DISTRIBUTION, STRUCTURE, COMPOSITION, USES AND THREATS TO BAMBOO NATURAL STANDS IN MARIASHONI AND NJORO AREAS, MAU FOREST COMPLEX, NAKURU COUNTY, KENYA

BY

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DECLARATION

Declaration of the Candidate

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without the prior written permission of the author and/or University of Eldoret.

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DEDICATION

I wish to dedicate this work to my family for their outstanding support during this Masters of Science study.

ABSTRACT

Increasing demand for bamboo products and clearing of bamboos for cultivation pose significant threats to indigenous bamboo forests in Mariashoni and Njoro forests. This study investigated bamboo distribution in Mariashoni and Njoro forests from 2000 to 2011, determined their structure, composition, uses and threats to the resource. Satellite images of the area for 2000 and 2011 and field survey data on forest characteristics for three blocks were compared. The blocks were selected by variation in elevation and perceived levels of disturbance. Structure and composition were characterized by density, frequency, diameter at breast height and height of trees. Questionnaires were also administered to 131 stakeholders to establish uses and threats to bamboo forests. Data were then analyzed by ANOVA and T-test for species diversity and similarity between blocks. Chi-square and pearson's correlation tested variation and relationship in responses by stakeholders. Results show that closed canopy bamboo increased by 295ha from 221ha in 2000 to 516ha in 2011, while 165ha were converted into farmlands. The surveys showed that closed canopy bamboo had a higher stocking of trees and seedlings than open canopy bamboo which had a higher stocking of saplings. Basal area was lower in closed canopy bamboo than open canopy bamboo. In blocks, block I (the less disturbed site) had a higher stocking of trees and seedlings than block II and III (the more disturbed sites) which had a higher stocking of saplings. Basal area was also larger in block I than in block II and III. The distribution of bamboo showed a reverse-J curve, while Oleaceae, Fabaceae and Cupressaceae families were dominant. Species diversity and composition were insignificantly different ($p>\alpha$) between blocks. Bamboo was exploited mostly for domestic uses, and poverty level was major the factor influencing extraction. Major threats to the forests were charcoal burning, logging and bamboo extraction. Sensitizing the local community on forest management and conservation, initiation of livelihood options in adjacent areas, and afforestation were mentioned as the best means of conserving the forests.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
a.s.l.	Above sea level
CAF	Community Forest Association
dbh	Diameter at breast height
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GoK	Government of Kenya
GPS	Global Positioning System
HSD	Honestly Significant Difference
INBAR	Internatioal Network for Bamboo and Rattan
IUCN	International Union for Conservation of Nature (or World Conservation Unions)
KEFRI	Kenya Forest Research Institute
KFS	Kenya Forest Service
KFWG	Kenya Forest Working Group
KWS	Kenya Wildlife Service
NEMA	National Environmental Management Authority
RS	Remote Sensing
SPSS	Statistic Package for Social Sciences
TM	Thematic Mapper
UNEP	United Nations Environmental Program
USGS	United States' Geological Survey

OPERATIONAL DEFINITIONS

Forest structure – refers to the distribution of individual tree species in the bamboo forests. It considers the number of stems per hectare, stems occupancy and height.

Forest composition – refers to all different tree species recorded in studied blocks, their respective families, level of dominance and diversity.

Species dominance – is the degree to which a species is more numerous in the study area.

Species diversity – is the variety of tree species found in the bamboo forests, their richness (number of different species encountered) and evenness (their relative abundance).

Bamboo stands – consider the bamboo thickness types where closed canopy bamboo is a near homogeneous bamboo stand mixed with less trees, while open canopy bamboo is an intermixture of bamboo with many other tree species.

Ecosystem goods and services – consist of direct or indirect benefits the local communities obtain from the bamboo forest ecosystem. These include timber, poles, posts, firewood, food, medicine, bark of trees and fresh water; water penetration and purification in the soil, erosion control; ceremonial sites for circumcision of boys; provision of animal habitat and production of atmospheric oxygen.

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Bamboo forest (31.5 million ha worldwide) is one of the important components of natural forest ecosystems in the tropical and subtropical regions (Zhou *et al.*, 2005) between 46^{o} north and 47^{o} south latitude (Lobovikov *et al.*, 2007). Bamboo is not only an economic investment that can be utilized in many different ways but also has enormous potential in solving many environmental problems owing to its complex root network system underneath the ground (Yiping and Henley, 2010). This makes bamboo forest more efficient than other forest types in holding soil particles together, reducing erosive impact of rainfall and protecting water resources in forested catchment areas (Zhou *et al.*, 2005). The forest also harbors montane plant communities and animals which rely on bamboo shoots for their survival (Bystriakova *et al.*, 2004).

Approximately 1200 bamboo species (Bystriakova *et al.*, 2004) are common in Southeast Asia, Africa, and Latin America. Africa has five indigenous species covering 2.4 million ha (FAO, 2005). In Kenya, the dominant indigenous bamboo species, *Yushania alpina K.Schum* formerly *Arundinaria alpine.* The species occur partly as pure forest and/or in mixed stands with other trees and shrubs inluding *Podocarpus procera (Thunb) Mirb, Juniperus Endl., Olea* and *Acacia* species (Maundu and Tengnäs, 2005 and KEFRI, 2008). The intermixing of trees is important as it makes the soil more permeable to rainwater due to deep penetration of roots of trees and improve contiuous water percolation and flow even in dry weather (Kassahun, 2003).

Most of bamboo forests (150000 ha) (KEFRI, 2008) are distributed in high altitude areas of Kenya ranging from 2400m and above, mainly high potential zones where competition for land is intense (INBAR, 2006). These areas include excised areas surrounding Mau Forest Complex from where human activities exert pressure on the forest. Forest resources extraction worsened after eviction of Ogiek community from Mau forest to degazetted areas in 2001 (Obare and Wangwe, 2005). This was followed by immigration of other communities into degazetted areas that opened the forests for encroachment and illegal harvesting practices to satisfy their day-to-day needs (GoK, 2009; Anaya, 2009). Consequently, in spite of cutting ban proclaimed in 1982, bamboo forest cover has declined through its clearing to provide areas for cultivation and settlement (Ongugo *et al*., 2000). Forests disturbance affects temporary or permanently forest structure and composition (Grainger, 1993), and has serious environmental, socio-econimic problem, particularly in developing countries (FAO, 2009).

Bamboo forests have long been regarded as a national treasure in Kenya (GoK, 2008). However, bamboo has not been planted in local farms in the excised areas, despite its exploitation for many years. In addition, Community Forest Association (CFA) has been launched in excised areas, but it lacked economic support to educate the local community about use and proper harvesting of bamboo resource. This study provides valuable information on the temporal distribution, current structure and composition of the forests. The intention was to come up with appropriate mitigation measures to reserve the current negative changes to the bamboo forests in Mariashoni and Njoro areas which are part of Mau Forest Complex, a major water tower in Kenya (GoK, 2008).

1.2 Problem statement

Despite the conservation measures in place in Mariashoni and Njoro forests, the loss of bamboo vegetation cover and reduction of trees in the forests are ongoing activities; mainly caused by increasing demand for agricultural lands and forest resources by people living in areas surrounding indigenous bamboo forests. The forests are characterized by various human activities such as cutting of bamboo, grazing and charcoal burning among others. These activities have gradually increased as the population increased around the forests. This has widened the gap between forest resource demand and supply. Consequently, the situation has affected the distribution and abundance of bamboo and other tree species in the forests. This situation puts the country at risk of losing natural habitats and ecosystem services. Impacts of this forest degradation would greatly affect the poor people living near the forests because they have few livelihood options to fall back to.

Previous research efforts have been limited to the use of bamboo as well as their ecological role and threats. These research efforts have never focused on the bamboo forests in the study area. The lack of previous data on the forest characteristics has also made it difficult to assess the number of declining tree species harboured by the forests. Hence, current data on structure and composition of the forests, use and threats to bamboo forest resources needs to be known for better management and conservation purposes.

1.3 Justification of the study

Bamboo forests in Mariashoni and Njoro forests are indigenous forests that are currently threatened by numerous human-induced activities that are progressively altering forest ecosystems. These forests are of great importance as they play important ecological, socio-economic and cultural role to the local communities living around them. Hence, the study in the forests is valuable to help curb its increasing threats and ensure wise use and sustainable management. Therefore, better scientific knowledge would be valuable to Kenya Forest Authority, KEFRI, environmentalists, development partners and public who are concerned with forests protection, conservation and management.

1.4 Objectives

The main objective of this study was to determine the temporal distribution, current structure and composition, use and threats to bamboo forest resources in Mariashoni and Njoro forests. In order to achieve this main objective, the study narrowed down to the following specific objectives:

1. To investigate the temporal changes in bamboo distribution in Mariashoni and Njoro forests from 2000 to 2011.
2. To determine variation between the current structure and composition in different bamboo forests in Mariashoni and Njoro forests.
3. To assess the perception of stakeholders on the levels of use of bamboo and threats to bamboo forest resources in Mariashoni and Njoro forests.

1.5 Null Hypothesis

1. There have not been any changes in the bamboo distribution in Mariashoni and Njoro forests from 2000 to 2011.
2. The different bamboo forests in Mariashoni and Njoro are not similar in structure and composition.
3. Bamboo and other forest resources in Mariashoni and Njoro forests are not used or threatened in any way.

1.6 Scope and limitation of the study

The study was limited to indigenous bamboo forests in Mariashoni and Njoro forests, East-Mau Forest Complex, Nakuru county, Kenya. The Mariashoni and Njoro forests cover approximately 22 square kilometers. The study focused on investigating temporal changes in bamboo distribution between 2000 and 2011. This period of study intended to coincide with excision of Eastern Mau in 2001, but the available satellite images of the study area were for 2000 and 2011. The study also intended to determined the current structure and composition, use and associated threats to the forests. The field survey took three months, from February to April 2012.

CHAPTER TWO

LITERATURE REVIEUW

2.1 Distribution and ecology of bamboo forests of Kenya

Bamboo plant is a member of grass family belonging to the sub-family of *Bambusoideae* in the family of *Poaceae Gramineae* (Kigomo, 2005). Bamboo grow naturally on mountains and highlands of Eastern African countries and in the medium lowlands of other African countries. In Kenya, *Yushania alpina* thrives in mountains and highland ranges including Mau escarpment (KEFRI, 2008). This species prevails in areas where annual rainfall is between 1200-1800 mm and flourishes particularly well on deep rich volcanic soils (Were, 1988). It is sustained by its rhizome system on which new culms shoot mainly in rainy season (Koshy and Harikumar, 2001).

Sporadic flowering of the species may occur every 30 to 50 years. Growing culms are soft and erect, green-yellow or brown and downy when young and become hard by deposition of silica in the walls and nodes (Scott, 1994; Koshy and Harikumar, 2001). Height and density of *Yushania* culms are also affected by topographic and elevation conditions. Tall culms are found on steep slopes while short culms occur on relatively flat areas. Uphill culms generally have a higher density when compared to valley bamboo. The light weight of bamboo culm and its absorptivity of water are the consequence of existence of free space and open porosity within bamboo material (Fokwa *et al.*, 2012). Culms are also hollow and can be split easily for weaving. These physical properties make *Yushania* an exceptional economic resource for a wide range of uses. In addition, its qualities of strength, light weight and flexibility make it a viable alternative to tropical timbers that supply the furniture and building materials industries. On the other hand, the extensive shallow rhizome-root system of *Yushania* and accumulation of leaf mulch are efficient agent in preventing soil erosion and conserving moisture (Zhou *et al.*, 2005).

2.2 Bamboo resource in Kenya

Bamboo resource is important for its socio-economic and cultural values in Kenya (Anaya, 2009). Approximately 48 local uses of bamboo were recorded (Ongugo *et al.*, 2000). Some of them are fencing, construction of roofs and walls, firewood as well as furniture making (Kigomo, 2000) such as baskets, chairs, beds and for making arrows and bows for hunting. In addition, bamboo plants are used for making temporal shelters where boys are kept and treated during circumcision ceremony. These various uses of bamboo provide job opportunities and entrepreneurship to the poor rural population living adjacent bamboo forests (Ongugo *et al.*, 2000).

2.3 Influence of human activities on bamboo forest dynamics

Understanding the influence of human induced factors on the bamboo forest dynamics becomes very crucial. Human activities on bamboo forests may be direct or indirect. Direct influences such as logging and clear cutting of bamboo cover affect the dominance of species and depress their recovery. Their low regeneration reduces resistance to extrenal threats like weather events (Zhou *et al.*, 2005) that can ruin natural ecosystem (INBAR, 2006).

Indirect influences include grazing by cattle which not only depresses the sprouting of new bamboo culms (Prasad, 1985), but also exposes the soil to erosion, compacts the topsoil and diminishes the capacity of the soil to hold water through trampling. Contrary, grazing may not necessarily be harmful as trampling by cattle can promote the growth of certain species that require open ground for establishment (Knapp *et al.*, 1999) such as exotic species. Cattle create opportunity for their dispersal and recruitment.

However, bamboo spreads where there is moderate disturbance by logging and form a dense closed canopy overhead (Koshy and Harikumar, 2001). Closed canopy bamboo may suppress the regeneration of other woody species (Clark, 1997). This explains how woody bamboo becomes dominant in forest ecosystems and occurs in almost homogeneous stands in some places (Bystriakova and Kapos, 2006). In this way, bamboo plays an important role in determining bamboo forest structure and dynamics. Sustainable removal of bamboo may ensure the vigor of the plant and allow for generation of new shoots (KEFRI, 2007).

Bamboo stands with dense dry undergrowth are also vulnerable to fires during the dry season (Liese, 1985). Effects of natural or human-made fires may increase if the forest community has been subjected to other disturbances such as drought and overgrazing (Brown *et al.*, 2001). However, fire helps bamboo of rain forests to recruit by reducing competition of fire-resistant species (Saha and Howe, 2001).

2.4 Forest structure

Forest structure can be defined as distribution of species and tree sizes on a forest area (Richards, 1996). Distribution of species comprises numerous components among other things diameter, height, canopy cover, density and volume (Spies, 1998) many of which are fundamental to the functioning and diversity of ecosytems. Understanding the forest structure is essential in order to manage forest resources in a sustainable basis. Knowledge of patterns of variation in forest structure over time and space can serve as the basis of forest management strategies that seek to sustain a broad array of forest goods and services (McComb *et al.*, 1993). Forest structure is also a product of forest dynamics and biophysical processes and as a pattern for biodiversity and ecosystem function (Spies, 1988). Consequently, understanding forest structure can help to unlock an understanding of the history, function, and future of a forest ecosystem. The forest structure is determined as a function of stocking or basal area of trees (Abed and Stephens, 2003).

2.4.1 Stocking, diameter at breast height and basal area

Stocking (stems/ha) reflects the spatial distribution of individuals within a forest (Brower *et al.*, 1990). Knowledge of the contribution of each individuals tree species at different tree sizes (trees, saplings and seedlings) to the overall stocking is important to manage future stands (Martin, 1996).

Diameter at breast height (dbh) indicates tree age. Small dbh trees equal to young trees (saplings and seedlings) while larger dbh trees indicate older trees. Diameter class structure assess the maturity of a stand. Knowledge on dbh helps to determine what tree sizes form the majority of the forest. Generally, uneven-aged tropical rain forests have diameter distributions representing all age classes in typical reversed-J shaped curve, especially small tree size. However, compared to an even-aged stand, there are more diameter-classes spatially intermixed throughout the stand (Smith, 1986). The general model can however be modified by factors (Denslow, 1995) such as tree cutting, competition for resources, differences in topography or soils, irregular or seasonal climatic events. Hence, diameter distributions are commonly used to assess the distribution effect within forests and to detect trends in regeneration patterns (Poorter *et al.*, 1996).

Basal area (m^2/ha) is another way of explaining the stocking or density of trees in a stand. Basal area is a good measure of the maximum occupancy of the site and thus of stand density (Brower *et al.*, 1990). It can vary with species for a given site and with site for a give species. For certain species like bamboo, the basal area may be reasonably constant over a considerable period of the development of the stand towards maturity.

2.4.2 Forest canopy

Forest canopy, also known as crown cover, has been defined as the proportion of the forest floor covered by the vertical projection of tree crowns (Jennings *et al.*, 1999). It affects pattern of light, precipitation and soil nutrients on the forest floor. It therefore influences the distribution and dominance of undestory plants. It can be therefore possible to study the distribution of shade-intolerant species like bamboo in forest gaps. Forest canopy plays major roles in controling microclimate and determining habitat (Spies, 1998). Estimation of forest canopy has been shown to be a multipurpose ecological indicator. Knowledge on forest canopy provides information on forest productivity, natural and anthropogenic disturbances below canopy processes, stand density and overall system change (Smith *et al.*, 2004).

2.4.3 Gap formation and gap dynamics

Knowledge on gap formation and its significance in ecosystem dynamics is essential in understanding of changes that occur after gap formation (Denslow, 1987). Forest gap is defined as openings in the canopy being created by death of individual canopy trees (Coates and Burton, 1997). Mortality of trees can be caused by natural factors such as senescence, wind, landslides and diseases among others, or human-made factors (Oliver and Larson, 1990). The gaps created thus, provide microclimate conditions such as light, temperature and competition between various competitors (Denslow, 1987) favoring establishment of shade-intolerant species (Yamamoto, 2000).

Gap dynamic theory predicts that shade-intolerant species, which cannot establish and grow in closed conditions, will be maintained in the equilibrium community by regenerating in gaps formed by minor disturbances (Yamamoto, 2000). Gap dynamic is the successional pattern and processes involved in replacing gaps (Coates and Burton, 1997). This indicates that a high recruitment of seedlings or saplings shows their population dynamics. In contrast, if seedling or sapling limitations dominate, their recruitment, abundance and distribution would be that of best competitors. Factors that favor recruitment of seedlings are seed source (mother trees), seeds dispersal, micro-climatic, light at the ground floor and edaphic factors (Scholl and Taylor, 2006). Being the more vulnerable to various abiotic and biotic agents, small tree size are commonly subjected to highest mortality rates of any stage in the plant life cycle.

2.4.4 Dynamic equilibrium model

The dynamic equilibrium model was introduced by Huston (1994). The concept predicts that an intermediate frequency of disturbance prevents competitive exclusion and thereby maintains species diversity. If a forest is in a dynamic equilibrium state, the abundance of each species remains approximately constant despite disturbances. When disturbance level and population growth are in "optimal" balance and hence, the highest diversity is obtained (Duarte *et al.*, 2006). However, if a forest is in a non-equilibrium state, many species may face the risk of extermination. Such a loss may be detrimental if the forest area is not supplied by external seed sources. When disturbance level is greater (or more frequent), populations of certain slow-growing (or shade tolerant) species cannot recover, while fast-growing (pioneer or shade-intolerant) species prevail (Yamamoto, 2000). Knowledge of dynamic equilibrium of small tree size such as saplings is important because they are good indicators of dynamic trends of forest communities, since they indicate how the forest is going to be in the next near-future (Duarte *et al.*, 2006). It can be therefore possible to predict their preservation measures in a non-equilibrium state forest.

2.5 Forest composition

Understanding the composition of the forest provides insights to issues that may arise as the forest develops to maintain its structure and conserve plant diversity (Bhat *et al.*, 2000). It also helps to understand how the forest grows, how it can change over time, and how trees may respond to disturbances either natural or human-induced. Many natural forests have been selected for conservation using species composition as the criteria for their selection. Plant species variation from site to site may be due to soil type, moisture content of soil, elevation, nature and level of disturbance. The most common measure of species composition is species diversity and abundance (Hughes, 1986; Isango, 2007).

Species diversity attracts particular attention in ecological study because of its significance in determining present and future species composition conditions. Diversity is a function of the number of species present (richness) and the eveness with which the individuals are distributed among species (Hurlbert, 1971). Understanding species diversity gives insights on stability of forest communities (Walker, 1988). This refers to its ability to recover to an equilibrium state after disturbance.

Diversity-stability hypothesis asserts that species vary in their traits, and that in a highly diverse system there will be some species that can compensate for the loss of others after disturbance (Thompson, 2009). Forest stability may therefore increase with diversity or number of components (Sagar *et al.*, 2003). The less diverse the forest is, the less individuals resist and survive to local disturbances. Diversity can be therefore used to assess vulnerability or resiliency of a forest to natural or human disturbance (Thompson *et al.*, 2009).

2.6 Remote Sensing (RS) and Geograpgic Information Sysytem (GIS) in bamboo vegetation cover change detection

In a disturbed bamboo forest, comprehensive information on changes in distribution of bamboo with time is required for designing effective conservation strategies. It is nearly impossible to acquire such information purely on the basis of field work survey. Remote sensing has become popular in natural resources assessment and monitoring including non-wood forest vegetation such as bamboo (Lobovikov *et al.*, 2007). The system is important because informations are collected at low cost and little time is consumed (Nagendra, 2001). Higher spatial and spectral images (such as LANDSAT) can offer an opportunity to observe ecosystem dynamics and development. For bamboo in a forest, its assessment requires sufficient ground-truth information, with the exact Global Position System coordinates.

Remote sensing system provides a systematic view of earth cover at regular time intervals, acquires images from remote sensors (such as satellites) and sends them to ground stations. Images are processed and analyzed at ground stations to provide necessary information and assessment. Detection of changes involves the comparison of satellite images taken in different times. According to Singh (1989), change detection is the process of identifying differences in the state of an object or phenomenon by observing it in different times.

The best analytic tool for quantifying such changes is GIS (McCloy, 1995; Gao, 2002). Integrating RS and GIS provides the most accurate means to store and analyze data, produce maps and statistics. This helps to estimate ecosystem changes over two or more time periods caused by environmental conditions and human actions (Miller *et al*., 1998). Understanding the processes and causes of vegetation cover change helps resource managers and policy-makers to decide where action should be taken and what kind of intervention is needed.

2.7 Mau Forest Complex

The Mau Forest Complex is one of remaining near contagious block of montane indigenous forest in East-africa (Akotsi and Gachanja, 2004). The forest is located in Rift Valley, covers an area of over 400,000 ha and serves as a catchment area for major rivers and lakes supporting the lives of more than five million people (Sang, 2001). Mau forest also provides vital ecological services in terms of reducing soil erosion and siltation among others and hosts a high diversity of fauna and flora (Nabutola, 2010). In addition, the forest provides goods such as timber to forestry sector, as well as firewood and medicinal plants to forest adjacent communities (Akotsi *et al.*, 2004).

2.8. Indigenous Ogiek community

Indigenous Ogiek community (Dorobo) inhabited Mau Forest Complex and were scattered throughout the forest (Sang, 2001; Anaya, 2009). Ogieks were honey and hunter/gatherers group living in harmony with the forest. They depended on the forest for food (fruits, roots), medicine, shelter and preservation of their culture. However, they have suffered dispossession of their ancestral lands because of forest ban proclaimed in 1982 (Ongugo *et al*., 2000). Since trouble started with this forceful eviction, the existence of the Mau Forest Complex has become increasingly threatened (Obare and Wangwe, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

3.1.1 Geographical position and size

Bamboo forests in Mariashoni and Njoro forests are located between latitudes $0^o24'S$ to $0^o28'S$ and longitudes $35^o55'E$ to $35^o49'E$ (Fig. 1.2). The forests cover an approximate area of 2162ha. Mariashoni and Njoro forests are situated in Nakuru county, Rift Valley province (Fig. 1.1), approximately 15kms towards the south of Elburgon town and 10kms towards the south-west of Njoro town. The study area is bordered by the degazetted zones of Mariashoni and Nessuit to the north, Njoro to the East, forest plantation of Mariashoni and Kiptunga to the west and south-west, Nessuit in North; indigenous forests of Chebuin and Logoman to the Southeast (Fig. 1.2).

3.1.3 Topography and rainfall

The altitude of Mariashoni and Njoro forests ranges from 2550m to 2975m above sea level (a.s.l.). The topography is predominatly sloping land with slopes ranging from 2% in valleys to more than 50% in the foothills. Geologically, the study area is characterized by volcanic soils that are highly porous and susceptible to erosion (KWS, 2004). The mean annual rainfall is 1059.32mm, bimodal, with long rains between March to June, short rains between September to November and relative dry period in December. The forests have many small rivers namely Rongai river which flows into Lake Baringo, Njoro and Nderit rivers which flow into Lake Nakuru (Fig. 1.1). There are other many springs and streams from Mariashoni and Njoro forests which provide source of water for livestock and local community living adjacent to the forests.

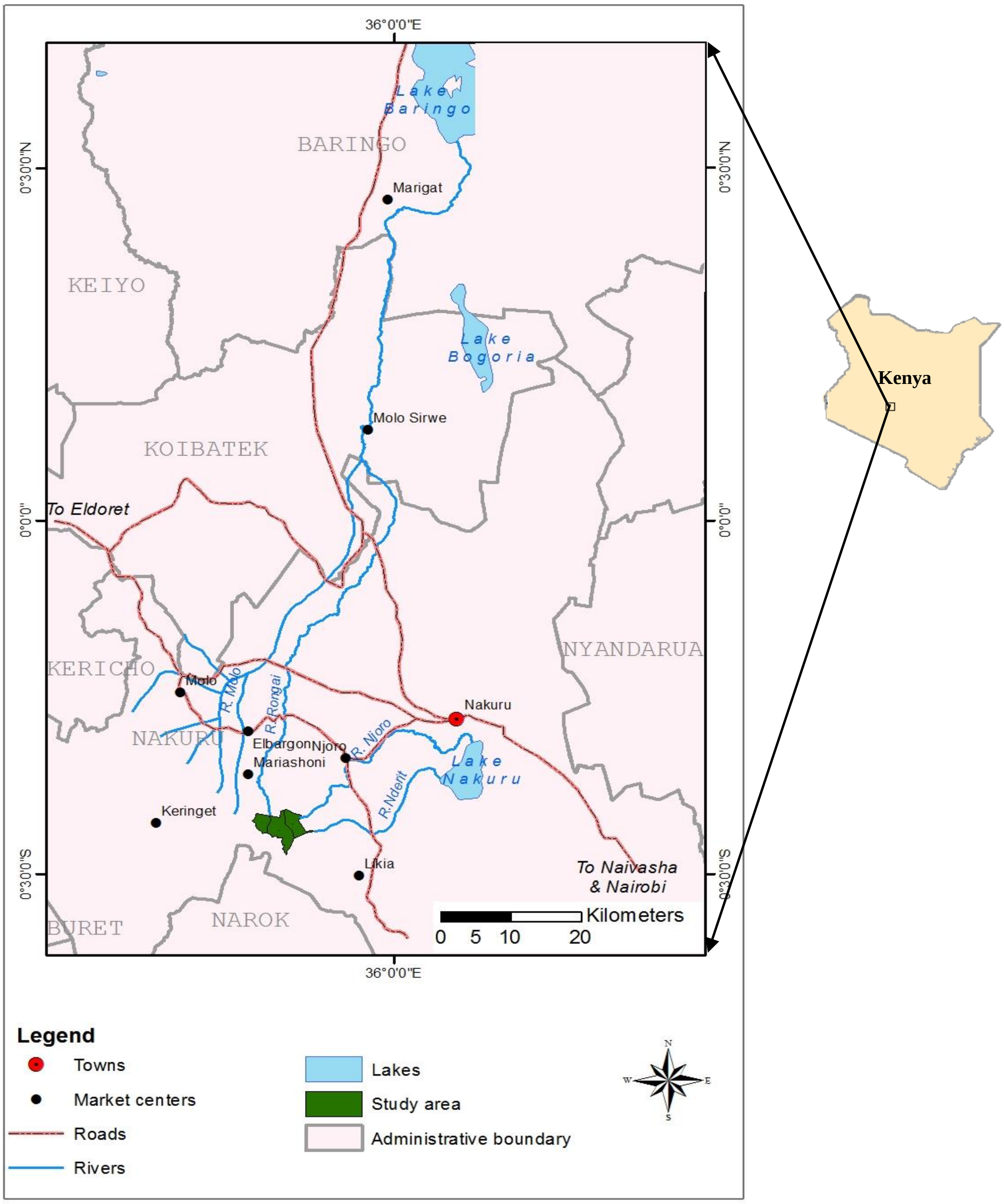


Figure 1.1: Location of the study area in Kenya. (Source: Adapted from Kenya Soil Survey)

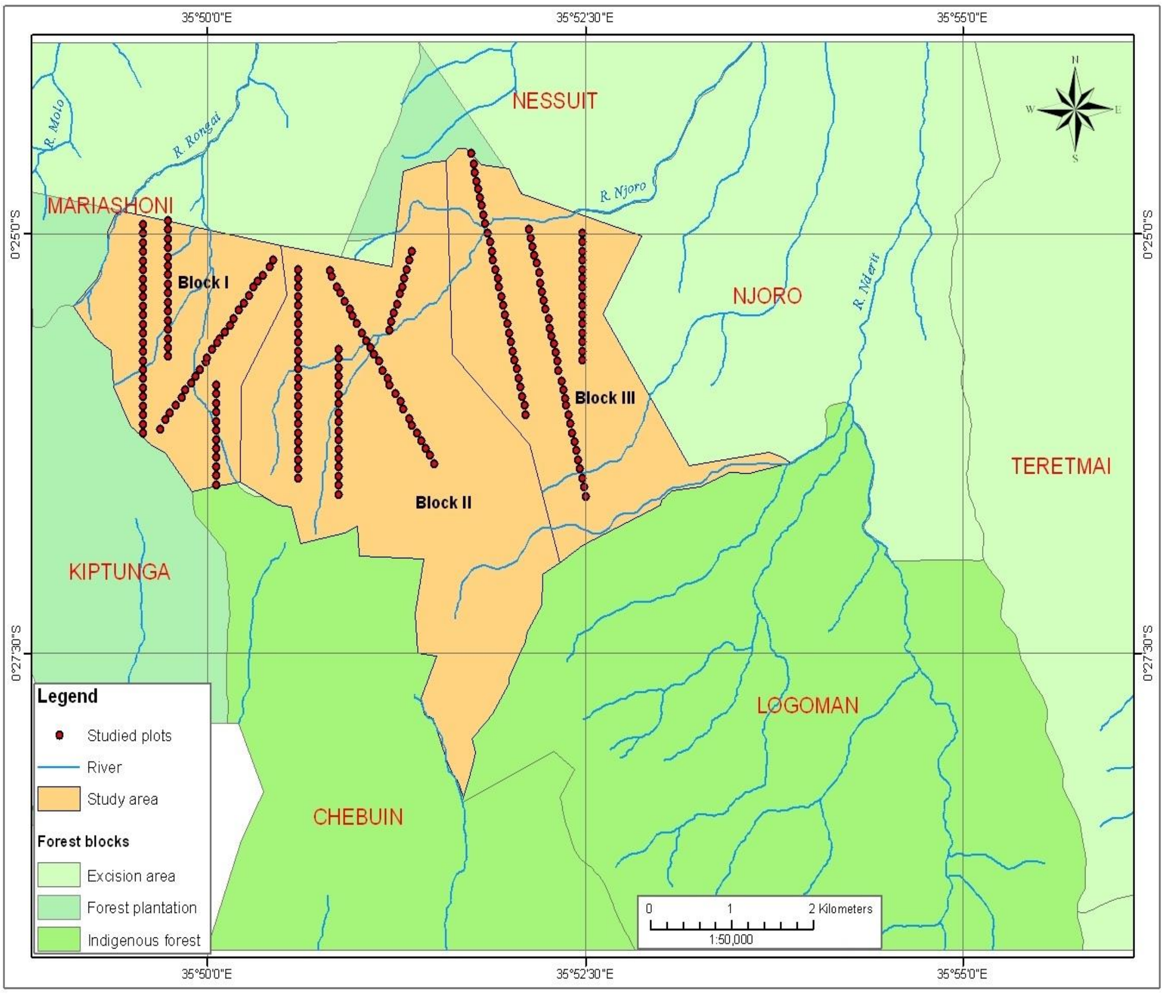


Figure 1.2: Details of the study area in Mariashoni and Njoro forests. (Source: Adapted from Kenya Soil Survey)

3.1.3 Ecological and socio-economic role of the forests in the study area

The role of bamboo forests in Mariashoni and Njoro forests lies in protection of water catchment area which feed many rivers and streams. These rivers supply water to rural and urban centres and support livelihoods, economic and tourism development (GoK, 2008). The forests provide timber, firewood, medicine, grazing land as well as ceremonial sites for the local community living around them (Kigomo, 2008). The bamboo forests are also a sanctuary for many birds as well as small and large animals. Some of these animals depend mostly on bamboo shoots and fresh tops during the dry seasons. These include Warthog (*Phacochoerus africana*), blue monkeys (*Cercopithecus allbogularis*) and bushbuck antelope (*Tragelaphus scriptus*).

3.2 Preliminary survey

Prior to data collection, a reconnaissance visit was conducted in February 2012 in bamboo forests of Mariashoni and Njoro forests. The intention of this reconnaissance was to understand the study area and get familiarized with the local community living around it. Two research assistants were selected from indigenous Ogiek community who knew the study area well. They also had knowledge in differentiating tree species and naming them in their mother tongue. Research assistants were trained on the task to be carried out during the exercise. The reconnaissance visit was also important to locate and avoid specific sites that were habitats for dangerous wild animals like buffaloes (*Syncerus caffer*) and this could pose danger to the study team.

3.3 Sampling methods

Stratified random sampling was used and the study area was divided into three blocks (Fig. 1.2) based on existence of bamboo thickets, elevation ranges and perceived levels of forests disturbance. Block I with highest elevation of between 2850-2975m a.s.l. was the less disturbed. Block II with medium elevation of between 2700-2850m a.s.l. and block III with the lowest elevation of between 2550-2700m a.s.l. were the more disturbed blocks.

In each block, nine to twelve line transects were laid down in which three to four line transects varying between 1 to 3kms were randomly selected. The length was determined using a tape measure and rope, while the direction by a compass. Starting and terminal points were determined by use of forest maps of Eastern Mau Forest (Scale: 1:10,000) from KFS, sheets number 13, 14, 18 and 19 showing the area covered by Mariashoni and Njoro forests. Line transects started at the edge of the forests, facing the North-South direction (Fig. 1.2). Ending points were predetermined, not exceeding the boundary of the study forests and not overlapping with the next block.

Along each line transect, circular plots were systematically located at intervals of 100m for data collection. Circumference was established by measuring the radius using a rope tied at the center point of the plot. Circular plot was convenient in bamboo forest survey due to easy plot layout, single central marker and minimization of the number of edge decisions.

Table 3.1: Approximate number of blocks, line-transects, plots and their size

Block (*approximate size: 600ha*)	Block I, *the highest elevation* (2850m-2975m)	Block II, *the medium elevation* (2700m-2850m)	Block III, *the lowest elevation* (2550m-2700m)	Total
Number of line transects (*1km – 3 km length*)	4	4	3	11
Number of circular plots (*6m radius*)	76	76	76	228

3.4 Data collection techniques

3.2.1 Data to be collected

Three types of data were required for this study. Satellites images data on distribution of bamboo, field survey data on forest characteristics and stakeholder's survey data on use and threats to the bamboo forest resources.

Concerning satellites images, required data was the extent (in ha) of bamboo stands of the study area in 2000 and 2011 to investigate changes of its distribution over a period of twelve years. Data on forest characteristics included the number of different tree species, their frequency, dbh and height in a sample plot to determine the structure (stocking and basal area) and composition (abundance and diversity) of the forests. Data on stakeholders' survey (forest officers and households) included their socio-economic characteristics. These are gender, age, education, occupation, number of children and their level of education. Household heads were also asked to provide information about the number of stems of bamboo and other tree species consumed per month and for what purpose, factors driving them to overexploit forest resources, existence of CFA, rules and regulations governing the forest resource exploitation, and major threats to the forests. Stakeholders were also asked to give their views on measures for effective forests management and conservation.

3.2.2 Data collection techniques

To address the first objective, Landsat Thematic Mapper (TM) of 17th January 2011 and Landsat Enhanced Thematic Mapper (ETM) of 17th January 2000 having path and row of 169 and 60, spatial resolution of 30m, were used for the study. They were acquired from the USGS Global Visualization Viewer (http://glovis.usgs.gov) through the KFS. An area of 22km^2 was delineated on landsat scenes covering the study area and a classification system was decided for bamboo thickets. Its intention was to categorize the forests into different bamboo stand types and determine thier respective extent (in ha). Two images were then compared to assess changes in bamboo stands distribution over the period between 2000 and 2011.

To address the second objective, tree species identification and measurement were conducted within concentric circles in each sample plot (Figure 3.1). Radius were established depending on the abundance and diameter at breast height (dbh) of tree species to be measured. Trees (dbh≥5cm) were recorded and measured within 6m radius, saplings (2cm<dbh<5cm) within 3m radius and seedlings (height ≤ 2cm) within 1.5m radius.

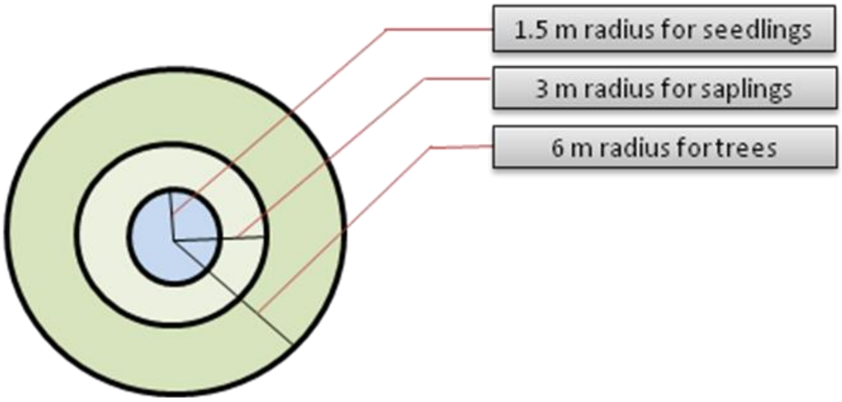


Figure 3.1: Shape of circular sample plots of 1.5m, 3m and 6m radius. (Source: Author)

Identified tree species were named in their local name by research assistants. Using Maundu and Tengnäs (2005), vernacular names were translated into their respective botanic names. The survey was only limited to bamboo and vascular plants, not shrubs and herbs. Dbh of trees was measured in centimeter (cm) at 1.3m above the ground on the uphill side of a tree (Spies, 1998) using a diameter tape. Tree height was estimated using Suunto clinometer (Abed and Stephens, 2003) and the Mean Dominant Height was performed (Leech, 2007) for bamboo. Forest canopy was estimated visually and categorized based on the percentage of the sky obstructed by tree canopies: open canopy (10-39%), moderately closed canopy (40-69%) and closed canopy (70-100%) (Hoobyar, 2004).

Sampling was done daily for three months from February to April, 2012. Three quarter of the line transect was completed daily. A total of 76 plots were assessed for each block, 228 plots in the entire study area. In blocks, plots were categorized in bamboo stand types to assess the effect of bamboo thickness on forest structure and composition.

To address the third objective, structured interview was conducted and two types of questionnaires were administered to forest officers and household heads (Appendix I). The forest officers were given questionnaires which they filled and returned back. For household heads, questionnaires were immediately filled by the researcher and the research assistant during the investigation. This was done to reduce incidences of loss of questionnaires or their being returned unfilled.

The target population consisted of households living within the excised zone at a distance of 2kms from the forests edge. These are people perceived to extract and use bamboo. Their number was determined through assistance of local leaders. The entire population was sampled (114 household heads) to achieve a desired level of precision since it was less than 200 (Israel, 2009). All forest officers (17) in the excised areas were also interviewed.

Documented data was obtained from literature on previous work on ecological and socio-economic roles played by bamboo forests and challenges they faced on global and regional level. These documents were acquired from Kenya Forestry Research Institute (KEFRI) and Londiani Forest College.

3.4 Data analysis

3.4.1 Determining the average annual rate of change of bamboo stands

The average annual rate of change (%) was calculated to assess changes in bamboo stands distribution between 2000 and 2011. Computation of the rate of change was determined following Were *et al.* (2011):

$$\Delta = \frac{[(A2 - A1) \div A1)] \times 100}{(T2 - T1)}$$

Where:

Δ: Average annual rate of change (%)

A1: Amount of ha covered by bamboo stand in time 1 (T1)

A2: Amount of ha covered by bamboo stand in time 2 (T2)

A2–A1: Magnitude (positive or negative depending on nature of changes).

T2 - T1: Number of years being observed (for this case, it is 12 years).

3.4.2 Measuring the structure and composition of bamboo forests

3.4.3 Determination of stocking

Stocking was determined to assess the number of stems per hectare of trees, saplings, and seedlings in blocks. Stocking was calculated based on Young and Giese (1990):

$$\text{Stocking (stems/ha)} = \frac{\sum n_i \text{ in plot}}{\text{Plot area in hectare}}$$

Where: n_i= number of individual tree species in a plot

Plot area= πr^2 and π(*pi)*= approximately 3.14.

r (radius) = 6m for trees, 3m for saplings and 1.5m for seedlings.

Stocking by diameter size distribution was determined for the dominant species (*Yushania alpina*). Six dbh classes were categorized. These were 5cm, 6cm, 7cm, 8cm, 9cm and 10cm.

3.4.4 Determination of basal area

Basal area estimated the maximum area occupied by trees in blocks. Basal area (m^2/ha) formula was adapted from the simple formula of the area of a circle (area= πr^2) (Elledge and Becky, 2010):

$$\text{BA } (m^2/ha) = \frac{\sum \pi \left(\frac{dbh}{200}\right)^2 \text{ in the plot}}{\text{Area of the plot in hectare}}$$

where: dbh= diameter at breast height

π (*pi*) = approximately 3.14.

3.4.5 Assessment of species diversity and similarity

Species diversity was used to assess the variability of tree species in blocks. Simpson's diversity index (*D*) (Ricklefs, 2001) was used. *D* value ranged from 1 (no heterogeneity and no diversity) to a maximum equal to the species richness community. *D* formula is:

$$D = \frac{1}{\sum_{i=1}^{s} (pi)^2}$$

Where: p_i = proportion of individuals of species 'i' in the community

s = number of species in the community

$\sum$= means sum of all the $(pi)^2$, one for each species in the community.

Species similarity was used to investigate the commonness of tree species in blocks. Peterson's Homogeneity Index (*I*) was calculated (Sadeghi and Husseini, 2009).

The closer the values of *I* are to 1, the more homogeneous the pair of blocks; the close the values are to 0, the less homogeneous the blocks. *I* formula is:

$I = 1 - \frac{1}{2}\sum\left|ai - bi\right|$ Where: a_i= proportion of species *i* in sample block A

b_i= proportion of species *i* in sample block B.

3.4.6 Determination of species abundance

Species abundance was used to assess the most numerous or dominant species in the blocks. Species abundance was evaluated by the Importance Value (I.V.) that considers the summation of the relative density, relative dominance, and relative frequency (Colinvaux, 1986; Curtis and Cottam ,1962).

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Total number of occurrence of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100$$

I.V.= Relative frequency+Relative density+Relative dominance.

Analysis was done using SPSS software, 16.0 version. Significant difference was considered to occur at significance level of $p \leq 0.05$: H_o was rejected or the assumption verifying one-way ANOVA was not met. Logarithmic transformation was performed (Osborne, 2002; Roberts, 2008) to convert original data which were not normally distributed into a new scale that normalizes data. Log(X+C) was used (X: original data, C=1). The constant number was added so that the lowest value in the dataset became 1 to avoid small data values such as 0 that cannot be transformed using logarithms. Log transformation was convenient because the data set included small values and standard deviation of sample data was proportional to the mean. Transformed data were then used in parametric techniques (e.g. ANOVA) without risk of error (Osborne, 2002). Parametric and non-parametric tests were used to analyse the data:

1. Shapiro-Wilks and Levene's Tests (parametric tests) were used to test normality of sample data and existence of homogeneity of variance.
2. Kruskal-Wallis Test (non-parametric test) was used to test normality of samples after data transformation.
3. ANOVA one-way and T-test independant sample (parametric tests) (Fowler *et al.*, 2002) were used to test variation of species diversity and composition in studied blocks and bamboo stands respectively.
4. The mean ($\overline{x}$) and standard deviation (*SD*) (parametric tests) were used to test variation in stocking and basal area. The bigger the *SD* the less close are the collected numbers.
5. Chi-square (χ^2) test for Goodness of Fit (a non-parametric test) was performed to compare responses from stakeholders. χ^2 determines whether observed frequency distribution is significantly different from expected frequency distribution.
6. Pearson's correlation (r) (a parametric test) was used to test the correlation between household heads characteristics and use of bamboo. Pearson's correlation value varies between -1 and 1 ($-1 \leq r \geq 1$):

   $r_s>0$: positive correlation: the variable (*y*) increases as (*x*) increases.

   $r_s<0$: negative correlation: *y* decreases as *x* increases.

   $r_s=0$: no linear relationship between *x* and *y* (variables are uncorrelated).

CHAPTER FOUR

RESULTS

4.1 Bamboo stands

Two classes of bamboo stands were categorized: Closed canopy bamboo and Open canopy bamboo. Isolated agricultural plots represented the encroached areas of the forests.

4.1.1 Location of identified bamboo stands

Results from the 2000 image (Fig. 4.1) show that closed canopy bamboo (FR-1) was mainly concentrated in the eastern part of the study area, while open canopy bamboo (FR-2) occupied the remaining parts of the forests.

However, results from the 2011 image (Fig. 4.2) show that closed canopy bamboo (FR-1) occurred in areas which were predominatly open canopy bamboo. In addition, the area which was initially covered by closed canopy bamboo in Eastern part (Fig. 4.1) has also been converted into isolated agricultural plots (AG-1C).

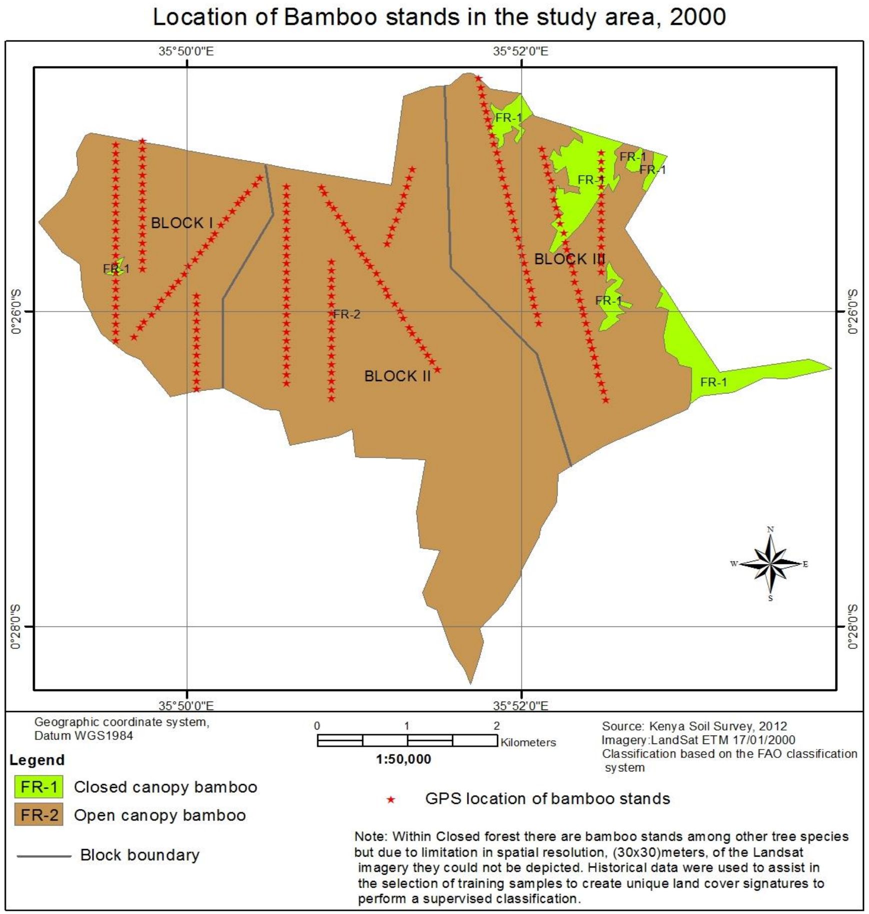


Figure 4.1: Location of bamboo stands of the 2000 ETM image.

(Source: Adapted from Kenya Soil Survey)

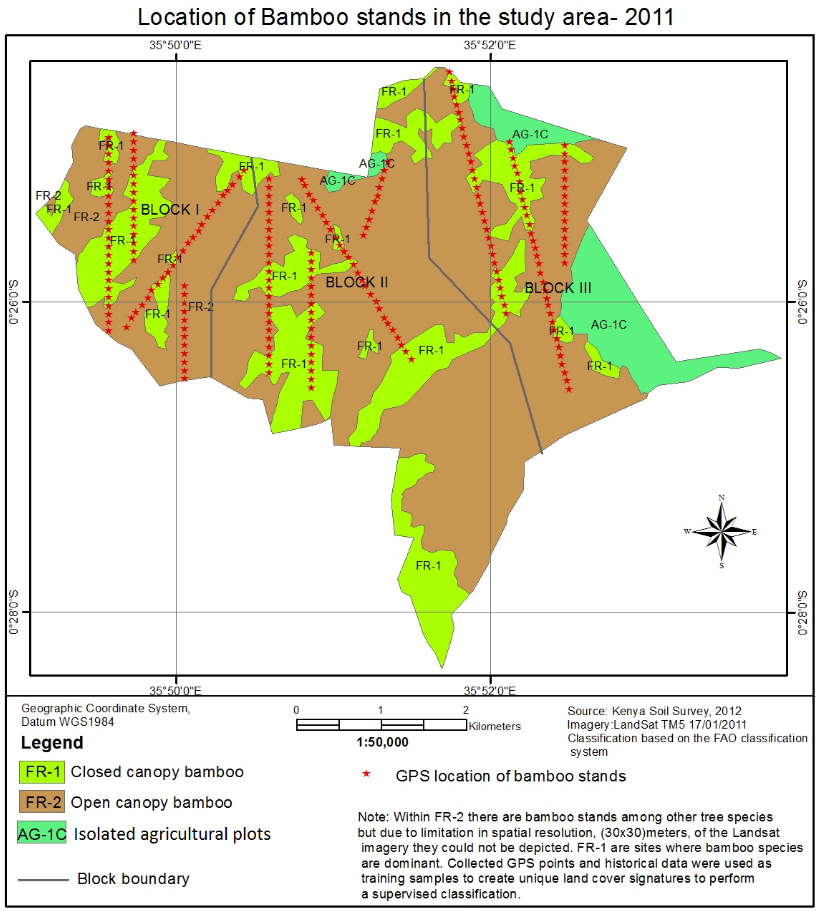


Figure 4.2: Location of bamboo stands of the 2011 TM image.

(Source: Adapted from Kenya Soil Survey)

4.1.2 Extent of bamboo stands of the 2000 ETM and 2011 TM images

Closed canopy bamboo increased by 295ha (11.1% annual rate increase) from 221ha in 2000 to 516ha in 2011. Open canopy bamboo decreased by 460ha (1.9% annual rate decrease) from 1941ha in 2000 to 1481ha in 2011. Isolated agricultural plots covered 165ha in 2011 (Table 4.1).

Table 4.1: Extent (ha) of bamboo stands and isolated agricultural plots

Bamboo Stands	Area in 2000	Area in 2011	Change in coverage from 2000 to 2011	
			Extent (ha)	Rate (%)
FR-1	221 ha (10.2%)	516 ha (23.9%)	+295	+11.1
FR-2	1941 ha (89.8%)	1481 ha (68.5%)	−460	−1.9
AG-1C	−	165 ha (7.6%)	+165	−
Total	2162 ha	2162 ha		

KEY: FR-1: Closed canopy bamboo, FR-2: Open canopy bamboo, AG-1C: Isolated agricultural plots, +: Increased in area, −: Decreased in area.

4.2 Structure and composition

4.2.1 Forest structure

A total of 3933 stems with dbh ≥ 5cm were counted in three blocks (Table 4.2), which were represented by 24 different tree species (Appendix IV) belonging to 18 families and 22 genera (Table 4.3). Open canopy bamboo recorded more stems than closed canopy bamboo (Table 4.2). Block I recorded more stems than block II and III.

Table 4.2: Number of counted stems of trees (dbh ≥ 5cm) in bamboo stands and in blocks

	Bamboo stands		
Blocks	Closed canopy bamboo	Open canopy bamboo	Total
Block I	1014	1571	2585
Block II	93	446	539
Block III	492	317	809
Blocks combined	1599	2334	3933

Considering the stocking in bamboo stands, closed canopy bamboo had a higher stocking of trees and seedlings. Open canopy bamboo had a higher stocking of saplings (Fig. 4.3).

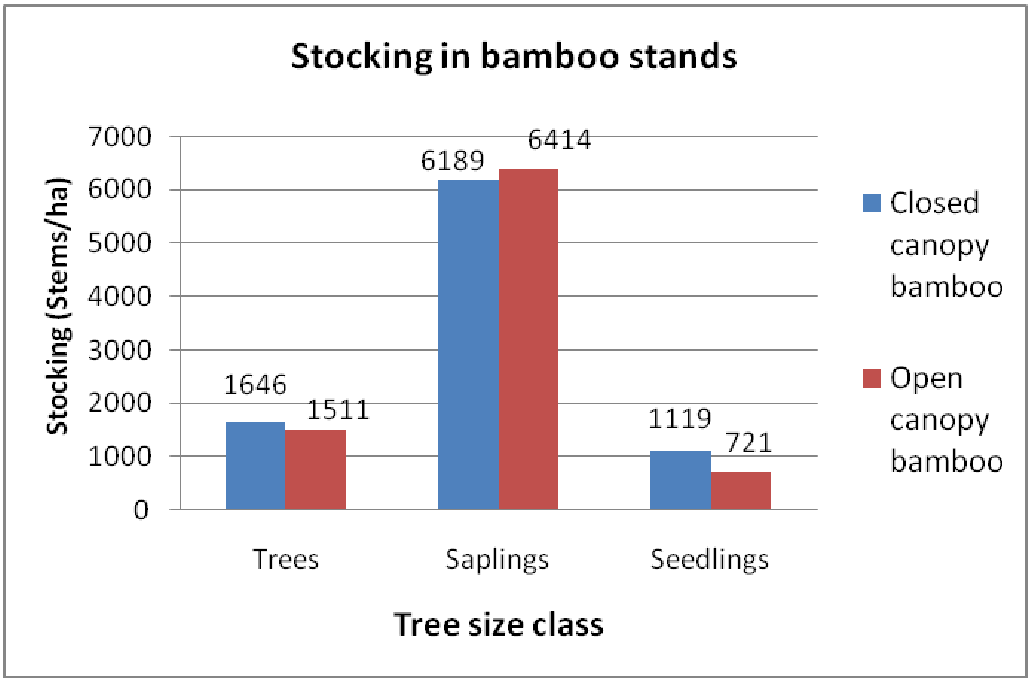


Figure 4.3: Stocking of trees, saplings and seedlings in bamboo stands

Compared to other species, *Yushania alpina* (bamboo species) recorded the highest stocking of trees, saplings and seedlings in both closed canopy and open canopy bamboo (Fig. 4.4). Stocking of old bamboo (trees) and seedlings was higher in closed canopy bamboo, while that of saplings was higher in open canopy bamboo (Fig. 4.4).

In other tree species, closed canopy bamboo had the lowest stocking of trees (Fig. 4.4). However, stocking of saplings and seedlings was higher in the site (Fig. 4.4).

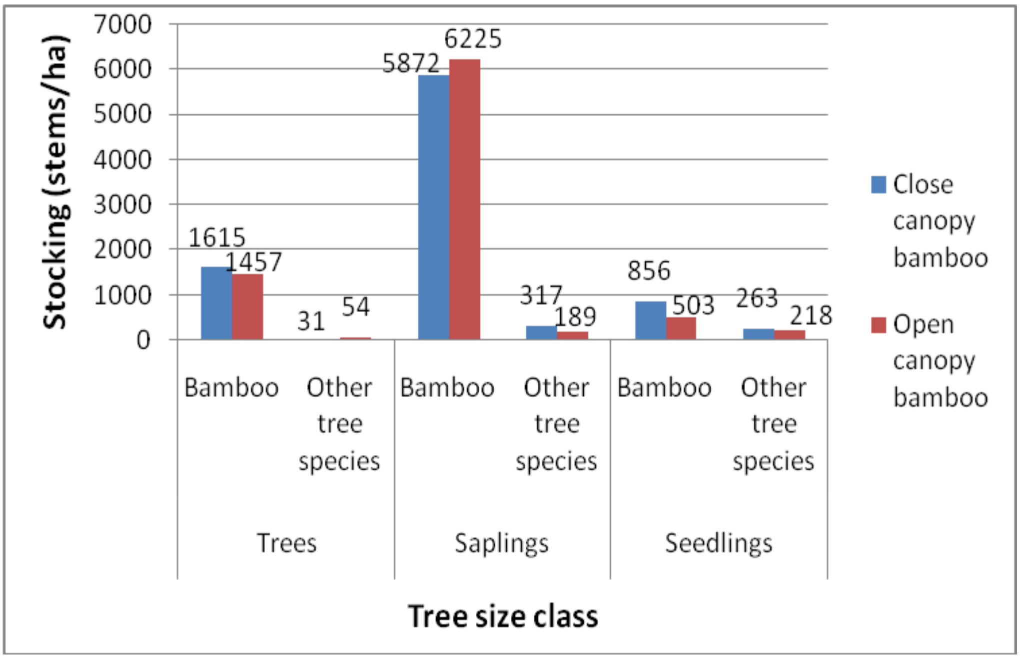


Figure 4.4: Stocking of *Yushania alpina* and other tree species in bamboo stands

Most bamboo stems ranged from 5cm to 6cm dbh classes in closed canopy bamboo (Fig. 4.5) with low mean basal area (11.85±5.9 m^2/ha) (Appendix II.1). On the other hand, most stems ranged from 7cm to 10cm dbh classes in open canopy bamboo (Fig. 4.5) with large mean basal area (13.62±10.2 m^2/ha) (Appendix II.1).

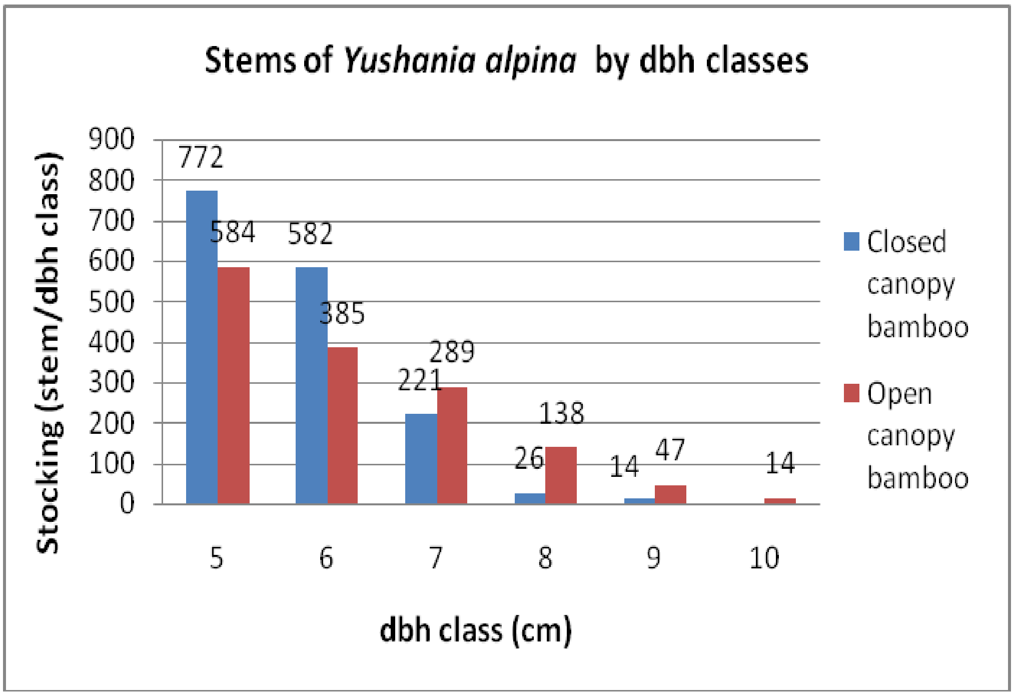


Figure 4.5: Distribution of *Yushania alpina* by dbh classes in bamboo stands

In the blocks, stocking and basal area varied with the level of disturbance. Block I the less disturbed block, had a high stocking of trees and seedlings, while that of saplings was low (Fig. 4.6).

Stocking of old bamboo was higher (2984±643.8 stems/ha) with larger mean basal area (17.01±8.8m^2/ha) (Appendix II.2). Stocking of bamboo seedlings was also higher (946±1082.5 stems/ha) in the site, while that of saplings was lower (3457±1813.2 stems/ha) (Appendix II.2).

In contrast, block II and III the more disturbed blocks, had a low stocking of trees and seedlings, while that of saplings was high. Stocking of old bamboo was lower in block II and block III (664±378.5 stems/ha, 961±397.3 stems/ha respectively) with lower basal are (2.8±1.9m^2/ha, 5.66±1.9m^2/ha respectively) (Appendix II.2).

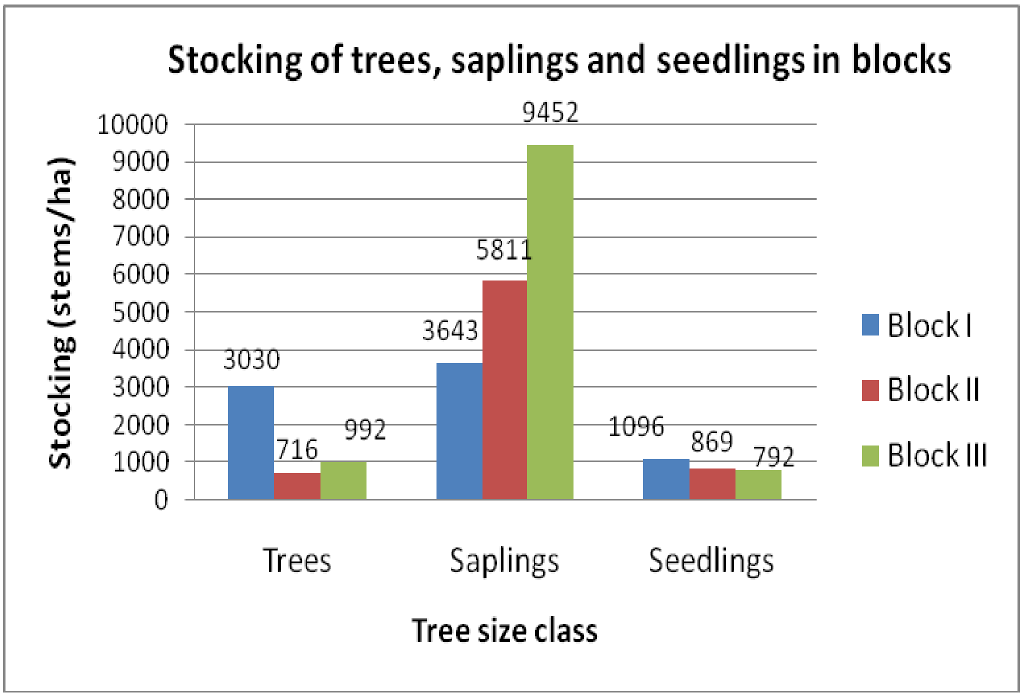


Figure 4.6: Stocking of trees, saplings and seedlings of all tree species combined in blocks

Generally, the distribution of bamboo stems in blocks based on dbh size classes gives a reverse-J curve (Fig. 4.7), showing that stocking decreased with increasing diameter class. The more disturbed block (block III) with low elevation, lacked stems ranging from 8cm to 10cm dbh classes. The largest bamboo stems in the block had 7cm dbh.

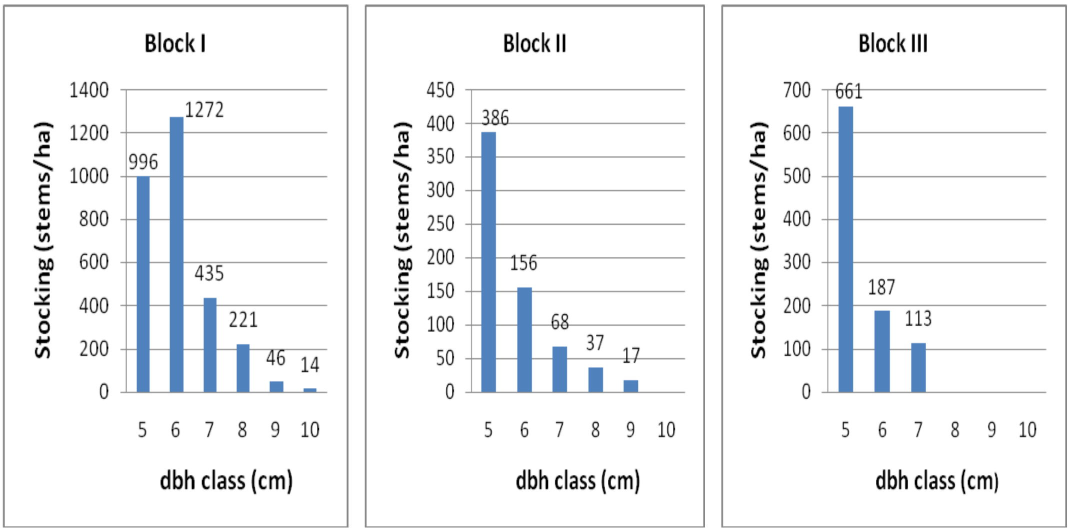


Figure 4.7: Diameter distribution of bamboo at dbh classes in blocks

The height of bamboo varied with the proportion of forest canopy cover in bamboo stands. Forest canopy cover ranged from 49.6% to 67.1% (Fig. 4.8) in closed canopy bamboo with lower average height of stems ranging from 8cm to 10cm dbh classes (Fig. 4.9). On the other hand, the forest canopy cover ranged from 35.3% to 52.2% in open canopy bamboo and most stems with 8cm, 9cm and 10cm dbh classes had a higher average height (Fig. 4.9).

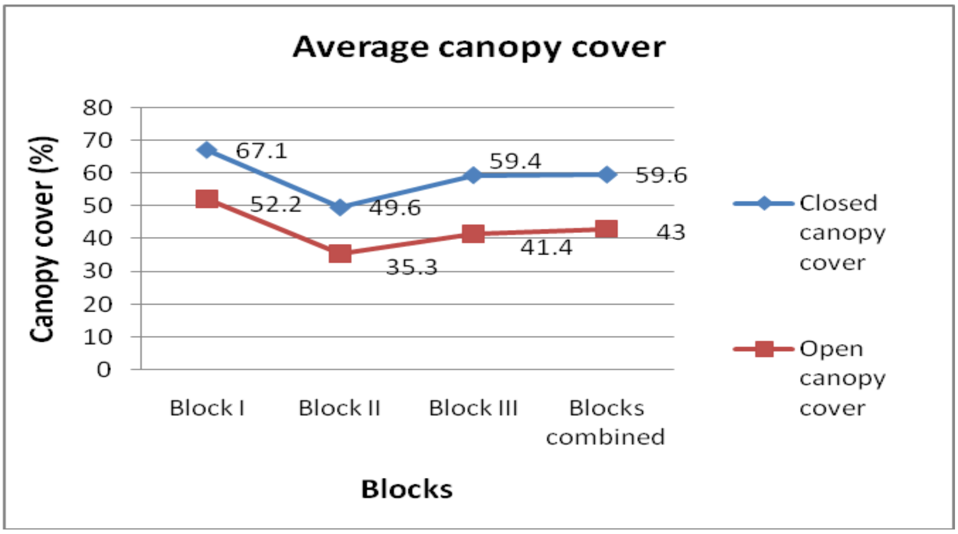


Figure 4.8: Average forest canopy cover in bamboo stands

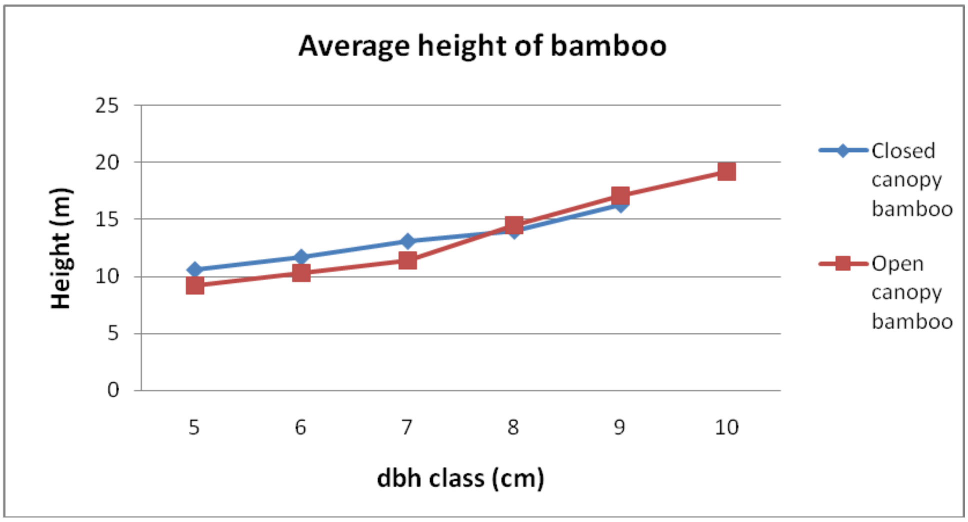


Figure 4.9: Average height of bamboo by dbh classes in bamboo stands

4.2.2 Species composition

The most dominant families in the three studied blocks were Oleaceae, Fabaceae and Cupressaceae (29.1%) (Table 4.3). Oleaceae family was represented by three species (*Olea capensis*, *Olea europaea* and *Schebera alata),* Fabaceae family by two (*Acacia kirkii* and *Acacia nilotica*) and Cupressaceae family by two (*Juniperus procera* and *Cupressus lusitanica*) (Appendix IV). Other families comprised 4.2% each (Table 4.3) while unidentified genus were *Rapania c.* and *Chelumbut(Local name)* representing 8.3%.

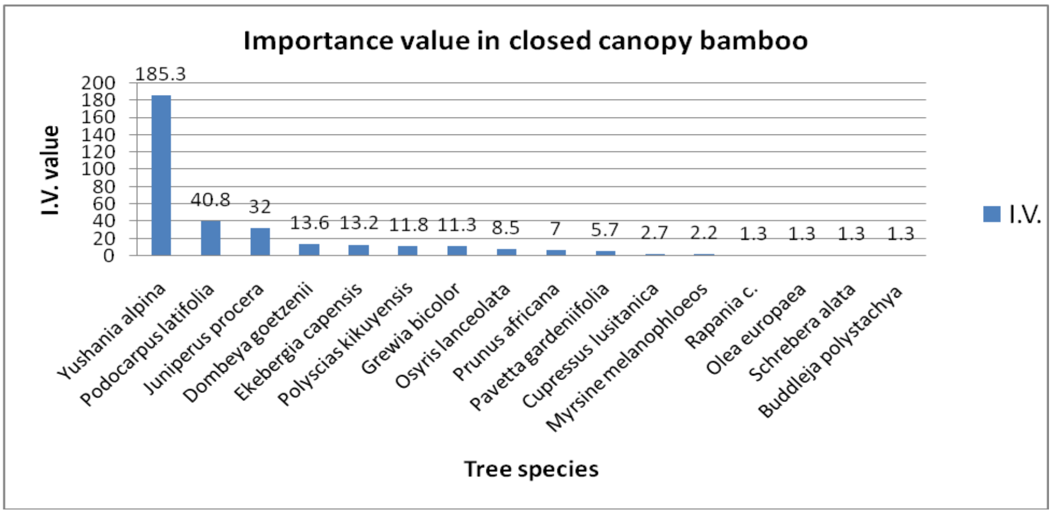
Table 4.3: Family, genus and respective number of trees species in blocks combined

N^{o}	Family	Genus	Number of species	%
1	Oleaceae	*Olea, Schrebera*	3	12.5
2	Fabaceae	*Acacia*	2	8.3
3	Cupressaceae	*Cupressus*, Juniperus*	2	8.3
4	–	*Rapania c.* (1), *Chelumbut(Loc. name) sps* (1)	2	8.3
5	Poaceae	*Yushania*	1	4.2
6	Loganiaceae	*Buddleja*	1	4.2
7	Sterculiaceae	*Dombeya*	1	4.2
8	Meliaceae	*Ekebergia*	1	4.2
9	Proteaceae	*Grevillea**	1	4.2
10	Tiliaceae	*Grewia*	1	4.2
11	Myrsianaceae	*Myrsine*	1	4.2
12	Santalaceae	*Osyris*	1	4.2
13	Rubiaceae	*Pavetta*	1	4.2
14	Pinaceae	*Pinus**	1	4.2
15	Podocarpaceae	*Podocarpus*	1	4.2
16	Araliaceae	*Polyscias*	1	4.2
17	Rosaceae	*Prunus*	1	4.2
18	Anacardiaceae	*Rhus*	1	4.2
19	Rutaceae	*Vepris*	1	4.2
Total	18 Families	22 Genera	24 species	100

KEY: ***=** Genus of exotic species, %= percentage.

Yushania alpina was the most important species with the highest Importance Value (I.V.) in both closed canopy bamboo and open canopy bamboo (Fig.4.10) and in blocks (Appendix III.2).

The species was followed by *Podocarpus latifolia*, *Juniperus procera* and *Dombeya goetzenii* (Fig. 4.10) in bamboo stands; *Podocarpus latifolia*, *Juniperus procera* and *Olea europaea* in block I, *Podocarpus latifolia*, *Juniperus procera* and *Dombeya goetzenii* in block II, *Ekebergia gardeniifolia*, *Polyscias kikuyensis* and *Dombeya goetzenii* in block III (Appendix III.2).



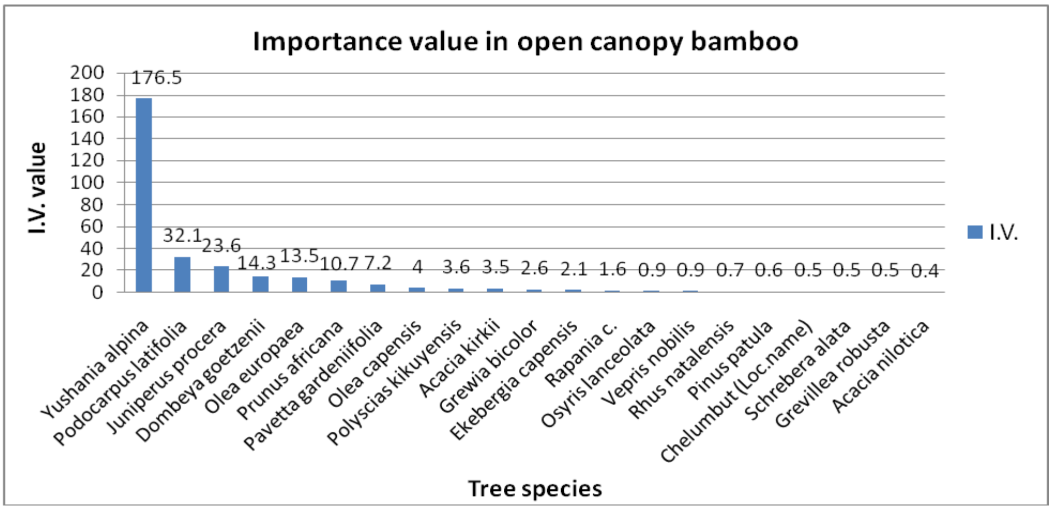


Figure 4.10: Individual tree species ranked by their Importance Value in bamboo stands

With regard to Simpson's diversity index (*D*) measures, minimal diversity was observed for trees, saplings and seedlings (*D*-values are approximately equal to 1) either in bamboo stands (Table 4.4) or within blocks (Table 4.5).

After data transformation, $p > \alpha$ for T-test in bamboo stands (Appendix V.3) and One way ANOVA within studied blocks (Appendix V.3). There was no significant difference in species diversity for trees, saplings and seedlings.

Table 4.4: Simpson's Index of diversity (*D*) and *p*-value in bamboo stands

Bamboo stands	Index of diversity	Tree size class		
		Trees	Saplings	Seedlings
Closed canopy bamboo	*D*	1.037	1.116	1.681
	SR	11	11	8
Open canopy bamboo	*D*	1.078	1.062	2.028
	SR	19	15	12
	***p*-value**	***0.527***	***0.856***	***0.983***

KEY: *D*: Simpson Index of diversity, *SR*: Species richness.

Table 4.5: Simpson's Index of diversity (*D*) and *p*-value within blocks

Blocks	Index of diversity	Tree size class		
		Trees	Saplings	Seedlings
Block I	*D*	1.032	1.100	1.352
	SR	11	7	6
Block II	*D*	1.199	1.039	1.330
	SR	14	10	5
Block III	*D*	1.067	1.101	4.545
	SR	12	13	11
	***p*-value**	***0.530***	***0.809***	***0.709***

KEY: *D*: Simpson Index of diversity, *SR*: Species richness.

Similarly to Simpon's diversity index and ANOVA test, Peterson's homogeneity index (*I* approximately equal to 1) and T-test ($p>\alpha$) revealed that there was no significant difference in species composition in bamboo stands and between the pair of compared blocks (Table 4.6). Thus, the identified species in the studied sites were almost similar.

Comparatively, *p*-values were very closer to 1 in blocks with low elevation variation (block I and II, block II and III), while it was less closer to 1 in blocks with high elevation variation (block I and III). This shows that there was slightly species similarity in the blocks with low elevation variation.

Table 4.6: Peterson's Homogeneity Index (*I*) and *p*-value in bamboo stands and between the pair of compared blocks

	Bamboo stands	**Pair of compared blocks**		
	Closed canopy bamboo and Open canopy bamboo	Block I *(high elevation)* and Block II *(medium elevation)*	Block I *(high elevation)* and Block III *(low elevation)*	Block II *(medium elevation)* and Block III *(low elevation)*
I	0.981	0.981	0.981	0.981
P	0.749	0.903	0.679	0.751

KEY: *I:* Peterson's Homogeneity Index, *p: p*robability.

4.3 Socio-economic characteristics of household heads

The general information about socio-economic characteristics of household heads were as follows: gender, age, number of children and their education level, education of household heads and their occupation.

More men (62.3%) than women (37.7%) were interviewed (Table 4.7).

Table 4.7: Household heads by gender

Gender	Frequency	Percentage
Male	71	62.3
Female	43	37.7
Total	114	100

Approximatly 79.8% of household heads varied from 20-49 years old, while 19.2% were above 50 years old. Only 0.9% were below 20 years old (Table 4.8).

Table 4.8: Age of household head

Age classes	Frequency	Percentage
10-19	1	0.9
20-29	32	28.1
30-39	33	28.9
40-49	26	22.8
50-59	7	6.1
60-69	7	6.1
70-79	5	4.4
80-89	3	2.6
Above 90	–	–
Total	114	100

Majority of household heads (79.0%) had children between 1 and 6, 18.4% had 7 to 9 children, while 2.6% didn't have children (Table 4.9).

Table 4.9: Number of children per household head

Age classes	Frequency	Percentage
No one	3	2.6
1-3	36	31.6
4-6	54	47.4
7-9	21	18.4
Above 10	−	−
Total	114	100

Among household heads, 65.8% attained primary school level, 14.9% secondary school level, while 19.3% didn't have formal education (Table 4.10).

Table 4.10: Education level of household heads

Education classes	Frequency	Percentage
Primary (1-8 years in school)	75	65.8
Secondary (9-12 years)	17	14.9
University	-	-
No formal education	22	19.3
Total	114	100

Crop farmers were approximately 99.1%, livestock keepers (92.1%), hunters (14.1%), self employed (2.6%) and business men (0.8%) (Table 4.11).

Table 4.11: Occupation of household heads

Occupation	Frequency	Percentage
Crop farming	113	99.1
Livestock keeping	105	92.1
Hunting (including bee keeping)	16	14.1
Self employement	3	2.6
Trader/Business	1	0.8

4.4 Uses of bamboo

Bamboo extracted from Mariashoni and Njoro forests was used by the local community for various purposes. The study established that 23.2% of the local community used bamboo for fencing, 21.9% for firewood, 19.8% for cultural activities, 18.7% for house constuction, 11.2% for medicine, and 5.2% for furniture making (Appendix VII.1). Over 83% of respondents used bamboo for fencing, firewood, cultural activities and house construction. Other uses of bamboo include making materials for water collection, arrows and bows for hunting.

Forest officers and the local community had differing perception on the use of bamboo. The results from Chi-square test for goodness of fit show that there was no significant difference in responses given by forest officers (p=0.216) (Appendix VIII.1), implying that bamboo was not used by the local community. On the contrary, responses from the local community were significantly different (p=0.000), indicating that they were using bamboo for various purposes.

4.5 Number and cost of bamboo stems utilized per day

Majority of households (48.2%) utilized 3-4 stems per day, 42.1% consumed 1-2 stems, while only 9.6% utilized 5-6 stems per day (Table 4.12). When 3-4 stems were utilized per day, this amounts of 84 to 112 stems per month/household, costing Ksh 1,680 to 2,240. In the sample population of 114 households, the number of bamboo stems utilized per month was 9576 to 12768 stems, costing Ksh 191,520 to 255,360 per month.

Table 4.12: Number of bamboo stems utilized per day

Number of stems utilized/day	Frequency	Percentage per household heads	Cost/stem (in Ksh)
1-2	48	42.1	
3-4	55	48.2	20
5-6	11	9.6	
Total	114	100	

4.5 Correlation among household heads characteristics and use of bamboo

4.5.1 Correlation of education of household heads and use of bamboo

Correlation analysis was conducted and the results (Appendix VI.1) indicates that household heads with primary level of education were positively related to those with secondary level of education with a strong correlation of r=1 which is significant at p=0.000. This significance value indicates that the use of bamboo was similar for educated people than those with no formal education.

4.5.2 Correlation between size classes of household families and use of bamboo

Correlation analysis was conducted and the results (Appendix VI.2) indicates that there was positive correlation (r=0.770, p=0.000), between families with 1 to 3 children and those with 4-6 children. This indicates that the use of bamboo was similar for large families than those with no children.

4.5.3 Cross-tabulation of occupation of household heads and use of bamboo

Self employment household heads were positively related to traders/business men with strong positive correlation of *r*=1, significant at *p*=0.000 (Appendix VI.3). This significance value indicates that the use of bamboo was more similar for self employed households than farmers, livestock keepers and hunters.

4.6 Perception on the status of bamboo forests in Mariashoni and Njoro areas

The status of a forest indicates whether it is disturbed or undisturbed. Results from table 4.13 shows that the forests were partly disturbed (46.6%), disturbed (40.5 %), undisturbed (12.2 %). Only 0.8% of stakeholders were not sure. Over 85% of the stakeholders agreed that the forests were disturbed.

Table 4.13: Status of bamboo forests in Mariashoni and Njoro forests

	Undisturbed		Disturbed		Not sure		Partly disturbed		
Respondents	F	%	F	%	F	%	F	%	Total
Forest officers	5	29.4	3	17.6	1	5.9	8	47.1	17
Local community	11	9.6	50	43.9	−	−	53	46.5	114
Total	16	12.2	53	40.5	1	0.8	61	46.6	131

KEY: F: Frequency; %: Percentage.

The level of disturbance of the forests was perceived differently by forest officers (*p*=0.098) and the local community (*p*=0.000) (Appendix IX.2). The significance difference in responses from the local community indicates that the forests were disturbed.

4.7 Threats to bamboo forest resources in Mariashoni and Njoro forests

Human activities in the forests exerted different threats to forest resources. Results from the study shows that selective cutting of trees (36.3%) was a threat to the forests, logging (33.7%) and cutting bamboos for domestic uses (19.8%). Other threats were cattle grazing (19.5%), fires by honey gatherers or charcoal burners (17.9%), encroachment (2.6%) and natural fires (0.8%) (Appendix VII.2). It was established that over 89% of the respondents agreed that charcoal burning, logging, and cutting bamboo for domestic uses were major threats to the forests.

It was established that the two groups of respondents had differing perception on prevailing threats to the forests. There was no significant difference (p=0.405) (Appendix VIII.3) in responses given by forest officers, suggesting that the forests were not threatened. On the contrary, responses from the local community were significantly different (p=0.000), indicating that the forests were threatened.

4.8 Factors driving the overexploitation of bamboo forest resources

The lack of awareness/Education (44.7%) and proximity to the bamboo forests (34.2%) were major factors that drove the local community to have easier access to forest resources, while the lack of other alternatives (14.0%) and poverty (7.0%) had less contribution in their extraction (Table 4.14).

Table 4.14: Factors stated by forest officers as driving overexploitation of forest resources

Factors	Frequency	Percent
Poverty	8	7.0
Lack of others alternatives	16	14.0
Living at proximity to the bamboo forests	39	34.2
Lack of awareness/Education	51	44.7
Total	114	100

4.9 Number of times the local community have access to the forest resources

Result from table 4.15 shows that the local community had access to forest resouces as many time as possible. The local community had access to the forests both daily and weekly (86%), rarely (6.9%) and monthly (6.1%).

Table 4.15: Number of times the local people have access to forest resources

Respondents	Daily		Weekly		Monthly		Rarely		Total
	F	%	F	%	F	%	F	%	
Forest officers	9	52.9	5	29.4	2	11.8	1	5.9	17
Local community	44	38.6	56	49.1	6	5.3	8	7	114
Total	53	40.5	61	46.6	8	6.1	9	6.9	131

KEY: F: Frequency; %: Percentage.

The number of times the local community have access to the forests was estimated differently by two categories of stakeholders. There was no significant difference (*p*=0.208) (Appendix VIII.4) in responses given by forest officers, suggesting that there was no or rare access to the forests by the local community. On the contrast, responses from the local community were significantly different (*p*=0.000), indicating that they had frequent access to the forests.

4.10 Rules and regulations that govern the use of bamboo forest resources

Majority of forest officers (58.8%) agreed that they were aware of existence of rules and regulations that govern the use of bamboo forest resources (Table 4.16). To ascertain this, they were asked to list regulations they knew. The following emanated from the list: no cutting of trees without legal permit, no timber sawing, no starting of fire in the forests, no burning charcoal and grazing without permit. Only 41.2% were unaware of existence of rules and regulations. This reflects that the rules and regulation governing the use of bamboo forest resources were not fully enforced.

Table 4.16: Sufficiency of rules and regulations that govern the use of forest resources

Response	Frequency	Percent
Yes	10	58.8
No	7	41.2
Total	17	100

4.11 Existence of Community Forest Association (CFA)

Majority of forest officers (76.4%) aggreed that CFA existed, reflecting that the local community benefited from the adjacent forest resources. On the contrast, 23.6% of forest officers confirmed that CFA was not known (Table 4.17). This indicates that almost one quarter of forest officers was unaware of participatory forest management and/or that CFA was not operational in excised areas.

Table 4.17: Perception of forest officers on existence of CFA in the excised area

Response	Frequency	Percent
Yes	13	76.4
No	4	23.6
Total	17	100

CHAPTER FIVE

DISCUSSION

5.1 Changes in bamboo stands distribution

The study had an objective of determining the temporal changes in bamboo distribution in Mariashoni and Njoro forests from 2000 to 2011. The study found that closed canopy bamboo increased by 295ha from 221ha in 2000 to 516ha in 2011. This was due to high regeneration of bamboo under forest gaps created by extraction of available trees in open canopy bamboo. Bamboo was a better competitor in open spaces than other shade-intolerant species in colonizing areas which were previously covered by trees. Open forest canopy influences sunlight penetration at forest floor and this favoured bamboo regeneration. A similar finding was reported by Hakim *et al.* (2002), stating that the absence of large trees in bamboo forest caused canopy gaps which enabled bamboo to grow well and spread. Bitariho and Mosango (2005) also found that bamboo culms thickness increases with decreasing tree canopy.

On the other hand, 165ha of closed canopy bamboo in 2000 was converted into isolated agricultural plots. This was due to increasing demand of farmlands by communities surrounding the forests, resulting in loss of natural ecosystems. This situation is contrary to the goal of the Government of Kenya of increasing the country's forest cover (currently equivalent to 5.9% of land area) to 10% by 2030 (GoK, 2010; NEMA, 2011). This goal is far from being achieved in Mariashoni and Njoro forests due to the persistent forests disturbance.

5.2 Bamboo forests structure and composition in compared sites

The study also intended to determine variation between the current structure and composition in bamboo forests in Mariashoni and Njoro areas. The study found that there was higher stocking of trees and seedlings in closed canopy bamboo. Similarly, block I had more trees and seedlings. This was attributed to high density and less exploitation of old bamboo in the sites. The low level of disturbance and existence of mother trees that provided seeds in the sites favored regeneration and recruitment of seedlings. Despite this, the overall stocking of bamboo (8954 stems/ha) obtained in closed canopy bamboo was lower than what was recorded in undisturbed stands of *Yushania alpina* ranging from 10000 to 17000 stems/ha (Kigomo, 1988 and Kant *et al.*1992). This indicates that the obtained stocking in this study was affected by natural or human-induced factors such as unsustainable harvesting of bamboo.

The open canopy bamboo and more disturbed blocks (block II and III) had low stocking of seedlings, contrary to expectations. Most researches found that the density of seedling is high in disturbed forests characterized by open canopy (Koirala, 2004). The disparity was due to relatively high level of disturbance in the sites. There was intensive damage of bamboo shoots through trampling by cattle. Bamboo shoots were also fed on by wild animals such as monkeys and warthogs during the dry season as a result of food scarcity. The drought conditions could have also affected their availability as shoots are produced by bamboo rhizomes mainly during the rain season (Kassahun, 2003). Low light intensity probably was a major factor that reduced recruitment of bamboo shoots in surveyed sites with high coverage of other tree species. Bitariho and Mosango (2005) also found that forest tree canopy impeded light penetration and inhibited the growth of bamboo shoots underneath.

The lower basal area of trees in closed canopy bamboo was mainly due to existence of more bamboo stems with low dbh classes (5cm to 6cm dbh classes). This low growth in width may be attributed to high intraspecific competition for nutrients among bamboo stems. On the other hand, the large basal area in open canopy bamboo was due to more bamboo stems ranging from 7cm to 10cm dbh classes. The large growth in width may be mainly attributed to low intraspecific competition for nutrients among bamboo stems, and partly the existence of interdependence of bamboo with other many tree species in the site. The other tree species provided humus to bamboo at forest floor and offered protection from strong winds. The role of bamboo rhizome system was that of binding the soil and hence minimizing soil erosion. Interdependence of bamboo with other tree species was also reported by Zheng and Hong (1998) who indicated that bamboo stands intermixed with broadleaved trees exhibited higher amounts of desirable soil nutrients and soil quality, including soil porosity, aeration, and bulk density, compared to homogenous bamboo stands.

The larger basal area of trees in block I was mainly due to lower extraction of trees in the site located far from human settlement. The low basal area in block II and III was attributed to intensive tree cutting and previous fires that consumed old bamboo. Ramirez-Marcial *et al*. (2001) correlated the decreasing density and basal area with disturbance intensity.

The high stocking of saplings obtained in open canopy bamboo and the more disturbed blocks (block II and III) was attributed to their high recruitment after fires (Plate 5.1). Bamboo was therefore the first successional species that colonized the ashy forest floor rich in minerals. The presence of underground bamboo rhizomes contributed to shoot development resulting to saplings observed in the blocks.

Large recruitment of bamboo saplings in more disturbed blocks (block II and III) was also facilitated by extraction of old bamboo and other trees (Plate 5.2) that reduced competition between stems. Changes in site conditions affected their regeneration. This finding was similar to that of Taylor *et al.* (2004) who reported that canopy openness modifys the ground level microclimate and therefore favor the abundance of understory vegetation. In addition, Koshy and Harikumar (2001) reported that harvesting of mature bamboos lead to high regeneration rates of culms with small diameter.

However, the growth in width and height of bamboo stems in block III could have been affected by low elevation and nearly flat slopes recorded in the block. The poor performance of bamboo in the block was evident from the color of stems. Stems turned yellow at bottom of hills with low elevation and became green at steeper slopes of medium and high elevation. Scott (1994) also reported that increasing altitude increased both the average height and width of bamboo. Although saplings are a good indicator of forest dynamic trends (Duarte *et al.,* 2006) the overall high stocking of saplings mainly in more disturbed blocks cannot be considered as proof of population dynamics. This is because successful recruitment of saplings was mainly that of bamboo. The low recruitment of other tree saplings was due to repeated disturbances in the sites.

Plate 5.1: Bamboo saplings growing up after previous fire. (Source: Author, 2012)

Plate 5.2: Gaps created by extraction of old bamboo and *Juniperus procera.* (Source: Author, 2012)

The obtained reverse-J curve for bamboo stems distribution at diameter size classes implied that there was ongoing bamboo recruitment that would provide trees. Loewenstein *et al.* (2000) also stated that the presence of small trees are essential component of uneven-aged stands because they are indicator of the long-term sustainability of forests. Despite the use of reverse J-distribution in natural forest stands as indicator of regeneration and therefore used as management tool (Isango, 2007), it is important to consider some factors that affected the existence of all age-classes of bamboo in block II and III. Intensive extraction of old bamboo and man-made fire have affected the availability of old bamboo with 8cm, 9cm and 10cm dbh classes in the sites.

Results showed that Oleaceae, Fabaceae, and Cupressaceae families (29.1%) dominated in the study area. This was attributed to their preference to high elevation areas varying between 2550m to 2975m. A similar finding was made by Maundu and Tengnäs (2005) who indicated that the distribution of *Olea* species (Oleaceae) and *Juniperus procera* (Cupressaceae) is in high elevation above 1800m, while *Acacia* species (Fabaceae) are found between 900m-2600m altitude. This finding was confirmed by the fact that in this study *Acacia nilotica* (Fabaceae) and *Schrebera alata* (Oleaceae) were only recorded in block III with the lowest elevation (2550m-2700m). In addition, families such as Oleaceae, Cupressaceae, Podocarpaceae were reported by Maundu and Tengnäs (2005) to form association with *Yushania alpina* (Poaceae) as it was observed during the study. This implies that some species regenerate and grow well at high elevation while others at low elevation. Titshall *et al.* (2000) concurred with this observation and indicated that elevation forms the main topographic factor that determines the microclimate and thus, controls the distribution and patterns of vegetation in mountain areas. The low representation of other families (4.2% each) may be attributed to their low adaptability under bamboo coverage. Wang *et al* (2011) reported that a high density of bamboo has a fatal influence on understory species diversity and tree regeneration.

Prevalence of *Yushania alpina* in the forests was mainly attributed to its highly competitive ability to large openess among other shade intolerant species, and partly to its uniqueness in genetic diversity (Lobovikov, 2007) that fits to such topographic and soil conditions.

The existence of exotic species like *Grevillea robusta, Pinus patula,* and *Cupressus lusitanica* in indigenous bamboo forests was attributed to closeness of exotic plantations to the forests. Their dispersal and establishment could have been facilitated by natural factors such as wind or animal activities such as cattle grazing. These animals could have carried seeds in their hooves from excised areas to the forests. Evidence of this was shown by the fact that seedlings and saplings of exotic species were found at forest edges, near paths and in open areas such as grazed and burnt areas. A similar report was made by Munyaradzi and Katerere (2003) who attributed preference of exotic species to disturbed soils and overgrazed areas. However, the existence of exotic species in the study area may not mean that there was competition between them and native species. Rather, it may reflect their relatively high seed dispersal and germination ability in disturbed sites. In this case, their dominance may reduce with time as competitively superior native species increase their local seed production (Siemann and Rogers, 2006). Monitoring of such species the study area should not be neglected in order to minimize their future competitive abilities. Munyaradzi and Katerere (2003) underlined that invasion of exotic species may affect the integrity of native ecosystems to supply environmental goods and services.

There was insignificant difference in species diversity between studied blocks ($p>\alpha$). According to the dynamic equilibrium model (Huston, 1994) and diversity-stability hypothesis (Thompson *et al.*, 2009), the obtained minimal diversity was a result of slightly high level of disturbance. Forest disturbance affected the abundance of preferred tree species in the study area. This finding was similar to that of Eilu and Obua (2005) who specified that the high intensity of human disturbance adversely affects tree species abundance, diversity and regeneration. Forest disturbance also depressed recruitment of saplings and seedlings. This led to a non-equilibrium state of other tree species in the bamboo forests, a situation described by Huston (1994). The loss of other trees in the study area also affected their resiliency to natural or human-induced disturbance. According to Hilldebrand *et al.*, (2008), the factors that increase or decrease the dominance of species in a community interferes with its resistance and/or resilience to disturbances. While resilience is the capacity to recover from severe disturbance such as logging, and return to a pre-disturbance state, maintaining biodiversity in a forest ecosystem is a key to maintain resilience (Thompson, 2009).

The slightly low species similarity between blocks with high elevation variation (block I and III) was due to elevation gradient, disturbance level or other unverified factors such as soil composition among others (Lü *et al.*, 2010).

5.3 Household characteristics and factors influencing extraction of bamboo

The study also looked at socio-econimic characteristics of household heads. Majority of respondents were males (62.3%). This was expected because of the culture of indigenous Ogiek where a husband is the head of household. Women were therefore found to be timid to talk when their husbands were around.

In degazetted areas, respondents were also more comprised of young and middle aged individuals (78% varied from 20-49 years old) with children varying between one to six (79%). Their major livelihood activitiy was crop farming, directly associated with forest resource utilization in terms of poles, posts and bamboo extraction. Member of families were therefore allocating more labour in collecting bamboo not only for domestic use but also for sale to generate income. As a result, the forests were disturbed. Correlation analysis showed that the use of bamboo was not similar for farmers and self employed households (Appendix 6.3). Mitinje *et al* (2007) highlighted that human activities are deeply rooted on daily needs of the communities in terms of forest products needed to cater for the growing human population. In addition, FAO (2003) indicates that population size and density have major consequences on the intensity of resource use. However, large families in a developing country like Kenya are considered an asset to the government when they are engaged in constructive activities that sustain their life. Otherwise, these large families can contribute to forest disturbance.

Less livelihood options of farmers and poverty in excised areas were manifested by few commercial and small-scale projects. Prevalence of poverty in areas surrounding the forests is evidenced by rural poverty incidence percent in Molo district of 37±5(SE) (Central Bureau of Statistics, 2005) with low daily income which is less than 1.25 US

Dollars/day (World Bank, 2010). It was established that increased number of poor farming families in areas surrounding forests is a major handicap to forest management and conservation plans.

Other characteristic of poverty in excised areas include the lack of formal education (19.3%) and low level of education of household heads (65.8% attained primarily school level). This contributed also to low enrollment of children in schools (58.2%). This was due to inadequate source of income and low consideration given to education by indigenous Ogiek that form majority of communities living near the forests. Consequently, the youth and their parents participated more in illegal activities such as charcoal burning to obtain a source of income. Despite the strong correlation of educated people in using bamboo (r=1, p=0.000), majority of them had alternative source of generating income other than entirely depending on exploitation of bamboo resource. These activities included hair cutting and braiding, commerce activities among others. According to Lingani *et al.* (2009) a higher level of formal school is associated with less forest cutting due to increased social status and economic opportunities and probably environmental conservation awareness. Hence, raising educational level can increase public awareness about the need for judicious use and preservation of adjacent forests.

The study had an objective of finding out different uses of bamboo extracted from the forests. There was differing perception on the use of bamboo by forest officers (p=0.216) and local community (p=0.000). This disparity was due to difference in knowledge on the use of bamboo. Nevertheless, the demand for bamboo was high (84 to 112 stems/month/household) due to its high availability, cheap cost and its simplicity in terms of its handling for various domestic uses. Similar report was made by Zhou *et al* (2005) who specified that bamboo stem is mostly used because of its ability to be split that makes it ready for multiple domestic uses. Bamboo is a preferred forest resource due to its straightness, light weight and ease of working with (Suzuki and Jacalne, 1986). This facilitated its transportation and sale to other places (e.g. in Njoro, Elburgon, and Molo centres). Among the various uses of bamboo, fencing (99.2%) was not only used to delineate homesteads boundaries but was also used in local farms to prevent Warthogs (*Phacochoerus africana*) from damaging crops at night. Fences are at least replaced every year and fresh bamboos were harvested from the forests for this purpose. Dry bamboo used as firewood (93.8%) was collected from the forests and old fences that needed to be replaced.

The study also intended to determine major threats to the bamboo forest resources. The study found that forest officers (p=0.405) and local community (p=0.000) differed in their perception concerning the major threats to bamboo forest resources. Difference was due to the fact that forest officers were accused by local community of colluding with loggers in illegal harvesting of trees for sawing, poles making and charcoal burning. Forest resources were openly carried by donkeys and bicycles from the forests to villages for use and sale. On the other hand, local community were also accused by forest officers for disturbing the forests through illegal activities like charcoal burning, cattle grazing and fire setting. Evidence shows that local community drove their cattle in the forests in the morning and returned them to villages in evening.

Despite the differing opinions, the forests were threatened by various human activities such as bamboo cutting, grazing and charcoal burning among others. This is because the forests were second livelihood source to the local community with low income. In excised areas, livelihood strategies were crop and cattle keeping. Evidence of illegal activities was indicated by the fact that loggers were observed moving into the forests far away from the edges, selecting specific trees and avoiding forest rangers pathes. Entry into the forests was during odd hours, at night and very early in the morning, on public holidays and weekends. These are the times they expected forest rangers not to be at work. Similarly, Marshall (2008) reported that pole cutting mainly takes place on weekends or during the night when the risk of being caught by forest patrol is least. Therefore, life trees were cut down for sawing, split for poles and firewood or cut into small sizes for charcoal burning.

Firewood was collected both for domestic use and for sale in nearby centres. Firewood was the only source of fuel for domestic consumption. It was not only collected from dead bamboo or tree branches, but also from cut and dried trees that are preferable for firewood by buyers such as *Olea* species.

Cattle grazing was also openly carried out in the forests because pastures were lacking in excised areas of Njoro and Nessuit. During the dry season, herdsmen fed their cattle on bamboo saplings. However, grazing is an illegal activity in forest reserves as specified by the Forest Act, article No. 31, section 3. The Act states that "*No cutting, grazing, removal of forest produce, hunting or fishing, shall be allowed in a nature reserve except with the permission of the Director granted in consultation with other conservation agencies, which permission shall be given with the object of facilitating research*" (GOK, 2005).

Fire risks mainly during the dry season in the bamboo forests were increased by man-made fires. Reported fire in the forests was crown-fire rather than ground or surface fire.

Crown-fire burned the entire bamboo and other fire sensitive trees and lead to their death (Plate 5.3). Such fire affected negatively the forest communities and ecosystems.

Plate 5.3: Inactive fire in Njoro forest. (Source: Author, 2012)

Findings from the questionnaire revealed that unawareness and living in proximity to the bamboo forests (78.9%) were two major factors that drove the local community to overexploit forest resources. This conforms to findings of Hoang *et al.* (2010) who specified that disturbance levels decrease with increased distance from villages, indicating that pressure of illegal logging and harvesting are closely connected to accessibility and transport cost.

The forests were considered as common property to which every one wanted to have access to. Tyler (2001) termed this situation as ‘Tragedy of the commons’ stating that “*...if I don’t use this resource, someone else will. The little bit I use is not enough to matter*”. In an attempt to exploit as much as possible from the forests for oneself, forest degradation occur and the costs are borne by all users and the whole nation. In addition, the location of rangers' residences also influenced effective patrol and deliverance of legal permit. The nearest residence was located at approximately four kilometers from the forest edge (e.g. Nessuit) and this affected the accessibility to the forests and the need to seek legal permit.

Forest resources extraction was also facilitated by daily and weekly access to them by the local communities (86%). The forests provided them with food (honey, wild fruits, game meat), pasture and water for their survival. In this way, the local community felt that they were oppressed by the ban imposed on them without provision of alternative options. Resource management that takes care of the needs of the community should be prioritized if the forest reserves are to be sustainable. However, people were always in fear while in the forests, avoiding major route and were on the look out throughout the illegal extraction. This implies that they knew and understood that free accessibility to the forest resources without permission was illegal.

According to forest officers, rules and regulations that govern the use of bamboo forest resources were not known (41.2%) by the local community. This unawareness could be attributed to lack of capacity building of forest officers in educating the local community on judicious extraction of forest resources. However, forest officers confirmed that few people went for permits in order to collect forest resources. This showed that some people were aware of existence of regulations and complied to them, while others were non-compliant. This lack of compliance could be also attributed to exclusion of local community in the process of formulation of forest rules and regulations. The lack of education of local community on how to efficiently benefit from the forests was also evidenced by ineffectiveness of CFA (23.6%) in excised areas. In addition, there were no cooperatives engaged in economic activities such as sustainable charcoal production.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the findings of this study, it was established that:

1. There were changes in bamboo distribution in the study area from 2000 to 2011. Closed canopy bamboo increased by 295ha from 221ha in 2000 to 516ha in 2011, while 165ha were converted into farmlands.
2. Bamboo forest stucture and composition varied between bamboo stands and within blocks. Closed canopy bamboo had a higher stocking of trees and seedlings with lower basal area. Block I (the less disturbed site) had a higher stocking of trees and seedlings with larger basal area. The distribution of bamboo showed a reverse-J curve. Species diversity and composition were insignificantly different. Oleaceae, Fabaceae and Cupressaceae families (29.1%) were dominant, while *Yushania alpina* was the most important species.
3. Bamboo was extracted mostly for domestic uses, and poverty level was the major factor influencing extraction. Major threats to the forests included charcoal burning, logging and cutting of bamboo. Threats were driven by unawareness and closeness of human settlement to the forests (77.9%).

6.2 Recommendations

Since the distribution of bamboo was high under gaps, the protection and management of the forests should focus on the following aspects:

1. Reducing intensive extraction of other trees in the study area. This would maintain the interdependence that exists between bamboo and other trees to sustain near-stable ecosystem function in the upper water catchment in Mariashoni and Njoro

forests. Preservation of existing mother trees would also promote regeneration and recruitment dynamics of seedlings.

2. Initiate afforestation of encroached areas as a way of mitigating the loss of bamboo coverage. This should also be combined with empowering of existing CFA and particularly that concerning bamboo plantation and use because of its environmental, socio-economic and cultural importance. *Yushania alpina* can be planted at strategic position in farms on slope areas, on riverside or at homesteads as ornamental plant. Bamboo has a fast growing ability and relatively low water uptake (KEFRI, 2008).
3. Prioritizing participation of the local community in forest management and conservation plan. The non-involvement of communities adjacent to forest in its protection, management and conservation can result in their discontentment that can increase illegal activities and conflict of interests. To protect indigenous forests, action must be taken to organize rural populations in such a way that they can contribute to forestry activities in a rational and coordinated manner, either independently or in junction with public or private agencies (FAO, 1985).
4. Coming up with new and modern livelihood options to the local community in excised areas such as initiating zero grazing and using economic stoves. This would reduce the amount of firewood needed and less trees would be destroyed in the forests.

AREA FOR FURTHER STUDY

The following are suggested areas for further reseach in the study area:

1. Study on genetic analysis of *Yushania alpina*, its gene pool, uniqueness and endemism in the forests.
2. Effect of bamboo forests degradation on water availability downstream.

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APPENDICES

APPENDIX I: INTERVIEWS

I. Interview reserved to the Local Community

Socio-economic characteristics of the household heads

Characteristic	Description	To be filled by the researcher
Household head	Male	
	Female	
	Age	
Marital Status	Married	
	Single	
	Number of children	
	Level of education of children	
Education	Primary (1-8 years in school)	
	Secondary (9-12 years)	
	Tertiary/ University (Over 13 years)	
	No formal education	
Occupation (or type of business)	Crop farming	
	Livestock keeping	
	Hunting (including bee keeping)	
	Salaried employment	
	Self employment	
	Trader/business	
	None	

<u>Information about bamboo</u>

1) Do you live near any forest (s)?

☐ Yes ☐ No

If yes, give the name (s) of forest (s) nearest to your homestead.

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2) Are you aware of the existence of any bamboo plants in the forest nearest to your homestead?

☐ Yes ☐ No

3) How are the bamboo plants distributed in the forest?

☐ Abundant ☐ Scattered

☐ Rare ☐ Others (specify)

4) What is the status of the bamboo plants in the forest?

☐ Undisturbed (not destroyed) ☐ Disturbed (destroyed)

☐ Partly undisturbed ☐ Not sure

☐ Others (specify) ☐

5) How often do you go to the forest nearest to you?

☐ Daily ☐ Weekly

☐ Monthly ☐ Rarely

☐ Not at all ☐ Others (specify)

Information about the use of bamboo from Mariashoni and Njoro forests

1) In your everyday activities/life do you use bamboo in your home?

☐ Yes ☐ No ☐ Not daily

If yes, what do you use it for and what is the approximate number of stem used? (*Multiple responses accepted*).

√		Number of stem/day	Number of stem/week	Number of stem/month
	Fencing			
	Construction			
	Furniture making			
	Firewood			
	Medicine			
	Cultural activities			
	Food			
	Others (specify)			

2) According to you, what are the four major threats to bamboo forest resource?

a) Logging of trees for sawing
b) Selective cutting of trees for charcoal burning
c) Cutting bamboo for domestic uses
d) Cattle grazing
e) Encroachment
f) Fires by honey gatherers or charchoal burners
g) Natural fires
h) Others (specify)

3) Suggest what can be done to protect and conserve the bamboo forests in Mariashoni and Njoro forests……………………………………………………………………………………….…
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II. Interview reserved for KFS forest officers and local leaders in Mariashoni and Nessuit regions

<u>Identification of the respondent</u>

Names……………………….…… Occupation (or Position)…………………Age.……..

How long have you lived/worked in this area (Years) …………….…………..

<u>Information about bamboo</u>

1) Are you aware of the existence of any bamboo plants in the forest that is under your care?

☐ Yes ☐ No

2) How are the bamboo plants distributed in the forest?

☐ Abundant ☐ Scattered

☐ Rare ☐ Others (specify)

3) What is the status of the bamboo plants in the forest?

☐ Undisturbed (not destroyed) ☐ Disturbed (destroyed)

☐ Partly undisturbed ☐ Not sure

☐ Others (specify) ☐

4) How often do you go to the forest?

☐ Daily ☐ Weekly

☐ Monthly ☐ Rarely

☐ Not at all ☐ Others (specify)

Information about the use of bamboo from Mariashoni and Njoro forests

1) Do the local communities use bamboo from Mariashoni and Njoro forests?

☐ Yes ☐ No

If yes, what do they use it for? (*Multiple responses accepted*).

☐ Constuction ☐ Fencing

☐ Furniture making ☐ Firewood

☐ Cultural activities ☐ Medicine

☐ Food ☐ Others (specify)

2) According to you, what are the four major threats to bamboo forest resource?

a) Logging of big forest trees for sawing
b) Selective cutting of trees for charcoal burning
c) Cutting bamboos for domestic uses
d) Cattle grazing
e) Encroachment
f) Fires by honey gatherers or charchoal burners
g) Natural fires
h) Others (specify)

4) What are the main factors that drive the local community to overexploit bamboo forest resource in Mariashoni and Njoro forests (*Multiple responses accepted*):

☐ Poverty ☐ Lack of other alternatives

☐ Living in close proximity to the bamboo forest ☐ Unawareness

☐ Others (specify) ☐

5) How do they access the bamboo forest resource?

☐ Obtain permits ☐ Freely

☐ Illegally ☐ Local sales agents

☐ Others (specify)

6) a) Are there any rules and regulations that govern the use of bamboo forest resource in Mariashoni and Njoro?

☐ Yes ☐ No

b) What are they?

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7) a) Are there any community members who plant bamboo in their farms?

☐ Yes ☐ No

b) Does Community Forest Association (CFA) exists for Mariashoni and Njoro forests?

☐ Yes ☐ No

If yes, what is the role of CFA in conservation and regulation of bamboos use?

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c) Is there any bamboo forest user group?

☐ Yes ☐ No

If yes, what are their major activities in management of Mariashoni and Njoro forests?

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8) What approaches can be applied to enhance the management and conservation of the bamboo forests.

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APPENDIX II: STOCKING AND BASAL AREA

II.1: MEAN STOCKING AND BASAL AREA IN BAMBOO STANDS

Bamboo stands	N°	Species	STOCKING (Stems/ha) Trees	Saplings	Seedlings	BASAL AREA (m^2/ha)
Closed canopy bamboo	1	*Buddleja polystachya*	00±00	00±00	16±149.24	00±00
	2	*Cupressus lusitanica*	1±9.3	103±345	00±00	0.05±0.4
	3	*Dombeya goetzenii*	3±20.7	38±125	49±260.7	1.69±4.6
	4	*Ekebergia capensis*	1±9.3	58±216.8	49±260.7	0.03±0.1
	5	*Grewia bicolor*	3±20.7	12±48.6	00±00	1.28±2.6
	6	*Juniperus procera*	4±22.6	12±48.6	49±260.7	8.15±33.3
	7	*Myrsine melanophloeos*	1±9.3	00±00	00±00	0.39±2.2
	8	*Olea europaea*	00±00	4±22.6	00±00	00±00
	9	*Osyris lanceolata*	3±20.7	4±22.6	00±00	1.1±11
	10	*Pavetta gardeniifolia*	2±13.4	00±00	00±00	2.14±14.4
	11	*Podocarpus latifolia*	11±62.1	4±22.6	00±00	10.32±35.1
	12	*Polyscias kikuyensis*	00±00	78±251.5	66±372.2	00±00
	13	*Prunus africana*	2±18.7	00±00	16±149.2	1.07±4.7
	14	*Rapania c.*	00±00	00±00	16±149.2	00±00
	15	*Schrebera alata*	00±00	4±22.6	00±00	00±00
	16	*Yushania alpina*	1615 ±589	5872± 2152.5	856± 1178.1	11.85± 11.85
Open canopy bamboo	1	*Acacia kirkii*	1±9.5	00±00	00±00	1.58±24.4
	2	*Acacia nilotica*	00±00	2±30.8	00±00	00±00
	3	*Chelumbut(Loc. name)*	1±9.5	00±00	00±00	0.16±2.5
	4	*Dombeya goetzenii*	8±56.3	12±96	38±411.7	3.86±42.2
	5	*Ekebergia capensis*	1±9.5	27±139.7	30±341	0.57±6.2
	6	*Grevillea robusta*	00±00	2±30.8	00±00	00±00
	7	*Grewia bicolor*	1±9.5	20±192.4	10±154	0.01±0.2
	8	*Juniperus procera*	7±47.4	54±323	30±331.7	9.52±59.4
	9	*Olea capensis*	3±27.5	5±54.4	10±154	0.65±6.7
	10	*Olea europaea*	3±27.5	5±54.4	10±154	4.13±36.7
	11	*Osyris lanceolata*	1±9.5	5±54.4	10±154	0.18±1.7
	12	*Pavetta gardeniifolia*	4±32.3	5±54.4	00±00	1.81±18.6
	13	*Pinus patula*	1±9.5	00±00	00±00	0.02±0.3
	14	*Podocarpus latifolia*	13±71.9	25±205.8	30±331.1	11.47±59.3
	15	*Polyscias kikuyensis*	2±21.2	10±75.9	20±216.5	0.29±2.8
	16	*Prunus africana*	4±31.3	10±75.9	10±154	3.56±25.1
	17	*Rapania c.*	1±9.5	7±62.2	20±216.5	0.16±1.4
	18	*Rhus natalensis*	1±9.5	00±00	00±00	0.16±1.3
	19	*Schrebera alata*	1±9.5	00±00	00±00	0.02±0.2
	20	*Vepris nobilis*	1±9.5	00±00	00±00	0.19±0.19
	21	*Yushania alpina*	1457± 567.1	6225± 3617.5	503±934.2	13.62± 10.2

II.2: MEAN STOCKING AND BASAL AREA IN BLOCKS

Blocks		Species	STOCKING (Stems/ha) Trees	Saplings	Seedlings	BASAL AREA (m^2/ha)
BLOCK I	1	*Yushania alpina*	2984±643.8	3457±1813.2	946±1082.5	17.01±8.8
	2	*Podocarpus latifolia*	21±48.5	9±55.5	19±166.7	13.94±31.4
	3	*Juniperus procera*	7±26.5	9±81.4	19±166.7	14.84±49.9
	4	*Cupressus lusitanica*	00±00	131±503.1	00±00	00±00
	5	*Dombeya goetzenii*	5±25.5	16±77.7	37±230.2	1.34±6.1
	6	*Rapania c.*	2±14.3	16±99.6	56±279.1	0.18±1.2
	7	*Prunus africana*	3±17.3	00±00	19±163.4	2.37±11.9
	8	*Pavetta gardeniifolia*	3±17.4	00±00	00±00	2.98±11.9
	9	*Chelumbut(Loc. name)*	1±10.2	00±00	00±00	0.16±1.0
	10	*Olea europaea*	2±11.2	5±40.9	00±00	3.78±3.78
	11	*Acacia kirkii*	1±10.2	00±00	00±00	1.58±1.58
	12	*Rhus natalensis*	1±10.2	00±00	00±00	0.16±0.16
BLOCK II	1	*Yushania alpina*	664±378.5	5697±2030.1	746±851.0	2.8±1.9
	2	*Podocarpus latifolia*	10±37.6	24±125.3	19±166.7	7.44±22.7
	3	*Juniperus procera*	10±40.6	23±107.7	56±372.1	2.83±8.4
	4	*Dombeya goetzenii*	10±44.1	9±57.4	00±00	3.39±12.0
	5	*Grewia bicolor*	2±20.3	9±83.1	00±00	0.53±3.5
	6	*Olea europaea*	2±20.3	9±83.1	19±166.7	0.23±1.3
	7	*Pavetta gardeniifolia*	7±31.6	5±40.9	00±00	0.97±11.9
	8	*Prunus africana*	3±17.4	00±00	00±00	1.37±5.3
	9	*Osyris lanceolata*	3±22.6	14±92.1	00±00	0.4±2.4
	10	*Cypressus lusitanica*	1±10.2	13±87.7	00±00	0.05±0.2
	11	*Myrsine melanophloeos*	1±10.2	00±00	00±00	0.39±1.8
	12	*Ekebergia capensis*	1±10.2	8±51.6	19±166.7	0.22±1.1
	13	*Olea capensis*	1±10.2	00±00	00±00	0.23±2.4
	14	*Pinus patula*	1±10.2	00±00	00±00	0.02±0.1
BLOCK III	1	*Yushania alpina*	961±397.3	8993±2992.9	343±670.1	5.66±1.9
	2	*Ekebergia capensis*	2±12.3	120±255.5	93±423.2	0.38±2.4
	3	*Polyscias kikuyensis*	3±17.4	122±260.1	112±450.1	0.29±1.5
	4	*Grewia bicolor*	3±22.2	40±131.2	19±163.4	0.76±5.5
	5	*Dombeya goetzenii*	2±13.0	49±152.8	93±482.0	0.82±2.7
	6	*Podocarpus latifolia*	6±35.1	12±76.7	19±164.5	0.41±2.4
	7	*Prunus africana*	3±14.1	19±119.3	19±164.5	0.89±4.6
	8	*Schrebera alata*	1±10.2	5±40.9	00±00	0.02±0.2
	9	*Osyris lanceolata*	3±17.4	00±00	19±164.5	0.96±5.0
	10	*Buddleja polystachya*	00±00	00±00	19±164.5	00±00
	11	*Olea capensis*	6±31.5	9±57.4	19±164.5	0.42±1.9
	12	*Juniperus procera*	00±00	68±236.0	37±164.5	00±00
	13	*Pavetta gardeniifolia*	00±00	5±40.9	00±00	00±00
	14	*Grevillea robusta*	00±00	5±40.9	00±00	00±00
	15	*Olea europaea*	1±10.2	00±00	00±00	0.12±1.0
	16	*Vepris nobilis*	1±10.2	00±00	00±00	0.19±1.7
	17	*Acacia nilotica*	00±00	5±40.9	00±00	00±00

APPENDIX III: IMPORTANCE VALUE

III.1: IMPORTANCE VALUE IN BAMBOO STANDS

Bamboo stands	No	Species	Ni	F	RF	RD	RDo	IV
Closed canopy bamboo	1	*Yushania alpina*	3049	86	56.58	96.03	32.64	185.3
	2	*Podocarpus latifolia*	11	11	7.24	7.24	26.32	40.8
	3	*Juniperus procera*	10	7	4.61	4.61	22.8	32.1
	4	*Dombeya goetzenii*	15	7	4.61	4.61	4.4	13.6
	5	*Ekebergia capensis*	18	10	6.58	6.58	0.08	13.3
	6	*Polyscias kikuyensis*	23	9	5.92	5.92	-	11.8
	7	*Grewia bicolor*	6	6	3.95	3.95	3.44	11.3
	8	*Osyris lanceolata*	4	4	2.63	2.63	3.28	8.5
	9	*Prunus africana*	3	3	1.97	1.97	3.04	6.9
	10	*Pavetta gardeniifolia*	2	2	1.32	1.32	3.04	5.7
	11	*Cupressus lusitanica*	29	2	1.32	1.32	0.08	2.7
	12	*Myrsine melanophloeos*	1	1	0.66	0.66	0.88	2.2
	13	*Rapania c.*	1	1	0.66	0.66	-	1.3
	14	*Olea europaea*	1	1	0.66	0.66	-	1.3
	15	*Schrebera alata*	1	1	0.66	0.66	-	1.3
	16	*Buddleja polystachya*	1	1	0.66	0.66	-	1.3
		Total	3175	152	100	100	100	300
Open canopy bamboo	1	*Yushania alpina*	4821	142	55.69	96.3	24.52	176.5
	2	*Podocarpus latifolia*	35	24	9.41	0.7	21.94	32.1
	3	*Juniperus procera*	37	15	5.88	0.74	16.95	23.6
	4	*Dombeya goetzenii*	22	16	6.27	0.44	7.53	14.3
	5	*Olea europaea*	8	9	3.53	0.16	9.8	13.5
	6	*Prunus africana*	5	9	3.53	0.1	7.11	10.7
	7	*Pavetta gardeniifolia*	9	10	3.92	0.18	3.11	7.2
	8	*Olea capensis*	9	6	2.35	0.18	1.5	4.1
	9	*Polyscias kikuyensis*	9	5	1.96	0.18	1.5	3.6
	10	*Acacia kirkii*	1	1	0.39	0.02	3.04	3.5
	11	*Grewia bicolor*	10	6	2.35	0.2	0.04	2.6
	12	*Ekebergia capensis*	16	1	0.39	0.32	1.35	2.1
	13	*Rapania c.*	7	3	1.18	0.14	0.27	1.6
	14	*Osyris lanceolata*	4	1	0.39	0.08	0.46	0.9
	15	*Vepris nobilis*	1	1	0.39	0.02	0.46	0.9
	16	*Rhus natalensis*	1	1	0.39	0.02	0.31	0.7
	17	*Pinus patula*	7	1	0.39	0.14	0.04	0.6
	18	*Chelumbut(Loc. name)*	1	1	0.39	0.02	0.04	0.5
	19	*Schrebera alata*	1	1	0.39	0.02	0.04	0.5
	20	*Grevillea robusta*	1	1	0.39	0.02	0.04	0.5
	21	*Acacia nilotica*	1	1	0.39	0.02	-	0.4
		Total	5006	255	100	100	100	300

KEY: **ni:** Number of individuals of the species, **F:** Frequency, **RF:** Relative frequency, **RD:** Relative dominance, **RDo**: Re;lative density, **I.V.:** Importance Value.

III.2: IMPORTANCE VALUE IN BLOCKS

Block	N°	Species	ni	F	RF	RD	RDo	IV
Block I	1	*Yushania alpina*	3343	76	63.87	97.49	28.94	190.3
	2	*Podocarpus latifolia*	21	17	14.29	0.61	24.8	39.7
	3	*Juniperus procera*	9	6	5.04	0.26	23.6	28.9
	4	*Olea europaea*	3	3	2.52	0.09	7.33	9.9
	5	*Prunus africana*	4	4	3.36	0.12	4.6	8.1
	6	*Pavetta gardeniifolia*	3	3	2.52	0.09	4.21	6.8
	7	*Dombeya goetzenii*	9	5	4.2	0.26	2.07	6.5
	8	*Acacia kirkii*	1	1	0.84	0.03	3.08	3.9
	9	*Chelumbut(Loc. name)*	1	1	0.84	0.03	0.78	1.7
	10	*Cupressus lusitanica*	26	1	0.84	0.76	-	1.6
	11	*Rapania c.*	8	1	0.84	0.23	0.27	1.4
	12	*Rhus natalensis*	1	1	0.84	0.03	0.31	1.2
		Total	3429	119	100	100	100	300
Block II	1	*Yushania alpina*	1776	76	56.72	95.84	14.53	167.1
	2	*Podocarpus latifolia*	16	14	10.45	0.86	28.84	40.2
	3	*Juniperus procera*	17	14	10.45	0.92	14.07	25.4
	4	*Dombeya goetzenii*	11	7	5.22	0.59	19.19	25
	5	*Pavetta gardeniifolia*	7	5	3.73	0.38	5.7	9.8
	6	*Prunus africana*	3	1	0.75	0.16	8.37	9.3
	7	*Grewia bicolor*	4	4	2.99	0.22	1.86	5.1
	8	*Osyris lanceolata*	5	4	2.99	0.27	1.4	4.6
	9	*Olea europaea*	5	3	2.24	0.27	1.51	4.1
	10	*Ekebergia capensis*	3	2	1.49	0.16	1.51	3.2
	11	*Olea capensis*	1	1	0.75	0.05	1.51	2.3
	12	*Myrsine melanophloeos*	1	1	0.75	0.05	1.28	2.1
	12	*Cypressus lusitanica*	3	1	0.75	0.16	0.12	1.1
	14	*Pinus patula*	1	1	0.75	0.05	0.12	0.9
		Total	1853	134	100	100	100	300
Block III	1	*Yushania alpina*	2751	76	49.03	94.93	41.92	185.8
	2	*Ekebergia capensis*	31	16	10.32	1.07	5.39	16.8
	3	*Polyscias kikuyensis*	32	14	9.03	1.1	6.09	16.2
	4	*Dombeya goetzenii*	17	8	5.16	0.59	7.73	13.5
	5	*Grewia bicolor*	12	9	5.81	0.41	6.56	12.8
	6	*Prunus africana*	7	5	3.23	0.24	7.73	11.2
	7	*Olea capensis*	8	6	3.87	0.28	6.09	10.3
	8	*Podocarpus latifolia*	9	6	3.87	0.31	5.15	9.3
	9	*Osyris lanceolata*	3	1	0.65	0.1	6.79	7.5
	10	*Juniperus procera*	20	5	3.23	0.69	-	3.9
	11	*Vepris nobilis*	1	1	0.65	0.03	2.81	3.5
	12	*Schrebera alata*	2	2	1.29	0.07	1.87	3.3
	13	*Olea europaea*	1	2	1.29	0.03	1.64	2.9
	14	*Grevillea robusta*	1	1	0.65	0.03	0.23	0.9
	15	*Buddleja polystachya*	1	1	0.65	0.03	-	0.7
	16	*Pavetta gardeniifolia*	1	1	0.65	0.03	-	0.7
	17	*Acacia nilotica*	1	1	0.65	0.03	-	0.7
		Total	2898	155	100	100	100	300

APPENDIX IV: FULL LIST OF TREES SPECIES ENCOUNTERED DURING THE STUDY SHOWING THEIR FAMILIES AND RESPECTIVE AUTHORS

N^{o}	Species and respective authors	Family
1	*Acacia kirkii subsp. Kirkii*	Fabaceae
2	*Acacia nilotica (L.) Willd. ex Del.*	Fabaceae
3	*Yushania alpina (K.Schum)W.C.Lin*	Poaceae
4	*Buddleja polystachya Fresen.*	Loganiaceae
5	*Chelumbut(Loc. name)*	–
6	*Cupressus lusitanica Mill*	Cupressaceae
7	*Dombeya goetzenii K.Schum*	Sterculiaceae
8	*Ekebergia capensis Sparrm.*	Meliaceae
9	*Grevillea robusta A.Cunn.*	Proteaceae
10	*Grewia bicolor Juss.*	Tiliaceae
11	*Juniperus procera Endl.*	Cupressaceae
12	*Myrsine melanophloeos (L.)R.Br.*	Myrsianaceae
13	*Olea capensis L.subsp.welwitschii (Knobl) Friis &P.S. Green*	Oleaceae
14	*Olea europaea L.subsp.africana (Mill.). P. Green*	Oleaceae
15	*Osyris lanceolata Hochst.&Steudel*	Santalaceae
16	*Pavetta gardeniifolia Hochst. ex A.Rich.*	Rubiaceae
17	*Pinus patula Schldl.&Cham.*	Pinaceae
18	*Podocarpus latifolia (Thunb) Mirb*	Podocarpaceae
19	*Polyscias kikuyensis Summerh*	Araliaceae
20	*Prunus africana (Hook.f.) Kalkm.*	Rosaceae
21	*Rapania c.*	–
22	*Rhus natalensis (Krauss)*	Anacardiaceae
23	*Schrebera alata (Hochst.)Welw.*	Oleaceae
24	*Vepris nobilis (Delile)W.Mziray*	Rutaceae

APPENDIX V: DIVERSITY INDEX

V1: DIVERSITY INDEX IN BAMBOO STANDS

Nº	Species	Trees	pi*pi	Saplings	pi*pi	Seedlings	pi*pi	ni	Ai
CLOSED CANOPY BAMBOO									
1	*Yushania alpina*	1570	0.96405	1427	0.8954	52	0.5847	3049	0.9603
2	*Podocarpus latifolia*	10	0.00004	1	0.0000	-	-	11	0.0035
3	*Juniperus procera*	4	0.00001	3	0.0001	3	0.0019	10	0.0031
4	*Dombeya goetzenii*	2	0.00001	10	0.0001	3	0.0019	15	0.0047
5	*Ekebergia capensis*	1	0.00000	14	0.0001	3	0.0019	18	0.0057
6	*Polyscias kikuyensis*	-	-	19	0.0002	4	0.0035	23	0.0072
7	*Grewia bicolor*	3	0.00001	3	0.0001	-	-	6	0.0019
8	*Osyris lanceolata*	3	0.00001	1	0.0000	-	-	4	0.0013
9	*Prunus africana*	2	0.00001	-	-	1	0.0002	3	0.0009
10	*Pavetta gardeniifolia*	2	0.00001	-	-	-	-	2	0.0006
11	*Cupressus lusitanica*	1	0.00000	28	0.0003	-	-	29	0.0091
12	*Myrsine melanophloeos*	1	0.00000	-	-	-	-	1	0.0003
13	*Rapania c.*	-	-	-	-	1	0.0002	1	0.0003
14	*Olea europaea*	-	-	1	0.000	-	-	1	0.0003
15	*Schrebera alata*	-	-	1	0.0000	-	-	1	0.0003
16	*Buddleja polystachya*	-	-	-	-	1	0.0002	1	0.0003
	Total	**1599**	**0.964**	**1508**	**0.896**	**68**	**0.595**	**3175**	**1**
	D		***1.037***		***1.116***		***1.681***		
OPEN CANOPY BAMBOO									
1	*Yushania alpina*	2248	0.927664	2523	0.941646	50	0.482253	4821	0.9630
2	*Podocarpus latifolia*	22	0.000089	10	0.000015	3	0.001736	35	0.0070
3	*Juniperus procera*	12	0.000026	22	0.000072	3	0.001736	37	0.0074
4	*Dombeya goetzenii*	13	0.000031	5	0.000004	4	0.003086	22	0.0044
5	*Olea europaea*	5	0.000005	2	0.000001	1	0.000193	8	0.0016
6	*Prunus africana*	5	0.000005	-	-	-	-	5	0.0010
7	*Pavetta gardeniifolia*	7	0.000009	2	0.000001	-	-	9	0.0018
8	*Olea capensis*	6	0.000007	2	0.000001	1	0.000193	9	0.0018
9	*Polyscias kikuyensis*	3	0.000002	4	0.000002	2	0.000772	9	0.0018
10	*Acacia kirkii*	1	0.000000	-	-	-	-	1	0.0002
11	*Grewia bicolor*	1	0.000000	8	0.000010	1	0.000193	10	0.0020
12	*Ekebergia capensis*	2	0.000001	11	0.000018	3	0.001736	16	0.0032
13	*Rapania c.*	2	0.000001	3	0.000001	2	0.000772	7	0.0014
14	*Osyris lanceolata*	1	0.000000	2	0.000001	1	0.000193	4	0.0008
15	*Vepris nobilis*	1	0.000000	-	-	-	-	1	0.0002
16	*Rhus natalensis*	1	0.000000	-	-	-	-	1	0.0002
17	*Pinus patula*	2	0.000001	4	0.000002	1	0.000193	7	0.0014
18	*Chelumbut(Loc. name)*	1	0.000000	-	-	-	-	1	0.0002
19	*Schrebera alata*	1	0.000000	-	-	-	-	1	0.0002
20	*Grevillea robusta*	-	-	1	0.000000	-	-	1	0.0002
21	*Acacia nilotica*	-	-	1	0.000000	-	-	1	0.0002
	Total	**2334**	**0.928**	**2600**	**0.942**	**72**	**0.493**	**5006**	**1**
	D		***1.078***		***1.062***		***2.028***		

KEY: **pi** and **ai**: proportion of individuals of species, **ni**: number of individuals of the species: ***D***: Simposon's Index of Diversity.

V2: DIVERSITY INDEX IN BLOCKS

BLOCK I

Nº	Species	Trees	pi*pi	Saplings	pi*pi	Seedlings	pi*pi	ni	ai
1	*Yushania alpina*	2544	0.9685301	751	0.90829	48	0.73469	3343	0.9749
2	*Podocarpus latifolia*	18	0.0000485	2	0.00001	1	0.00031	21	0.0061
3	*Juniperus procera*	6	0.0000054	2	0.00001	1	0.00031	9	0.0026
4	*Olea europaea*	2	0.0000006	1	0.00002	-	-	3	0.0009
5	*Prunus africana*	3	0.0000014	-	-	1	0.00032	4	0.0012
6	*Pavetta gardeniifolia*	3	0.0000014	-	-	-	-	3	0.0009
7	*Dombeya goetzenii*	4	0.0000024	3	0.00002	2	0.00127	9	0.0026
8	*Acacia kirkii*	1	0.0000002	-	-	-	-	1	0.0003
9	*Rhus natalensis*	1	0.0000002	-	-	-	-	1	0.0003
10	*Chelumbut*	1	0.0000002	-	-	-	-	1	0.0003
11	*Cupressus lusitanica*	-		26	0.00108	-	-	26	0.0076
12	*Rapania c.*	2	0.0000006	3	0.00002	3	0.00287	8	0.0023
	Total	**2585**	**0.969**	**788**	**0.91**	**56**	**0.73979**	**3429**	**1**
	D		***1.032***		***1.100***		***1.352***		

BLOCK II

Nº	Species	Trees	pi*pi	Saplings	pi*pi	Seedlings	pi*pi	ni	ai
1	*Yushania alpina*	492	0.833207	1246	0.962562	38	0.7458	1776	0.9584
2	*Podocarpus latifolia*	9	0.000279	6	0.000022	1	0.00052	16	0.0086
3	*Juniperus procera*	9	0.000279	5	0.000016	3	0.00465	17	0.0092
4	*Dombeya goetzenii*	9	0.000279	2	0.000002	-	-	11	0.0059
5	*Pavetta gardeniifolia*	6	0.000124	1	0.000001	-	-	7	0.0038
6	*Prunus africana*	3	0.000031	-	-	-	-	3	0.0016
7	*Grewia bicolor*	2	0.000014	2	0.000002	-	-	4	0.0022
8	*Osyris lanceolata*	2	0.000014	3	0.000006	-	-	5	0.0027
9	*Olea europaea*	2	0.000014	2	0.000002	1	0.00052	5	0.0027
10	*Ekebergia capensis*	1	0.000003	1	0.000001	1	0.00052	3	0.0016
11	*Olea capensis*	1	0.000003	-	-	-	-	1	0.0005
12	*Myrsine melanophloeos*	1	0.000003	-	-	-	-	1	0.0005
13	*Cypressus lusitanica*	1	0.000003	2	0.000002	-	-	3	0.0016
14	*Pinus patula*	1	0.000003	-	-	-	-	1	0.0005
	Total	**539**	**0.834**	**1270**	**0.963**	**44**	**0.752**	**1853**	**1**
	D		***1.199***		***1.039***		***1.330***		

BLOCK III

Nº	Species	Trees	pi*pi	Saplings	pi*pi	Seedlings	pi*pi	ni	ai
1	*Yushania alpina*	782	0.936679	1953	0.907605	16	0.16000	2751	0.9493
2	*Ekebergia capensis*	2	0.000006	24	0.000137	5	0.01563	31	0.0107
3	*Polyscias kikuyensis*	3	0.000014	23	0.000126	6	0.02250	32	0.0110
4	*Dombeya goetzenii*	2	0.000006	10	0.000024	5	0.01563	17	0.0059
5	*Grewia bicolor*	2	0.000006	9	0.000019	1	0.00063	12	0.0041
6	*Prunus africana*	2	0.000006	4	0.000004	1	0.00063	7	0.0024
7	*Olea capensis*	5	0.000038	2	0.000001	1	0.00063	8	0.0028
8	*Podocarpus latifolia*	5	0.000038	3	0.000002	1	0.00063	9	0.0031
9	*Osyris lanceolata*	2	0.000006	-	-	1	0.00063	3	0.0010
10	*Juniperus procera*	-	-	18	0.000077	2	0.00250	20	0.0069
11	*Vepris nobilis*	1	0.000002	-	-	-	-	1	0.0003
12	*Schrebera alata*	1	0.000002	1	0.000000	-	-	2	0.0007
13	*Olea europaea*	1	0.000002	-	-	-	-	1	0.0003
14	*Grevillea robusta*	-	-	1	0.000000	-	-	1	0.0003
15	*Buddleja polystachya*	-	-	-	-	1	0.00063	1	0.0003
16	*Pavetta gardeniifolia*	-	-	1	0.000000	-	-	1	0.0003
17	*Acacia nilotica*	-	-	1	0.000000	-	-	1	0.0003
	Total	**808**	**0.937**	**2050**	**0.908**	**40**	**0.220**	**2898**	**1**
	D		***1.067***		***1.101***		***4.545***		

KEY: **pi** and **ai**: proportion of individuals of species, **ni**: number of individuals of the species: ***D***: Simposon's Index of Diversity.

V3: TEST OF NORMAL DISTRIBUTION (Shapiro-Wilks and Kruskal-Wallis), HOMOGENEITY OF VARIANCE (Levene's test), ONE-WAY ANOVA AND T-TEST

DATA TRANSFORMATION

Variables	**Status of data**	**Statistics analysis**	**Trees**	**Saplings**	**Seedlings**
In bamboo stands	Original data	Shapiro-Wilks	0.000*	0.000*	0.000*
		Levene's test	0.000*	0.000*	0.000*
	Transformed Data	Kruskal-Wallis	0.213**	1.000**	0.884**
		Levene's test	0.921**	0.539**	0.630**
		p-value (T-Test)	*0.527***	*0.856***	*0.983***
Within blocks	Original data	Shapiro-Wilks	0.000*	0.000*	0.000*
		Levene's test	0.000*	0.000*	0.000*
	Transformed Data	Kruskal-Wallis	0.214**	0.648**	0.321**
		Levene's test	0.729**	0.783**	0.964**
		p-value (One-way ANOVA)	*0.530***	*0.809***	*0.709***

KEY: *p*: *p*robability, *: Not met at $p \leq 0.05$, **: Met at $p > 0.05$.

T-TEST IN BAMBOO STANDS (SPECIES DIVERSITY)

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Trees	Equal variances assumed	.010	.921	-.639	35	.527
Saplings	Equal variances assumed	.385	.539	.183	35	.856
Seedlings	Equal variances assumed	.237	.630	.021	35	.983

ONE WAY ANOVA IN BLOCKS (SPECIES DIVERSITY)

		Sum of Squares	Df	Mean Square	F	Sig.
Trees	Between Groups	.683	2	.342	.646	.530
	Within Groups	21.173	40	.529		
	Total	21.857	42			
Saplings	Between Groups	.284	2	.142	.214	.809
	Within Groups	26.601	40	.665		
	Total	26.885	42			
Seedlings	Between Groups	.125	2	.063	.347	.709
	Within Groups	7.228	40	.181		
	Total	7.354	42			

INDEPENNDENT SAMPLES TEST (SPECIES SIMILARITY)

T-TEST IN BAMBOO STANDS

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	Sig.	T	Df	Sig. (2-tailed)
Equal variances assumed	.422	.519	-.322	46	.749

T-TEST IN BLOCKS

Pair of compared blocks		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	T	df	Sig. (2-tailed)
Block I and Block II	Equal variances assumed	.083	.775	.123	46	.903
Block I and block III	Equal variances assumed	.751	.391	.417	46	.679
Block II and block III	Equal variances assumed	.387	.537	.320	46	.751

APPENDIX VI: CORRELATION MATRIX BETWEEN EDUCATION, OCCUPATION OF HOUSEHOLD HEADS IN USE OF BAMBOO

VI.1: Correlation between education of household heads and use of bamboo

		Primary	Secondary	None
Primary	Pearson Correlation		1.000**	.182
	Sig. (2-tailed)		.000	.066
	N		78	103
Secondary	Pearson Correlation	1.000**		.117
	Sig. (2-tailed)	.000		.307
	N	78		78
None	Pearson Correlation	.182	.117	
	Sig. (2-tailed)	.066	.307	
	N	103	78	

**. Correlation is significant at the 0.01 level (2-tailed).

VI.2: Correlation between family size classes of households and use of bamboo

		No one	1-3	4-6	7-9 and above
No one	Pearson Correlation		0.019	.019	-.412
	Sig. (2-tailed)		.954	.954	.183
	N		12	12	12
1-3	Pearson Correlation	0.019		0.770**	0.085
	Sig. (2-tailed)	0.954		0.000	0.405
	N	12		166	98
4-6	Pearson Correlation	.019	.770**		.085
	Sig. (2-tailed)	.954	0.000		.405
	N	12	166		98
7-9 and Above	Pearson Correlation	-.412	0.085	.085	
	Sig. (2-tailed)	.183	0.405	.405	
	N	12	98	98	

VI.3: Correlation between occupation of household heads and use of bamboo

		Crop farming	Livestock	Hunting	Self employment	Trader/ Business
Crop farming	Pearson Correlation		.034	-.107	-.099	.770
	Sig. (2-tailed)		.652	.596	.625	.230
	N		175	27	27	4
Livestock	Pearson Correlation	.034		-.254	-.240	-.139
	Sig. (2-tailed)	.652		.202	.228	.861
	N	175		27	27	4
Hunting	Pearson	-.107	-.254		.149	.058

	Correlation					
	Sig. (2-tailed)	.596	.202		.457	.942
	N	27	27		27	4
Self employment	Pearson Correlation	-.099	-.240	.149		1.000**
	Sig. (2-tailed)	.625	.228	.457		.000
	N	27	27	27		4
Trader/Business	Pearson Correlation	.770	-.139	.058	1.000**	
	Sig. (2-tailed)	.230	.861	.942	.000	
	N	4	4	4	4	

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX VII: USE OF BAMBOO AND THREATS TO BAMBOO FOREST RESOURCES

VII.1: Different uses of bamboo

Respondents	Fencing		Construction		Furniture making		Firewood		Medicine		Cultural activities		Total
	F	%	F	%	F	%	F	%	F	%	F	%	
Forest officers	17	25.4	13	19.4	6	9.0	10	14.9	8	11.9	13	19.4	67
Local community	113	22.9	92	18.6	23	4.7	113	22.9	55	11.1	98	19.8	494
Total	130	23.2	105	18.7	29	5.2	123	21.9	63	11.2	111	19.8	561

KEY: F: Frequency; %: Percentage.

VII.2: Threats to bamboo forests of Mariashoni and Njoro forests

Respondents	Logging of trees for sawing		Selective cutting of trees for charcoal burning		Cutting of bamboo for domestic uses		Encroachment		Cattle grazing		Fires by honey gatherers or charcoal burners		Natural fires		Total
	F	%	F	%	F	%	F	%	F	%	F	%	F	%	
Forest officers	12	14.1	14	16.5	17	20	8	9.4	14	16.5	13	15.3	7	8.2	85
Local community	112	19.6	113	19.8	113	19.8	9	1.6	114	20	104	18.2	5	0.9	570
Total	124	33.7	127	36.3	130	19.8	17	2.6	128	19.5	117	17.9	12	1.8	655

KEY: F: Frequency; %: Percentage.

APPENDIX VIII: CHI-SQUARE TEST FOR GOODNESS OF FIT

VIII.1: Use of bamboo

Test statistics	Respondents	
	Forest officers	Local community
Chi-Square	7.060	78.794
Df	5	5
Sig. (*p-value*)	0.216	0.000

VIII.2: Status of bamboo forests

Test statistics	Respondents	
	Forest officers	Local community
Chi-Square	6.294	28.895
Df	3	2
Sig. (*p-value*)	0.098	0.000

VIII.3: Threats to bamboo forest resources

Test statistics	Respondents	
	Forest officers	Local community
Chi-Square	6.165	191.404
Df	6	6
Sig. (*p-value*)	0.405	0.000

VIII.4: Number of times the local community have access to forest resources

Test statistics	Respondents	
	Forest officers	Local community
Chi-Square	9.118	67.474
Df	3	3
Sig. (*p-value*)	0.028	0.000