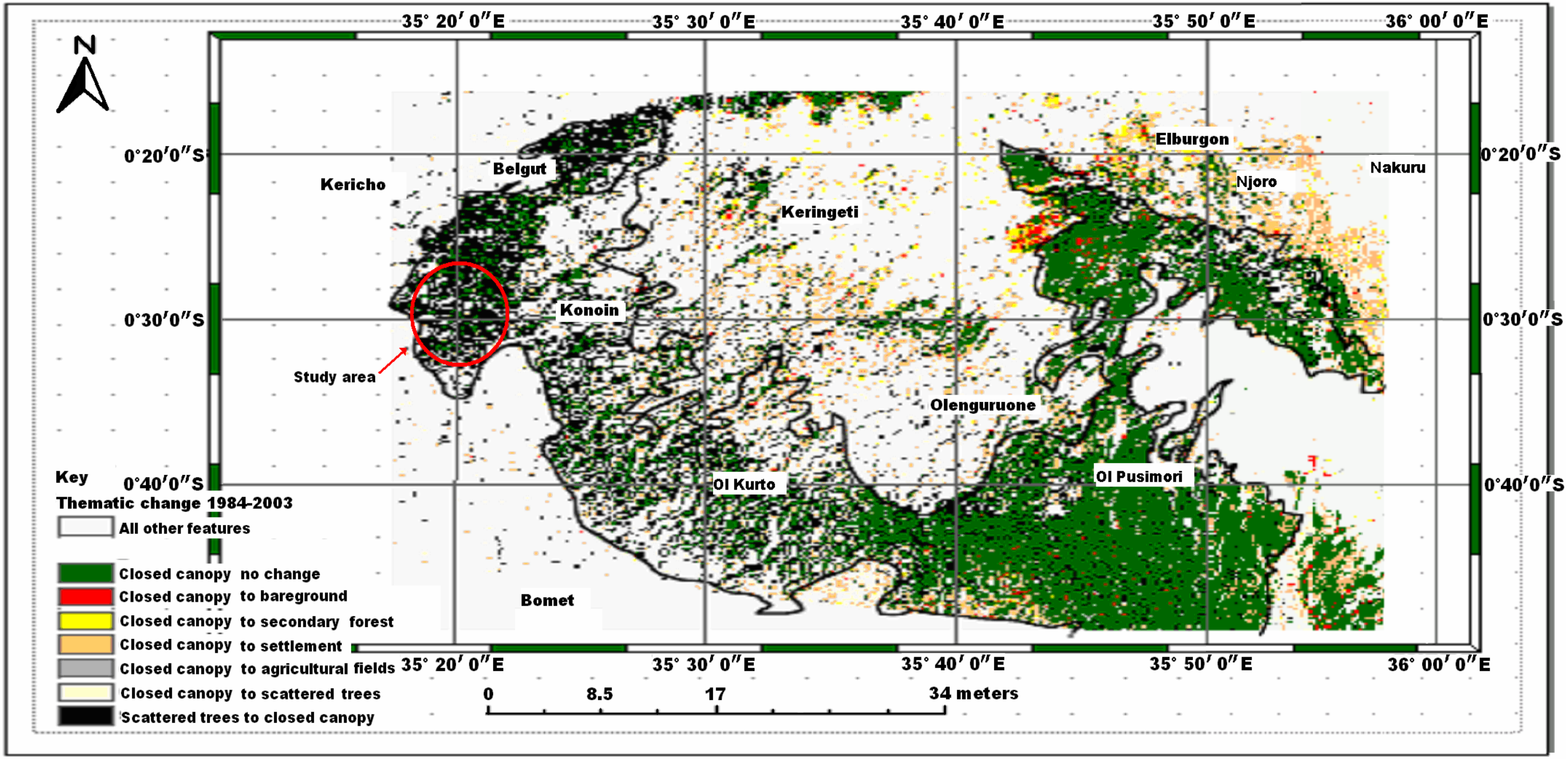


Fig. 4.7.4 Changes in closed canopy forest cover 1984 – 2003

The figure shows a representation of the thematic change from close canopy forests to other thematic classes. Between 1984 and 2003 most of the change, that has occurred involved change from close canopy to settlement. On the positive side, some changes from scattered trees to close canopy especially on the fringes of the forest were noted.

5. DISCUSSION

Ecosystems, especially the tropical rainforests that harbour vast biological riches, provide services that clean our air and water, and provide food, medicines, energy, and raw materials. They regenerate soils and pollinate crops, regulate the climate, control floods, and offer recreational opportunities and spiritual renewal (Nature Conservancy 2005). Terrestrial ecosystems act as carbon sinks when net primary production exceeds heterotrophic respiration and losses due to disturbances. Concern over the global implications of tropical deforestation have paid attention on sparse literature on ecosystem dynamics in both secondary tropical forests and dry tropical forests (Armarson and Lambert 1982; Murphy and Lugo 1986; Brown and Lugo 1990). Dry or seasonally dry forests and montane forests have received less scientific attention compared to lowland wet tropics. Studies on the influence of human activities on productivity and nutrient cycling especially in the seasonally dry forests are limited (Murphy and Lugo 1986; Brown and Lugo 1990; Martinez-Yrizar and Sarukhan 1990; Castellanos et al. 1991; Kauffman et al. 1993 and Campo et al. 2001). Yet they are important components of the changing global biogeochemical cycles, because of their areal extent and suitability for human habitation (Murphy and Lugo 1986).

In the past 50 years, human activity has changed the diversity of life on Earth – our biodiversity – more than any other time in history (Daily et al. 1997, MEA 2005a, 2005b 2005c). These changes include biodiversity loss that harms the natural systems, known as ecosystems, which sustain all life on the planet (Daily 1997).

The rural poor in developing countries are often hit hardest because they are more directly dependent on the resources and services that ecosystems provide (MEA 2005a).

The Millennium Ecosystem Assessment (MEA 2005a), documents how the growing human population is depleting resources and degrading the ecological systems that provide the fundamentals of life – clean water, breathable air, productive soil and a stable climate. MEA acknowledges that people are integral parts of ecosystems: “With the changing human condition serving to drive, both directly and indirectly, changes in ecosystems." At the same time, it documents that change in ecosystems "cause changes in human well-being".

It has been observed elsewhere that the rates and causes of land-use change vary by region and scale (Kaimowitz and Angelsen 1998). Deforestation is often considered a one-way process, but the landscape is a dynamic mosaic of land uses and vegetation types, with transitions both to and away from forest (Houghton et al. 2000). Natural factors, such as forest fires and pests, as well as socio-economic processes, many of which are not seen at the local level, interact in complex ways, complicating analysis. Understanding the causes of this mosaic of land-use and/or land-cover transitions in order to understand and predict the net effect on deforestation rates remains a challenge.

Kaimowitz and Angelsen 1998 argue that conversion of forests to pasture and cropland has been the most important proximal cause of tropical deforestation, with non-sustainable logging being the leading factor in parts of Southeast Asia whereas excessive harvest of wood fuel has been important only in specific sub-country regions and in some African countries. According to Bawa and Dayanandan (1997), the causes (correlates) of deforestation are many and varied, with complex interactions. Overall, Bawa and Dayanandan found that population density, cattle density, and external debt were the key factors. In Africa, the most important factors have been extraction of fuel wood and charcoal and demand for cropland; in Asia, it has been cropland, while in Latin America, cattle density (Bawa and Dayanandan 1997).

Most analyses of land-use change and forestry have concentrated on proximal reasons for land-use and/or land-cover change; that is, on land uses such as agriculture, pasture, and timber extraction that replace forests. However, Meyer and Turner (1992) have identified six "underlying" forces: (1) population, (2) level of affluence, (3) technology, (4) political economy, (5) political structure, and 6) attitudes and values. The influence of each varies by region and country but the net result is the same, the reduced capacity of forest ecosystems to provide goods and services for the well-being of humanity now and in the future.

The current study discusses the status of ecosystem health in relation to anthropogenic disturbance in the SW Mau, a montane tropical forest reserve in Kenya. The relationship between biophysical attributes related to species abundance richness and eventually diversity, forest structure, regeneration capacity as well as litter fall in the fine litter compartment and provision of ecosystem services are underscored. The socioeconomic assessment of the adjacent community provides perceptions and attitudes about the provision of goods and services from the forest reserve.

5.1 VEGETATION COMPOSITION AND STRUCTURE

Two potential avenues for exploring ecosystem health have been ecological processes (e.g., succession, nutrient cycling, energy cycling) and the products of these processes (e.g., species, nutrients and energy). Many ecological treatments of ecosystem health fall within the category of processes (e.g., Rapport et al. 1985; Schaeffer et al. 1988; Bertollo 1998). However, in order to comprehend a process it is imperative to investigate its products for example when we consider how the understanding of photosynthesis (Salisbury and Ross, 1978), chemical reactions (Mahan 1975) and evolution (Darwin 1859; Wallace 1878) developed. Since ecology is central to assessing ecosystem health (Cairns 1995; Kevan et al. 1997a, b; Belaoussoff and Kevan 1998) norms describing ecological products must be defined. Hence ecologists need to define which end products of ecosystem processes generate indicators, and subsequently provide adequate tests for degrees of departure from them (Belaoussoff and Kevan 2003).

In most cases the determination of objective indicators has been overlooked (Costanza et al. 1992; Suter 1993; Suter et al. 1993; Callicott 1995, Wicklum and Davies, 1995; Rapport et al. 1985). Kevan and Belaoussoff (2003) have argued that since considerable effort has been made to determine and describe species diversity (see Southwood 1978; Magurran 1988), and diversity is an end point of ecological processes it (species diversity) may be key to forest ecosystem health indicators.

It is generally accepted that species diversity is critical to the maintenance of ecosystem functions (May 1975; Hutchinson 1978; Tilman and Downing1994; Nilsson and Grelsson 1995): The significance of species diversity for the functioning of ecosystem was proven by the work of Tilman and Downing (1994) on grassland biodiversity. They found that study plots with greater plant species diversity were more resilient to the effects of drought than those with less diversity. This finding generated much excitement that relate to ecosystem health in many ecosystems (e.g., Epstein et al. 2003; Kemp et al. 2003; Aoki 2003; Valone and Hoffman 2003) and even contradictory findings (Kennedy et al. 2003).

Changes in species diversity have often been used by ecologists to determine the effects of disturbance (May 1975; Hutchinson 1978; Magurran 1988). Based on information theory (Begon, et.al. 1996; Magurran 1988; Roth et.al. 1994; Rosenzweig 1995) diversity is the measure of order (or disorder) within a particular system. Mara B disturbed had the highest Shannon Wiener diversity index (see Fig. 4.1.2). The diversity index for the total area sampled was 1.82 with an evenness of 0.50. The combined diversity index for disturbed sites was recorded as 1.98 with an evenness of 0.59 slightly above the total diversity of the species in both disturbed and undisturbed plots. On the other hand, the index in the undisturbed plots was 1.97 with an evenness value of 0.60 (see Table 4.1.3).

Values of H fell within the recommended 1.5 - 3.5 for normal communities (Begon, et.al. 1996; Magurran 1988; Rosenzweig 1995; Roth et.al. 1994). In general, based on the Shannon-Wiener diversity index there was no significant difference in species diversity between disturbed and undisturbed plots.

Disturbance was evident with the presence of species such as *Croton megalocarpus* and *Spathodea campanulata*, which are commonly planted as shade and ornamentals in homesteads in disturbed sites. The abundance and dominance of secondary successional species such as *Neoboutonia macrocalyx,* and *Tabernamontana stapfiana* (Bussmann 2001; Chege and Bytebie 2005) in the disturbed sampling plots indicated constant disturbance either from human or natural causes. It is important to mention that the presence of *Vernonia auriculifera* that characterize recently disturbed sites (Dale and Greenway 1961; Noad and Birnie 1990) also emphasized the level of disturbance in the sampling plots (Beentje 1994). Evidence of selective logging included occurrences of large solitary trees of *Prunus africana* in the disturbed sites as compared to the undisturbed.

From the results of the current study it was evident that there was a higher representation of primary over storey species in the undisturbed sites such as

Xymalos monospora, *Syzigium guienense*, *Albizia gummifera, Celtis africana*, *Aningeria adolfi-friederieri* and *Zanthoxylum gilletii* indicating fewer disturbances. This has also been observed by Chege and Bytebier (2005) in the Kenyan Taita hills forest fragments. The presence of the *Cassipourea malosana* in undisturbed sites indicates a mosaic-climax without a single species becoming dominant (Bussmann 2001).

The variation in tree species richness in the study sites were significantly influenced by the state of the sites i.e. whether they were disturbed or undisturbed ($F = 57.81$, $P < 0.05$ partial Eta squared = 0.264). The interaction between state of the site and the forest sites as well as between the plots also significantly affected species richness. Based on this finding, human activities have an influence on species richness in the study area. Independent samples t test however showed that disturbed sites had higher species richness than the undisturbed; the important question now remains how useful are the species found in the disturbed sites in meeting ecosystem functioning as well as those of the community. Since the goods and services derived from the reserve are as a result from the interactions of species and the abiotic environment, negative impacts are envisaged from unsuitable utilization of the reserve. In turn if species diversity is reduced then there is a possibility of impairment of the reserves capacity to provide goods and services.

In view of the above ecologists and forest resource managers need measures to judge the success or failure of management regimes designed to sustain biological diversity. The relationships between potential indicator species and total biodiversity are not well-established (Lindenmayer et al. 2000). Diversity indices can be useful because they provide rapid and easily calculated ecological measures. They can also enhance comparisons between similar studies, which use same indices. Though they are commonly used, they are only of use for comparison between sites, or on sites over time. Diversity indices are statistical artifices and have no intrinsic biological meaning (Southwood 1978; Magurran 1988). The use of different indices on the same data may result in different conclusions (Belaoussoff 2000; Belaoussoff et al. 2003). Hence the use of species diversity indices to assess ecosystem health should be with caution.

The structure and complexity of vegetation can be used to assess forest ecosystem health when combined with other indicators. Structure-based indicators can be used in addition or as alternatives to indicator species. These are stand-level and landscape-level (spatial) features of forests such as stand structural complexity and plant species composition, connectivity, and heterogeneity (Lindenmayer et al. 2000). Although the adoption of practices to sustain (or recreate) key characteristics of forest ecosystems appear intuitively sensible and broadly consistent with current knowledge, information is lacking to determine whether such stand- and landscape-level features of forests will serve as successful indices of (and help conserve) biodiversity.

In the SW Mau forest reserve differences in mean diameter and height among disturbed and undisturbed plots indicated levels of wood extraction in the former. Mean basal area for the undisturbed plots was similarly higher when compared with the disturbed plots Trees with large diameters have been extracted (evidence of tree stumps) either for timber, firewood, or poles and posts. Holdridge's complexity index was similarly higher in the undisturbed plots.

Results from the socioeconomic survey also indicate that wood products of larger size dimensions had been extracted from the disturbed sites for building of homesteads. Some have also been lost through natural forces like wind throw. Similarly individual trees have been lost or damaged due to incidences of disease and insect pests. Selective removal of higher diameter classes has a reducing effect on the basal area hence the lower basal areas in the disturbed plots.

In the same way height is directly correlated with complexity of structure. We are more likely to find taller trees in communities with less incidences of disturbance. Once again as trees with large diameters are removed we tend to loose taller ones as well. With evidence of removal in the disturbed plots it is quite likely as the results show a reduction in basal area. The density of individuals per unit area in the two sites also varied in favour of the undisturbed sites. This could be attributed to extraction and use of the areas of the reserve by people living in close proximity to the reserve to meet their daily needs of firewood and construction.

The distribution of tree heights, diameters and basal area were significantly influenced by state of forest site (F = 26.07 Eta squared = 0.078, F = 6.14 Eta squared = 0.123 and F = 8.14 Eta squared = 0.026 for height diameter and basal area respectively. The interaction between forest sites and the state of the sites also significantly affected the distribution of these variables. The activities of man in the reserve therefore remain a significant factor in the the physisognomic description of the reserve which in turn affects structural complexity. This is however, dependent on site factors, which in turn have a significant effect on the provision of goods and services. Structural complexity results in diverse habitats, higher diversity which in turn yields diverse goods and services.

Given our limited knowledge of both indicator species and structure-based indicators, Lindenmayer and others (2000) have advocated the following four approaches to enhance biodiversity conservation in forests: (1) establish biodiversity priority areas (e.g., reserves) managed primarily for the conservation of biological diversity; (2) within production forests, apply structure-based indicators including structural complexity, connectivity, and heterogeneity; (3) using multiple conservation strategies at multiple spatial scales, spread out risk in wood production forests; and (4) adopt an adaptive management approach to test the validity of structure-based indices of biological diversity by treating management practices as experiments. These approaches would aim to provide new knowledge to managers and improve the effectiveness of current management strategies (Lindnmayer et al. 2000)

5.2 REGENERATION CAPACITY AND POTENTIAL

Natural regeneration and recruitment of species in disturbed environments are primarily substrate and soil driven process that is governed by in situ sources and dispersal characteristics (Grime 1989; Grime and Hillier 2000). However, degraded forests under regular protection may regenerate vegetation, and maintain ecological stability (Houghton 1990; Olderman et al. 1990; Islam et al 2000).

In the current study most of the seedlings enumerated on the forest floor belonged to families, genera and species represented in the over storey and under storey strata of the vegetation. This was a clear indication that the forest floor offered favourable conditions for the germination and subsequent growth of the seedlings. However, for successful regeneration to occur it is important to address the issue of successful recruitment of the germinant. This is controlled by a number of factors including but not restricted to illumination intensity, temperature, rainfall, grazing and browsing, pathological and entomological factors.

Among the twenty-five genera, sampled 25 species recorded as seedlings in the study area with *Syzigium guineense* having the highest frequency of occurrence of almost 18% (see Table 1c). Other tree species that had remarkable occurrences included *A. gummifera, N macrocalyx, P. mahonii, T. stapfiana, P. africana* and *S. terminale*. Some species, for example *C. megalocarpus A. adolfi-friederieri* and *Hagenia abyssinica* had only one individual represented. The composition of the seedling strata and that of the community had very high correlation.

The distribution (Fig. 4.2.2) from the sampling plots indicated higher number of families, genera and species in the disturbed plots than the undisturbed plots. All genera recorded in the disturbed sites were also present in the undisturbed ones. However, the genera *Alangium, Dovyalis, Aningeria* and *Diospyros* were only recorded in the undisturbed sites. More genera were recorded in the undisturbed sites than in the disturbed.

Various species had remarkable appearance in the vegetation but very little in the seedling stages, both in the disturbed and undisturbed plots. Their seed phenology and germination requirements need to be understood in order to make any conclusions about their occurrences. For example Teketay and Granström (1997) found differences in seed longevity and dormancy characteristics in eight afromontane tree species of Ethiopia. Furthermore, many tropical pioneer species depend on the presence of high seed densities in the soil for successful recruitment following canopy disturbance (Fornara and Dalling 2005).

However, determinants of variation in the composition and abundance of soil seed banks remain poorly understood. Seed bank densities can be affected by rates of seed predation and pathogen infection on the surface and in the soil, by intrinsic rates of loss in viability following dispersal, and by variation in the timing and duration of fruit production (Fornara and Dalling 2005).

Most of the species found in undisturbed sites belong to the middle and emergent forest layers. These are low light demanding, shade tolerant and slow growing species. They only emerge after the removal and or death of the pioneer species. The saplings and seedlings persist on the forest floor until such favourable conditions are available.

The species composition from seedlings in the disturbed plots implies recent human settlement in the forest reserve where the sampling took place. This is evident by the presence of species like *Spathodea campanulata* and *Croton megalocarpus* (Noad and Birnie 1990; Beentje 1994). This two species are mainly planted as shade and ornamental trees around homesteads and are not native to the forest reserve. The presence of *Vernonia auriculifera* also indicated high levels of clearance that gave rise to its colonization of clear fell sites (Dale and Greenway 1961).

However, species composition and density of seedlings from both sites indicated there was potential for regeneration. Consequently, the sites have the capacity to restore original site vegetation from in situ sources of propagules. This is based on the fact that the species composition between the disturbed and undisturbed was not significantly different.

Tree seedling species richness was higher in the disturbed plots. This could be attributed to the higher number of niches available for colonization. As the process of succession progresses some species are out competed leading to less species in the more stable community. Disturbance also leads to other favourable conditions for the germination and establishment of some plants by creating seedbeds or exposing propagules to favourable conditions for germination. For example, when an opening on the forest floor is occasioned by clearing vegetation, seed reserves in the soil are given a chance to germinate. Seeds from the persistent seed bank hence can express themselves in the vegetation. When an area is also disturbed it forms a favourable ground for deposition of propagules on transit for example by grazing domestic animals, birds and even humans.

On the other hand, density of the seedlings was higher in the undisturbed plots. This could be attributed to the fact that inter-specific competition is over the community is more stable and hence competition for resources and relationships such as allelopathy are minimal leading to higher numbers. At the same time seeds and propagules may be generated from mature mother plants within the vicinity depending on seed dispersal characteristics of individual species.

Germinations from the previous season's seed rain (see Table 4.3.1) indicated no significant differences for species richness between disturbed and undisturbed plots. However, the seedling density was significantly higher in undisturbed plots.

Euphorbiaceae had higher germination success from previous season seed rain in the study area. The prevalence could be attributed to the high seeding nature of its species and their seed dispersal mechanisms (Dale and Greenway 1961). For example *N macrocalyx* has the capacity to disperse seeds over a wide area because of its split splash mechanism. The family has also many species having high ecological amplitude. Members of the family range from early succession stages either as colonizers, pioneer, transitional or even emergent forest species for instance, *N. macrocalyx, M kilimandscharica and Croton macrostachyus* respectively (Dale and Greenway 1961).

Most of the seedlings that germinated from seed rain from the previous season originated from the mature mother trees in the reserve. This was attributed to the similarities in composition. This emphasizes the importance of forest remnants in regeneration of disturbed sites (Turner et al. 1996). However low numbers in Alariaceae, Monimiaceae and Rizophoraceae need to be investigated to determine the seed properties and germination requirements of the members of these families represented in the reserve.

Relatively, seedling density was higher in the undisturbed plots. However, their distribution was uneven with almost 50% belonging to three species. This is in contrast with the disturbed plots that showed rather uniform distribution of individuals among recorded species.

Results from the seed bank assay indicated a poor seed bank. This was because very few germinants were recorded in the study period with respect to dominant tree species in the reserve. However, it is important to note that some families that had little or no representation in the vegetation samples were recorded in the seed bank for example Ulmaceae and Oleaceae. Results also indicated that the seed bank in the sampling plots was not significantly different. Consequently disturbed and undisturbed sites had similar chances of regenerating from the seed bank.

Variation in the tree species richness of seedlings recruited from the germinations of the previous season seed rain was significantly influenced by the state of the site ($F = 14.33$, Eta Squared = 0.022). However germination from seasonal seed rain and seed bank was not significantly influenced by state of the site. Hence, regeneration potential and capacity of the forest is critical after germination of the seedlings. The effects of human activities only become a clear threat after germination of the propagules. Hence efforts should be geared towards enhancing survival and recruitment of the germinants into the next stage of growth.

According to SNFPA 2004, on unmanaged landscapes, trees establish through natural seeding, usually from freshly fallen seed from nearby trees. Numerous factors affect successful germination and seedling establishment, including: proximity to seed source (distance, topographic location); adequacy of seed crop; location of seed source relative to prevailing winds; seedbed type and condition (mineral soil, organic matter); micro site conditions; presence of seed predators, insects, and disease; and available soil moisture.

Once seedlings are established, their persistence in the environment is not assured. Additional challenges facing seedlings include competition (inter- and intra-specific); adequacy of sunlight for growth (needs. vary by species); suitability of air and soil temperatures; predation (herbivory); presence of insects and pathogens; adequacy of soil moisture; and physical hazards (trampling, crushing, burying, fire).

Assuming that seed sources for a mix of tree species are locally available, differential effects of the above factors through time will determine the ultimate composition of seedling and sapling recruitment into mature stands. According to Daily (1997) the presence of humans in the vicinity of forests creates potential and observed disturbances consequently affecting the productivity and regeneration potential of these forests by extracting parts of plants, seeds, fruits and other consumables for daily subsistence and even commercial needs.

5.3 STAND FINE LITTER PRODUCTION AND NUTRIENT CYCLING

More information is available to support generalizations about litter fall than those about another ecosystem-level aspect of tropical forests (Vitousek and Sanford Jr 1986). Litter fall is one facet of nutrient cycling in forests, however, and not always the one of greatest interest. Nevertheless, knowledge of the amounts of nutrients cycled through litter fall can be most useful because litter fall represents a major pathway for transferring nutrients from aboveground vegetation to soils, and the relative rate at which forest vegetation loses organic matter versus particular nutrients provides an index of the efficiency of nutrient use within vegetation (Hirose 1975; Vitousek 1982).

According to Vitousek (1982) forest ecosystems systematically produce more litter fall dry mass per unit of nitrogen in sites with less aboveground nitrogen circulation. This pattern has been observed both within and among tropical, temperate deciduous, coniferous, Mediterranean, and fertilized ecosystems. Observed litter fall turnover differences among sites are probably related to differences in soil nitrogen availability. Patterns of nitrogen use for root and wood production further accounts for differences in the litter fall turnover (Vitousek and Sanford 1986).

In the current study significant mean differences in litter in production among sampling plots in the months of May June, July, August, and September (see Welch Test Table 4.5.1) and January, March, and April (see ANOVA Table 4.5.1) were recorded. Disturbed plots showed higher means for most of the months as indicated by LSD test (Table 4.5.1).

According to the results disturbed sites had a higher fine litter total annual turnover than the undisturbed sites however; monthly variations in the sites were not significantly different. Conversely, monthly fine litter production varied across the plots with undisturbed plots having higher turnover. This had an effect on the turnover of biomass and eventually nutrients returned to the sites via this pathway.

In the recent past research on nutrients in tropical forest litter fall was reviewed by Proctor (1984) and Vitousek (1982) indicating that forests on moderately fertile soils return more litter at high nutrient concentrations with low organic/nutrient ratios than This has a major implication for nutrient cycling since litter fall is a major pathway for nutrient cycling in natural forest vegetation (Vitousek 1982; Vitousek 1986; Vitousek and Sanford 1986). The differences could be attributed to removal of vegetation in the disturbed plots that has reduced vegetation cover and density. Hence, human disturbance in the reserve may have contributed to reduced litter inputs that could in turn affect nutrient turnover and cycling.

Undisturbed plots had higher percent nitrogen, phosphorus, potassium, magnesium and calcium content in the litter. There was a distinct difference in the mean values of the C: N and C: P ratios as indicated by the 95% confidence interval plot (Fig. 4.6.5) with disturbed plots having higher means. Site quality definitions based on C: P and C: N ratios from the litter implied that undisturbed plots had higher site litter quality than the disturbed. Based on this premise one can attribute the loss in site quality to human activities.

Nutrient (N, P, K and Ca) inputs from the fine litter were higher in the undisturbed sites than the disturbed. The litter compartment in the undisturbed sites cycles larger quantities of the nutrients than in the disturbed sites. The higher levels of N improve the litter quality and aids in faster mineralization and release of the nutrients. This makes nutrients more available in the undisturbed sites. This coincided well with the results that the site quality was better in the undisturbed sites based on C: P and C: N ratios.

Consequently, in defining the site state of health, using nutrient inputs then undisturbed sites would be ranked higher than the disturbed in view of the amount of nutrients within the fine litter compartment. Measured against the causes of the forest disturbance, human activities would be a factor that negatively influences the state of health of forest ecosystem especially with reference to nutrient budgets.

Similarly, within stand mean annual nutrient use efficiency (defined as kilogram's of dry fine litter mass per kilogramme of nutrient content) for C, N, P, K, and Ca were lower in the undisturbed plots indicating higher efficiency in the utilization of the nutrients. This is because less of the minerals were found per kilogram of dry mass litter than in the disturbed. However magnesium values were higher in the undisturbed plots implying less efficiency in use of magnesium in the undisturbed plots. This implies that higher amounts of nutrients were retained in other somatic (for the example the tree trunk and branches and growing parts) before litter fall.

Conversely, sites that were categorised as disturbed with human activities showed reduced within stand nutrient use efficiency with higher fine litter nutrient content. This implies that less of the nutrients are apportioned to reproductive parts like the tree trunk before litter fall. In defining forest ecosystem health based on within stand nutrient use efficiency human activities have a negative effect on the within stand nutrient use efficiency.

In summary annual fine litter inputs from the study sites were not influenced by the state of the sites. Site litter quality defined by C: N ratios was however, significantly influenced by the state of the site (F = 532.30 Eta Squared = 0.826). The interactions effects between forest sites, state of the site were strongest. On the contrary C: P litter ratios were not significantly different across forest sites, state of sites and plots. The significance of nutrient use efficiency is summed by studies by Vitousek (1982) s indicating that patterns for nitrogen and other nutrients circulation and their use efficiency in forests have important implications for ecosystem-level properties, including the development of low nutrient availability in soil.

Although this study was restricted to production and nutrient cycling in the fine litter compartment it is important to recognise other pathways especially root biomass and the contribution of mycorrhizal associations in forest ecosystems.

5.4 ROOT BIOMASS AND NUTRIENTS

Root production and nutrient cycling are difficult to study in any forest ecosystem. The understanding of belowground processes hence continues to lag behind that of their aboveground counterparts (Vitousek and Sanford 1986). However, a considerable body of information has been collected on root biomass and its vertical distribution in soils (Jenik 1978; Richards 1952; Whitmore 1975); with the existence of root mats above the soil surface in some tropical sites being particularly well documented. Less information is however, available on the nutrient content of the roots or nutrient turnover.

Informed by the source link theory (Bloom et al.1985), trees should allocate more energy to roots on infertile sites, since this investment in nutrient acquisition should yield increased growth and or reproduction in a nutrient limited site. Consequently, greater root biomass and or root-shoot ratios might be expected on less fertile soils (Waring and Schlesinger 1985). Comparisons of tropical forests within a region (Klinge and Herrera 1983; Bongers et al.1985) or a cross a wide range of sites (Klinge 1984) have suggested elevated root/shoot ratios on nutrient poor sites. The allocation of nutrients to roots versus shoots on fertile soils has however, not been well documented.

The turnover of fine roots is extremely difficult to measure and the different methodologies used in temperate zone forests yield widely varying results (Aber et al.1985; Keyes and Grier 1981; Vogt et al.1983). Studies on root turnover and nutrient cycling in tropical forest ecosystems could greatly increase the understanding of nutrient cycling in tropical forests and hence the definition of ecosystem health. More current efforts (Dannoura et al. 2006) are being directed towards the development of an automated chamber system for long-term measurements of CO_2 flux from roots. It is not still possible to generalize for results for landscapes since most studies are based on root turnover for particular species on specific sites (Valverde-Barrantes et al. 2006). In the tropics this would be difficult due to the high species diversity with different rooting patterns and intensities on different sites.

5.5 MYCORRHIZAL TURNOVER AND NUTRIENTS IN THE FOREST

The turnover of mycorrhizal hyphae in the soil could also contribute to nutrient cycling in tropical forest soils. The magnitude of this flux is however unknown (Vitousek and Sanford 1986). Mycorrhizae are essential for the growth and survival of many tropical trees (Janos 1980; Janos 1983), with different types of mycorrhizae being found on different tropical soils (St. John and Coleman 1983). Went and Stark 1968 suggested that tropical mycorrhizae are capable of transferring nutrients from litter directly to roots. Surface root mats in spodosols/psamment sites are known to retain labelled calcium and phosphorus efficiently (Stark and Jordan 1978), and mycorrhizae in root mats can transfer labelled phosphorus from decomposing leaves to roots (Herrera et al 1978). No evidence has been however, adduced that the mycorrhizae of trees actually decompose litter. Nevertheless, the intimate contact between mycorrhizae and decomposing litter on the forest floor is undoubtedly important to the phosphorus economy of many tropical (and temperate) plants (Janos 1980).

While it is now widely accepted, even by ecologists, that most plants in the majority of ecosystems are infected by mycorrhizal fungi, few experiments have been designed to investigate the function of the mutualism at the community level (Francis and Read 2006). Those involved with mycorrhizal research have been largely preoccupied with questions of the mineral, particularly phosphorus, nutrition of individual plants, while plant community ecologists have too often found it convenient, even when acknowledging the presence of infection, to ignore its possible function in the ecosystem.

An examination by Francis and Read (2006) of selected seminal papers by plant community ecologists revealed that by having direct adverse effects upon seedlings of many ‘r’ selected species, while at the same time being beneficial, if not essential, to those that are ‘K’ selected, the activities of the mycelium of VA fungi have a direct bearing upon community composition. They conclude that those attempting scientifically to understand, or managerially to manipulate, plant communities, without recognizing the role of the mycorrhizal mycelium, do so at their peril, and it is recommended that scientists involved in research on mycorrhiza extend their vision beyond the limited horizons which are currently so often defined by considerations of the phosphorus nutrition of individual host plants. Similarly, Read and Perez-Moreno (2003), observe that there is a need to examine the extent of involvement of mycorrhizal fungi in the changing patterns of plant distribution, which are arising globally in response to the nutritional disturbances induced by human activities.

5.6 FOREST COVER DYNAMICS AND LAND USE CHANGE

Ecosystems, the services they provide, and the people who use and manage them comprise complex adaptive systems (Bohensky and Lynam 2005). Since complex systems are mostly nonlinear, variable and uncertain, they are seldom predictable (Costanza et al.1993; Lee 1993; Gunderson and Holling 2002). Within the complex couplings of people and nature, experimentation, adaptation and co-evolution have taken place and a wealth of information generated from the long history of human experience with ecosystem change that is valuable to the current understanding that ultimately enhances sustainability.

From the results of forest cover change analysis (1984-2003) in the Mau complex there is considerable evidence that forest cover has been on a rapid decrease as observed elsewhere in Kenya (Bleher et al. 2006; Wass 1995; KIFCON 1993; Matiru 2000: Mutanga 1996; Gathaara 1999). This is attributed to both legal and illegal forest clearing that has been rampant in the area (Wass 1994; KIFCON 1993). According to Matiru (2000) large tracks of forest land have been cleared to pave way for settlements in the Mau complex with the largest excisions having taken place only in the last decade alone. According to Matiru 2000, 28% of forest cover in the reserve was lost between 1967 and 1989 through such excisions.

The Mau complex has not been left out when it comes to carving out forests for the sole purpose of settling the “landless”. In postcolonial Kenya each successive government has been keen to settle people along the forest boundaries or within the clear felled forest plantations. Unfortunately, a number of recent excisions have also targeted the western part, which contains the most valuable, and intact tracts of closed canopy forests (Bird Life International 2003; Matiru 2000). Such excisions into the study area confounded by human activities affects the livelihood of millions of people living within and outside the reserves including those across international boundaries (KIFCON 1993).

On a worldwide basis, the operations of the lumber and forest products industries are second to that of agriculture as a direct cause of reduced forest cover (Badruddin et al. 1990; IUCN 1995; Shankar et al.1998; Islam et al 2000). According to Islam et al. (2000), chances of restoring tree cover reduce when violent storms wash away seed reserves with the topsoil.

Population growth has been widely cited as a major cause of deforestation. Whether population pressures lead to forest degradation or to positive changes (e.g., afforestation, improved forest management, and better technology) depend largely on social structure. Extensive migration may also lead to deforestation and soil erosion. Simplistic assumptions about population and deforestation also do not apply where high population densities and/or growth rates are accompanied by forest conservation and reforestation programmes. In India, for example, deforestation rates have declined since 1980, despite population growth, owing to effective forest conservation legislation (Ravindranath and Hall 1994).

Factors related to social structure and political economy in enhancing deforestation have not been studied widely, but studies at the country and regional levels (Palo and Uusivuori 1999; Tole 1998) exist. Nevertheless, increasingly the following factors favour deforestation: growing landlessness and persistent inequalities in access to land, insecure land tenure, land speculation, rising external debt, large-scale expansion in commercial agriculture, erosion of traditional systems of resource management and community control, and widespread migration of impoverished people to ecologically fragile areas.

Landlessness or to be realistic, functional landlessness can plainly reflect population pressures. Often, it derives from environmental factors when land degradation has virtually eliminated the productive value of erstwhile farmlands, whereupon there is less worthwhile land to go around in communities that may already find population pressures make individual holdings unduly small. Landlessness usually stems too from a number of political, economic, social and legal problems; and is often a poverty problem. It is unusually acute in Mexico, Colombia, Ecuador, Peru, Egypt, Nigeria, Ethiopia, Kenya, Tanzania, Pakistan, India, Bangladesh, Vietnam, Indonesia, China and Philippines. Their aggregate populations today total 3.2 billion (56% of humankind), projected to reach 4.6 billion (56%) by 2025 (Alexandratos 1995).

There are economic development change patterns that affect land-use, for example, affluence usually increases consumption. The maintenance of ecosystems tends to improve with increasing and better distribution of wealth, as well as with proper institutional structures and sound development strategies. The demand for and interest in forests and their services is the driving force for the technological and economic capacity to maintain forests. In addition, wealthy societies tend to be urbanized and this may reduce destructive pressures on forests. Technological development provides efficient tools for land-use change and for high-value, alternative uses. Technology can also limit encroachment. As seen by the “green revolution” in agriculture, technological development can increase productivity on intensively managed land, thereby releasing other land areas from agriculture (Waggoner 1994). Nevertheless, there is always the risk of leakage (i.e., tendencies to transfer destructive operations from the developed to less developed areas and countries), or the possibility that technology development and transfer will have positive spill over effects (Brown et al. 2000; Noble et al. 2000).

In many countries, especially those seeking development of frontier areas, subsidies are provided for activities promoting economic development. Land clearing may be subsidized directly or by providing property rights to cleared land. Frontier development is often considered desirable for security or on disputed area.

Land-use change is driven largely by efforts perceived as “best and highest” use of the land. Nevertheless, benefits of the land that are non-market and/or external to the direct user (e.g., watershed protection, biodiversity, and carbon mitigation) may be ignored by land managers. For example, the decision to convert forestland to agriculture may ignore the many external and non-market benefits lost. Moreover, where long-term land rights are insecure, lands may be used to generate short-term benefits, with disregard for long-term benefits.

5.7 SOCIO-ECOLOGICAL CHARACTERIZATION

Many physical causes of deforestation have been identified and are the focus of considerable research aimed at minimising ecological damage. However, not all causes of forest degradation and loss are direct and obvious; social processes and economic policies also play a major role. Sorting out the various factors and interrelationships and how they affect the condition of forests and forest-dwellers is a challenge for researchers (CIFOR 1999).

Kaimowitz and Angelsen (1998) argued that national and multi-country regression models are of limited value and recommend a shift toward household and regional-level studies, which should shed greater light on factors that influence decisions by agents who are directly involved in forest use and clearing. The conventional paradigm has been that improved agricultural productivity resulting from technological advances lessens the pressure on forest resources, thereby supporting forest conservation aims. CIFOR researchers (CIFOR 1999) found many instances in which innovations in the agriculture sector have created new opportunities for farmers, who have thereby cleared land more rapidly than they might otherwise have done. In particular, the research suggests, capital-intensive technologies suited for agricultural frontier conditions, and production for export, are likely to increase conversion of forestland.

This study examined the linkages between household well being and forest ecosystem health by characterizing household socioeconomic parameters and socio-ecological parameters to define household socio-ecological well being of a community living in the neighbourhood of the SW Mau forest reserve.

In order to determine household well being a demographic profile was characterized. The average age in years of household heads among the respondents was 49.There were more males than females per household with a mean household size of seven. These are in the range of those recorded by the Kenya National Bureau of Statistics (KNBS 2007b). The length of period of occupancy from time of settlement to the time the study was carried out ranged from 2-86 years. The distance from the homestead to the forest reserve boundary ranged from 0-4 Km (see Table 4.6.1).

Majority of the sampled households were headed by men. Among the sample household, majority were married, while the rest were single and divorcees, widows or widowers (see Fig. 4.7.1.1).

Slightly over 80% of the households sampled lived in semi permanent houses constructed of posts and poles with mud walls and corrugated iron sheet roofs. Others had permanent houses constructed of raw stonewalls and corrugated iron sheet roofs. Less than 10% lived in grass-thatched houses while less than five percent had temporary structures. This shows the pressure of the forest in the provision of these materials for the building of these dwelling facilities. The roofing also demands timber from the forest reserve. The size of houses also varied among the households sampled. Majority being medium sized with a few having small houses. An equal proportion of the sample had large and several housing units (see Fig. 4.7.1.2).

The major sources of income were listed as sales from tea and sale of livestock and livestock products. Other sources of income in the sampling area include business, formal employment, remittances, casual labour, sale of firewood and honey.

Household expenditure on firewood was the highest among other forest-based goods. This is comparable to the national scenario where 68.3% of the households in Kenya use fuel wood for domestic energy (KNBS 2007b). The expenditure on pasture and fodder was nearly half that on firewood. Household income was also used for the purchase of charcoal and honey.

Livestock keeping is an integral part of the lifestyle of the people living in the study area. Grazing animals both cattle, sheep and goats are a familiar part of the landscape in the reserve. The type of livestock kept range from indigenous native types, pedigree to crosses between the two types herein referred to as improved.

The mean number of improved and indigenous cattle per household was 2.9 ± 3.81and 1.6 ± 2.61 respectively. The results (see Table 4.6.2) however, indicate more indigenous goats and sheep. These livestock statistics have implications for resource use and management in the forest reserve since it is the main source of forage for the livestock. This is important as grazing and browsing by the livestock affect the ecological system by specifically impacting on re-growth.

The respondents described several ways their livestock were grazed (see Table 4.6.2). Majority of the respondents have set a side part of their land for grazing, while some graze their animals solely in the forest reserve. A few graze their stocks along the roadsides. Others, complement the set aside land with forest grazing while at the same time graze the stocks both along the roadsides and in the forest.

The main methods of grazing as indicated by the respondents (Table 4.6.2) include free range in the forest, tethering and padlocking. Zero grazing an intensive practice where the livestock are fed from shelters in the homestead is not popular.

Health care in the study area is provided by different institutions. However, from the survey results 96.7% of the respondents got health care from the divisional health centres while 17.3% visit herbalists within the area. Interesting to note is the 32.7% who individually use herbal medicine for taking care of their ailments. This shows the importance of the forest reserve in the provision of health care to those living around the reserve (see Fig. 4.7.1.3).

A casual description of the social set up of the community reveals three subjective categories. The definition of the classes was informed by visual observation of the nature of the households' type of occupation of household head, type and size of housing, access to health care, land tenure and annual income. Majority of the households fell in the middle class while a few belonged to the upper and lower classes (see Fig. 4.7.1.5).

Apart from the forest dwelling Ogiek who have lived in the Mau since time immemorial, survey results indicate that the earliest formal settlement in the area was in 1920. Majority of the immigrations occurred between 1947 and 1973. The period between 1974 and 2004 had remarkable immigrants into the study area. Land in the study area is owned privately by individuals. The forest reserve is however, trust land owned by the county council. Among the sampled households land tenure arrangements included land with title deeds, land without titles, either hired or rented land and squatter status (see Fig. 4.7.2.2).

The initial land use at time of settlement was forest. Some of those who settled in this area also found it as pasture. Probably the 64% who settled on forested land were the early and midterm settlers while the 36% are late immigrants who have bought land from the earlier settlers. However, current land use indicates a complete change of the alienated land, with most land being categorized as farmland (see Fig. 4.7.2.2).

An evaluation of the condition of the forest at present revealed a reduction in the number of storeys. The number of dominant species was however, still varied with majority indicating the presence of numerous species of trees.

However, the percentage of those indicating the presence of several and few species increased from 4.7% at time of settlement to 11.3% and 0 to 8% respectively. There was a reduction in the percentage of those who perceive the forest to contain large or big trees from 89.3% at time of settlement to 82.7% at present. The percentage of those who viewed the forest to contain very big trees also reduced when the two periods were compared. The percentage of those who viewed the population of wildlife as high at time of settlement was

85%; however, 90% of the respondents think that at present very few wildlife exist in the reserve. This could be presenting a chronological sequence of events and displaying a delayed pattern of settlement from the first settlement to the most recent. This shows that those who settled earlier could have found virgin forest with three distinct storeys; however, those who came in later found only fewer species of trees and fewer trees on the edges of the forest.

Respondents in the survey acknowledged loss of forest cover in the SW Mau forest reserve. This was also revealed by the thematic change analysis for the period 1984-2003. In the this study increasing human population was cited as one of the major causes of loss in forest cover in the area. Population increase further increased the effects of human related activities that had direct or indirect bearing on forest health. Hence, expansion in agriculture, fuel wood collection, timber/logging, overgrazing, land use changes, land subdivision, introduction of exotic species (Pines, Cypress and Eucalyptus) were viewed as agents of forest degradation in the SW Mau forest reserve. Human population increase was ranked as a very important cause of forest degradation, followed by firewood collection. Those rated as important to moderately important included agricultural expansion, land subdivision, firewood collection, land use change, introduction of exotic species, overgrazing and infrastructural development. Charcoal conversion, wild fires, timber processing, logging and land subdivision were ranked as not important causes of forest degradation. Land subdivision results in uneconomically small land holdings that can not support household subsistence needs has subsequently increased the need for more land from the forest reserve both legally and illegally.

In the recent past, poor people and their shifting agricultural practices were seen as the main driving force behind deforestation. However, evidence has increasingly indicated that commercial factors and macroeconomic changes have far greater impacts (CIFOR 1999). Comparative studies in Indonesia, Cameroon and Bolivia have demonstrated how national economic crises and subsequent government macroeconomic policies affect local patterns of livelihood and forest use.

In 1998 for example, CIFOR researchers (CIFOR 1999) analysed the results of surveys in Cameroon to determine how changes in market prices and a massive currency devaluation that followed a national economic crisis in the 1980s influenced crops planted and the amount of land used. One important finding was that, as global market prices fell, small-scale farmers shifted from production of export crops such as cocoa to subsistence crops, and they did so by clearing more forest land rather than using land previously cleared for agriculture (They retained their export crop plots in the hope that prices would eventually revive).

The forest reserve is an important source of goods and services to the community living in the neighbourhood. Food sources from the reserve were ranked as very adequate to adequate by the respondents. Less than 5% ranked them as inadequate. The forest similarly was viewed as a very adequate source of firewood, while less than 3% thought firewood from the forest was inadequate. The reserves provision of timber was below expectation being ranked moderately adequate to inadequate.

Similarly, quantities of charcoal sourced from the reserve were inadequate for household energy requirements for majority of the respondents. Honey, fodder/pasture and medicinal plants provisions from the forest were adequate. Among some households, requirements for poles and posts were not adequately met from the reserve. Charcoal, timber, tannins, gums and resins seemed to be in short supply from the forest. Household requirements for honey were higher than what was sourced from the reserve; however, this was attributed to the effort to harvest the honey but not to the reserves capacity to provide. Medicinal plants and firewood were also reported to be in short supply.

5.8 FOREST GOODS AND SERVICES IMPORTANCE AND ADEQUACY

According to Breckling and Reuter 2004, society depends on natural system and processes but can however, develop in a comparably autonomous way following internal dynamics as long as goods are not substantially limiting. They also observe that while the human induced matter turnover in the biosphere is much smaller than the turnover in the natural biogeochemical cycles, both develop relatively independent and hence the impact of human activities lies within the buffer capacity of natural systems and processes. Hence, if we strike a balance between the capacity of ecosystems to supply goods and service, the ecosystems can provide this goods to eternity.

In the current study the reserves capacity to provide goods and services has been impaired through human activities. Survey results indicated perceived shortages of several goods including timber, charcoal, firewood gums and resins and even medicinal plants. This reflects on the level of health of the forest in the different parts and the effects on the forests' ability to provide goods and services. Some responses to confirm shortage showed resentment to conservation measures in place that regulate forest use and hence unpopular to the inhabitants. Such could however, be appreciated though not in the affirmative as it underscores the need for strengthening management efforts to offset the tendency of overexploitation of the forest.

However, the reported shortages cannot totally be blamed on the condition of the forest but on several factors as already shown in earlier sections. In spite of the fact, it is still an important indicator of the condition of the forest especially in human dominated landscapes. Important to separate is the shortage caused by conservation efforts as this only depicts apparent shortages that are interpreted in the light of the enforcement of regulations and rules regarding exploitation of the resources within the forest reserve boundaries. However, illegal access was rampant with evidence of stumps; tree debarking, numerous cattle trails and grazing animals.

Charcoal and timber supplies could have been in short supply due to surveillance and restrictions from the exploitation of the forest for these products. Hence, this could be a true but informative response to expose the need for exploitation of these goods. Tannins, gums and resins appeared as a shortage since no known apparent use by the community.

In fact, one would consider this response a responsive way of trying to victimise state authorities for denying the local people access to the resource. However, the local population would want a free and open situation that subsequently is abused leading to further degradation of the reserve. The inherent services therein are lost as well since agricultural systems are "mining" activities and resultant goods are exported from the sites instead of recycling them.

The forest reserve is regarded as important for water catchments, scenic beauty, erosion control and soil conservation as well as a windbreaks. Similarly, it was described as important for its role as a wildlife sanctuary, climatic amelioration and a place to perform rituals and ceremonies. It was ranked as a very important source of firewood, medicinal plants, pasture fodder, and food. The reserve was ranked as an important source of honey. The use of the forest as a source of timber was rated as not important by the respondents and similarly for charcoal and not important at all for posts and poles, and pasture/fodder.

Service roles of the forest were also recognised and highly ranked. Such included its role in water catchments windbreak, soil conservation, erosion control ceremonies, shade, wildlife sanctuary and for its aesthetic values. Accordingly, the perception of the reserves condition was rated between very good and good. In view of all the above the question remains what is the linkage between ecosystem health and household well being.

Ecosystem degradation is often linked to the poverty of the people in the vicinity and hence the importance of this variable in defining forest health. However, it is also important to define the poverty of the people in terms of the “poverty” of the ecosystems that are supposed to provide the goods and services that in turn define the wealth of the people. In this case, it is logical to state that “poor ecosystems” will give rise to poor inhabitants who will then accelerate the state of “poverty” of the environment.

The result collaborates quite well with the distribution of the contributing factors treated under this study for example household wellbeing, forest condition and the provision of goods and services. This indicates that the higher the value of this variables the healthier the state of the household as described by the respondents. This shows that increases in the value of the categories of current land use have a reducing effect on the socio-ecological health of the household (see Table 4.6.6).

Accessibility to goods and services and the household wellbeing values had positive but non-significant correlations with the value of household socio-ecological well being. However, uncontrolled access of the reserve would lead to adverse effects on the reserves health status.

5.9 PERCEIVED INTERVENTIONS TO AID CONSERVATION EFFORTS

The government through the ministry of environment and natural resources and its relevant institutions are charged with the sole responsibility of managing Kenyan forest resources. Hence, they have the authority and responsibility of coordinating, enforcing and regulating the use of forest reserve resources. These are currently embedded in the proposed forest bill. Funding, enforcement and political goodwill remain the main challenge.

An even greater challenge is the inclusion of all relevant stakeholders in the management of the reserve. The potential of integrating the local people's knowledge and skills in the management of the reserve is yet to be tapped. The above will ensure erosion of suspicion when introducing new ideas in the management of the reserve, hence creating a sense of belonging and trust.

The trend of decentralisation that is occurring in many tropical countries is another extra-sectoral factor that is affecting how forest resources are managed and by whom. Decentralisation in Bolivia for example has brought benefits to many poor rural people in heavily forested areas, including greater access to forest resources, restricted encroachment by large timber companies and ranchers, and a greater voice in policymaking (CIFOR 1999). Nevertheless, there are major obstacles that could undermine sustainable management and use, including weak local technical capacity, limited national support and organisational problems among small-scale loggers.

In the SW Mau, the forest service could achieve some of the above by involving the community in the decision-making frameworks concerning the management of the reserve. Production and distribution of seedlings for planting, employment of officers from the community, stepping up health services with funds accruing from the use of the reserve to reduce dependence on herbal medicine, training and provision of equipment for research towards forest conservation and diversifying sources of energy to reduce dependency on fuel wood were cited as possible investment possibilities.

Education and awareness creation among the forest dwelling communities on the need to protect the forest for posterity is an important point of departure in the quest for sustainable forest use. Emphasis on the non-consumptive uses of the forests, such as bee keeping, eco-tourism, water catchments and cultural and aesthetic considerations could go along way in helping in the conservation of the reserve. Empowering the local communities to participate for example by obtaining legal entry into the reserve, planting indigenous tree species on water catchments, introduction of energy saving strategies, planting of more trees on their farms and starting of individual or group tree nurseries. Majority insisted on educating and creating awareness among their children on the importance of the forest reserve as the starting point in all this efforts (see Table 14.6.7).

In the not-too-distant past, attitudes toward management of the world's remaining primary forests exhibited a fundamental, and seemingly irreconcilable, dichotomy. Fervent conservationists advocated designating these forests as reserves to ensure protection of their rich biodiversity (CIFOR 1999). Forest managers, in contrast, tended to view them primarily as sources of timber, especially in developing countries where income from timber sales has contributed substantially to national economies (FAO 2003).

Lately, however, a major shift in thinking has occurred. Forests are viewed as complex ecosystems that must be managed wisely as part of the landscape to provide a balance of goods and services while minimising long-term environmental damage (Bleher et al. 2006). Thus, forests should benefit humankind for years to come.

The concept of "sustainability" is now a guiding principle for natural resource management in many countries. Yet management for sustainability is complex, and much remains to be learned about how to achieve it. However, several concepts and approaches (CIFOR 1999) have been developed to achieve this. Such include: 1) reduced-impact logging (RIL) to counter the effects of highly destructive conventional logging practices. 2) Biodiversity conservation multi disciplinary studies to determine the impacts of disturbances such as logging, non-timber forest product extraction and forest fragmentation on in situ conservation of biodiversity with a goal to acquire generalisable data from representative eco-regional research sites to generate and test spatial and process models. Monitoring and evaluation of biodiversity status using Plant Functional Types (PFTs), which reflect plant adaptation to changing physical environments is necessary to establish potentially useful linkages between vegetation structure, key groups of plant and animal species, PFTs and ecosystem functions such as soil nutrient availability, erodibility and hydrology. 3) Studies on potential role of Non Timber Forest Products (NTFP) markets in degradation of forest resources are necessary (CIFOR 1999). This may expose the underlying difficulty in achieving a balance between improving the livelihood of forest-dependent people and forest conservation. Increased dependency of rural dwellers on medicinal plants because of a national economic crisis may actually lead to forest degradation (see Wollenberg and Ingles 1998). 4) Plantation forestry, especially on degraded or low-potential sites, should be a major focus of research because of the need to meet the national and eventually world's huge appetite for lumber, pulp and other wood products. Much of this work should include efforts to optimise the productivity of plantation forests. 5) Secondary forests, regenerating on native forest that has been cleared for ranching or agriculture, are an important focus because of growing evidence that they help counter the loss of primary forest. 6) Analog forestry (CFAN) is a complex agro-forestry system where farmers re-create the architectural structure and ecological function of the local natural forest ecosystem by planting tree and other plant species that provide them with a range of products for personal consumption or sale in the marketplace. Farmers benefit from the diversity of products that they harvest while at the same time restoring the natural environment and supporting key ecological processes. 7) It is important to explore and seek solutions to problems hampering the implementation of community-oriented forestry policies. We need simpler and more consistent policies that accommodate local institutions for effective implementation, monitoring and evaluation.

6. CONCLUSION AND RECOMMENDATION

Tropical forests are diverse, and so is the range of people who look to forests to meet a variety of subsistence and income needs. These multiple interests entail overlapping management systems, traditional management for local people's access to cultural sites, forest land, products and jobs; industrial management for timber and plantation crops; and governmental efforts to manage for conservation and other goals.

There is a need for ways of managing forests in a manner that preserves ecological integrity and human well-being while addressing these diverse demands. Historically, however, most forest management approaches have been conventional, "top-down" systems that give greater voice and control powerful interests while minimising the concerns and needs of local people. As a result, forest-dwelling people often have declining access to resources that are vital to their families' welfare and lack fair representation in forest-related decisions that affect their daily lives.

In this study forest ecosystem health (its ability to yield goods and services for use by humans) is largely dependent on the biophysical system defined by vegetation composition, regeneration potential and capacity, site nutrient cycling and use efficiency as well as structural complexity based on the distribution of storeys and diameter classes, basal area and the evenness of the diversity of species. These directly dictate ecosystem characteristics especially the distribution of functional groups of primary importance that in turn provide conditions for habitation by other plants and animal species for general ecosystem functioning processes. Such ecological complexity is observed for the less disturbed forest areas based on data from the undisturbed sites. From the study however, the above parameters operate against a socio-economic-cultural backdrop of financial, social, human and physical capital relevant to the management and utilization of natural resources at the household level as shown by data from disturbed sites. The presence of disturbance indicator species like *Neoboutonia macrocalyx*, *Croton megalocarpus* and *Vernonia auriculifera* in the vegetation community indicates considerable levels of human disturbance in the reserve representing a retrogression in the vegetation succession pathway.

The vertical stratification of the forest reserve depicts a high proportion of shrubs and under storey tree species based on height and diameter classes, being evidence of secondary re-growth as shown by the abundance of seedling and wildling densities. This clearly indicates that the community still has potential to recover and hence is resilient to perturbations. With respect to vegetation densities, the difference between disturbed and undisturbed sites was also evidence of disturbance especially due to extraction.

There is potential for natural regeneration of tree vegetation after natural or anthropogenic disturbance from in situ, annual seasonal seed rain and the soil seed bank. The forest reserve capacity to regenerate from these three sources of propagules largely depends on the perturbation type. However, this is only possible where disturbance frequency and intensity from livestock grazing in the forest, logging and any other activities that would reduce the internal capacity of the reserve to regenerate is minimized. It is however important to note that the soil seed bank was equally poor both in disturbed and undisturbed sites, a caution when dealing with regeneration on highly disturbed sites that may require direct intervention by enrichment planting in order to realize regeneration goals.

In order to encourage in situ regeneration, further degradation should be prevented and existing islands of the old vegetation preserved to serve as exogenous sources of propagules for areas where in situ sources are insufficient. Controlled experiments to determine and evaluate the germination requirements and seed phenology of endangered and rare species should be top priority towards restoring such species. Similarly seed bank reserve inventories to establish the size and composition regarding such species is vital. Studies on the seed longevity and storage characteristics are important especially in view of creating seed banks for future reforestation programmes.

High litter production annual turn over in disturbed sites, coupled with lower nutrient content and nutrient use efficiency as well as higher fine litter C: N and C: P ratios defines them as poorer sites compared to the undisturbed sites. Since the pattern of N and P circulation and use efficiency has important implications for ecosystem level properties, it is possible to conclude that disturbed sites are poorer in quality than the undisturbed. Consequently, as expected human activities have led to adverse effects on nutrient cycling in the SW Mau forest reserve as shown by the fine litter nutrient budgets.

A chronological degradation in the condition of the forest over time is apparent. A continued reduction in the number and density of once dominant tree species as well as structural physiognomy is shown. Households in the SW Mau experience an increasing decline in the supply of once abundant important goods including fuel wood, timber, medicinal plants poles etc. Disappearance of abundant and common wildlife species is also recorded. All these point towards an increasing state of degradation in the forest reserve. The ranking of the reserve for the importance and adequacy of provision of goods and services remains above average. Degradation of the reserve is seemingly driven indirectly by rapid expansion in human population. Direct causes include agricultural expansion, land subdivision, firewood collection, land use changes and infrastructural development. Specifically current land uses have a negative significant effect on the health of the reserve as indicated by the negative significant correlation with household socio-ecological well-being. On the contrary, household welfare and accessibility of the reserve have positive but insignificant effect on the health of the reserve.

Traditionally, setting aside ecologically fragile sections of forest as protected areas has been part of forest management strategies worldwide. Despite acknowledgement of their importance for biodiversity preservation and other benefits, however, protected areas have been a contentious issue because of competing interests and resentment about restrictions on the utilisation of natural resources. With growing recognition of the need to represent the interests of diverse stakeholders in forest management, decisions about protected areas have become even more complex because of complicated issues related to jurisdiction and control.

Reconciling the tensions surrounding protected areas to meet environmental objectives without jeopardising the well-being of local inhabitants is imperative. This should be centred on the participatory development of new strategies for cooperative planning and management of protected areas in view to improving land use policy and practices in areas where traditional agriculture and conservation interests tend to clash. In embracing sustainability ecological, economic and social goals must be balanced in the development agenda. There is a need to treat protected areas as part of larger ecosystems, rather than as isolated and self-contained reserves, and to develop more comprehensive and "pluralistic" management plans that reflect this broader scope of impact.

According to Fischer et al. (2006) biodiversity conservation in forestry and agricultural landscapes is important because (1) reserves alone will not protect biodiversity; (2) commodity production relies on vital services provided by biodiversity; and (3) biodiversity enhances resilience, or a system's capacity to recover from external pressures such as droughts or management mistakes. Landscapes should include structurally characteristic patches of native vegetation, corridors and stepping-stones between them, a structurally complex matrix, and buffers around sensitive areas. Management should maintain a diversity of species within and across functional groups. Highly focused management actions may be required to maintain keystone species and threatened species, and to control invasive species. Zoning of the forest reserve could be used to achieve multiple use areas where human use is allowed, a core conservation area of no consumptive use and a buffer zone that separates the two. This is imperative since we already have a human population in the neighbourhood dependent on the reserve.

Alternative sources of resources otherwise derived from the reserve, including timber, firewood poles and posts should be sought in order to reduce pressure on the reserve. Such include investment in other sources of renewable energy such as solar and wind. Encourage farm forestry by providing incentives in order to supplement national wood requirements. Farm forestry should be popularized also as in other farming options with economic goals as other agricultural sectors for example tea, coffee, horticulture etc. Initiatives on the model of “Analog Forestry” would go a long way in addressing socioeconomic and ecological issues in forest conservation.

Exploitation of the forest reserve in quest for life support materials including firewood, food, posts and poles, timber, charcoal, pasture and other goods is resulting in general loss of forest cover and consequently degradation of the general Mau forest complex. Forest cover change analysis in the complex between 1984 and 2003 indicates a 15% change from closed canopy to settlements, agriculture and other land uses in some sites, with highest loss of forest being conversion to settlements and agricultural fields.

The utilization of the reserve by the inhabiting communities has had impacts on the forests vegetation composition, dynamics and function as shown by comparison of species composition, vegetation structure, regeneration potential and capacity, litter production and nutrient content between disturbed and undisturbed sites in the SW Mau forest reserve. Hence, these inhabiting communities affect the health of the forest. This has implication for management of forest ecosystems in human dominated landscapes.

In the SW Mau forest reserve, solutions to issues and problems related to encroachment on forestland and related disturbance activities lie in clear land use policy and legislation designating particular uses to particular land categories. This is urgently required to deal with the issues related to unsustainable land use. This would prevent the change of forestland for settlement or any other use arbitrarily by politicians or any other person. In turn, it would reduce pressure on existing natural forests, as they would be designated as conservation and sustainable use (UNCBD) areas and not residential or agricultural lands. This should be followed by a clear forest policy and legislation detailing management of natural forests and taking into consideration the human populations living in and around these resources through the implementation of Ecosystem Approach of the Convection on Biological Diversity (CBD)). In general, careful evaluation of the relationships between biophysical condition (state of vegetation composition structure and diversity) in the context of changes in demographics, policy, land use, and management practices should provide a basis for informed evaluation of the state of health of forests in human dominated landscapes.

6.1 FUTURE RESEARCH PERSPECTIVES

The issues and problems related to forest encroachment and related disturbance activities by forest frontier communities is a big challenge for ecosystem based management strategies and approaches. Research in this field should try and address areas such as:

1) Carry out stakeholder analysis and investigate the potential roles of each one of them in the development of sustainable forest use guidelines that have socio-ecological and cultural relevance in order to bridge the gaps in current forest management policies that tend to exclude resource users. It will be important to explore problems hampering the implementation of community-oriented forestry policies and how they might be overcome.
2) Inventory of the impacts of current logging practices on fundamental forest ecosystem health indicators and cross checking them with established benchmarks for reduced-impact logging (RIL).
3) Studies on potential role of non timber forest products (NTFP) markets in degradation of forest resources and or their use to promote sustainable forest use.
4) The applicability of plantation forestry, especially on degraded or low-potential sites as a tool to ease pressure on natural indigenous forests.
5) Focus on secondary forests, regenerating on former native forest sites to counter loss of primary forest. Important areas would include regeneration capacity, species abundance studies, seed phenology and longevity studies, site productivity and rotation periods.
6) Carry out exploratory studies on the applicability of analog forestry (a complex agro-forestry system where farmers re-create the architectural structure and ecological function of the local natural forest ecosystem) by planting tree and other plant species that provide a range of products for personal consumption or sale in the marketplace while taking care of the environment this could begin with the screening of high value indigenous trees with marketable non timber products.
7) Documentation of potential role of forest ecosystems in attaining the Millennium Development Goals (MDGs) especially in human dominated forest landscapes is crucial in highlighting their importance and hence sustainable management.

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8. APPENDICES

8.1 VEGETATION COMPOSITION AND STRUCTURE

8.1.1 Descriptive statistics for tree species richness

Table shows the mean tree species richness and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed).

Plot	Site Name	Site description	Mean	SD	N
A	Mara Mara Forest reserve	Disturbed	10.2464	4.90217	207
		Undisturbed	6.0726	3.82867	248
		Total	7.9714	4.81751	455
	Itare forest reserve	Disturbed	17.5534	9.52162	103
		Undisturbed	13.4783	11.78514	92
		Total	15.6308	10.81556	195
	Total	Disturbed	12.6742	7.60474	310
		Undisturbed	8.0765	7.66943	340
		Total	10.2692	7.97124	650
B	Mara Mara Forest reserve	Disturbed	6.0674	5.33494	267
		Undisturbed	6.7158	5.69909	190
		Total	6.3370	5.49244	457
	Itare forest reserve	Disturbed	18.7548	10.07784	155
		Undisturbed	13.0196	12.65611	153
		Total	15.9058	11.76871	308
	Total	Disturbed	10.7275	9.62450	422
		Undisturbed	9.5277	9.94921	343
		Total	10.1895	9.78322	765
Total	Mara Mara Forest reserve	Disturbed	7.8924	5.54770	474
		Undisturbed	6.3516	4.73650	438
		Total	7.1524	5.22825	912
	Itare forest reserve	Disturbed	18.2752	9.85843	258
		Undisturbed	13.1918	12.31386	245
		Total	15.7992	11.39850	503
	Total	Disturbed	11.5519	8.87248	732
		Undisturbed	8.8053	8.91086	683
		Total	10.2261	8.99330	1415

8.1.2 Multiple comparisons for tree floristic composition

The table shows the least significant mean differences (LSD) between the sampling plots for number of families, genera and species. In the Table MAD Mara A Disturbed, MAU Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variable	(I)	(J)	(I-J)	S E	Sig	Variable	(I	(J)	(I-J)	S E
Family	MAD	MAU	3.17*	0.54	0.000	Genera	MBD	IBU	-6.80*	0.78
		MBU	2.80*	0.57	0.000	Species	MBU	IBD	-11.88*	0.83
		IBU	-1.59*	0.61	0.009		IAD	IAU	3.91*	1.10
		IAD	-7.76*	0.67	0.000			IBU	4.53*	0.98
		IBD	-8.09*	0.59	0.000		IBD	IAU	5.12*	1.01
	MBD	IAU	-3.38*	0.69	0.000			IBU	5.74*	0.87
		IBU	-5.04*	0.58	0.000		IBU	IAD	-4.53*	0.98
	MBU	IAD	-7.39*	0.70	0.000		MAD	MAU	4.25*	0.73
		IBD	-7.72*	0.62	0.000			MBU	3.60*	0.78
	IAD	IAU	4.67*	0.82	0.000			IAU	-3.16*	0.97
		IBU	3.01*	0.73	0.000			IBU	-2.70*	0.83
	IAU	IBD	-5.00*	0.75	0.000		MAU	IAD	-11.41*	0.91
	IBD	IBU	3.34*	0.65	0.000			IBD	-12.68*	0.79
Genera	MAD	MAU	4.25*	0.72	0.000		MBD	IBU	-6.95*	0.79
		MBU	3.60*	0.77	0.000		MBU	IAD	-10.77*	0.95
		IAU	-3.16*	0.96	0.001			IBD	-12.04*	0.84
		IBU	-2.55*	0.82	0.002		IAD	IAU	4.00*	1.11
	MAU	IAD	-11.32*	0.90	0.000			IBU	4.46*	0.99
		IBD	-12.53*	0.78	0.000		IAU	IBD	-5.28*	1.02
	MBD	IAU	-7.41*	0.93	0.000		IBD	IBU	5.74*	0.88

* The mean difference is significant at the 0.05 level.

8.1.3 Tree species diversity in the sampling plots.

The tables below show the calculation of Shannon Wiener diversity index (H') and Evenness (HE) in the sampling plots

Mara A Disturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
MAD	*P. fulva*	2	0.961538	-0.03922	-0.03771
	T. stapfiana	2	0.961538	-0.03922	-0.03771
	N. macrocalyx	33	15.86538	2.76414	43.85414
	Z. gilletii	11	5.288462	1.665527	8.808077
	A. gummifera	4	1.923077	0.653926	1.257551
	M. kilimandscharica	1	0.480769	-0.73237	-0.3521
	S. guineense	17	8.173077	2.100845	17.17037
	C. malosana	1	0.480769	-0.73237	-0.3521
	C. battiscombei	8	3.846154	1.347074	5.181052
	G. coffeiodes	3	1.442308	0.366244	0.528237
	P. mahonii	45	21.63462	3.074295	66.51118
	P. africana	55	26.44231	3.274965	86.59764
	C. africana	11	5.288462	1.665527	8.808077
	E. capensis	3	1.442308	0.366244	0.528237
	C. macrostachyus	10	4.807692	1.570217	7.549121
	D. torrida	1	0.480769	-0.73237	-0.3521
	H. abyssinica	1	0.480769	-0.73237	-0.3521
S	17	208	100	H	245.3099
lnS	2.833213			HE	86.58362

Mara B Disturbed

MBD	Species	Freq	pi%	lnpi%	pi%lnpi%
	P. fulva	10	3.745318	1.320507	4.945718
	T. stapfiana	18	6.741573	1.908293	12.8649
	N. macrocalyx	133	49.81273	3.908271	194.6816
	Z. gilletii	11	4.11985	1.415817	5.832953
	A. gummifera	13	4.868914	1.582871	7.706862
	M. kilimandscharica	5	1.872659	0.627359	1.17483
	S. guineense	10	3.745318	1.320507	4.945718
	C. malosana	1	0.374532	-0.98208	-0.36782
	C. battiscombei	8	2.996255	1.097363	3.287979
	G. coffeiodes	2	0.749064	-0.28893	-0.21643
	P. mahonii	13	4.868914	1.582871	7.706862
	P. africana	21	7.865169	2.062444	16.22147
	T. nobilis	2	0.749064	-0.28893	-0.21643
	C. africana	4	1.498127	0.404216	0.605567
	E. capensis	1	0.374532	-0.98208	-0.36782
	B. micrantha	1	0.374532	-0.98208	-0.36782
	C. macrostachyus	2	0.749064	-0.28893	-0.21643
	D. torrida	8	2.996255	1.097363	3.287979
	V. infausta	4	1.498127	0.404216	0.605567
S	19	267	100	H	262.1153
lnS	2.944439			HE	89.02046

Mara A Undisturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
MAU	*P. fulva*	5	2.016129	0.701179	1.413668
	T. stapfiana	24	9.677419	2.269795	21.96576
	N. macrocalyx	78	31.45161	3.44845	108.4593
	Z. gilletii	15	6.048387	1.799792	10.88584
	A. gummifera	5	2.016129	0.701179	1.413668
	M. kilimandscharica	3	1.209677	0.190354	0.230267
	S. guineense	36	14.51613	2.67526	38.83442
	C. malosana	6	2.419355	0.883501	2.137502
	D. lucida	45	18.14516	2.898404	52.59201
	C. battiscombei	5	2.016129	0.701179	1.413668
	G. coffeiodes	5	2.016129	0.701179	1.413668
	P. mahonii	5	2.016129	0.701179	1.413668
	P. africana	4	1.612903	0.478036	0.771025
	A. chinense	5	2.016129	0.701179	1.413668
	T. nobilis	1	0.403226	-0.90826	-0.36623
	C. africana	1	0.403226	-0.90826	-0.36623
	A. adolfi-friederieri	1	0.403226	-0.90826	-0.36623
	E. capensis	1	0.403226	-0.90826	-0.36623
	B. micrantha	2	0.806452	-0.21511	-0.17348
	C. macrostachyus	1	0.403226	-0.90826	-0.36623
S	20	248	100	H	242.3535
lnS	2.995732			HE	80.89959

Mara B Undisturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
MBU	*P. fulva*	2	10.052632	0.051293	0.053993
	T. stapfiana	48	25.26316	3.229347	81.58351
	N. macrocalyx	28	14.73684	2.690351	39.64727
	Z. gilletii	6	3.157895	1.149906	3.631281
	A. gummifera	37	19.47368	2.969064	57.81862
	M. kilimandscharica	1	0.526316	-0.64185	-0.33782
	S. guineense	20	10.52632	2.353878	24.77767
	C. malosana	3	1.578947	0.456758	0.721197
	D. lucida	1	0.526316	-0.64185	-0.33782
	C. battiscombei	6	3.157895	1.149906	3.631281
	G. coffeiodes	1	0.526316	-0.64185	-0.33782
	P. mahonii	8	4.210526	1.437588	60.053001
	E. capensis	23	12.10526	2.49364	30.18617
	B. micrantha	2	10.052632	0.051293	0.053993
	C. macrostachyus	2	10.052632	0.051293	0.053993
	R. urcelliformis	1	0.526316	-0.64185	-0.33782
	X. monospora	1	0.526316	-0.64185	-0.33782
S	17	190	100	H	246.5229
lnS	2.833213			HE	87.01176

Itare A Disturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
IAD	*P. fulva*	3	2.941176	1.07881	3.17297
	Z. gilletii	2	1.960784	0.673345	1.320283
	A. gummifera	2	1.960784	0.673345	1.320283
	M. kilimandscharica	2	1.960784	0.673345	1.320283
	S. guineense	18	17.64706	2.870569	50.6571
	P. mahonii	22	21.56863	3.07124	66.24243
	P. africana	4	3.921569	1.366492	5.358791
	B. micrantha	2	1.960784	0.673345	1.320283
	C. macrostachyus	5	4.901961	1.589635	7.79233
	D. torrida	1	0.980392	-0.0198	-0.01941
	A. abyssinica	7	6.862745	1.926108	13.21838
	V. lasiopus	13	12.7451	2.545147	32.43814
	L. giberroa	6	5.882353	1.771957	10.42328
	S. campanulata	9	8.823529	2.177422	19.21255
	D. goetzenii	1	0.980392	-0.0198	-0.01941
	C. myricoides	3	2.941176	1.07881	3.17297
	C. perviflora	2	1.960784	0.673345	1.320283
S	17	102	100	H	218.2515
lnS	2.833213			HE	77.03321

Itare B Disturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
IBD	*P. fulva*	1	0.645161	-0.43825	-0.28275
	T. stapfiana	3	1.935484	0.660357	1.278111
	N. macrocalyx	1	0.645161	-0.43825	-0.28275
	Z. gilletii	4	2.580645	0.948039	2.446553
	A. gummifera	10	6.451613	1.86433	12.02794
	M. kilimandscharica	1	0.645161	-0.43825	-0.28275
	S. guineense	31	20	2.995732	59.91465
	C. battiscombei	1	0.645161	-0.43825	-0.28275
	P. mahonii	8	5.16129	1.641187	8.470641
	P. africana	2	1.290323	0.254892	0.328893
	E. capensis	1	0.645161	-0.43825	-0.28275
	C. macrostachyus	4	2.580645	0.948039	2.446553
	D. torrida	3	1.935484	0.660357	1.278111
	H. abyssinica	9	5.806452	1.75897	10.21337
	A. abyssinica	7	4.516129	1.507655	6.808766
	V. lasiopus	62	40	3.688879	147.5552
	C. myricoides	4	2.580645	0.948039	2.446553
	C. megalocarpus	1	0.645161	-0.43825	-0.28275
	D. lucida	2	1.290323	0.254892	0.328893
S	19	155	100	H	253.8477
lnS	2.944439			HE	86.2126

Itare A Undisturbed

Plot	Species	Freq	pi%	lnpi%	pi%lnpi%
IAU	*P. fulva*	2	2.173913	0.776529	1.688106
	T. stapfiana	24	26.08696	3.261435	85.08092
	N. macrocalyx	2	2.173913	0.776529	1.688106
	Z. gilletii	2	2.173913	0.776529	1.688106
	A. gummifera	7	7.608696	2.029292	15.44026
	M. kilimandscharica	1	1.086957	0.083382	0.090632
	S. guineense	2	2.173913	0.776529	1.688106
	C. malosana	5	5.434783	1.692820	9.200106
	C. battiscombei	4	4.347826	1.469676	6.389896
	P. mahonii	8	8.695652	2.162823	18.80716
	T. nobilis	3	3.260870	1.181994	3.854328
	A. adolfi-friederieri	1	1.086957	0.083382	0.090632
	B. micrantha	3	3.260870	1.181994	3.854328
	C. macrostachyus	2	2.173913	0.776529	1.688106
	X. monospora	5	5.434783	1.692820	9.200106
	S. campanulata	11	11.95652	2.481277	29.66744
	D. macrocalyx	1	1.086957	0.083382	0.090632
	S. schefferi	1	1.086957	0.083382	0.090632
	L. kilimandscharica	8	8.695652	2.162823	18.80716
S	19	92	100	H	209.1048
lnS	2.944439			HE	71.01685

Itare B Undisturbed

	Species	Freq	pi%	lnpi%	pi%lnpi%
IBU	*P. fulva*	5	3.267974	1.18417	3.869837
	T. stapfiana	10	6.535948	1.877317	12.27005
	N. macrocalyx	52	33.98693	3.525976	119.8371
	A. gummifera	12	7.843137	20.059639	16.15403
	S. guineense	14	9.150327	2.21379	20.2569
	C. battiscombei	1	0.653595	-0.42527	-0.27795
	P. mahonii	4	2.614379	0.961027	2.512488
	P. africana	5	3.267974	1.18417	3.869837
	A. abyssinica	4	2.614379	0.961027	2.512488
	V. lasiopus	8	5.228758	1.654174	8.649275
	S. campanulata	2	1.30719	0.267879	0.350169
	C. myricoides	30	19.60784	2.97593	58.35156
	D. lucida	6	3.921569	1.366492	5.358791
S	13	153	100	H	253.7146
lnS	2.564949			HE	98.91601

8.1.4 Descriptive statistics for tree diameter

Table shows the mean tree diameter and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed).

Site Name	Site description	Plot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	29.6667	18.42239	27
		B	17.6000	5.84494	50
		Total	21.8312	13.10424	77
	Undisturbed	A	25.0943	18.28436	53
		B	28.7059	18.22668	51
		Total	26.8654	18.25763	104
	Total	A	26.6375	18.34359	80
		B	23.2079	14.62827	101
		Total	24.7238	16.41581	181
Itare forest reserve	Disturbed	A	15.4091	7.45564	22
		B	14.6857	6.56986	35
		Total	14.9649	6.86857	57
	Undisturbed	A	34.0400	20.03462	50
		B	26.5556	13.13929	27
		Total	31.4156	18.18715	77
	Total	A	28.3472	19.18711	72
		B	19.8548	11.52595	62
		Total	24.4179	16.59889	134
Total	Disturbed	A	23.2653	16.10871	49
		B	16.4000	6.28339	85
		Total	18.9104	11.38424	134
	Undisturbed	A	29.4369	19.58174	103
		B	27.9615	16.58543	78
		Total	28.8011	18.31648	181
	Total	A	27.4474	18.70503	152
		B	21.9325	13.59336	163
		Total	24.5937	16.46827	315

8.1.5 Descriptive statistics for total tree height in metres

Table shows the mean tree height and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed).

Site Name	Site description	Plot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	20.8889	11.19180	27
		B	14.2000	4.81494	50
		Total	16.5455	8.25346	77
	Undisturbed	A	15.1887	7.73368	53
		B	17.3529	11.24958	51
		Total	16.2500	9.63383	104
	Total	A	17.1125	9.37812	80
		B	15.7921	8.78330	101
		Total	16.3757	9.04939	181
Itare forest reserve	Disturbed	A	9.5455	3.72542	22
		B	8.2286	3.37016	35
		Total	8.7368	3.53819	57
	Undisturbed	A	18.4600	9.73571	50
		B	12.7778	5.10153	27
		Total	16.4675	8.80129	77
	Total	A	15.7361	9.30696	72
		B	10.2097	4.75338	62
		Total	13.1791	8.01582	134
Total	Disturbed	A	15.7959	10.31580	49
		B	11.7412	5.18274	85
		Total	13.2239	7.69498	134
	Undisturbed	A	16.7767	8.87266	103
		B	15.7692	9.78592	78
		Total	16.3425	9.26426	181
	Total	A	16.4605	9.33900	152
		B	13.6687	7.96989	163
		Total	15.0159	8.75588	315

8.1.6 Descriptive statistics for basal area

Table shows the mean tree basal area and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed).

Site Name	Site description	Plot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	947.4369	1016.14091	27
		B	269.4434	170.35903	50
		Total	507.1814	691.37000	77
	Undisturbed	A	751.8226	1205.15083	53
		B	902.5345	1201.40282	51
		Total	825.7294	1199.85026	104
	Total	A	817.8424	1142.14304	80
		B	589.1231	914.93083	101
		Total	690.2145	1024.96582	181
Itare forest reserve	Disturbed	A	228.0425	327.46512	22
		B	202.2160	274.36641	35
		Total	212.1841	293.38929	57
	Undisturbed	A	1218.3828	1374.98911	50
		B	684.0839	7140.05499	27
		Total	1031.0312	1207.98322	77
	Total	A	915.7788	1244.00028	72
		B	412.0617	563.29359	62
		Total	682.7157	1017.45308	134
Total	Disturbed	A	624.4435	858.43501	49
		B	241.7615	220.24209	85
		Total	381.6975	575.16324	134
	Undisturbed	A	978.3082	1305.20761	103
		B	826.9170	1058.47003	78
		Total	913.0678	1204.27194	181
	Total	A	864.2334	1188.50271	152
		B	521.7746	802.27119	163
		Total	687.0245	1020.15868	315

8.1.7 Multiple comparisons for forest structure

The table shows the least significant mean differences (LSD) between the sampling plots for mean dbh, height and basal area. In the Table MAD Mara A Disturbed, MAU Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

	(I)	(J)	(I-J)	SE	Sig		(I)	(J)	(I-J)	SE
DBH	MAD	MBU	-4.21*	2.12	0.047	HGT	MBU	IAD	1.72*	0.85
		IAU	-13.43*	2.28	0.000			IBD	1.88*	0.75
	MAU	MBD	6.16*	1.70	0.000		IAD	IAU	-7.23*	1.00
		IAD	7.64*	2.10	0.000		IAU	IBD	7.39*	.91570
		IBD	7.41*	1.84	0.000	BA	MAU	MBD	482.38*	189.96
	MBD	MBU	-9.61*	1.79	0.000			IAD	592.02*	248.44
		IAU	-18.83*	1.98	0.000			IBD	549.61*	209.86
	MBU	IAD	11.08*	2.18	0.000					
		IBD	10.86*	1.92	0.000			MBU	-633.09*	191.76
	IAD	IAU	-20.30*	2.34	0.000			IAU	-948.94*	192.70
	IAU	IBD	20.08*	2.10	0.000		MBU	IAD	742.73*	249.82
								IBD	700.32*	211.49
HGT	MAD	MBU	-1.82*	0.70	0.009		IAD	MAU	-592.02*	248.44
		IAU	-7.33*	0.87	0.000			IAU	-1058.58*	250.55
							IAU	IBD	1016.17*	212.35
	MBD	IAU	-6.02*	0.84	0.000					

* The mean difference is significant at 0.05 levels. (LSD)

8.2 REGENERATION CAPACITY AND POTENTIAL

8.2.1 Recruitment and seedling survival from seasonal seed rain

Table shows the mean tree seedling species richness and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed) from recruitment and survival from seasonal seed rain in SW Mau forest reserve.

Site Name	Site description	Plot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	11.8284	2.77347	134
		B	6.9000	4.81578	110
		Total	9.6066	4.54435	244
	Undisturbed	A	7.0208	3.72380	144
		B	5.0686	2.85719	102
		Total	6.2114	3.51963	246
	Total	A	9.3381	4.07963	278
		B	6.0189	4.09017	212
		Total	7.9020	4.39960	490
Itare forest reserve	Disturbed	A	10.4571	6.94238	35
		B	12.0652	9.63190	46
		Total	11.3704	8.56219	81
	Undisturbed	A	6.9630	4.80770	27
		B	14.2364	11.99994	55
		Total	11.8415	10.73528	82
	Total	A	8.9355	6.30605	62
		B	13.2475	10.98581	101
		Total	11.6074	9.68927	163
Total	Disturbed	A	11.5444	4.01924	169
		B	8.4231	6.98758	156
		Total	10.0462	5.84584	325
	Undisturbed	A	7.0117	3.89870	171
		B	8.2803	8.62453	157
		Total	7.6189	6.61741	328
	Total	A	9.2647	4.55843	340
		B	8.3514	7.83920	313
		Total	8.8270	6.35762	653

8.2.2. Comparisons for seedling floristic composition and densities

The table shows the least significant mean differences (LSD) between the sampling plots for mean number floristic composition and densities for seedling survival and recruitment in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MAU Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variable	(I)	(J)	(I-J)	SE	Sig	Variable	(I)	(J)	(I-J)	SE
Family	MAD	MAU	4.44*	0.52	0.000	Genus	IAU	MAD	-4.87*	1.15
		MBU	5.98*	0.57	0.000			IBD	-4.75*	1.32
		IAU	5.25*	0.92	0.000	Species	MAD	MAU	4.81*	0.68
	MAU	IAD	-2.43*	0.82	0.003			MBU	6.76*	0.74
		IBD	-3.20*	0.74	0.000			IAU	4.87*	1.19
	MBD	MBU	1.47*	0.60	0.014			IBU	-2.41*	0.90
		IBU	-4.95*	0.72	0.000		MAU	IAD	-3.42*	1.06
	MBU	IAD	-3.98*	0.85	0.000			IBD	-5.04*	0.96
		IBD	-4.74*	0.77	0.000		MBD	MBU	1.83*	0.78
	IAD	IAU	3.24*	1.11	0.004			IBU	-7.34*	0.93
		IBU	-2.44*	0.94	0.010		MBU	IAD	-5.39*	1.11
	IAU	IBD	-4.01*	10.05	0.000			IBD	-7.00*	1.00
	IBD	MAU	3.20*	0.74	0.000		IAD	IAU	3.49*	1.45
Genus	MAD	MAU	4.81*	0.65	0.000			IBU	-3.78*	1.22
		MBU	6.76*	0.72	0.000		IAU	MAD	-4.87*	1.19
		IAU	4.87*	1.15	0.000			IBD	-5.10*	1.37
		IBU	-1.97*	0.87	0.024		IBD	MAU	5.04*	0.96
	MAU	IAD	-3.44*	1.02	0.001			MBU	7.00*	1.00
		IBD	-4.70*	0.92	0.000	Density	MAD	MBU	-0.43*	0.15
		IBU	-6.78*	0.86	0.000			IBU	-0.42*	0.18
	MBD	MBU	1.83*	0.75	0.014		MAU	MBU	-0.50*	0.15
		IBU	-6.90*	0.90	0.000		MBD	MBU	-0.39*	0.16
	MBU	IAD	-5.39*	1.06	0.000			IBU	-0.38*	0.19
		IBD	-6.65*	0.97	0.000		MBU	IBD	0.50*	0.21
	IAD	IAU	3.49*	1.39	0.012		IBD	IBU	-0.49*	0.24
		IBU	-3.34*	1.17	0.005		IBU	MBD	0.38*	0.19

- The mean difference is significant at the 0.05 level

8.2.3 Germinations from seasonal seed rain (species richness)

Table shows the mean tree seedling species richness and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed) from germinations of seasonal seed rain in SW Mau forest reserve.

Site Name	Site description	Poot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	10.3684	5.46921	19
		B	4.4500	2.92853	20
		Total	7.3333	5.23819	39
	Undisturbed	A	7.2308	5.43375	13
		B	6.5000	6.03776	12
		Total	6.8800	5.62228	25
	Total	A	9.0938	5.59008	32
		B	5.2187	4.38277	32
		Total	7.1563	5.35181	64
Itare forest reserve	Disturbed	A	8.0000	6.48074	16
		B	11.4167	6.35979	12
		Total	9.4643	6.54037	28
	Undisturbed	A	6.3529	6.26440	17
		B	7.0000	5.46648	35
		Total	6.7885	5.68568	52
	Total	A	7.1515	6.32515	33
		B	8.1277	5.96226	47
		Total	7.7250	6.09415	80
Total	Disturbed	A	9.2857	5.98317	35
		B	7.0625	5.59918	32
		Total	8.2239	5.86676	67
	Undisturbed	A	6.7333	5.83647	30
		B	6.8723	5.55454	47
		Total	6.8182	5.62824	77
	Total	A	8.1077	6.00813	65
		B	6.9494	5.53751	79
		Total	7.4722	5.76333	144

8.2.4 Multiple comparisons for species richness and density

The table shows the least significant mean differences (LSD) between the sampling plots for mean species richness and densities for seedling germination from seasonal seed rain in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variable	(I)	(J)	(I-J)	SE	Sig
Species richness	MAD	IAU	4.01548(*)	1.84984	0.032
		IBU	3.36842(*)	1.57895	0.035
	MBU	IBD	-4.91667(*)	2.26208	0.031
	IBD	IAU	5.06373(*)	2.08914	0.017
		IBU	4.41667(*)	1.85357	0.019
Species density	MAD	IBU	-3.43910(*)	1.40224	0.015
	MBD	IBU	-2.92857(*)	1.37933	0.036
	IAD	IBU	-3.29107(*)	1.48501	0.028
	IBD	IBU	-3.72857(*)	1.64612	0.025

8.2.5 Seed bank assay species richness

Table shows the mean tree seedling species richness and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed) from germinations from nursery seed bank trials in SW Mau forest reserve.

Site Name	Site description	Plot	Mean	SD	N
Mara Mara Forest reserve	Disturbed	A	24.5882	15.36660	17
		B	20.7805	14.86188	41
		Total	21.8966	14.97798	58
	Undisturbed	A	26.0476	15.98898	21
		B	25.4737	15.61825	19
		Total	25.7750	15.61309	40
	Total	A	25.3947	15.51902	38
		B	22.2667	15.13316	60
		Total	23.4796	15.28103	98
Itare forest reserve	Disturbed	A	33.1429	10.23300	35
		B	30.6667	13.40325	18
		Total	32.3019	11.34017	53
	Undisturbed	A	38.0000	.00000	9
		B	29.1000	15.18018	30
		Total	31.1538	13.79462	39
	Total	A	34.1364	9.31263	44
		B	29.6875	14.41358	48
		Total	31.8152	12.38035	92
Total	Disturbed	A	30.3462	12.66133	52
		B	23.7966	15.03534	59
		Total	26.8649	14.29335	111
	Undisturbed	A	29.6333	14.39943	30
		B	27.6939	15.29325	49
		Total	28.4304	14.89681	79
	Total	A	30.0854	13.23967	82
		B	25.5648	15.20715	108
		Total	27.5158	14.52884	190

8.2.6 Multiple comparisons for tree seedling composition.

The table shows the least significant mean differences (Dunnett T3) between the sampling plots for mean floristic composition for seedling germination from nursery seed bank trials in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variable	Test	(I)	(J)	(I-J)	SE	Sig
Family	Dunnett-T3	MBD	IAU	-6.26829(*)	1.04358	0.000
		IAU	IBD	3.58333(*)	0.94101	0.008
Genus	Dunnett-T3	MAD	IAU	-12.88889(*)	3.31652	0.025
		MBD	IAU	-16.00000(*)	2.17693	0.000
		IAU	IBD	7.95833(*)	1.96218	0.004
Species	Dunnett-T3	MAD	IAU	-13.88889(*)	3.54605	0.023
		MBD	IAU	-17.21951(*)	2.32104	0.000
		IBD	IAU	-8.31250(*)	2.08042	0.005

*The mean difference is significant at 0.05 levels.

8.3 FINE LITTER PRODUCTION NUTRIENT INPUTS AND SITE QUALITY

8.3.1 Litter mineral element content summary of analyzed samples

The table shows the descriptive statistics for sample litter mineral content values (Mg/l) from the sampling plots in the SW Mau forest reserve

Sn	Plot	Month	H2o (F)	Wgt (Mg)	%C	%N	Wgt (g)	P (Mg/l)	K (Mg/l)	Mg (Mg/l)	Ca (Mg/l)
1	MUD	July	1.13	5.01	49.65	2.82	2.00	1.04	7.86	4.20	14.12
2	MD	October	1.12	5.16	42.11	2.38	2.00	1.03	7.75	3.53	14.46
3	IUD	December	1.10	4.96	37.37	1.59	2.00	1.11	14.7	3.62	10.88
4	ID	July	1.13	5.03	49.86	1.97	2.00	0.91	5.35	2.91	9.90
5	MUD	November	1.12	5.03	43.44	2.71	2.00	1.10	11.90	3.53	12.24
6	MUD	February	1.12	5.04	52.44	2.61	2.00	0.86	10.86	3.92	12.20
7	MD	April	1.13	4.95	47.51	3.32	2.00	1.27	3.71	3.48	16.53
8	IUD	April	1.13	5.00	40.04	2.08	2.00	1.04	4.13	3.22	13.43
9	ID	May	1.13	5.01	41.63	1.89	2.00	0.98	4.92	3.19	11.40
10	MD	June	1.13	4.95	44.28	2.00	2.00	0.96	7.00	4.47	14.07
11	MD	January	1.12	4.98	32.78	1.33	2.00	0.93	9.10	3.47	13.92
12	MD	February	1.12	4.96	49.32	2.13	2.00	0.87	11.03	3.42	12.44
13	MD	May	1.13	4.99	50.77	30.05	2.00	1.08	5.08	4.49	16.72
14	ID	January	1.12	5.01	36.19	2.94	2.00	0.85	7.91	3.16	10.62
15	ID	June	1.12	5.00	36.53	1.28	2.00	0.82	6.73	2.80	11.70
16	MD	November	1.12	4.95	48.42	2.35	2.00	0.96	9.84	3.41	13.43
17	ID	February	1.12	5.01	45.62	1.58	2.00	0.86	6.50	2.98	10.01
18	IUD	July	1.12	5.03	50.23	2.50	2.00	0.97	10.31	4.68	14.13
19	ID	April	1.14	4.93	39.94	1.88	2.00	1.04	2.68	3.65	12.82
20	ID	December	1.11	5.02	43.66	1.54	2.00	0.95	13.94	3.65	11.53
21	IUD	February	1.12	5.02	46.27	2.19	2.00	0.94	9.07	3.91	12.77
22	IUD	November	1.12	50.05	46.16	2.30	2.00	1.07	6.93	4.00	14.19
23	ID	November	1.12	4.95	49.08	1.65	2.00	0.77	7.53	3.34	10.46
24	IUD	January	1.12	4.99	46.83	2.24	2.00	0.95	10.46	3.61	12.60
25	IUD	May	1.13	4.99	51.06	2.78	2.00	1.07	7.56	4.22	14.20
26	IUD	June	1.12	4.98	40.58	2.11	2.00	0.86	12.87	4.44	14.83
27	MD	July	1.13	4.99	38.76	2.18	2.00	1.14	7.84	4.43	15.71
28	IUD	October	1.13	50.05	41.98	2.15	2.00	1.13	12.64	3.55	11.29
29	MUD	April	1.13	4.96	50.20	3.08	2.00	1.08	3.66	2.92	16.13
30	ID	October	1.13	4.94	42.38	1.59	2.00	0.80	5.58	3.29	11.85
31	MUD	June	1.14	4.97	48.63	1.74	2.00	0.99	8.48	4.69	13.72
32	MUD	May	1.13	4.94	49.73	3.49	2.00	1.31	6.94	4.41	15.03
33	MUD	December	1.12	5.03	32.20	1.73	2.00	1.08	13.32	4.02	13.63
34	MD	December	1.12	4.99	40.34	1.94	2.00	0.90	10.79	3.91	15.14
35	MUD	January	1.12	4.98	45.48	2.62	2.00	0.98	9.66	3.95	12.88
36	MUD	October	1.13	5.01	39.87	2.57	2.00	1.29	7.63	4.28	15.49

8.3.2 Descriptive statistics monthly fine litter turnover

The table shows the descriptive statistics for mean monthly litter values (Kg/ha) for the combined study sites as well as the disturbed and undisturbed sites

	All sampling plots N = 120 (Kg/ha)			Disturbed (N = 60) (Kg/ha)			Undisturbed (N = 60) (Kg/ha)		
Month	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE
June	92.19	86.92	7.93	74.74	43.89	5.67	109.63	112.66	14.54
May	128.75	79.92	7.30	115.49	73.39	9.47	129.44	110.27	14.24
October	146.15	102.63	9.37	154.24	84.57	10.92	134.40	68.79	8.88
February	148.81	106.74	9.74	162.22	75.93	9.80	138.43	56.46	7.29
April	152.39	90.54	8.27	162.86	92.29	11.92	142.01	84.50	10.91
July	154.01	78.63	7.18	163.21	133.51	17.24	145.43	109.83	14.18
March	156.57	100.66	9.19	167.71	90.12	11.63	150.54	96.83	12.50
August	168.66	94.15	8.59	169.58	93.75	12.10	155.93	59.40	7.67
September	173.52	81.55	7.44	191.11	96.20	12.41	175.09	109.68	14.14
December	190.56	99.21	9.06	195.44	104.68	13.52	185.67	940.05	12.14
November	243.98	178.04	16.25	258.36	228.28	29.47	229.59	106.78	13.79
January	265.38	123.64	11.29	284.17	112.36	14.51	246.59	132.24	17.07
Annual	2020.94	680.89	62.16	2099.14	751.44	97.01	1942.7	598.31	77.24

8.3.3 Descriptive statistics for total annual litter input

Table shows the mean total annual litter input in Kg/ha/yr and standard deviations in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed).

Forest site	State of site	Plot	Mean	SD	N
Itare	Disturbed	A	2143.7867	927.93105	15
		B	1679.5733	523.54007	15
		Total	1911.6800	777.00372	30
	Undisturbed	A	1746.8133	794.52483	15
		B	1831.2267	344.21470	15
		Total	1789.0200	603.15237	30
	Total	A	1945.3000	872.46122	30
		B	1755.4000	442.11802	30
		Total	1850.3500	692.37960	60
Mara Mara	Disturbed	A	2245.9467	692.88799	15
		B	2327.2400	703.43411	15
		Total	2286.5933	687.28228	30
	Undisturbed	A	2184.3200	535.59272	15
		B	2008.6267	591.92311	15
		Total	2096.4733	561.79412	30
	Total	A	2215.1333	609.29101	30
		B	2167.9333	658.99750	30
		Total	2191.5333	629.67979	60
Total	Disturbed	A	2194.8667	806.31927	30
		B	2003.4067	692.59217	30
		Total	2099.1367	751.43997	60
	Undisturbed	A	1965.5667	701.95295	30
		B	1919.9267	484.23508	30
		Total	1942.7467	598.31218	60
	Total	A	2080.2167	758.37080	60
		B	1961.6667	593.97243	60
		Total	2020.9417	680.88835	120

8.3.4 Monthly comparisons for litter input in the sampling plots

The table shows the least significant mean differences (LSD) between the sampling plots for mean monthly fine litter inputs in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MAU Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed, I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

	(I)	(J)	(I-J)	SE	Sig		(I)	(J)	(I-J)	SE
January	IAD	IBU	103.15*	42.40	.017	May	IAD	IBU	-129.76*	22.65
	IAU	MBD	-97.08*	42.40	.024		IAU	MAD	-62.79*	22.65
	IBD	IBU	113.68*	42.40	.008			MBD	-97.53*	22.65
	MAD	IBU	111.04*	42.40	.010		IBD	IBU	-154.88*	22.65
March	IAD	IBU	-75.16*	42.40	.032			MBU	-55.21*	22.65
	IAU	MAD	-114.61*	34.69	.001		IBU	MAD	129.95*	22.65
		MBD	-87.80*	34.69	.013			MBD	95.20*	22.65
	IBD	IBU	-76.95*	34.69	.029	June†	IBD	MBU	-88.51*	21.64
	MAD	MAU	90.89*	34.69	.010	July	IAD	IBU	127.20*	36.59
		MBU	81.36*	34.69	.021		IBD	MAU	-82.03*	36.59
April	IAU	MAD	-135.67*	34.69	.000		IBU	MAD	-116.59*	36.59
		MBD	-100.51*	35.33	.005			MBD	-77.45*	36.59
	MAD	MAU	86.63*	35.33	.016	August	IAD	IBU	108.84*	26.54
		MBU	910.05*	35.33	.011	September	IAD	IBU	64.17*	28.81
May	IAD	IAU	62.97*	22.65	.006		IBU	MAD	-92.23*	28.81
								MBD	-84.43*	28.81

***The mean difference is significant at 0.05 level † Dunnetts-T3 test**

8.3.5 Litter nutrient content

Table shows the mean fine litter mineral content (% C, %N, P, K, Mg and Ca content in mg/100g of litter) and standard deviations in all study plots and the state of the plots disturbed or undisturbed in the SW Mau forest reserve.

	All sampling plots(N = 36) Mg/100g of litter		Disturbed plots(N = 18) mg/100g of litter		Undisturbed plots(N = 18) mg/100g of litter	
	Range	Mean(SD)	Range	Mean(SD)	Range	Mean(SD)
%C	32.20-52.44	44.20(5.39)	32.78-50.77	43.29(5.27)	32.20-52.44	45.12(5.49)
%N	1.65 -34.92	9.84(9.78)	1.65-20.02	6.72(6.58)	1.73-34.92	12.97(11.53)
P	43.46-73.89	56.23(7.51)	43.46-72.07	53.55(7.29)	48.10-73.89	58.91(6.93)
K	15.30-81.73	47.13(16.99)	15.30-77.51	41.57(15.48)	20.66-81.73	52.70(16.99)
Mg	156.77-265.87	210.41(30.21)	156.77-254.30	198.72(28.93)	164.74-265.87	222.09(27.44)
Ca	55.80-94.64	74.44(10.50)	55.80-94.64	72.75(12.44)	60.33-90.97	76.12(8.13)

8.3.6 Multiple comparisons site litter nutrient content

The table shows the least significant mean differences (LSD) between the sampling plots for mean fine litter nutrient content in the SW Mau forest reserve. In the Table MD Mara Disturbed, MUD Mara Undisturbed, ID Itare Disturbed, IUD Itare Undisturbed, I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variable	(I)	(J)	(I-J)	SE
Phosphorus	MUD	ID	10.91(*)	3.14
	ID	IUD	-6.96 (*)	3.14
Magnesium	ID	MUD	-43.51 (*)	12.19
		IUD	-38.20(*)	12.19
Calcium	MD	IUD	9.04(*)	3.58
	MUD	ID	15.78(*)	3.58
	ID	IUD	-10.96 (*)	3.58

* The mean differences are significant at 0.05 levels.

8.3.7 Descriptive statistics litter quality (C: N) ratio

Table shows the mean litter C: N ratios in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed) in the SW Mau forest reserve.

Forest site	State of site	Plot	Mean	SD	N
Itare	Disturbed	A	5.4603	0.53887	15
		B	5.3050	0.38193	15
		Total	5.3827	0.46567	30
	Undisturbed	A	3.4463	0.29958	15
		B	3.7256	0.52082	15
		Total	3.5859	0.44095	30
	Total	A	4.4533	1.11019	30
		B	4.5153	0.92008	30
		Total	4.4843	1.01138	60
Mara Mara	Disturbed	A	8.5084	1.61585	15
		B	9.2995	1.28658	15
		Total	8.9040	1.49044	30
	Undisturbed	A	3.7083	0.48196	15
		B	3.8023	0.37627	15
		Total	3.7553	0.42752	30
	Total	A	6.1084	2.70770	30
		B	6.5509	2.94662	30
		Total	6.3296	2.81446	60
Total	Disturbed	A	6.9844	1.95024	30
		B	7.3022	2.23518	30
		Total	7.1433	2.08587	60
	Undisturbed	A	3.5773	0.41618	30
		B	3.7639	0.44813	30
		Total	3.6706	0.43898	60
	Total	A	5.2808	2.21492	60
		B	5.5331	2.39527	60
		Total	5.4070	2.30063	120

8.3.8 Descriptive statistics litter quality C: P ratio

Table shows the mean litter C: P and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed) in SW Mau forest reserve.

Forest site	State of site	Plot	Mean	SD	N
Itare	Disturbed	A	87.7930	5.17810	15
		B	89.1770	4.22428	15
		Total	88.4850	4.69618	30
	Undisturbed	A	78.6709	1.09245	15
		B	77.3534	.90760	15
		Total	78.0122	1.19279	30
	Total	A	83.2320	5.91949	30
		B	83.2652	6.72063	30
		Total	83.2486	6.27887	60
Mara Mara	Disturbed	A	77.2738	27.55812	15
		B	90.6702	67.88727	15
		Total	83.9720	51.36073	30
	Undisturbed	A	90.3671	43.48229	15
		B	71.6799	24.19145	15
		Total	81.0235	35.85517	30
	Total	A	83.8205	36.38301	30
		B	81.1751	50.99678	30
		Total	82.4978	43.93995	60
Total	Disturbed	A	82.5334	20.20376	30
		B	89.9236	47.26597	30
		Total	86.2285	36.23017	60
	Undisturbed	A	84.5190	30.80117	30
		B	74.5166	17.06591	30
		Total	79.5178	25.19735	60
	Total	A	83.5262	25.84483	60
		B	82.2201	36.07780	60
		Total	82.8732	31.25597	120

8.3.9 Comparisons for site litter quality

The table shows the least significant mean differences (Dunnett T3) between the sampling plots for mean fine litter C: N and C: P ratios in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MA U Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Variables	(I)	(J)	(I-J)	SE	Sig	(I)	(J)	(I-J)	SE
C: N	IAD	IAU	2.01*	0.30	0.000	IAU	IBD	-1.86*	0.30
Dunnett-T3		IBU	1.74*	0.30	0.000		MAD	-5.06*	0.30
		MAU	1.75*	0.30	0.000		MBD	-5.85*	0.30
		MBU	1.66*	0.30	0.000	IBU	MAD	-4.78*	0.30
	IBD	IAU	1.86*	0.30	0.000		MBD	-5.57*	0.30
		IBU	1.58*	0.30	0.000	MAD	MAU	4.80*	0.30
		MAU	1.60*	0.30	0.000		MBU	4.71*	0.30
		MBU	1.50*	0.30	0.000	MBD	MAU	5.59*	0.30
							MBU	5.50*	0.30
C: P	IAD	IBU	10.44*	1.36	0.000	IAU	IAD	-9.12*	1.37
Dunnett-T3	IBD	IBU	11.82*	1.12	0.000		IBD	-10.51*	1.13

*The mean differences are significant at 0.05 levels.

8.3.10 Litter nutrient inputs

Table shows the mean fine litter nutrient inputs and standard deviations in all study plots and the state of the plots disturbed or undisturbed in the SW Mau forest reserve.

	Annual litter inputs (Kg/ha/yr)					
	All sampling plots (N = 120)		Disturbed (N = 60)		Undisturbed (N = 60)	
	Mean	SD	Mean	SD	Mean	SD
C	895.29	299.49	914.08	329.76	876.49	267.30
N	188.26	86.94	135.01	54.27	241.51	80.83
Mg	49.75	19.06	56.61	21.41	42.90	13.37
Ca	150.05	5.55	15.37	6.33	14.74	4.67
P	11.42	3.95	11.33	4.31	11.50	3.59
K	9.76	3.76	8.86	3.43	10.66	3.92

8.3.11 Site comparisons for litter nutrient inputs

The table shows the least significant mean differences (LSD) between the sampling plots for mean fine litter nutrient inputs in the SW Mau forest reserve. In the Table MAD Mara A Disturbed, MAU Mara A Undisturbed, MBD Mara B Disturbed, MBU Mara B Undisturbed, IAD Itare A Disturbed, IAU Itare A Undisturbed, IBD Itare B Disturbed, IBU Itare B Undisturbed I and J are the plot means, I-J the plot mean difference SE standard error of the mean difference and Sig the significance.

Input	(I)	(J)	(I-J)	SE	Sig	Input	(I)	(J)	(I-J)	SE
N	IAD	IAU	-59.54*	24.56	0.017	K	IAD	IAU	-3.04*	1.30
		IBU	-54.83*	24.56	0.028			MBU	-2.99*	1.30
		MAU	-99.98*	24.56	0.000		IBD	IAU	-4.65*	1.30
		MBU	-68.12*	24.56	0.006			IBU	-3.85*	1.30
	IBD	IAU	-88.55*	24.56	0.000			MAU	-3.58*	1.30
		IBU	-83.84*	24.56	0.001			MBU	-4.60*	1.30
		MAU	-128.98*	24.56	0.000	Mg	IAD	IAU	34.59*	6.02
		MBU	-97.13*	24.56	0.000			IBU	33.26*	6.02
	IAU	MAD	113.99*	24.56	0.000			MAU	28.02*	6.02
		MBD	119.65*	24.56	0.000			MBU	23.96*	6.02
	IBU	MAD	109.27*	24.56	0.000		IBD	IAU	18.81*	6.02
		MBD	114.93*	24.56	0.000			IBU	17.49*	6.02
	MAD	MAU	-154.42*	24.56	0.000			MAU	12.24*	6.02
		MBU	-122.56*	24.56	0.000	Ca	IAD	MBU	-3.81*	1.78
	MBD	MAU	-160.08*	24.56	0.000		IBD	MAU	-5.37*	1.78
		MBU	-128.22*	24.56	0.000			MBU	-6.63*	1.78
P	IAD	MBU	-2.65*	1.30	0.049		IAU	MAD	-6.56*	1.78
	IBD	MAU	-3.98*	1.30	0.003			MBD	-5.86*	1.78
		MBU	-4.94*	1.30	0.000		IBU	MAD	-5.82*	1.78
	IAU	MAD	-3.56*	1.30	0.009			MBD	-5.12*	1.78
		MBD	-3.02*	1.30	0.025		MBD	IAU	5.86*	1.78
	IBU	MAD	-2.91*	1.30	0.031			IBU	5.12*	1.78

8.3.12 Nutrient use efficiency in the SW Mau reserve

Table shows the mean tree species richness and standard deviation in the study plots (A and B) in the forest sites (Mara Mara and Itare forest reserves) and the state of the plots disturbed or undisturbed). Within stand nutrient use efficiency (NUE) defined as kilograms of dry litter mass (annual litter turnover) per kilogram of nutrient content (Annual litter nutrient input) for the disturbed and undisturbed sites

	All plots (N = 120)		Disturbed (N = 60)		Undisturbed (N = 60)	
Element	Mean	SD	Mean	SD	Mean	SD
K	223.62	95.49	254.46	104.47	192.78	74.44
P	187.18	72.65	198.23	85.89	176.13	54.94
Ca	143.14	53.32	148.77	62.38	137.50	42.17
Mg	44.38	22.03	41.62	27.23	47.15	14.91
N	12.26	5.36	16.39	4.73	8.13	0.99
C	2.26	0.09	2.30	0.11	2.22	0.04

8.4 FOREST COMPOSITION AND STRUCTURE DATA TALLY SHEETS

Habitat characterization plot data tally sheet (over storey species dbh >30cm)

Plot Number		Location	Date		
S/N	Species		E/N	DBH cm	Height m

N = Native E =Exotic

Habitat characterization plot data tally sheet (under storey species dbh 10-30cm)

Plot Number		Location	Date		
S/N	Species		E/N	DBH cm	Height m

E = Exotic N = Native

Habitat characterization plot data tally sheet. (Sub-canopy dbh < 10 cm h >1.3 m)

Plot Number		Location	Date		
S/N	Species		E/N	DBH cm	Height m

E = Exotic N = Native

Habitat characterization plot data tally sheet (ground storey seedlings < 1.3 m height)

Plot number		Location	Date	
S/N	Species		E/N	Height

E = Exotic N = Native

Potential soil seed bank seedling assay data tally sheet

Plot Number		Location	Date		
SN	Species		E/N	Tally	No of seedlings

E = Exotic N = Native

8.5 HOUSEHOLD SURVEY QUESTIONNAIRE.

NAME OF HOUSEHOLD HEAD		GENDER	M	F
1District	**2 Location**	**3 Distance from the fore(KM)**		

Personal information of the Household head					
4 Socio class	**(x)**	**5 Occupation**	**(x)**	**6 Marital status**	**(x)**
1 Upper		1 Farmer		1 Married	
2 Middle		2 Civil servant		2 Single	
3 Lower		3 Teacher		3 Widowed/divorced	
		4 Businessman			

7Type of housing		8 Size of house	
1 Permanent (stone)		Small	
2 Semi permanent (iron sheet roof)		Medium	
3 Semi permanent (Thatched)		Large	
4 Temporary		Several houses	

What are your sources of income				
9 Sources of income	**Y**	N	**10 Monthly Ksh**	**11 Annual Ksh**
Income from sale of cash crops				
Income from sale of livestock				
Employment (Salaries and wages)				
Remittances				
Casual labour				
Sale of charcoal				
Small scale business				
Sale of firewood				
Sale of wild fruits				
Sale of honey				

Health facilities	
12 How far is the nearest health centre from your home (km)	
13 Where do you get health care from	
Provincial hospital	
District hospital	
Private hospital	
Divisional health centre	
Private clinics	
Use medicine from the forest	

14 Household size			
Category	Male	Female	Total
Adult > 55 years			
Adult (18-55 yrs)			
Children (under 18 yrs)			
Others			
Total			

Land tenure and land use					
15 Tenure category	**(x)**	**16 Original land use**	**(x)**	**17 Current use**	**(x)**
1 Land with title		1 Forest		1 Forest	
2 Land without title		2 Grassland		2 Grassland	
3 Communal		3 Wetland		3 Wetland	
4 Hired/rented		4 Pasture		4 Pasture	
5 Squatter.				5 Farmland	

18 Which crops do you grow on your farm?			
Cash crops	Area (ha)	Subsistence crops	Area in (ha)
1 Tea		1 Maize	
2 Coffee		2 Beans	
3 Pyrethrum		3 Peas	
		4 Potatoes	
		5 Carrots	

19 Which livestock types do you keep on your farm?				
Type	Improved	Number	Indigenous	Number
1Cattle				
2 Sheep				
3 Goats				
4 Pigs				
5 Poultry				
6 Donkeys				

20 Where do you graze the livestock?		21 How do you graze your livestock?	
1 Forest		1 Tethering	
2 A long the roadside		2 Free range grazing in the forest	
3 Part of farm set aside		3 Zero grazing	

22 Which products do you get from the forest? (X)		23 Importance rank	24 Adequacy rank
1 Food			
2 Firewood			
3Timber			
4 Charcoal			
5 Honey			
6 Pasture			
7 Medicinal plants			
8 Thatching grass			
9 Resins and gums			
10 Tannins and gums			

Rank 1 Very important, 2 Important, 3 Moderately important, 4 Not very important, 5 Not important at all Adequacy of quantity 1. Very adequate 2. Adequate 3. Not very adequate 4. Inadequate 5. Very inadequate

25 What services do you derive from the forest (X)		26 Importance Rank
1Water catchments		
2 Aesthetic value		
3 Wildlife sanctuary		
4 Shade		
5 Soil conservation		
6 Wind break		
7 Erosion control		
8 Ceremonial		
9 Rituals		

Rank 1 Very important, 2 Important, 3 Moderately important, 4 Not very important, 5 Not important at all

27 Are goods and services freely accessible (x)	Yes		No	
28 If no what are the barriers to inaccessibility (x)				
1 Forest policy				
2 The forest is degraded				
3 The goods and services are no longer available				
4 One has to walk long distances to obtain the goods				
5 Getting the license is difficult				

29 What is the average monthly household expenditure on		
Commodity	Units	Quantity per month
Timber	(m^3)	
Firewood	head loads	
Fodder	Head loads	
Charcoal	Bags	
Thatching grass	Head loads	
Medicines		
Honey	Litres	

30 What are the causes of forest degradation in this area?		
Cause	Cause **(x)**	Ranking
1 Increase in human population		
2 Land subdivision		
3 Increased logging activities		
4 Intensified agriculture		
5 Introduction of exotic species		
6 Road construction		
7 Charcoal burning		
8 Firewood collection		
9 Overgrazing		
10 Changes in land use		
11 Timber related activities		

Rank 1 Very important, 2 Important, 3 Moderately important, 4 Not very important, 5 Not important at all

8.6 FOCUS GROUP DISCUSSION INTERVIEW SCHEDULE

1 Do you think it is important to have this forest in this location?
2 If yes what are the benefits of the forest to the people living in this location
3 In comparison with the past what would you say is the state and condition of the forest
4 Could you please narrate briefly how the forest looked like in the past?
5 What are the presumed causes of forest degradation in this location?
6 Are goods and services freely accessible
7 If no what are the barriers to accessibility
8 What services do the community derive from the forest?
9 What is the main source of grazing for the community
10 Under what type of tenure is the land held
11 What are the main sources of income in this community
12 Does the community derive any products from the forest reserve
13 What is the average land holding size per household in this location
14 How far is the closest homestead to the forest reserve boundary
15 Which livestock types are kept in this location
16 List some cultural artefacts advantageous for the conservation of forest
17 List some cultural artefacts disadvantageous for the conservation of forest
18 List some forest tree species that are of cultural importance to the community
19 What is the frequency of floods, drought, fires in this location
20 Do you experience shortages of firewood, charcoal timber, building poles thatching grass, wild fruits etc

8.7 TABLE OF TREE SPECIES AND AUTHORITIES

Local name (Kipsigis)	Common name	Botanical name	Authority*
	_____________	*Cylicomorpha parviflora*	(Urb)
_________	________________	*Aningeria adolfi-friederieri*	(Engler.) Robyns&Gilbert
_________	Nandi flame	*Spathodea campanulata*	(Seem)
_________	_______________	*Strombosia schefferi*	(Engler)
Aonet	Parasol tree	*Polycias fulva*	(Hiern) Herms
Arorwet	Cape ash	*Ekebergia capensis*	(Fresen) A. Rich
Bondet	Rosewood	*Hagenia abyssinica*	(Bruce) J.F. Gmel
Chemakwangiet	Forest rothmannia	*Rothmannia urcelliformis*	(Schneinf ex Hiern) Bullock ex Robyns
Chepchabaiyet	Forest sword leaf	*Casearia battiscombei*	(R.E. Fries)
Chepkelelyet	White stinkwood	*Celtis Africana*	(Burm)
Chepkurbet	__________	*Lobelia giberroa*	Hemsel
Chepokyot	_________	*Galiniera coffeiodes*	(Del)
Cheptabiribir	___________	*Dovyalis macrocalyx*	(Oliv). Warb
Cheptuiyet	Giant diospyros	*Diospyros abyssinica*	(Hiern)
Emitiot	Wild Olive	*Olea europea var. africana*	(Mill)
Kelelwet	Musine	*Croton megalocarpus*	(Hutchinson)
Kimolwet	Mountain wild medlar	*Vangueria infausta*	(Burch)
Kombeito	____________	*Psychotria mahonii*	CH Wright
Kubusto	_______________	*Alangium chinense*	(Laur.) Rehdr
Kuryot	Small-fruited teclea	*Teclea nobilis*	(Del)
Lemeiywet	Forest water berry	*Syzigium guineense*	(Willd) DC
Lukumeito	_____________	*Macaranga kilimandscharica*	(Pax)
Mangoita	Pillar Wood (Onion wood)	*Cassipourea malosana*	(Baker) Alston
Masaita	East African Olive	*Olea capensis*	(L.)
Mororta	_______________	*Allophylus abyssinicus*	(Hochst) Radlk
Mutereriet	Mitzeerie	*Bridelia micrantha*	(Baill)
Nukyat	Glossy sourberry	*Dovyalis lucida*	(A.Rich) Warb
Rerendet	Wild magnolias	*Tabernaemontana stapfiana*	(Britten)
Ruandet	____________	*Lasianthus kilimandscharicus*	(K. Schum)
Sakawaita	African Satinwood	*Zanthoxylum gilletii*	(De Wild) P Waterman
Sebetet	Lace-leaf	*Neoboutonia macrocalyx*	(Pax)
Seet	Smooth bark flat crown	*Albizia gummifera*	(J.F. Gmel)
Sewerweryet	Lemon wood	*Xymalos monospora*	(Harv) Baill
Silibwet	Mukeo	*Dombeya goetzenii*	(K. Schum)
Singorwet	Butterfly bush	*Clerodendrum myricoides*	(Hochst). R.Br. ex Vatke
Tebengwet	___________	*Vernonia auriculifera*	Hiern
Tebeswet	_____________	*Croton macrostachyus*	(Hochst)
Tendwet	Red stinkwood	*Prunus aricana*	(Hook.f.) Kalkakm

**Source, Dale and Greenway 1961;Noad and Birnie 1990; Beentje 1994*