

**EFFECTS OF HUMAN ENCROACHMENT ON
NATURAL REGENERATION OF INDIGENOUS TREES SEEDLINGS IN
KIMAKIA FOREST, MURANG'A COUNTY, KENYA**

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University

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DEDICATION

I dedicate this thesis to my parents Mr. and Mrs. Muriithi and my siblings; Elias Murimi, Saint Zawadi, and Marjah Wanje.

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LIST OF ABBREVIATIONS AND ACRONYMS

CFA	Community Forest Association
CITES	Convention on International Trade on Endangered Species
FAO	Food Agricultural Organization
HH	House Holds
IDPs	Internally Displaced People
IUCN	International Union for Conservation of Nature
KDHS	Kenya Demographic Health Survey
KFS	Kenya Forest Service
KSH	Kenya Shilling
NEIMs	National Environmental Information Management Systems
NRITs	Natural Regeneration of Indigenous Trees Seedlings
NTFPs	Non-Timber Forest Products
PELIS	Plantation Establishment Livelihood Improvement Scheme
SDGs	Sustainable Development Goals
SEM	Sustainable Environmental Management
SPSSs	Statistical Program for Social Sciences
SSR	Seedling Species Richness
UNEP	United Nations Environmental Program
WCMC	World Conservation Monitoring Centre

ABSTRACT

Degradation of the world's forests has been increasing due to human induced activities. As the world population continues to increase so is degradation. Natural regeneration of indigenous trees seedlings is the most effective way of rehabilitating degraded forests. The main objective of the study was to assess the effects of human encroachment on natural regeneration of indigenous trees seedlings in Kimakia Forest. A descriptive research design was used while mixed research method was used to collect the data in the field. By use of photography, human encroachment was identified inside Kimakia Forest. Ecological data were obtained from twenty quadrats with an inter-quadrant spacing of 40 Meters that were laid systematically in ten (10) transects, each measuring 800 Meters long and laid perpendicular to the forest edge at an inter-transect spacing of 500 Meters. Indigenous trees seedlings in each quadrat were counted and recorded respectively. To determine the extent of human activities by the members of the community in the forest, questionnaires were administered to a sample of 218 households through stratified random sampling technique. Interviews were conducted on key informants selected through purposive sampling technique. Ecological data was analyzed using Shannon Wiener Diversity Index while quantitative data was analyzed using SPSS software version 20. Qualitative data was grouped into themes and was later used to back up quantitative data. Species diversity was established to be moderately good with an index of 2.01. Regression analysis showed that there was no significant relationship between the total regeneration of indigenous seedlings counts and the distance from the forest edge with a P-value of 0.076. The study rejected the hypothesis that the diversity of indigenous tree seedlings in Kimakia Forest is significantly affected by the distance from the forest edge with a P-value of 0.675. Land scarcity and readily available market for forest products were major factors leading to human encroachment. Other factors included unemployment and low income per month. The study concluded that human activities in Kimakia Forest affect natural regeneration of indigenous trees seedlings. Market availability for forest products and population pressure will continue causing negative impacts in Kimakia Forest if there is no proper forest management. This study recommends Kenya Forest Service to map out regeneration curves of indigenous trees seedlings in the forest into various categories; for example, good, average and poor so as to monitor sustainability through natural regeneration. This will also enhance viable track of the various reasons attributed to low and high counts of indigenous trees seedlings in the forest.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Population growth-rate, high rate of unemployment coupled with poverty around the globe has consequently affected forest cover (Hailu *et al.*, 2012). In their research findings, Nyukuri (2012) realized that high dependency on forest resources by communities within the precincts of Kieni Forest of Aberdare ranges, resulted to over-exploitation of forest resources. Over exploitation of forest resources puts majority of them at the verge of extinction. Access of forest resources involves tampering with ecosystem services such as water cycle, carbon sequestration and natural regeneration of seedlings which predicts future forest cover (Marques *et al.*, 2019). As a result, natural regeneration of indigenous tree seedlings has also been affected (Chazdon, 2014). According to Laurance *et al.* (2011), human encroachment in the world's largest forest, Amazon has highly influenced species diversity by reduced natural regeneration of indigenous trees seedlings within its precincts.

In Mexico, human impacts on the terrestrial ecosystem reflect reduced productivity and biodiversity leading to high intensity of natural disturbance. This triggers a reduction in habitat distribution and species dominance (Holmgren *et al.*, 2006). In their Himalaya study findings, Rawal *et al.* (2012) found that low elevation *Q. leucotrichophora* (Camus) and *Q. semecarpifolia* (James Edward Smith) oak forests demoed high predisposition towards disturbance intensities. The conclusions from the findings depicted that, forests that were close to human habitation had high disturbance

frequency hence affecting regeneration of the oak tree species resulting to its degradation.

Interference of natural regeneration of indigenous tree seedlings in the Fluvanna Forest of Southwestern Ethiopia has been as a result of human encroachment (Tadasse, 2014). Grazing activities and conversion of natural forests for settlements are outcomes of population pressure coupled with increasing demands for wood (Tadesse *et al.*, 2014).

In their study, Mugagga *et al.* (2017) found that increased degradation in Bwindi National Park of Uganda together with eastern slopes of Mt Elgon was as a result of human encroachment. This includes activities of agriculturalist, uncontrolled exploitation, and selective timber harvesting which led to loss of indigenous tree seedlings.

Human encroachment in Kakamega forest for selective timber Seswa (2016) and herbs has interfered with the regeneration of indigenous tree seedlings in the forest (Zamorano-Elgueta, 2014). Factors such as grazing and gathering of wild fruits are also experienced at different parts in the forest resulting in variations on diversity in the same forest (Esther *et al.*, 2014). Cultural activities and practices in the Mt Kenya forest are additional human-induced activities that interrupt natural regeneration of indigenous tree seedlings leading to degradation (Okumu, 2017).

1.2 Statement of the Problem

High rate of deforestation in Kenya has continued to affect various development sectors such as; building and construction, infrastructure, manufacturing, and tourism (Andrée *et al.*, 2019). This is because the resources required to achieve growth have all been directed towards efforts of achieving the 10% forest cover against 7% where Kenya's

forest stands (KFS, 2010). Conservation of indigenous trees is important following their numerous advantages in our society (Tab 4.5). In Africa, population growth rate has exacerbated the need for more land for settlement and food production making forests an easy target (Shirley *et al.*, 2012). Even though population is increasing in every country, Kenya is amongst the top countries where population is rapidly increasing per (1million) annum (KNBS, 2019). Population increase in Kenya lays within ecological zones that record high and adequate rainfall to support agriculture (KNBS, 2013). Most of these places where the population is on the increase are adjacent to catchment areas of tremendous importance to Kenya.

The other major driving force of forest degradation in Kenya according to Hertel and Rosch (2010) is extreme poverty and rate of unemployment coupled with an increasing population. Hertel and Rosch (2010) further explain that demand for more land to sustain livelihoods lay pressure on the expanding households. The option of forest resources becomes an alternative out of a ready market. All these factors lead to human encroachment (Duguma *et al.*, 2015).

Human encroachment highly interferes with natural regeneration leading to degradation (Guarnaschelli *et al.*, 2012). These activities make sustainability of the forests in unachievable where Kimakia Forest is not an exception. The outcomes of degradation in Kenya's forests have been low water levels of rivers such as Mara River, drying up of dams like Ndakaini which is a major source of water for Kiambu and part of Nairobi's residents (Kiptum, 2017). Another impact of forest degradation is climate change where we have shift of short rains to long rains resulting to submerged species. Other research has been done to show the impacts of human activities on the general vegetation cover in the forest. Conservation of specific mature tree stands have also been researched on,

living out regeneration of indigenous tree seedlings which is a simulation of mature tree stands in future. The research adopted use of indicator species of human encroachment to assess the impacts. Indicator species were *Neoboutania macro calyx* (Airy Shaw), *Rauvolfia caffra* (Sond) and *Teclea nobilis* (Delile) indigenous trees seedlings. Their presence shows human intrusion on natural forest growth. Therefore, the study focused on the effects of human encroachment on the natural regeneration of indigenous tree seedlings in Kimakia Forest, Murang' a County.

1.3 Objectives

The main objective of this study was to assess the effects of human encroachment on the natural regeneration of indigenous trees seedlings in Kimakia Forest.

1.3.1 Specific Objectives

This study was guided by the following specific objectives

1. To analyze regeneration of indigenous tree seedlings in Kimakia Forest as affected by human encroachment from the forest edge
2. To determine indigenous tree seedlings diversity in Kimakia Forest as affected by human encroachment from the forest edge
3. To assess the factors leading to human encroachment in Kimakia Forest

1.4 Research Questions

This study sought to answer the following research questions

1. How is the regeneration of indigenous seedlings in Kimakia Forest affected by human encroachment from the forest edge?

2. How is the diversity of indigenous tree seedlings in Kimakia Forest affected by human encroachment from the forest edge?
3. What are the factors leading to human encroachment in Kimakia Forest?

1.5 Research Hypotheses

1. Regeneration of indigenous tree seedlings abundance in Kimakia Forest is significantly affected by the distance from the forest edge
2. The diversity of indigenous tree seedlings in Kimakia Forest is significantly affected by the distance from the forest edge

1.6 Significance of the Study

The adjacent community to Kimakia forest draws a lot of biodiversity related services from the forest including medicine, firewood, honey and others that could be an incentive to conserve the forest for posterity and thereby supporting global conservation goals. Kimakia Forest is part of the larger Aberdare Ranges (Chikamai, 2014) which drains its water to Ndakaini dam, a major water source to Kiambu and part of Nairobi's residents (Tibaijuka, 2007). It is therefore important to protect natural regeneration of trees seedlings in Kimakia Forest which enhances ecological services. In the quest to satisfy community members conterminous to Kimakia Forest, there's the need to use the forest sustainably.

The results of regeneration and diversities along the areas of study, in this case; the distances (40-800) Meters are a measure to the trend happening deep in the forest. Presence of animals such as rats has large surface area to volume ratio. According to Lunn *et al.* (2018), incidences of strong wind could also sweep away the seedlings to

other points in the forest resulting to high seedlings counts at some points while other points could be low or zero counts.

The research findings could be used by policymakers to ensure that prompt decisions based on found facts will be implemented and applied to monitor and safeguard natural regeneration of indigenous tree seedlings. This will enhance sustainable environmental management practices and forest health. It will also enhance the influence of wellbeing and social outcomes such as purification of water. The findings could be a reference point to other upcoming scholars as they endeavor to chip in towards knowledge on forest management. The information gained from this study could be imperative to successful planning and decision making, which could be used to strengthen the National Environmental Information Management System (NEIMs).

1.7 Conceptual Framework

Forest degradation is directly or indirectly influenced by social-economic factors, climatic factors, and policy & legislation guidelines. Collection of medicinal plants, expansion of roads, settlements, plantation establishment and livelihood improvement scheme (PELIS), and grazing, are among the social-economic factors of forest degradation. On the other hand, climatic factors such as temperature, rainfall, wind, and light intensity could also naturally lead to forest degradation.

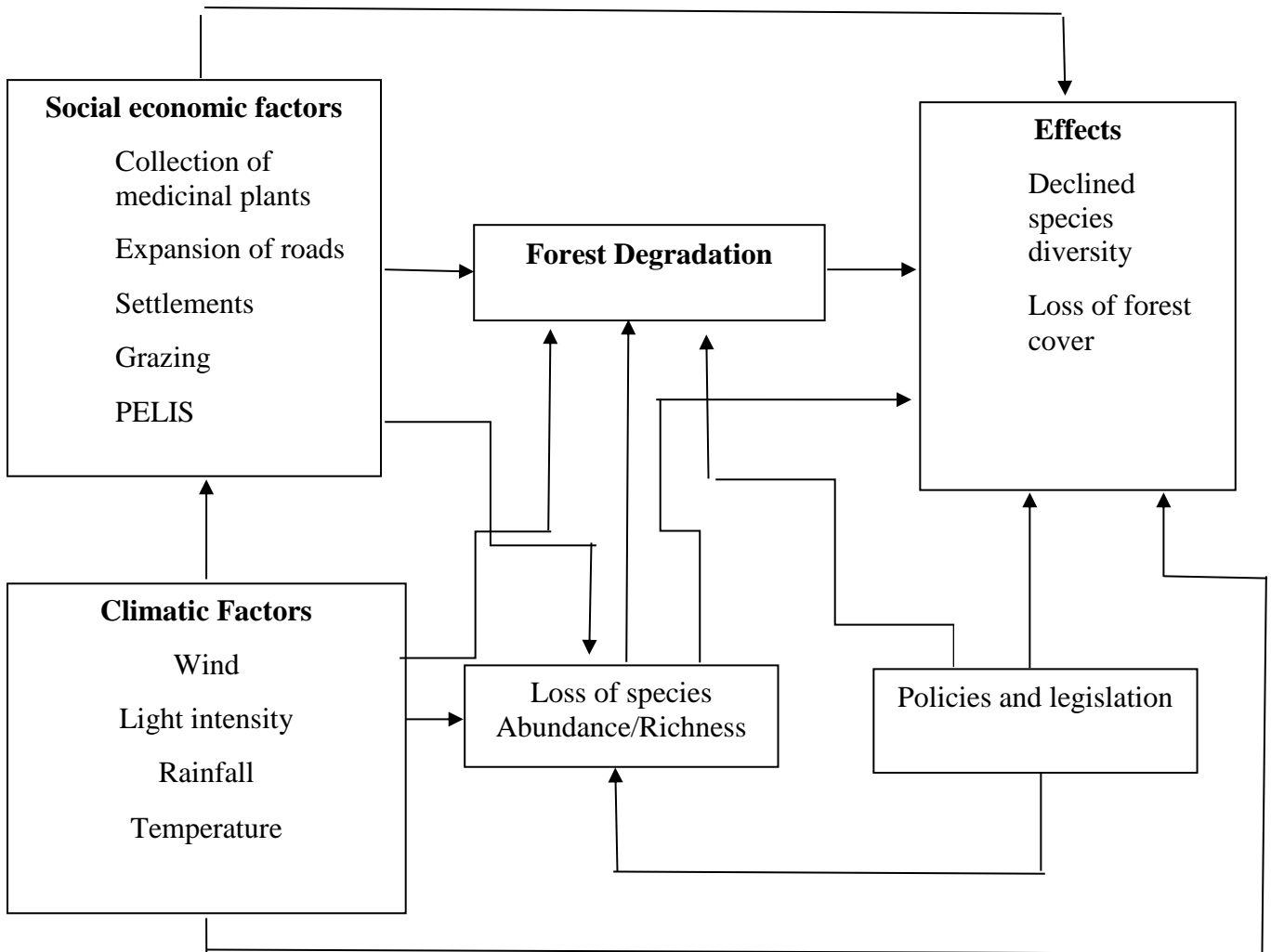


Figure:1.1 Conceptual Framework

Additionally, loss of species as a result of climatic and/or social-economic factors could also contribute to degradation. Weak policies and legislation guidelines as well as poor implementation of sound ones have over the decades impeded efforts to curb forest degradation. These factors act synergistically to negatively influence species diversity and natural regeneration. The independent variables are the social-economic factors and climatic factors, while the dependent variables are the loss of species and forest degradation. This is because loss of species and degradation depend on the human

activities or climatic factors for them to occur. The measures (intervening variables) employed to enhance forest health by the government are the policies and legislation.

1.8 Definition of Terms

Arbore scent	Tree-like in growth or appearance (Xie <i>et al.</i> , 2019)
Biodiversity	A variability among living organisms from all sources including inter-alia terrestrial marine and other aquatic ecosystem and species between species and ecosystems (Danis <i>et al.</i> , 2020)
Catchment	An area where water is collected by the natural landscape (Cecchi <i>et al.</i> , 2020)
Degradation	Changes within the forest which negatively influence the sustainability of forest resources in terms of providing products or services (Chaz don, 2014)
Human Encroachment	The spread of people, transportation frameworks, utilities, structures, and other advancement into regions not withstanding it is because of improvement, agribusiness, or moving populaces (Zarzo-Arias <i>et al.</i> , 2020)
Forest	A large area with a high diversity of trees that forms a closed canopy and harboring many plants and animal species (Bastin <i>et al.</i> , 2019)
Forest encroachment	Any human-induced activity in the forest that is detrimental to the survival of a forest. It may result in gaps in the forest

or changes in vegetation characteristics, or a total clearance of the forest (Cheyne *et al.*, 2013).

Indicator species	A species whose status provides information that reflects on the quality and changes in environmental conditions as well as aspects of community compositions (Baughman <i>et al.</i> , 2019).
Indigenous trees	Availability of a specie to a given region whose presence is as a result of a natural process, with no human intervention (Deur & Bloom 2020).
Natural regeneration	restoration of tree cover, usually seedlings which naturally grows after previous forest or trees have been removed (Lewis <i>et al.</i> , 2019).
Pioneer Species	These are those species that colonize a barren land that could have been reduced by human activities in the forest or climatic conditions colonizing open spaces that previously supported vegetation (Jakovac <i>et al.</i> , 2021).
Species Abundance	Total number of individuals per different families (Flora & Fauna) present in a particular ecological unit (Tiusanen <i>et al.</i> , 2019).
Species Richness	The total number of different families (Flora & fauna) represented in an ecological unit (Tiusanen <i>et al.</i> , 2019).
Tree seedling	A tree that is less than three feet in height (Gebeyehu <i>et al.</i> , 2019)

CHAPTER TWO

LITERATURE REVIEW

2.0 Income Generation

Drivers of illegal forest resource extraction are both employment and unemployment (Schaafsma *et al.*, 2014). On employment, sufficient finances would enhance illegal extraction of forest resources, in addition to the factor of the tragedy of the common who are after their selfish gains exceeding the benefit that a certain forest resource would hold to the adjacent community (Zeller & Birner, 2012). On the other hand, unemployment would drive one to the forest to do all they can to the best of their abilities to fulfill their basic needs amongst them shelter and food.

In their findings, Steel & van Lindert, (2017) established that farming in Mentigi forest was one of the biggest and profitable activities in Cameroon. This happened in that any open government land was converted to farming for agriculture expansion to enhance economic value (Jiao *et al.*, 2015). These activities however led to the degradation of Mentigi Forest Reserve in Cameroon (Zin & Ahmad, 2014).

Lack of other means of livelihood makes a population to move inside the forests (Greiner & Sakdapolrak, 2013) intending to generate income to sustain families and individuals in the growing population. This is evident in that urban life tends to be more expensive than rural livelihood (Patel & Burke, 2009).

2.1 Relationship between Human Activities and Natural Regeneration in the Forest

Degradation in Amazon Forest is attributed to the rate at which agricultural expansion and increased farming activities are taking place. In addition, another factor of

encroachment is rapid population increase (Laurance, 2011). In the northern Peruvian Andes Forest, issues of degradation have been due to interfered regeneration as a result of encroachment attributed to activities of collection of edible fruits, flowers, tubers, roots and leaves for food and medicine, grazing of livestock and collection of marketable non- timber forest products (De Peralta, 2015).

In areas where non - timber forest products were collected, natural regeneration of indigenous tree seedlings was inhibited (Jevon and Shackleton, 2015). Human-induced activities in the forest of Bligiri Rangan Hills in India include; harvesting of non-timber forest products (NTFP), fuel wood collection, and cattle grazing (Mallegowda, 2015).

Selective logging, charcoal production, and timber management are said to have hindered regeneration of indigenous tree seedlings in Luquillo forest (Lugo *et al.*, 2014). According to Lugo *et al.* (2014), impacts remained apparent in terms of shifts in species and regeneration of canopy species around the abandoned charcoal kilns. The impacts were said to have had adverse impingements on forest regeneration and increased spatial heterogeneity of the forest.

Kenyan forests are as well degraded Korir (2016), since agricultural practices and settlements took place in Mau forests (Lambretchts *et al.*, 2003). Other human activities in Kakamega forests are collection of medicinal herbs and grazing which highly interfered with natural regeneration of indigenous trees seedlings (Esther *et al.*, 2014).

Activities of exploitation of *Prunus africana* (Hook.f), *Funtumia africana* (Benth), *Antiaris toxicaria* (Lesch), *Uvariopsis congensis* (Adolf Engler) and *Aningeria altissima* (Fusée Aublet) tree species in Kakamega Forest have led to their decline from natural regeneration (Yeshitela, 2008). In his study, Althof, (2005) found out that the

rate at which the species were regenerating was different between the highly disturbed areas and those areas that were left undisturbed; an indication that regeneration in most disturbed areas affects seedlings species richness (SSR).

2.2 Leading Causes of Forest Encroachment

2.2.1 Demand Increase over the Carrying Capacity

Population growth rate in Ghana and Tanzania has led to conflicts between the respective governments and human encroachment in the forest as a means of their livelihoods (Akabzaa, 2009). In Kenya, population increase in Mau region brought fire breakouts in the forest which brought down some trees and other vegetation (Githumbi *et al.*, 2021). This greatly degraded Mau Forest by affecting seedlings regeneration and tree stands (IBID). Rapid population increase will continue exerting great pressure on the environment due to demand increase over the carrying capacity. Population pressure will lead to competition of space for settlement, farming, and agriculture to support the growing population. With such conditions, forest resources become alternatives to livelihood security.

2.2.2 Rural-Urban Migration

Rural-urban migration influences one to eye forest resources resulting to forest encroachment (Komugabe *et al.*, 2019). According to their findings, Komugabe *et al.* (2019) further realized that moving to towns increases financial demand over house rent, water bills, and transportation bills which are more expensive unlike in the villages where the mode of transportation is cheap. Addition of buildings for settlement leads to unsustainable harvesting of value timber trees such as camphor which exposes it to further degradation (KFS, 2010).

Urbanization in Kakamega town has led to the interference of the Kakamega forest. This is because of increased demands of forest resources following high unemployment rates in Kenya and a readily available market for goods such as charcoal, firewood, and timber (Cadman *et al.*, 2017).

2.2.3 Agriculture

Farming is one of the biggest and profitable activities in Cameroon (Steel and van Lindert 2017). Steel and van Lindert (2017), realized that such activities involve growing and export of plantation products such as tea, flowers, vegetables, and fruits in Malaysia (Allias *et al.*, 2014). Following their high demands in Malaysia, these activities have caused illegal agriculture and farming.

Farmers in Cameroon take advantage of government land, in that any open land was converted to land for farming and agriculture. These activities of encroachment however led to degradation of Mentigi forest reserve in Cameroon. This is because indigenous tree species of economic value were jeopardized (Nasution, 2008).

2.3 Tree Species Diversity

Globally, Moist Tropical Forests and Woodlands have most species richness habitat and harbor immense terrestrial and aquatic biodiversity (Mace *et al.*, 2012). Indigenous forests are essential habitats for ecosystem services. These services include biomass production, pollination, seed dispersal, fire regulation and mitigation, pest regulation of native and invading insects, carbon sequestration, and cultural ecosystem services, concerning forest type, structure, and diversity (Brockerhoff *et al.*, 2017).

In their study findings Omoro *et al.* (2010) found that as expected in the tropics, indigenous forests have higher species richness. They further argued that high species

richness could be attributed to higher levels of disturbances their study area had undergone.

Modern agriculture, since the last 25 years, overstocking and charcoal production for Brazil steel industry has immensely led to the decline of the Brazilian Cerrado (savanna) biome (May, 2010). This compares to destruction of 13% of the Brazilian Amazon Forest, (Morton *et al.*, 2006).

In Ecuador and Peru, explorations of oil and gas blocks cover more than 2/3 of the Amazon (Haselip & Romera, 2011). This happens in Bolivia and western Brazil as well. These exploration activities are simulated to increase rapidly (Lilleskov *et al.*, 2018) further affecting species diversity as a result of human influences.

Conversion of natural vegetation to farmlands in Uganda under the influence of market and population pressure highly affected species richness and diversity (Newbold *et al.*, 2015). This was as a result of the large tracks involved in clearing the natural forest to sustain agricultural activities for the improvement of livelihoods. From such activities, Uganda's farms largely influenced the loss of indigenous tree species diversity (Boffa *et al.*, 2008).

A study done in Tanzania at Kitulanghalo forest by Stangeland (2008), showed that out of 133 arboreal species in 31 families, 69% is split to 12 categories of uses. From this, major uses showed to be charcoal and firewood, medicine, and poles respectively. This in a way indicating that a tree with many uses, may end up being over-exploited at a rate that exceeds their regeneration affecting diversity (Ibid).

Stangeland (2008) realized that in Kitulanghalo forest, 98% tree species of *Milletia sp.* (Wight and Arn) and *Dialium holtzii* (Harms) were used for wooden poles, construction

of dwellings and storage facilities; these trees are at a risk of depletion due to their high demands. A study done in Mau Forest by Mutiso *et al.* (2015) showed that anthropogenic disturbances such as logging led to diversity loss of species in the forest which affected sustainability and resilience of the forest.

Mutiso *et al.* (2015) assert that a study done in the year 1990 in the Mau Forest and one done in the year 2015 showed a decrease in plant species in that the family with the highest species diversity was *Rutaceae* with six species in the year 2015 while in the year 1990 to the contrary, were *Rubiaceae* (20 species), *Compositae* (17 species), *Acanthaceae* (14 species) and *Asplenium* with 14 species. The loss of the species within the time difference reflects biodiversity loss.

Studies in Chepalungu Forest, showed reduced forest cover and diversity into shrub level especially at the edge (Kiprotich, 2016). Other studies done in western Mau block among the selected areas including Keriso, Londiani, Mt Blackett, and Kericho blocks by Kipkorir *et al.* (2013) showed low diversity due to high disturbance of human activities (Ibid).

2.4 Natural Regeneration

In Peruvian lowlands forests, natural disturbances of tree fall, hurricanes, landslides, and anthropogenic effects of selective logging have negatively affected natural regeneration of indigenous tree seedlings (Quilter, 2005). From the study, Quilter (2005) realized that anthropogenic effects interact with natural forces to enhance recuperation. The findings were that anthropogenic disturbances can determine landscape patterns of damage due to disturbances such as hurricane and fires to counter effects on species composition and forest structure (Ibid).

2.5 Climatic Factors Affecting Natural Regeneration

2.5.1 wind

Wind is a factor that affects natural regeneration of indigenous tree seedlings through physiological and mechanical impact (Dey *et al.*, 2019). Physiological impact is how the cells of a seed work. Wind results in increased rate of drying up of a seed by replacing humid air by hot dry air in the inter cellular spaces (Gangopadhyay *et al.*, 2020). In their research findings Gangopadhyay *et al.* (2020) realized that physiological impacts of acute wind results to drying up of the seedling intercellular spaces hindering its growth, consequently affecting its regeneration. Mechanical seed destruction includes disturbance on soil conditions. At higher wind speeds, trees stand begin to uproot or experience stem breakage, they may knock off branches, break or uproot adjacent trees as they fall through the canopy. This results to deposition of seedlings to different parts in the forest again affecting regeneration where at points, there may have high seedlings counts while other points could record low or no counts.

2.5.2 Rainfall

Another factor affecting natural regeneration is Rainfall. Rainwater has a more elevated level of oxygen and is liberated from harmful minerals found in tap water (Al-Taai, 2021). In a situation where there is less moisture in the soil, nutrients run off leads to poor plant growth. On the other hand, too much of rain water can lead to mold, fungus growth in the soil again hindering growth. In their study on effects of diversity and species richness, Yadav *et al.* (2020) realized that in areas where volcanic eruptions are common, acid rain is common. Yadav *et al.* (2020) further explains how acidic nature removes nutrients from the soil which in turn deteriorate plant growth hence affecting natural regeneration of indigenous tree seedlings.

2.5.3 Temperature

During the warm springs and summers, temperatures tend to raise even in the forests (Wondzell *et al.*, 2019). Wondzell *et al.* (2019) realized that a corresponding decrease in the availability of water increased the rate of evaporation. In their findings Wafuta *et al.* (2019) realized that this increased the risk of wild fires in Mau Forest consequently reducing diversity and vegetation cover. Prolonged droughts consequently affect plant growth, as one of the conditions necessary for germination is water. Inadequate water hinders regeneration of seedlings in the forest as the seedlings require a lot of water to burst out the seedling sprout to enhance its growth. All these factors considerably affect natural regeneration of indigenous trees seedlings where Kimakia Forest is not an exception.

2.6 Literature Gap

Natural regeneration of indigenous tree seedlings is a profound simulation of future forest indigenous tree species diversity, that will account to the 10% forest cover as targeted. Factors affecting indigenous trees species diversity are such as; activities in the natural forest which results to human encroachment of forest habitation. However, there are no published studies which have tried to research on the extent of the effects of species population structure in the forest. In addition, there exists no attempts to study trends of natural regeneration in relationship to the distance from the forest edge around the globe. Other factors are such as climate change which has brought shift of short rains to long rains causing submerged seedlings. Moreover, research on climate change exist but not in comparison to regeneration of indigenous seedlings in the forest. Studies done are such as; distribution, utilization, and management of *Prunus africana* (Hook.F) in Gichugu, Kirinyaga County by Weru, (2012) and micro-propagation of

endangered medicinal and indigenous multipurpose tree species: *Erythrina abyssinica* (Lam & DC) by Kirika *et al.* (2015). These studies on forest degradation have concentrated on the importance of specific indigenous trees and how best they can be used sustainably. They all specified more on indigenous trees without studying their seedlings regeneration which is a determinant of future indigenous tree stands.

From the literature reviewed, it is evident that there exist gaps in natural regeneration as a result of human encroachment on natural forests. The study sought to find out the effects of human encroachment on natural regeneration of indigenous tree seedlings in Kimakia Forest, Muranga County, Kenya.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

The study took place in Kimakia Forest which cuts across Kariara and Gatakaini Wards in Murang' a County (Fig 3.1). The forest occupies a total land area of 12,997.20 hectares (Lambrechts *et al.*, 2003). Kimakia Forest station has the second largest indigenous forest of 6,941.1 ha after Ol-bolossat station which has 9,335 ha (KFS, 2010).

Kimakia Forest experiences bimodal rainfall where; long rains occur from March to May and short rains from October to November (Lambrechts *et al.*, 2003). Rainfall goes to a maximum of 2600 mm annually on the southern slopes and drops to less than 900 mm a year on the northern slopes (Anderson & Christian 2003). Kimakia Forest lies between Latitude of 0° 45' 0'' S and 0° 47' 30'' S, longitudes 36° 43' 30'' E and 36° 48' 0'' E, with annual mean temperatures of 12°C minimum and 24°C maximum (Ibid).

The forest has rich volcanic soils with vegetation consisting of plantation forest 1130.70 hectares, bamboo 4852.40 hectares, and glades covering 50 hectares and tea-zone covering 23 hectares (Lambrechts *et al.*, 2003). The plantation forest contains three dominant exotic species namely *Cupressus lusitanica* (Mill), *Pinus patula* (Schiede ex schltl. & Cham), and *Eucalyptus grandis* (Maiden). Dominant indigenous tree species in the forest include; *Macaranga kilimandscharica* (Pax), *Neoboutonia macrocalyx*, *Rauvolfia caffra*, *Teclea nobilis*, *Xanthoxylum giletii* (De Wild), *Ocotea usambarensis* (Eng.) *Podocarpus falcatus* (Thunb), *Syzgium guineense* (Wall) and *Prunus africana* (Hook.F) (Nyukuri, 2012).

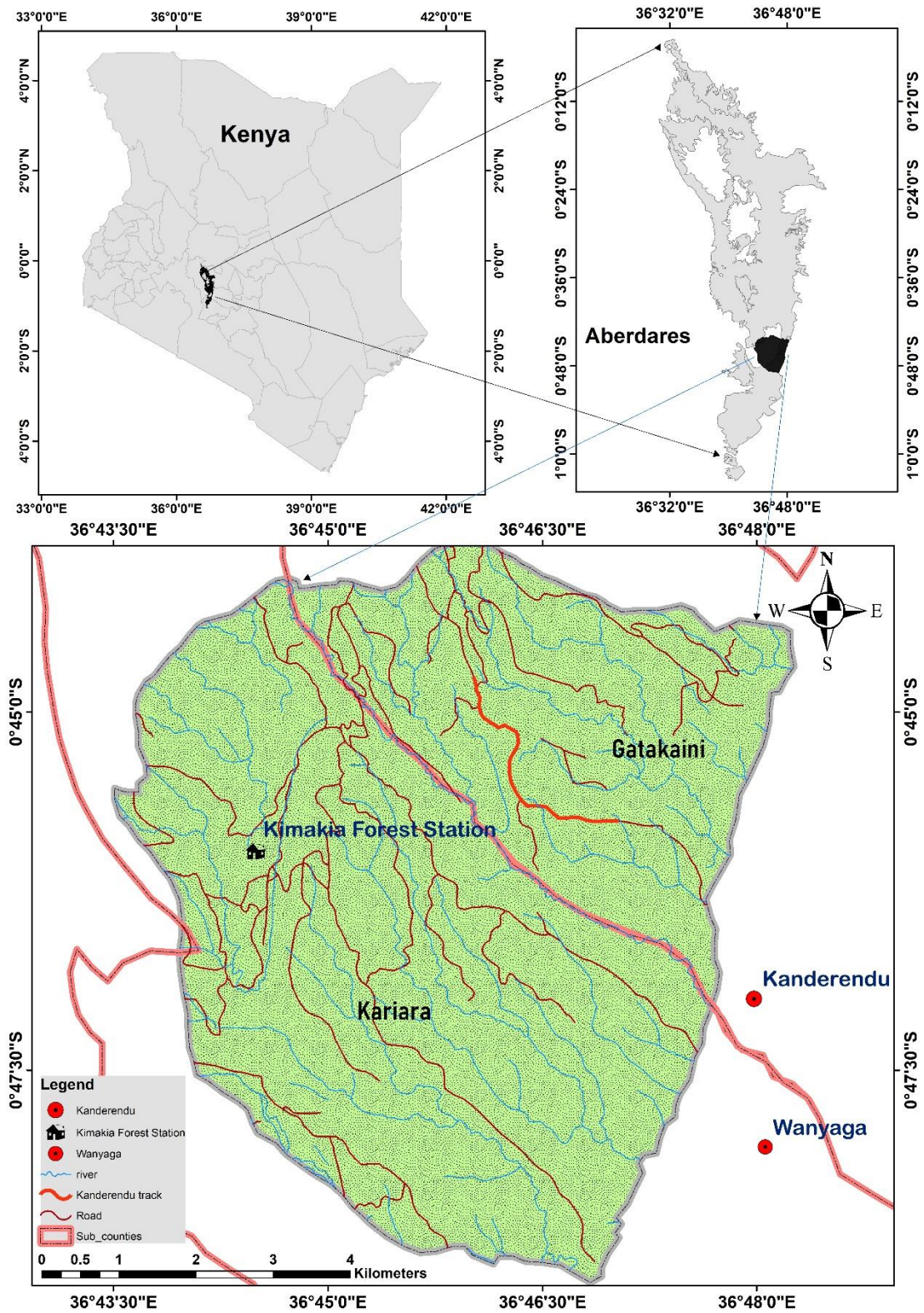


Figure: 3.1 Map of the Study Area

Kimakia Forest is also an important bird area with bird species such as African ibis, Ayres dark eagle, African crowned eagle, stripped fluff tail, and Bailon's crake which are regionally threatened (Nyukuri, 2012). The people bordering Kimakia Forest especially Kariara and Gatakaini Wards engage in farming and smallholder economic activities. Kimakia Forest is divided into two blocks by one major road (Plate 3.1).



Plate: 3.1 A Major Road that Divides Kimakia Forest into Two Blocks

The road leads towards plantation forest and is used by farmers to access their farms in the plantation. The forest is a water catchment area and a source of three rivers namely: Thika, Kimakia, and Kayuyu with a chain of streams bisecting the forest. The ecosystem is a vital source of water to the community and drain into Ndakaini dam which is the main supplier of water to Kiambu and Kenya's capital Nairobi's residents. It is located at an elevation of 2,444 Meters above sea level and is 125.2 kilometers away from Kenya's capital Nairobi (Lambrechts *et al.*, 2003).

3.2 Research Design

A descriptive research design was used in the study. Descriptive research design was used to describe the situation, population and phenomenon using mixed research method. For descriptive survey, questionnaires and interviews were used to collect information from respondents on human encroachment in Kimakia Forest station. A combination of line transects and the quadrant method was used in forest vegetation survey.

3.3 Sample Size and Sampling Techniques

The sample size was calculated using Yamane (1967) formula

$$n = \frac{N}{1 + N(e^2)}$$

Where:

N - is the population size of the study segment

n - Sample size of the study segment

e - is the desired margin of error (0.05)

The total population of Gatakaini and Kariara wards is 1452 people (KNBS, 2019). The two wards have a total of 478 households, with 279 households in Kariara ward and 199 households in Gatakaini ward (KNBS, 2019). Since the sampling unit was the household, applying the formula, out of the total 478 households gave 218 households as the sample size. Simple random sampling technique was used for the household selection. The questionnaires were administered proportionally in the two wards 127 questionnaires in Kariara ward and 91 questionnaires in Gatakaini ward. Two

CFA chairpersons and two foresters both the Chair and the assistance from Kimakia Forest Station formed the key informants who were selected through purposive sampling technique for the specific information required in the study.

3.4 Data Collection Procedure

In a descriptive survey, data collection involved administering questionnaires to the household heads. Distribution of the questionnaires was done through stratified random sampling where the strata unit was the ward. Questionnaires were therein distributed beginning with the nearest household to the forest. A GPS tool was used to mark the first and the last household for future retrieval. Human activities in the forest were observed, recorded, and documented (Appendix 3).

Interviews were conducted for the selected key informants; two Community Forest Association chairpersons (CFAs) and Kimakia Forester. An electronic device (android phone) was used for accurate and detailed information recording from the respondents then transcribed to writing as applied by Matlala & Matlala (2018), whose research realized that the use of smartphones in collecting qualitative data is an important procedure and tool for research.

For ecological data collection, 10 transects were sampled. This is because the acceptable limit ranges (10-100) transect (Turner *et al.*, 2018). Each transect measured 800 meters long and was laid perpendicular to the forest edge towards the core. Along each transect, 20 quadrats measuring 1m by 1m each were laid systematically at intervals of 40 meters. Therefore, 200 quadrats were sampled and recorded. The choice of the size of quadrats was adopted from the book of practical ecology where Slingsby & Cook (2016) explains the use of the smallest sized quadrat as a more accurate method

to achieve data collection on seedlings and saplings research. In each quadrat, observable seedlings were counted and recorded per species (Appendix 4). GPS points were also marked at the beginning and at the end of each transect to enhance waypoints to be relocated in future.

Prior to the study, a reconnaissance was conducted to provide a basis of the areas where the process of laying quadrats begun at 00⁰ 48.031 minutes to the south and 036⁰ 46.393 minutes to the East. This is because the forest was divided by a major road that was used by the forest authorities for surveillance and was also used by the community adjacent Kimakia Forest to access their farms in the plantation forest.

3.5 Data Collection Tools

Data collection tools were questionnaires (Appendix 1), interview schedule (Appendix 2), observation checklist of human activities taking place in Kimakia Forest (Appendix 3) and seedlings regeneration counts for the 10 transects (Appendix 5).

3.6 Data Analysis

Regression and correlation were used to analyze total regeneration and diversity of indigenous trees seedlings using SPSS and Microsoft excel. Qualitative data was grouped in to themes and was further used to back up quantitative data. Ecological data was analyzed by Shannon Wiener Diversity Index (H) which applies the formula;

$$H = -\sum(P_i x \ln p_i)$$

Where;

$\sum P$ - Proportion of the total number of species

$\ln p_i$ - Natural logarithm of the proportion of the total number of species

This was important in determining species richness and evenness. The study adopted Shannon Wiener since it is more reasonable that higher richness represents higher biodiversity in contrast to Simpson Index which measures the relative abundance of species and dominance

The statistics run involved descriptive statistics used to get the mean and standard deviation in the frequency tables. Regression analysis was run to tell the level of significance which was applied to either reject or accept the hypothesis.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter outlines the research findings and discussions of the study. The results of the study are presented in form of figures, plates, percentage, and frequency distribution tables. The chapter presents the socio-economic characteristics of the respondents in Kariara and Gatakaini Wards, regeneration trends of various indigenous trees seedlings together with their diversities, other factors contributing to different regeneration trends and diversities, and the causes of human encroachment in Kimakia Forest.

4.2 Response Rate and Socioeconomic Characteristics of the Respondents in

Kariara and Gatakaini Wards.

One hundred percent of the respondents were available for the study. This response rate was attained because the questionnaires were administered with the aid of research assistants engaged for the exercise. The responses provided were adequate for analysis, recommendations and conclusions. According to Frankel and Wallen, (2004) a response rate of over 95% in any study is deemed to be adequate.

4.2.1 Education level of the Respondents in Kariara and Gatakaini

Majority (54.58 %) of the respondents had acquired primary education as their highest level where as 22.01 % of the respondents had not attended any formal education (Table 4.1).

Table: 4.1 Comparison of Gender and Highest Level of Education of the Respondents in Kariara and Gatakaini Wards

Gender	Education level									
	No education		Primary education		Secondary education		College		University	
	n	%	n	%	n	%	n	%	n	%
Male	20	9.17	76	34.86	28	12.84	6	2.75	1	0.46
Female	28	12.84	43	19.72	7	3.21	4	1.83	5	2.29
Total	48	22.01	119	54.58	35	16.05	10	4.58	6	2.75

The findings indicated that men were more represented at the various levels of education qualification apart from the university level, where women were more presented than men. This is following the opportunity of income generating activities availed by the forest that influenced majority of men into illegal activities over progress in academics, especially at higher education hence lowering the number of men at the university level.

The study findings corroborate those of Garibaldi *et al.* (2017) that out of financial constraints, small scale farming guardians/parents prefer to support the expanding population with food at the expense of education. According to the respondents, their low income coupled with unemployment forces them to forego education for food, clothes, and shelter.

4.2.2 Occupation

Majority 79% of the respondents were farmers while 21% were in other forms of occupation (Figure 4.1).

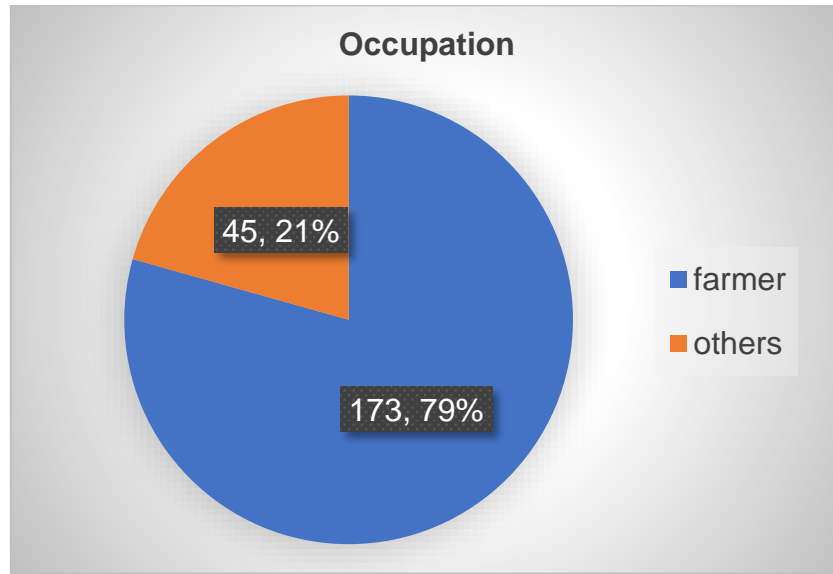


Figure 4.1 Occupation of the Respondents

The findings indicate that farming was the main economic activity taking place within Kimakia Forest precincts. The current study concurs that of Jones *et al.* (2018) whose findings were, that a community living adjacent to a forest relies more on farming following a wide variety of advantages that comes with it. These study findings also corroborate those of Cheruiyot (2019), where factors such as availability of open government forest lands entice farmers to illegally convert to land for farming for more produce and income. The current study findings also concur with that of Wambugu (2018) in that, conversion of government land to farms has since intensified with introduction of PELIS where farmers take advantage as they get to their farms past the natural forest. Conversion of open lands ends up being a form of encroachment, where areas that should be left for natural regeneration to take place are used for other purposes. This negatively influences availability of species Richness which lowers diversity in the entire forest.

4.2.3 Purpose of land gained illegally

Majority 53% of the respondents had acquired illegal land for farming while 47% had acquired land for settlement (Figure 4.2).

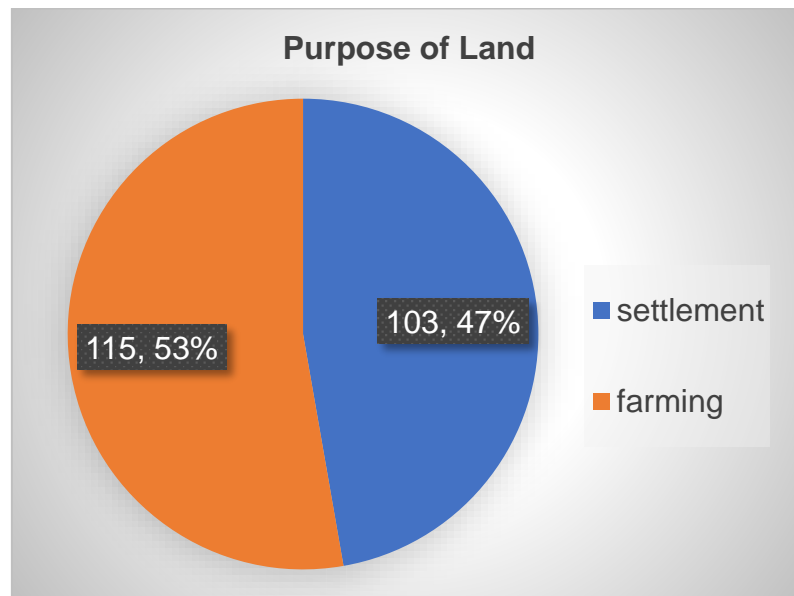


Figure 4.2 Purpose of Land gained Illegally

From one-on-one dialogue, it was evident that the respondents had their way of acquiring either land for settlement or land for farming. From the CFA chairperson, some of the respondents have it in their mind that if one is neighboring a portion of the forest that is not fenced, one can use it to benefit themselves. This made them feel more sense of ownership without knowing the dangers posed to natural regeneration of indigenous tree seedlings. For a community to feel sense of ownership and enhance sustainability, PELIS was introduced. Despite the introduction and implementation of PELIS, the current study findings go in line with those of Parker, (2018) that out of ignorance and selfishness of some individuals, forests resources are mishandled to benefit the various individuals forgetting the impacts they pose on global importance of a tropical forest, such as Kimakia Forest. The ease of acquiring either land for

settlement or farming was as a result of edge effects of incomplete fencing, fishing activities and presence of nursery/seedlings beds in the natural forest. (Plate 4.1)



Plate 4.1 fish pond inside Kimakia Natural Forest

The process of accessing the fish pond and the nursery/seedling beds involves trampling along the regeneration curves resulting to different patterns where some places experiences high counts while others experiencing low or equal to no counts.

4.2.4 Duration of stay

Majority 39.4% of the respondents had stayed within Kimakia Forest precincts for more than 9 years while 7.8% had stayed between 1 to 2 years (Table 4.2).

Table 4.2: Duration of stay

Duration of stay on the illegal land (years)	Frequency (n)	Percentage (%)
1-2	17	7.8
3-4	41	18.8
5-6	22	10.1
7-8	52	23.9
More than 9	86	39.4
Total	218	100

Majority of the respondents who had stayed on the illegal land for more than 9 years were those who settled within the precincts long ago, while minority were those who did not have a share of a portion in the plantation forest. The unproportioned division of land was out of increased population prompting one to take advantage of the open forest land to homes for settlements while other land was converted to tea/agricultural farms.

The current study findings concur with those of Hak *et.al.* (2018) that Grabbing of forest land results to human encroachment through the various activities of cattle grazing, fishing, hunting, and harvesting of barks of trees for medicinal purposes amongst others on forested lands. This means reduced forest productivity and quality hence interfering with spaces for natural regeneration which negatively impacts regeneration patterns, again affecting forest diversity.

4.2.5 Average income per month

Majority 34.9% of the respondents earn between two thousand to two thousand and five hundred Kenya Shillings, while only 7.3% earn more than four thousand Kenya Shillings per month (Table 4.3).

Table 4.3: Average income per month

Income in (ksh) per month	Frequency (n)	Percentage (%)
Up to 500	57	26.1
1000-1500	26	11.9
2000-2500	76	34.9
3000-3500	43	19.7
More than 4000	16	7.3
Total	218	100

The few who were earning four thousand Kenya shillings and above were those in the category of other forms of occupation as in (figure 4.1). From the respondents it was evident that Farming wasn't for commercial but for subsistence to support the growing population as per households (Table 4.2). It was also evident that the average income per month of the respondents wasn't sufficient to support the growing households in numbers hence any chances of income opportunities played a vital role to add in the income per month. Kenya's average lowest income for a farmer is 11,160 Ksh, while for a civil servant is 58,600 Ksh. From this, it clearly indicates reasons to land grabbing of open forest so as to fulfil all the necessities of a large household. Factors such as needs for land to settle and farm results to one relying more on forest resources for their livelihood hence interfering with natural regeneration of indigenous tree seedlings.

4.2.6 Household Size

Majority (59.6%) of the respondents had a household size between 5 to 7 members, while only 0.5% had a household size of one member (Table 4.4).

Table: 4.4 Household Sizes in Gatakaini and Kariara Wards

Household Size	Frequency (n)	Percentage (%)
1	1	0.5
2-4	68	31.2
5-7	130	59.6
8-10	19	8.7
Total	218	100

According to KDHS (2014), the average household size in rural Kenya is four individuals. However, most of the houses with large households were those that had hosted children who had been abandoned due to harsh conditions of financial constraints. It was evident that most of the abandoned children were from their nuclear families and hence taking up the roles of caregiving and providence. According to Arndt *et al.* (2012) large household size in a rural setting reflects characteristics of poverty. The larger the household size the more the land needed for settlement and farming to cater for the needs of each individual (Ibid). According to KNBs (2019), rapid population increase (17.79%) in Gatanga Sub County will increase the number of individuals per house asserting pressure on the carrying capacity as well as over consumption of available forest resources. This will continue degrading Kimakia Forest.

This study substantiates that of Estes *et al.* (2012) that increase in population will result in land-use changes which includes converting areas set for agriculture to settlement, and forested areas to areas for farming and agriculture to support the growing population. Population increase in addition to high rates of unemployment in Kenya

puts forest resources at the risk of degradation due to over-exploitation. The house which had one member belonged to a young individual who had been left as an orphan

4.3 Presence of human activities in Kimakia Forest

Majority 90% of the respondents acknowledged that there were human activities taking place in the natural forest while 10% rejected (Figure 4.3).

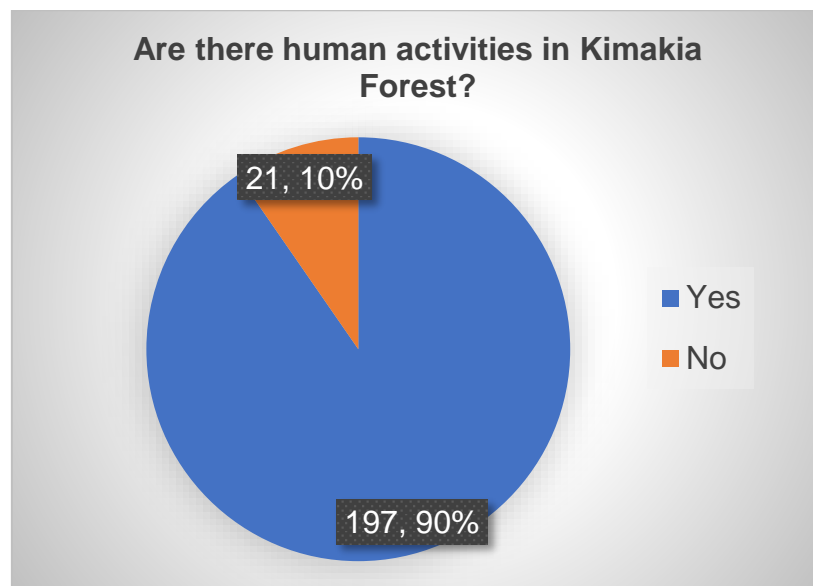


Figure 4.3 Presence of Human Activities Taking Place in Kimakia Forest

Presence of human activities in Kimakia Forest means human encroachment in forested lands. Human activities present in Kimakia Forest are such as water obstruction evidenced through presence of drilled metallic pipes (Plate 4.4), cattle grazing (4.6), fishing; presence of a fish pond (Plate 4.1), human footpaths (Plate 4.2) and, hunting evidenced through presence of animal traps set by human beings (Plate 4.3)

4.4 General regeneration trend of indigenous tree seedlings in Kimakia Forest.

A total of 7 indigenous tree species were enumerated in Kariara and Gatakaini Wards across Kimakia Forest. Dominant indigenous tree species were *Neoboutania*

macrocalyx, *Teclea nobilis*, and *Rauvolfia caffra* with many seedlings occurring at the edge of the forest resulting to a negative gradient. Due to their multiple ecological characteristics, total indigenous trees seedlings regeneration in the forest was recorded low at some points while other areas recorded high seedlings counts (Fig 4.4).

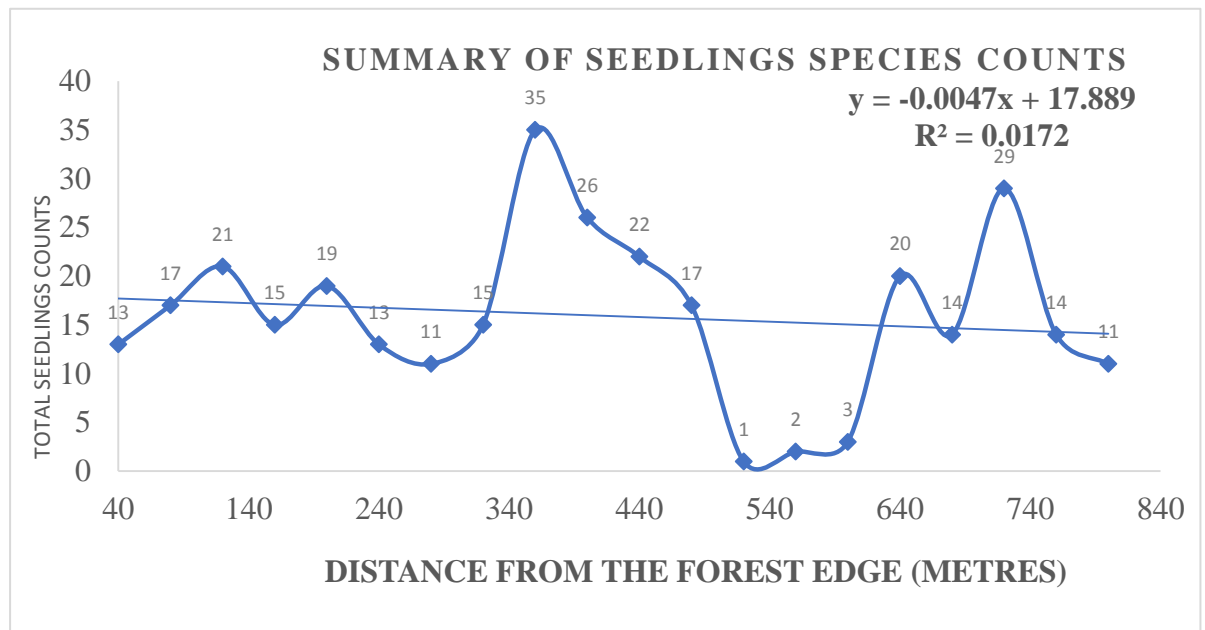


Figure: 4.4 Natural Regeneration Trends of Indigenous Tree Seedlings in Kimakia Forest.

The highest seedlings count was (n) =35 while the lowest count was (n) =0. Seedlings counts increased from 600-750 Meters towards the core of Kimakia Forest. However, there was a precipitous decrease in seedlings counts from (400 – 600) Meters indicating a decrease in natural regeneration of indigenous trees seedlings. It could be possible that some of the indigenous trees seedlings had regenerated from the seed bank of the soil before previous vegetation destruction. Seedlings counts increased with increase in distance from the forest edge. From the graph above change in the X variable resulted to change in Y variable. This indicates that increase in the distance from the forest edge resulted to decrease in the seedlings counts of indigenous tree seedlings. The decrease in counts resulted to a negative gradient. From photographic evidence of activities in

the natural forest, decrease in counts could be attributed to the presence of human footpaths within those areas (Plate 4.4).



Plate: 4.2 Human Footpaths in Kimakia Forest

Other causes of low natural regeneration of indigenous trees seedlings as observed in the forest were activities of human footpaths and hunting. These influences species richness and evenness. The findings concur with those of Sharma *et al.* (2014), where logging in the forest highly affected regeneration of indigenous trees seedlings affecting their abundance and diversity.

Presence of animal traps was evident in the forest. This indicated that hunting was taking place in Kimakia Forest. Hunting activities contribute to disturbance of seedlings in that as one sets the traps, will have to trample on the seedlings hence interrupting on natural regeneration of indigenous trees seedlings in the forest (Plate 4.5).



Plate: 4.3 Animal Traps in Kimakia Forest

Other factors affecting natural regeneration of indigenous seedlings included community and forest management rivalry. This was as a result of restrictions by the forest rangers to access forest resources such as grass and seedlings. The findings corroborate those of Mbuvi, (2018) on ‘impacts of decentralized governance on forest conservation and community livelihoods’ that community restrictions without solidarity in conservation by the management makes the neighboring communities feel denial for sense of ownership. The outcomes are unnecessary conflicts that lead to conservation hardships. The communities engaged in the Plantation Establishment and Livelihood Improvement Scheme (PELIS) would pretend they were going to their farms which are adjacent to the natural forest, but in the process hide their bikes/vehicles and deviate deep in the indigenous forest as far as they could. Despite the restrictions to access the natural forest, water abstraction was apparent within the

forest. Drilled water pipes of 30 centimeters diameter were found 600 meters towards the core of the forest (Plate 4.5).



Plate: 4.4 Drilled Metallic Pipe in Kimakia Forest

According to the forest rangers, illegal water abstraction was done by connecting small pipes in the drilled metallic pipes towards the areas of personal interests. In the process of piping, one could easily trample on the seedlings hence negatively interfering with their natural regeneration.

There was insufficient information from the forest management on the issue of who was licensed to get in the forest and who was not. This weakened the power to control who should go into the forest and who should not. It also invalidated the issue of arresting and the extent of issuing fines. Human activities in the forest resulted to low quality production of resources in Kimakia Forest. In Mexico, Holmgren *et al.* (2006) established that human impacts on terrestrial ecosystem reflect reduced productivity

and biodiversity leading to high intensity of natural disturbance. These disturbances are such as strong winds resulting to felling off trees and seed dispersal that results to high counts at some points and low counts at other points (Plate 4.9).

The current study findings corroborate those of Holmgren *et al.* (2006) in those human activities in the forest trigger poor natural regeneration of seedlings from the forest edge towards the core. The study further corroborates that of Hanief *et al.* (2016), on natural regeneration dynamics of dominant trees seedlings where interruptions in Kimakia Forest involved trampling on seedlings which hindered successful natural regeneration. Despite the negative gradient (Figure 4.4), the study failed to accept the hypothesis that the total regeneration of indigenous tree seedlings in Kimakia Forest is significantly affected by the distance from the forest edge with a P-value of 0.076. This implies that there was no relationship between natural regeneration of indigenous tree seedlings with increase in distance from the forest edge.

4.4.1 Natural regeneration trend of *Teclea nobilis* in Kimakia Forest

There were few seedlings count of *Teclea nobilis* at 40 meters but the count increased between 50 to 440 Meters. The general natural regeneration trend of *Teclea nobilis* increased from the forest edge towards the core with a relationship of $R^2 = 0.1252$. This implied that an increase in distance from the forest edge resulted to increase in seedlings counts as indicated by a positive gradient (Fig 4.5).

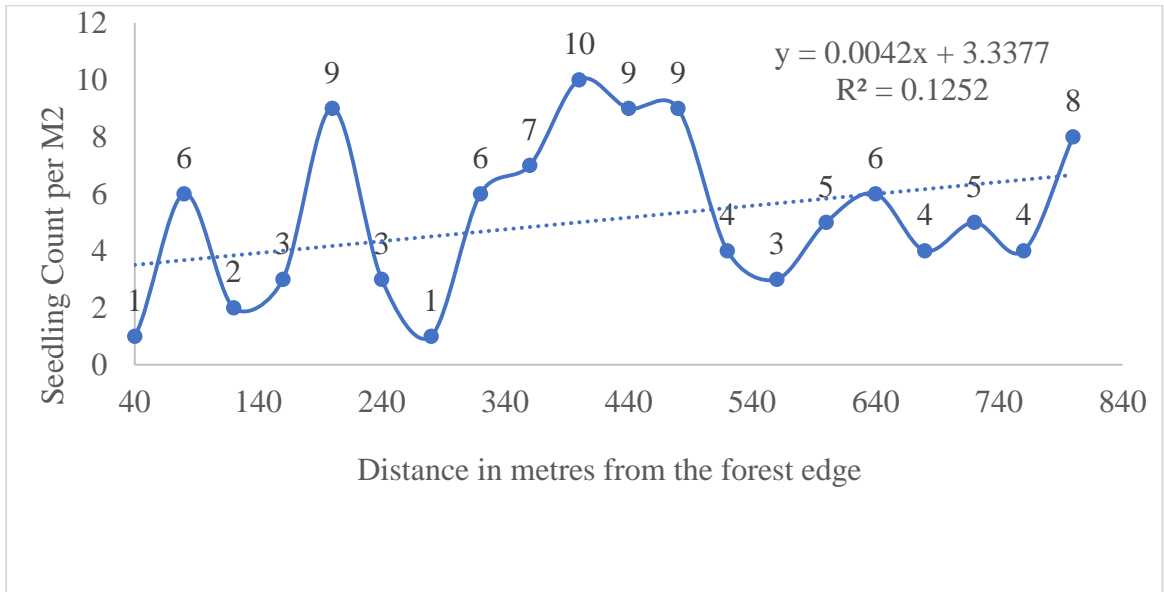


Figure: 4.5 Natural regeneration trend of *Teclea nobilis* in Kimakia Forest

The current study concurs with that of Potts *et al.* (2009) on ‘floristic heterogeneity between forested sites in Kibale National Park of Uganda’ in that *Teclea nobilis* seeds are easily dispositioned by climatic factors of wind intensity and seedbanks brought by landslides caused by loosened soils in the forest. Blösch (2008) realized that *Teclea nobilis* is both an edge and a thicket tree species in that its seeds can thrive under the conditions both in the thickets and at the edge of the forest. In addition, Gebrehiwot & Hundera (2014) found out that its regeneration occurs where there were previous disturbances. The current finding corroborates those of Blösch (2008) and Gebrehiwot & Hundera (2014) since its seedlings were realized throughout the areas of study (40-400) Meters.

4.4.2 Natural Regeneration Trend of *Rauvolfia caffra* in Kimakia Forest

Regeneration trend of *Rauvolfia caffra* in Kimakia Forest showed an upward trend similar to that of *Teclea nobilis* from the forest edge towards the core. An increase in

its seedlings counts towards the core of Kimakia Forest resulted to a positive gradient (Figure 4.6).

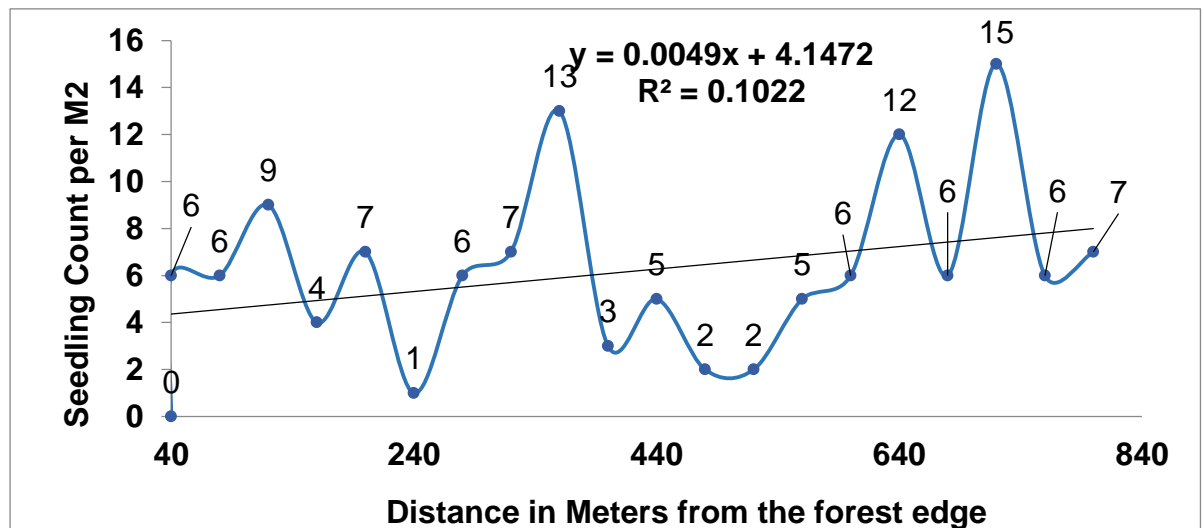


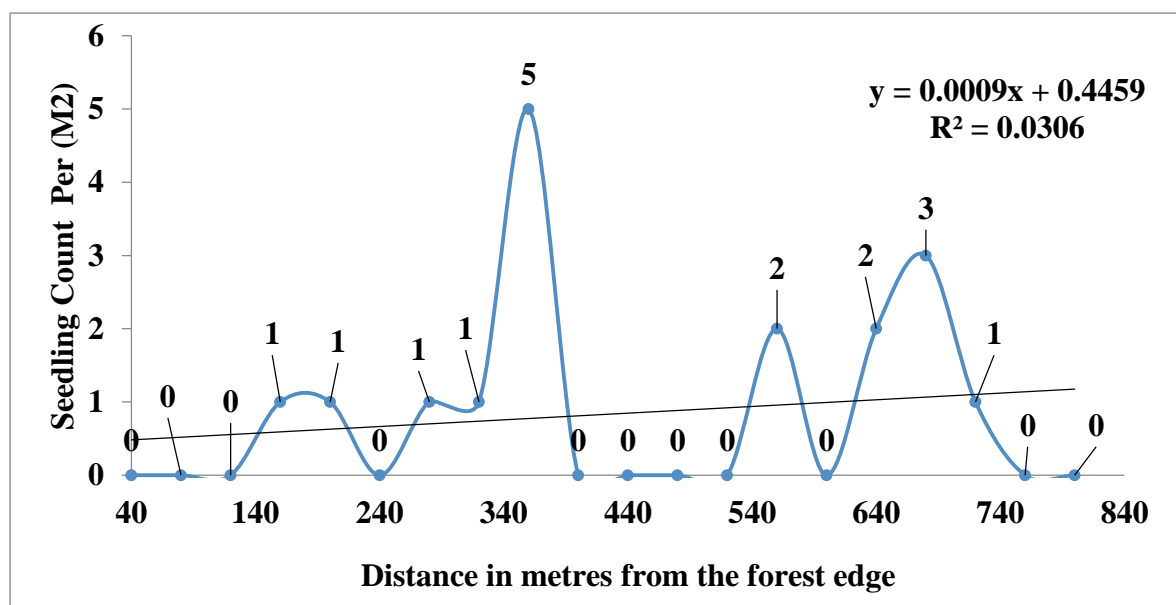
Figure: 4.6 Natural Regeneration of *Rauvolfia caffra* in Kimakia Forest

Change in X resulted to change in Y. This implied that increase in distance from the forest edge resulted to increase in the seedlings counts of *Rauvolfia caffra*. *Rauvolfia caffra* naturally regenerates by coppice, suckers, seed, and root suckers (KFS 2010). The species is also a prolific seed producer, has shade tolerant seedlings, and attracts biotic dispersal agents (Roy, 2016). The current study concurs with that of Roy (2016), where such characteristics would be the probable reason of the behaviour of the regeneration curve presented above (Figure 4.6). However, human activities showed negative impacts to the regeneration of this species and distribution in Kimakia Forest. In addition, Khatri *et al.* (2016) realized that the bark of *Rauvolfia caffra* is used to treat malaria and colic in children. The current study realized that from this health benefit, collection of its seedlings could affect its abundance in the near future. The current study finding corroborates those of Hanief *et al.* (2016) on ‘natural regeneration dynamics of dominant tree seedlings since human activities of harvesting of its bark

and collection of its seedlings/wildings processes involves trampling on the same seedlings which ends up dying.

4.4.3 Natural Regeneration Trend of *Macaranga kilimandscharica* in Kimakia Forest

Unlike other species in Kimakia Forest, seedlings count of *Macaranga kilimandscharica* from 40 – 120 Meters was zero. However, the seedlings count increased towards the core of the forest resulting to a positive gradient. The highest count was recorded at 360 Meters seedlings while most of the distances recorded zero



counts (Fig 4.7).

Figure: 4.7 Natural Regeneration of *Macaranga kilimandscharica* in Kimakia Forest

However, from 280 Meters to 360 Meters there was an increase in its seedlings counts. Between 400 Meters and 520 Meters, there were no seedlings observed at all. However, the general increase in distance from the forest edge resulted to increase in seedlings counts per Meter square with a weak relationship of $R^2 = 0.0306$. This rate of increase was small compared to that of *Teclea nobilis* and *Rauvolfia caffra*. This could be

attributed to the high demand of *Macaranga kilimandscharica* seedlings/saplings which left the people of Kariara and Gatakaini Wards taking the risks of harvesting it as deep as one could get towards the core of the forest. The residents harvest the species from the wild for local use of medicine and source of poles and timber. *Macaranga kilimandscharica* is a fast-growing tree species that naturally fills the gaps in the forest (Bussmann, 2001). However, due to the mentioned high demand, natural regeneration is seriously hampered.

These findings go in line with Tuck-Po, (2016) who during his study on ‘walking with Batek hunter-gatherers in the forests of Pahang’, Malaysia realized that the shorter the distance and the greater the demand of a seedling, the higher the chances to its degradation due to over-exploitation. This explains why no seedlings regeneration was recorded at the edge of the forest. According to Gibson & Joel (2017) *Macaranga kilimandscharica*’s high demand for timber and economic value in the market reduces the chances of its availability from point to point. Its high demand by the local adjacent communities of Kariara and Gatakaini Wards has led to its over-exploitation which would place it at the verge of extinction in future.

The current study findings corroborates that of Szymanski (2017), on ‘detection of anthropogenic environmental impacts in Holocene East Africa’, that, demands for firewood, charcoal, timber and poles, places *Macaranga kilimandscharica* at the threat of intense degradation if sustainable management is not enhanced.

4.4.4 Natural Regeneration Trend of *Ocotea usambarensis* in Kimakia Forest

From 40 to 360 Meters, regeneration of *Ocotea usambarensis* seedlings counts was zero. The highest seedling count was recorded at 580 meters with a total of 5 seedlings.

There were a decline of Seedlings counts from 760 to 800 meters. However, the natural regeneration of *Ocotea usambarensis* showed an upward trend from the forest edge towards the core (Figure 4.8).

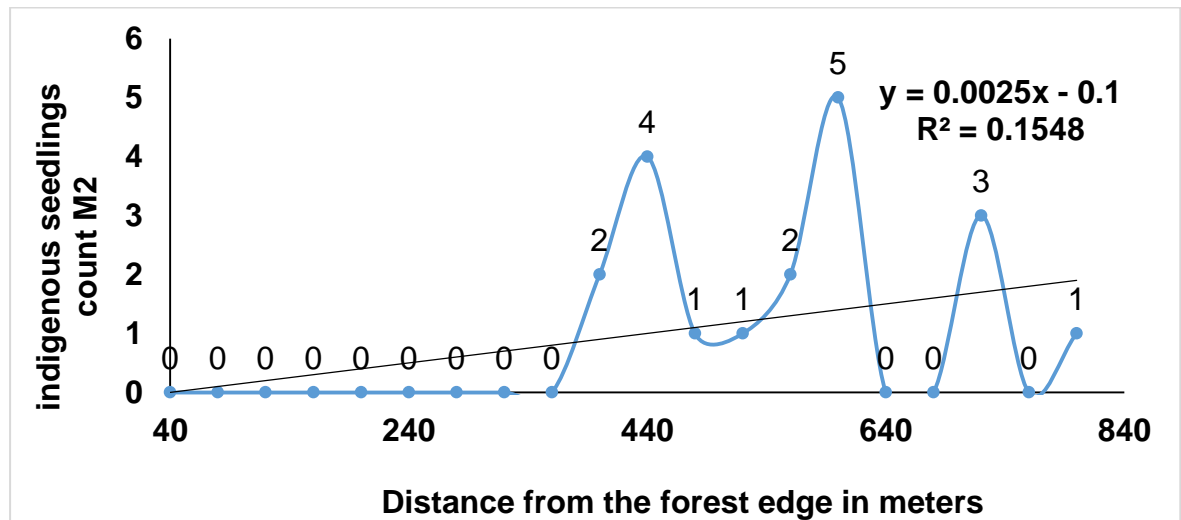


Figure: 4.8 Natural Regeneration of *Ocotea usambarensis* in Kimakia Forest

Distance from the forest edge inwards resulted to increase in seedlings counts per meter square as indicated by the positive gradient with a relationship of $R^2 = 0.1548$ (Fig. 4.8). Poor natural regeneration of *Ocotea usambarensis* near the forest edge could be attributed to its high timber value making it a target of poaching which puts it at the threat of extinction. The findings corroborate those of Kleinschroth *et al.* (2013) who realized that due to its high timber value, *Ocotea usambarensis* is at the danger of facing extinction even after a conservation measure of using vegetative approach was adopted (GM *et al* 2018). Seswa *et al.* (2016) also found that high value for good timber used for construction, furniture and plywood puts *Ocotea usambarensis* at the risk of extinction in future. The process of illegal logging also results in trampling on the seeds/seedlings hence, interfering with its natural regeneration. Illegal logging could have led to low numbers of seedlings counts at the forest edge (Plate 4.5).



Plate: 4.5 Illegally harvested logs in Kimakia Forest

The seedlings of *Ocotea usambarensis* are also harvested as wildings then transferred to private tree nurseries or sold since they have high economic value. Poverty in a fast-growing population lures an individual to draw such resources to cater for their needs of a home to live, furniture, and an extra income to support their growing household.

4.4.5 Natural regeneration trend of *Podocarpus falcatus* in Kimakia Forest

Between 40-80 Meters there were no seedlings of *Podocarpus falcatus*. Seedlings counts increased towards the core of the forest. The highest counts were recorded at 540 Meters with 6 seedlings. The counts decreased from distance 740 to 800 Meters. However, the general regeneration trend of *Podocarpus falcatus* showed an upward trend towards the core of Kimakia Forest as shown by a positive gradient (Figure 4.9) with a weak positive relationship of $R^2 = 0.0415$.

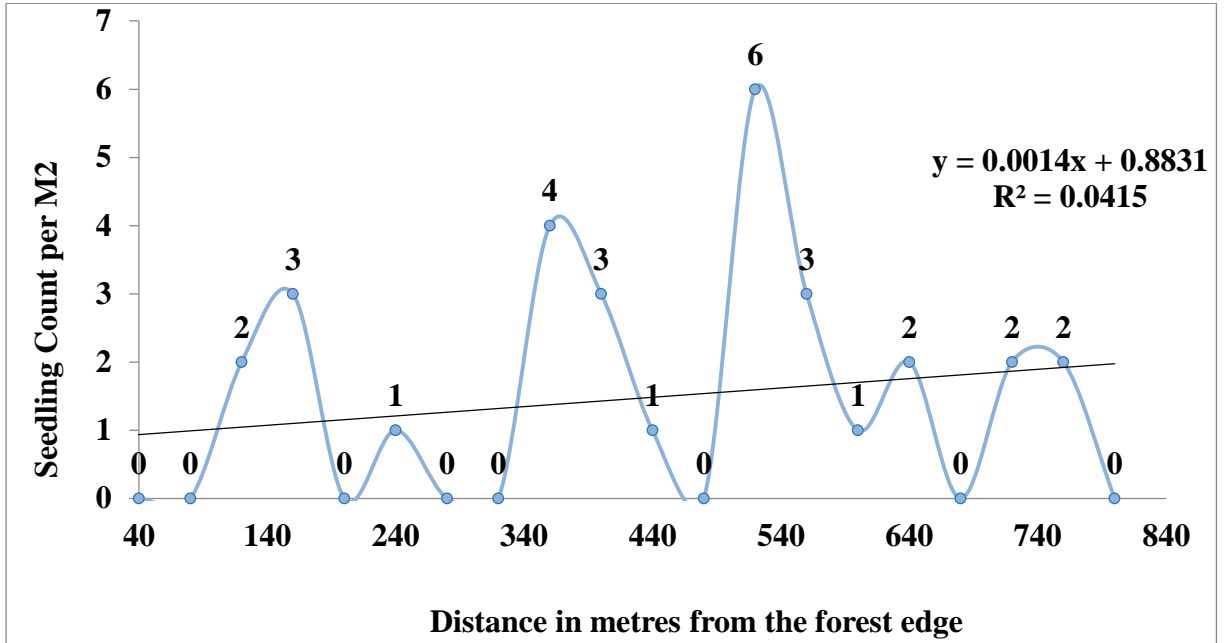


Figure: 4.9 Natural regeneration of *Podocarpus falcatus* in Kimakia Forest

In addition, seedlings counts do not increase with increase in distance from the forest edge. According to Grams & Lüttge (2010), the seeds of *Podocarpus falcatus* forms seedlings bank on the floor of the forest and can remain viable for many years even after vegetation clearing. This explains the possible reason for the distribution of its seedlings within the area of study. Cattle grazing (Plate 4.7) along the forest edge was observed and this could have led to trampling thus interfering with its natural regeneration.



Plate: 4.6 Cattle grazing in Kimakia Forest

Podocarpus falcatus produces edible fruits which are fed and dispersed by animals such as monkeys, baboons, and birds. Wassie *et al.* (2010) noted that from its preferences by birds for feeding, seed viability and dispersal at different regions enhances *Podocarpus falcatus* distribution.

Dispersal of *Podocarpus falcatus* seeds enhances its distribution throughout the forest. According to Simpson, (2017) seedlings of *Podocarpus falcatus* can survive everywhere in the forest. Simpson, (2017) realized that seedlings of *Podocarpus falcatus* can also flourish deep in the thickets since its germination is not affected by closed-canopy formation that causes poor light penetration. The current study findings concur with those of Simpson, (2017) since the species seedlings were well distributed from the forest edge to the core.

4.4.6 Natural Regeneration Trend of *Prunus africana* in Kimakia Forest

The highest seedlings count of *Prunus africana* was 5 at 520 meters. However, the general regeneration trend was increasing towards the core of the forest. The increase resulted to a positive gradient with a coefficient of determination of $R^2 = 0.2569$ (Fig 4.10).

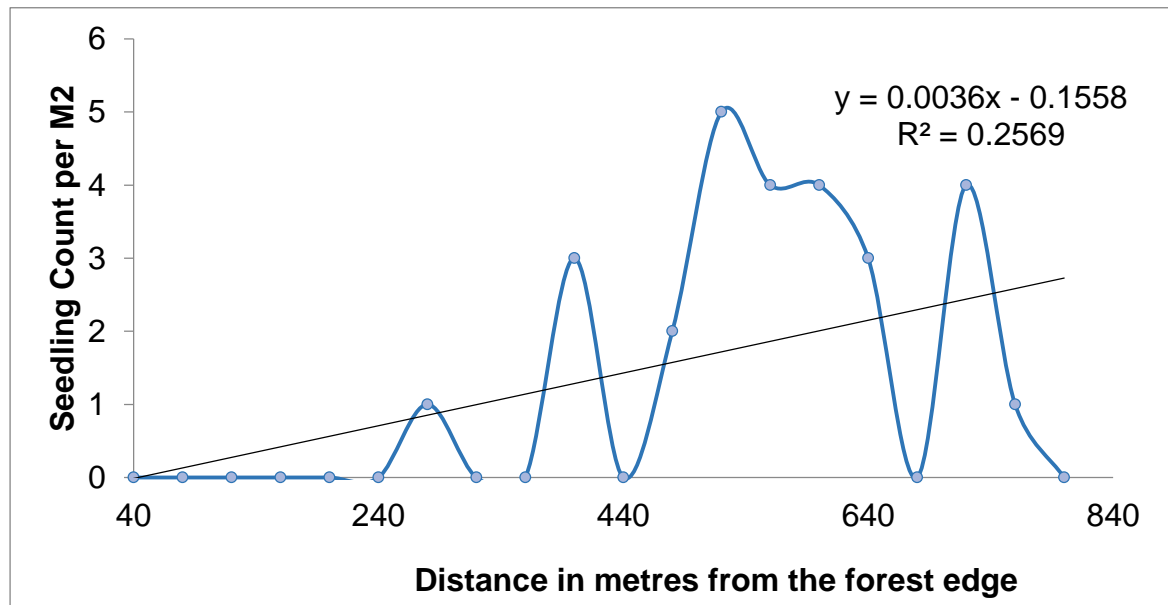


Figure: 4.10 Natural Regeneration of *Prunus africana* in Kimakia Forest.

Prunus africana is listed under CITES Appendix II meaning that although its trade is not banned, it must be strictly regulated under a licensing regime. The specie is also listened in the database of the World Conservation Monitoring Centre (WCMC, 1999) under the red list category of the risk to extinction. Its absence at the forest edge shows the demand it has in the communities of Kariara and Gatakaini Wards.

4.4.7 Regeneration Trend of *Neoboutonia macro calyx* in Kimakia Forest

Seedlings counts of *Neoboutonia macrocalyx* were relatively high between 40-340 Meters but decreased further inside the forest. The highest seedling count was 11 at 140

and 340 Meters. The lowest seedling count was recorded towards the core of the forest from (360- 800 Meters) of study (Fig 4.11).

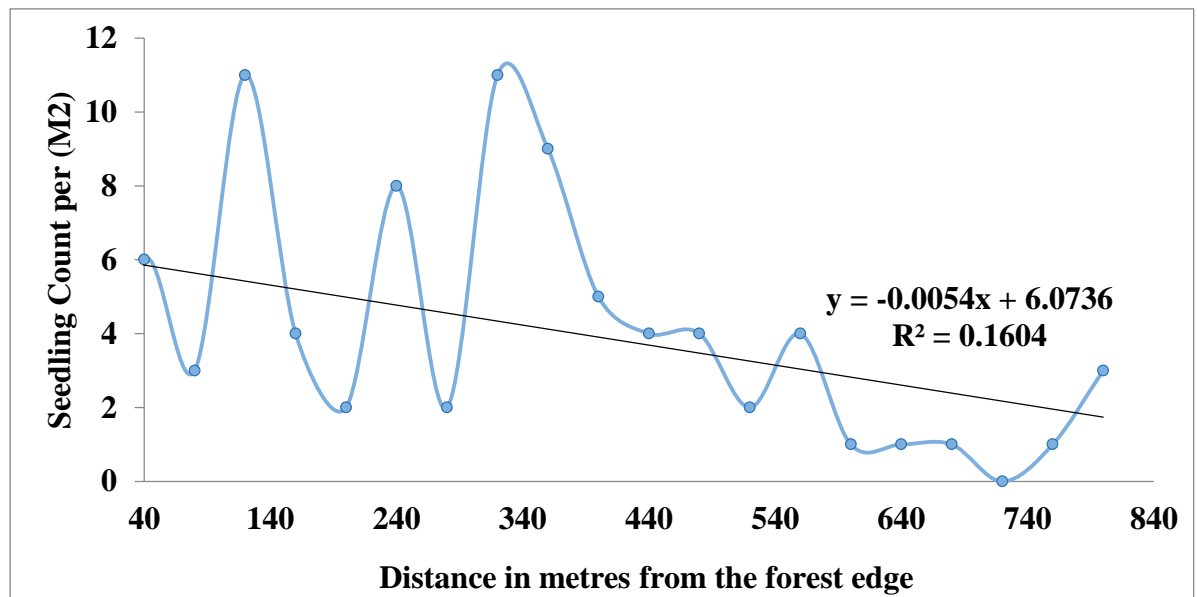


Figure: 4.11 Natural Regeneration of *Neoboutonia macro calyx* in Kimakia Forest

This resulted to a negative gradient where an increase in the distance towards the core of the forest resulted to decrease in seedlings counts with a relationship of $R^2 = 0.1604$. Unlike other indigenous trees seedlings in the study, *Neoboutonia macrocalyx* showed a general downward regeneration trend towards the core of Kimakia Forest.

This trend could be associated with previous disturbances since *Neoboutonia macrocalyx* is a pioneer specie - one that grows where there is an opening in the forest (Piironen *et al.*, 2017). Its observed behavior shows the effects of human activities of cattle grazing, cutting of grass, seedlings collections, logging, human footpaths, and hunting as evidenced in Kimakia Forest. This was also evidenced from the Key informant, the forest rangers and the forester from headquarters at Thika that almost 32

people are arrested on a daily basis. Evidence that actually there are illegal activities in Kimakia Forest contributing to diversity loss.

Neoboutania macrocalyx is a shade-intolerant species in that it does not survive in the canopies (KFS, 2010). This explains the probability of its regeneration trend. According to their research findings, Piironen *et al.* (2017) found *Neoboutania macrocalyx* to be an indicator species of encroachment. Increased count of its seedlings especially at the edge of the forest was evidence of human encroachment in Kimakia Forest.

4.4.8 Indigenous Tree Seedling Species Richness from the Forest Edge to the Core of Kimakia Forest.

The species richness increased with a relationship of $R^2 = 0.2739$ from the forest edge towards the core. The Y equation represents the gradient line which signifies the relationship of Change in X variables. Increase in distance from the forest edge resulted to increase in species richness counts (Fig 4.12).

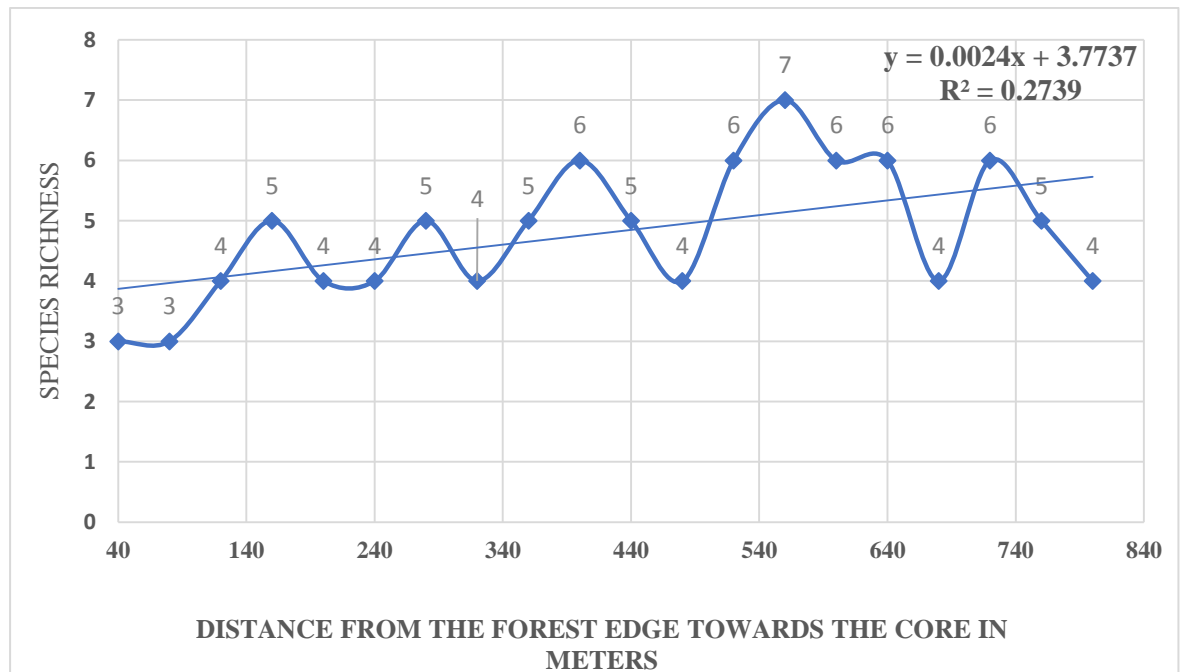


Figure: 4.12 Species richness and Distance from the Forest Edge Inwards

Species richness varied from one point to another but on the overall, it was higher towards the core of the forest (Fig 4.12). It was established that, previously, Kimakia Forest had nine dominant indigenous tree species namely; *Macaranga kilimandscharica*, *Podocarpus falcatus*, *Teclea nobilis*, *Rauvolfia caffra*, *Prunus africana*, *Ocotea usambarensis*, *Neoboutania macro calyx*, *Syzygium guineense* and *Xanthoxylum giletii* (KFS, 2010). The current study recorded seven dominant indigenous tree seedlings where *Syzygium guineense* and *Xanthoxylum giletii* were missing from all the sampled quadrats (n=200) in all the transects (n=10). The decline of dominant tree species by two shows long term effects of activities taking place in the forest. Their decline could act as a signal to continuous degradation of other indigenous trees species if proper management is not put in place. The absence of *Syzygium guineense* and *Xanthoxylum giletii* indigenous trees seedlings is an indication that diversity loss of indigenous trees is an unseen process. The loss of the two species in Kimakia Forest is an indicator that degradation of indigenous tree species is happening and that their decline at whatever rate might result in loss of tropical forests which are of tremendous importance to the global environment. Species richness increased from the forest edge to the core of the forest as far as the distance of the study was concerned.

4.5 Diversity of Indigenous Tree Seedlings in Kimakia Forest from the Edge towards the Core

The lowest diversity was realized at the edge of the forest while the highest diversity was realized towards the core of Kimakia Forest. The relationship of increase in diversity of species from the edge to the core of the forest was $R^2 = 0.225\%$. The overall diversity in Kimakia Forest was 2.01 (Figure 4.13)

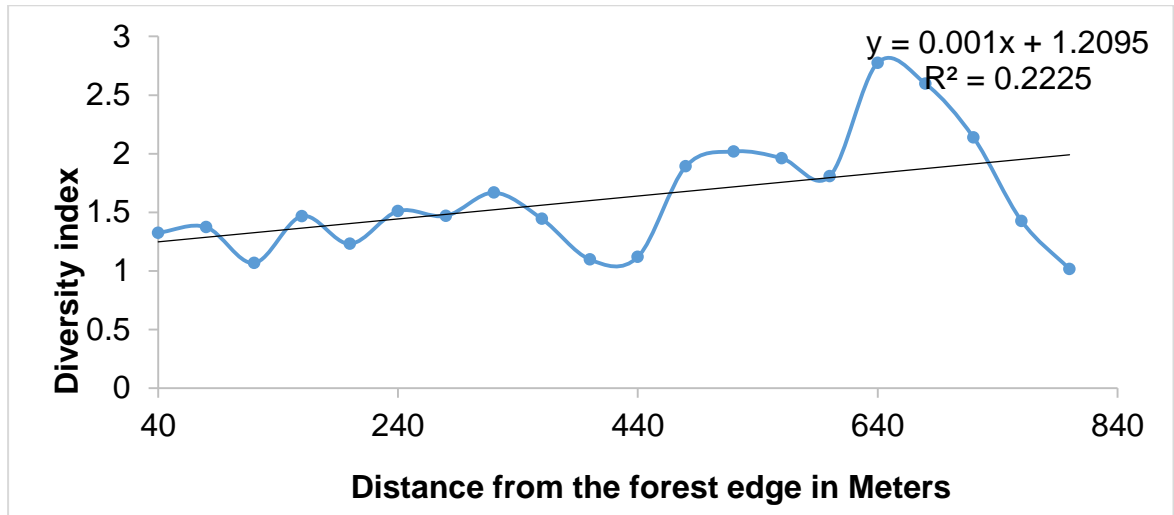


Figure: 4.13 Diversity of Indigenous Tree Seedlings from Forest Edge towards the Core

The highest diversity was realized at 700 Meters with a Shannon Wiener index of H 2.775 while the lowest diversity was realized towards the core of the forest with an index of H 1.015. There was a steep decrease in diversity from 720 to 800 Meters from H 2.596 to H 1.015. The decrease attributed to the presence of wild animals such as elephants whose bolus was frequently observed. The elephant foot is large enough to trample on 5-10 indigenous trees seedlings/seeds all together hence affecting diversity.

The overall diversity of 2.01 is relatively okay since typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. However, forest management efforts must be put in place to avoid any further degradation of the forest.

Poor natural regeneration of seedlings will result in depletion of forest resources. The study findings corroborate those of Chazdon, (2014) who realized that human activities in the forest impede natural regeneration causing degradation in the Tropical Forests thus affecting diversities. The study findings validate those of Laurance, (2011) in that

human encroachment highly influences species diversity by affecting natural regeneration of seedlings within its precincts.

The study rejected the hypothesis that the diversity of indigenous tree seedlings in Kimakia Forest is significantly affected by the distance from the forest edge with a P-value of 0.675. Despite the behavior of diversity as it appears in the graph the increment was not significant.

4.5.1 Diversity of Indigenous tree seedlings in Kimakia Forest per Transect

Different transects showed different diversities of indigenous trees seedlings. The highest diversity was 2.593 the lowest diversity was 0.935 (Figure 4.14).

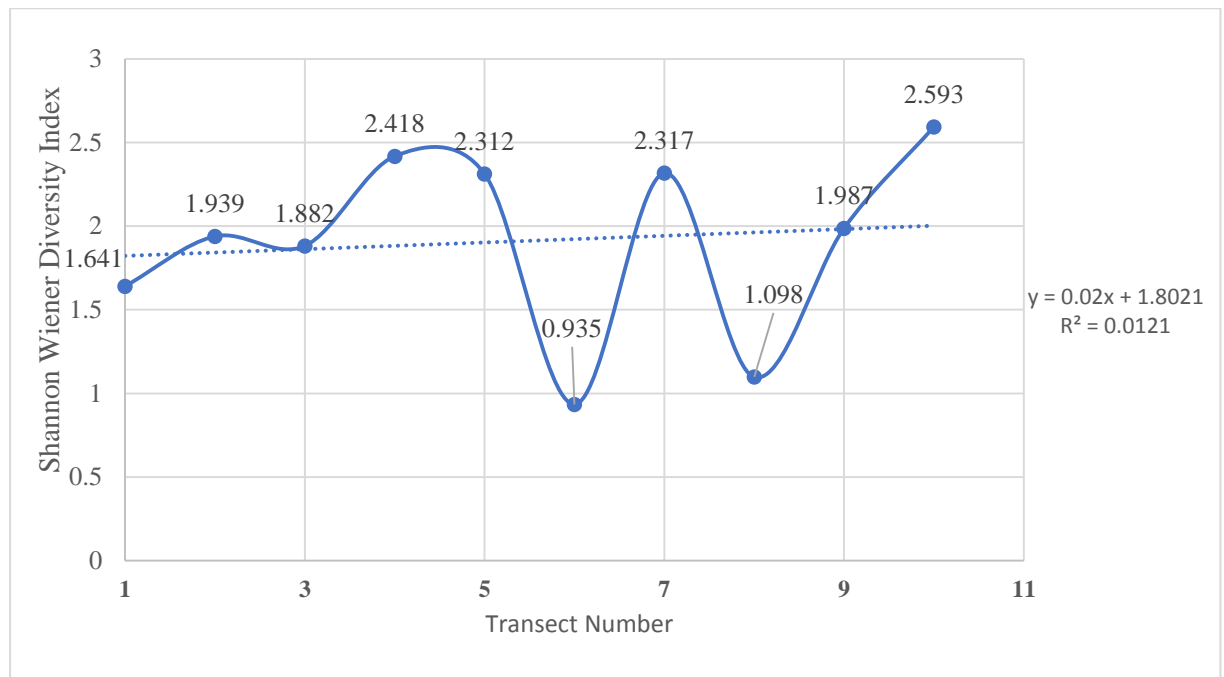


Figure 4.14 Diversity of indigenous tree seedlings per transect number

Diversity increased from transect one to transect number ten with a weak positive relationship of $R^2 = 0.0121$, resulting to a positive gradient. This is because increase in diversity per transect number (1-10) depended with the position each transect was laid. Factors affecting diversity ranged from edge effects of easy accessibility in the forest

and inadequate forest patrols. Activities of harvesting of barks and seedlings collection was evidenced within these areas which negatively influenced the presence of indigenous trees seedlings whose absence consequently affected their diversity. Diversity in Kimakia Forest behaved differently in the various transects since they were laid at different positions with different illegal human activities around the same positions.

Transect six had the lowest diversity of 0.935. This transect was laid near the plantations where human activities of farming were concentrated. Low diversity could be attributed to the rotational farming PELIS (Plantation Establishment and Livelihood Improvement Scheme) which involved communities being allowed into the forest to collect forest products once in a while. It is during this period when the people of Kariara and Gatakaini Wards make maximum use of the forest by accessing indigenous wildings/seedlings for their economic value and demand. Other activities included cutting of grass and hunting activities whose process involved interference with the young seeds as they thrived to mature. Activities of putting up nursery beds of indigenous trees seedlings within the natural forest interfered with regeneration affecting indigenous trees seedlings diversities.

As noted earlier the respondents indicated collection of seedlings as one of human activities in Kimakia Forest. These findings go in line with those of Althof (2005), where natural regeneration of tree species varied between highly disturbed areas and those areas that were left undisturbed, an indication that regeneration in the most disturbed areas was compromised consequently affecting species diversity. The highest diversity was realized at transect number 10 with a diversity index of 2.593. This transect was laid near the forest entrance where forest guards and rangers were located.

Results indicated that diversity was moderately good at the areas of maximum surveillance (Natural Forest entrance) and poor at the areas where patrol by forest guards was minimal (plantation forest). This explains why diversity was highest near the forest guard's post (transect number 10).

4.6 Other Factors affecting Diversity in Kimakia Forest

Other factors affecting diversity in Kimakia Forest was wind where there was presence of uprooted trees. The current study findings corroborate those of Mitchell, (2013) that at higher wind speeds, trees within stands begin to uproot or experience stem breakage, they may knock off branches, break or uproot adjacent trees as they fall through the canopy (Plate 4.9)



Plate : 4.7 fallen trees

Other factors affecting natural regeneration could be the morphology of the species. This is where some seeds such as *Macaranga kilimandscharica* requires a lot of water for it to soak in water and burst open to release the sprout to enhance growth. Other

seedlings are such as *Ocotea usambarensis* that has to be crushed to break its dormancy and facilitate its growth.

In addition, climate change of shift of short rains to long rains has affected the agricultural sectors where we have submerged species hindering regeneration by curtailing seed sprouts hence low counts especially within the flooded regions. This could also explain the differences in counts in the forest where there are high counts at some points while other parts have low to zero counts of regenerated indigenous seedlings.

4.7 Factors Leading to Human Encroachment in Kimakia Forest

Human encroachment in Kimakia Forest was caused by various reasons. The greatest reason being the availability of land for settlement and farming (85.5%) while the least reason was one living near the forest (22.5%) (Figure 4.15).

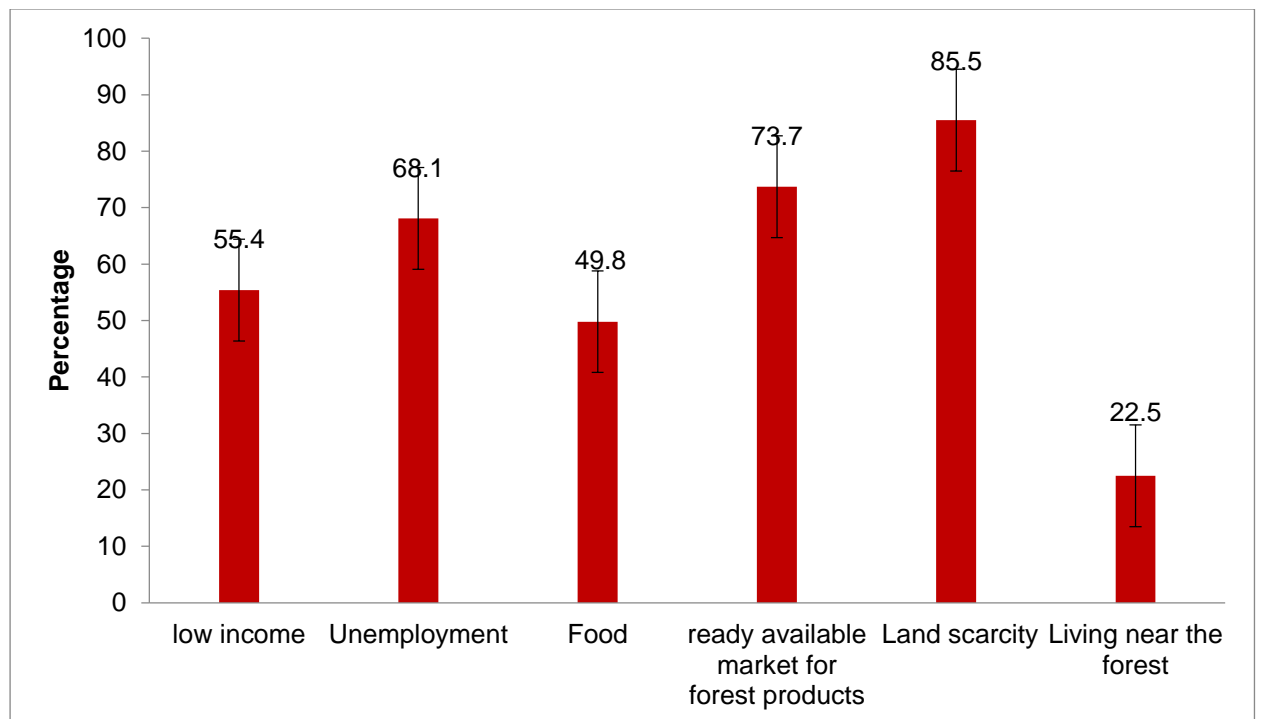


Figure: 4.15 Causes of Human Encroachment in Kimakia Forest

The rationale behind human encroachment in Kimakia Forest was scarcity of land which was related to factors of large numbers per household. With such conditions, it was hard for people of Kariara and Gatakaini to satisfy their basic needs including education which is a Childs' right as far as Kenya constitution is concerned. In the absence of adequate land for planting their own trees, the respondents acknowledged that they poached indigenous trees from Kimakia Forest for timber, construction poles for their houses, and for selling. The increasing demand for land due to growing population has made the people of Kariara and Gatakaini Wards to slowly convert forest land to farms.

Activities of illegal logging were ways of self-employment as a result of unemployment which has made life difficult for area residents to meet their basic needs. The majority of the people involved in tree logging, who were not necessarily the neighboring communities, took the risks of getting deeper in the forest to get high-value tree species for example; *Ocotea usambarensis*. These are people with capital or funding from various sources since forest restrictions and guidelines comes with heavy penalties that a mere villager cannot manage to risk themselves to access the forest.

Unemployment conditions of the people in Kariara and Gatakaini Wards makes them more dependent on Kimakia Forest thus engaging in other activities such as collection of indigenous trees seedlings and selling of timber. Others (49.8%) responded that being near the forest meant using its full potential to bring income for supporting their families and for harvesting any edible fruits or vegetables to provide sufficient supply of food for the household. From the study findings, it was clear that the people of Kariara and Gatakaini wards were only aware that Kimakia Forest existed but did not have the knowledge of the advantages that come with conservation and proper management of the forest near them.

Causes of human encroachment in Kimakia Forest gave headlights that the people of Kariara and Gatakaini wards did not have the right attitude on issues to do with management and protection of the forest near their homes. The forester indicated that the same people did not turn up for sensitization meetings to help them enhance skills on the protection and management of the Kimakia Forest Ecosystem. Men and women interact and influence sustainability differently. Women involved themselves in collection of edible wild fruits and vegetables for food for their children and the entire families. Other activities included collection of seedlings of *Prunus africana*, *Ocotea usambarensis*, and *Podocarpus falcatus*. Indigenous trees seedlings were collected from the natural forest to help them meet their basic needs. Selling of seedlings involved (4-5) women members who would form a group to start seedlings bed whose income would be shared equally among all members. According to Seswa (2016) activities of selective removal of timber and herbs had interfered with the natural regeneration of indigenous tree seedlings in Kakamega Forest. Seswa (2016) further noted that in Kakamega Forest, the neighboring communities get in the forest to collect wild vegetables and fruits amongst others to support their families.

An increase in population means an increase in demand for more lands for settlement and subsistence farming to cater for the growing population. It was established that there was competition of nursery beds between the forest seedlings/nursery beds and the community seedlings/ nursery beds. This is because the members of the Community Forest Associations sell their seedlings to organizations and institutions to fund themselves to support the growing population and for personal development.

PELIS was meant to enhance forest cover as the community farm other produce to improve their livelihoods. However, PELIS seemed to have negatively contributed to

diversity of natural regeneration in Kimakia Forest. The community takes advantage of this opening to illegally extract materials from the forest. Mugagga *et al.* (2017) found out that increased degradation in Bwindi National Park of Uganda together with eastern slopes of Mt Elgon was as a result of encroachment. Mugagga *et al.* (2017) reported that activities of agriculturalists, uncontrolled exploitation, and selective timber harvesting led to the loss of indigenous tree species in Bwindi National Park. The loss includes abundance, diversity, and regeneration.

Steel & van Lindert, (2017) also reported that illegal farming and agriculture rises as a result of available government lands, in that open lands in the forests are converted for farming to enhance economic value. However, such activities led to degradation of Mentigi Forest reserve in Cameroon as noted by Zin & Ahmad, (2014).

In their study, Louppe *et al.* (2009) found out that illegal farming and tree logging in the larger Aberdare Forest are some of the factors affecting the natural regeneration of indigenous tree seedlings. The majority of bordering communities tend to use these resources just because they live near the forest. Others is the community believe that whatever is within their precincts tend to be theirs and thus feel they own it to use it whenever they need and to generate income for selfish gains against reasonable facts.

4.7.1 Importance of Indigenous Trees to the People of Kariara and Gatakaini

Wards

Indigenous trees in Kimakia Forest possess more than one advantage that is of great importance to the neighboring communities (Table 4.5). A tree with multiple advantages to the people of Kariara and Gatakaini Wards was at a higher risk of over-harvesting putting it at the risk of local extermination.

Table: 4.5 Importance of some Indigenous Tree Species to the People of Kariara and Gatakaini Wards

Scientific Name	Local Name	Uses
<i>Ocotea usambarensis</i>	Muthaiti	- Home construction, Timber, furniture, plywood, and heavy construction work. - Malaria treatment
<i>Macaranga kilimandscharica</i>	Mukuhakuha	- Firewood, charcoal, timber, and poles. - Treatment of fever and digestive problems
<i>Prunus africana</i>	Muiri	- Timber, furniture, and firewood. - Treatment of malaria stomach upsets, fever, chest, and stomach pains.
<i>Podocarpus falcatus</i>	Muthengera	- For furniture - Treat gonorrhoea
<i>Rauvolfia caffra</i>	Mwerere	- Poles, pipes and firewood - Treatment of pneumonia, malaria, and colic in children
<i>Neoboutonia macrocalyx</i>	Mutundu	- Firewood, timber, soil conservation
<i>Teclea nobilis</i>	Munderendu	- Firewood, charcoal, timber, poles, post, tool handles, spear shafts, bows, clubs, and walking stick. - Control of menstrual pains and belly pains.

Kimakia Forest community is made up of people with different believes. From the respondents, it was evident that almost everyone including children at primary level understood the benefits of most of indigenous trees in Kimakia Forest. One of their most common values is that they have medicinal advantages. Health benefits of these indigenous trees to the community indicated clear evidences of encroachment in

Kimakia Forest. This is because to access a specific tree species, one had to get in the forest. The process of accessibility involves trampling on the seedlings/seeds which affects their natural regeneration, seedlings abundance and diversity.

The indigenous trees targeted were as a result of their characteristics and the values they hold to the surrounding community thus making them more susceptible to decline. Trees with multiple advantages such as *Prunus africana* had poor regeneration and were more affected with no seedlings present at the edge of Kimakia Forest. The most targeted indigenous tree seedlings in Kimakia Forest were *Prunus africana*, *Ocotea usambarensis*, *Podocarpus falcatus*, and *Macaranga kilimandscharica* which have a wide range of importance to the people in Kariara and Gatakaini Wards. This may lead to their over-exploitation in the future resulting in their degradation and consistent decline if proper management policies are exempted.

According to Muriuki *et al.* (2012), advantages for medicinal purposes of indigenous trees species have the potential to entice one to unsustainable harvesting leading to their degradation. This is because out of their high demands, they can generate sufficient cash flow which comes from readily available markets and this makes their seedlings vulnerable.

Muriuki *et al.* (2012) further ascertained that their timber is excellent for construction and is used widely in heavy construction. The current study findings were in line with those of Paquette & Messier, (2010) in that failure to protect and properly manage these indigenous trees species will result in their consistent decline like in the case of *Prunus africana*.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Regeneration trend of indigenous trees seedlings in Kimakia Forest as affected by the distance was increasing towards the core of Kimakia Forest within the areas of study. Natural regeneration trend of individual seedlings was also increasing towards the core of Kimakia Forest except for *Neoboutonia macro calyx* whose seedlings counts were many at the forest edge.

Natural regeneration of indigenous tree seedlings was low in counts at the edge of Kimakia forest. The average diversity index in this area was 1.36. There were fewer disturbances on regeneration from distance 500 meters towards the core. Indeed, diversity in Kimakia Forest increased from the forest edge towards the core. Diversity in Kimakia Forest differed depending on the location where the transects were laid in addition to different human activities taking place within the same areas. The overall diversity of indigenous tree species in Kimakia Forest was 2.01.

Factors leading to human encroachment in Kimakia Forest were land scarcity due to rapid population increase in addition to a readily available market of forest products, unemployment and low income by the populations of Kariara and Gatakaini wards.

5.2. Conclusions

1. The total regeneration of indigenous tree seedlings in Kimakia Forest increased from the forest edge to the core as affected by the distance.
2. The overall diversity was 2.01.

3. The main factors leading to human encroachment in Kimakia Forest were land scarcity, a readily available market of forest products, unemployment and low income.

5.3 Recommendations

1. Kenya Forest Service needs to map regeneration curves of indigenous trees seedlings in the forest in to various categories; for example, good, average and poor so as to monitor sustainability through natural regeneration. This will also enhance viable track of the various reasons attributed to low and high counts of indigenous tree seedlings in the forest.
2. Kenya Forest Service should employ species enrichment planting of exotic/native species as they have high resilient characteristics even with harsh climatic conditions. This will consequently increase forest diversity.
3. Kenya Forest Service also need to employ more forest rangers or modern technologies, for instance drones to enhance consistent surveillance especially in the in accessible areas to man the various human footpaths in order to curtail human encroachment.

5.4 Areas for further research

1. Further research can be carried out factoring out a specific human activity in the forest and its influences to diversity in Kimakia Forest.
2. A similar study can be carried out, but laying out longer transects to see what happens to biodiversity deeper into the forest.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

My name is Florence Muriithi. I am researching the effects of human encroachment on the natural regeneration of indigenous tree seedlings. This study is purely for academic purposes. I kindly request you to co-operate and fill out the questionnaire which seeks your views on this issue. The information that you give shall be treated confidentially and will only be used for academic reasons.

SECTION A: RESPONDENTS BACKGROUND INFORMATION. (*Tick where necessary*).

Highest level of Education	No Education	Primary School	Secondary School	College	University
Occupation	Farmer in the plantation of Kimakia Forest				
	Other				
land acquired out of stay within the forest precincts	farming				
	settlement				
Duration of holding	1-2 year	3 -4years	5-6years	7-8 years	More than 9 years
Average Income/per month	Up to 500	1000-1500	2000-2500	3000-3500	More 4000
Household Size	1	2-4	5-7		8-10

Section B: HUMAN ACTIVITIES IN THE FOREST.

1. Are there human activities taking place in Kimakia Forest?

YES ___ NO ___

(B). if yes which one amongst these? (*Tick against the activities*)

- | | |
|--------------------------------------|----------------------------|
| 1, Farming and Agriculture | 2, burning of charcoal |
| 3, Collection of non-timber products | 4, Collection of firewood |
| 5, lumbering grazing | 6, cutting of grass |
| 7, Cultural practices | 8, Collection of seedlings |
| 9, Harvesting of honey | 10, Grazing |

List any other, -----, -----

-----,-----

(C). According to you, what are the reasons that make individuals derive their livelihoods from Kimakia Forest resources?

1. Low income
2. Unemployment
3. for food
4. Readily available market for forest products
5. land scarcity
6. Any other -----,-----,-----

-----,-----,-----

2. As an individual do you acquire Kimakia Forest resources for your livelihood?

YES__NO__

b. If yes what activities do you practice? (*List the activities down*)

C. what are some of the reasons that you depend on the forest resources?

-----,-----,-----,-----,-----

3. What types of timber is used for construction of houses and other furniture in your areas? (*Please list them in any language you understand*)

B. Where do you think the timber comes from? (*Tick where necessary*)

1. Kimakia Forest

2. Other forests

3. Not aware

4. According to you, is Kimakia Forest facing any danger if issues happening to it are ignored?

YES__

NO__

B, if yes, explain_____

5 According to you what can overreliance on Kimakia Forest resources result to?

- Low-quality production
- Depletion of forest resources
- Availability of space for settlement
- Land for agriculture
- Poor rates of regeneration

B. List other outcomes

APPENDIX 2: INTERVIEW SCHEDULE FOR KEY INFORMANTS (KI)

1. Do you ever get people inside the natural forest?
2. What activities do the people in your area benefit from the natural forest?
3. How many people per day do you get collecting seedlings in the natural forest?
4. How many people are arrested for illegal logging?
5. How many people have you observed abstracting water unlicensed from the natural forest?
6. What do you feel could be the reasons affecting natural regeneration in Kimakia Forests?
7. As a leader what challenges do you face in overcoming degradation as a result of human activities?
8. In your opinion, what do you think is the possible way forward to enhance natural regeneration in the forest?

APPENDIX 3: OBSERVATION CHECKLIST

WHAT WAS TO BE OBSERVED	WHAT WAS OBSERVED	REMARKS
Settlements structures in the forest.	Presence of gardens	There is a settlement in the forest
Grazing	Presence of cattle hoof marks	There's is grazing in the forest
Charcoal kilns	Abandoned charcoal kilns	Burning of charcoal in the forest
Farming and agriculture	Maize plantations and tea farms	Conversion of natural forest
Nature trails	Human footpaths near Kimakia shrine	Cultural; activities in the forest
Logging	Logs lain on the ground	Illegal logging in the forest
Collection of wildings	Uprooted seedlings of <i>Ocotea usambarensis</i> , <i>Macaranga kilimandscharica</i> and <i>Prunus africana</i>	Hunting of valuable seedlings in the forest
Hunting	Animal traps in the forest	hunting in the forest.


**APPENDIX 4: SCIENTIFIC AND LOCAL NAMES OF DOMINANT
INDIGENOUS TREE SPECIES RECORDED IN KIMAKIA
FOREST**

Indigenous tree seedling	Scientific Name	Local Name
<i>Prunus Africana</i>	<i>Prunus africana</i>	Muiri
<i>Neoboutonia macrocalyx</i>	<i>Neoboutonia macrocalyx</i>	Mutundu
<i>Ocotea usambarensis</i>	<i>Ocotea usambarensis</i>	Muthaiti
<i>Teclea Nobilis</i>	<i>Teclea Nobilis</i>	Munderendu
<i>Rauwolfia caffra</i>	<i>Rauwolfia caffra</i>	Mwerere
<i>Podocarpus falcatus</i>	<i>Podocarpus falcatus</i>	Muthengera
<i>Macaranga kilimandscharica</i>	<i>Macaranga kilimandscharica</i>	Mukuhakuha

**APPENDIX 5: INDIGENOUS TREE SPECIES COUNTS FROM 40 -800
METERS FOR THE 10 TRANSECTS**

Distance (m)	<i>Teclea nobillis</i>	<i>Rauvolfia caffra</i>	<i>Macaranga kilimandscharica</i>	<i>Prunus africana</i>	<i>Podocarpus falcatus</i>	<i>Ocotea usambarensis</i>	<i>Neoboutania macrocalyx</i>
40	1						6
80	6	5					3
120	2	3			2		11
160	3	2	1		3		3
200	9	4	1				2
240	2	1			1		8
280			1	1			2
320		1	1				11
360	1	7	5		4		9
400	2	5		3	3	3	5
440	3	3			1	2	4
480	10	2		2		1	3
520	19	2		3	6		3
560	1	4	2	4	4	2	2
600		1		3	1	4	2
640		2	2	4	2		2
680	2	5	3				1
720	1	10	1	4	3	3	
760		6		1	3		3
800	6	6				1	

APPENDIX 6: RESEARCH PERMIT


KENYA
Forest Service

Kenya Forest Service
Karura, Off Kiambu Rd
P.O. Box 30513-00100
Nairobi, Kenya

Ref: No. RESEA/1/KFS/VOL. III (143) Date: 27th August 2018

Muriithi Michere Florence
P. O. Box 43844 00100
Nairobi.

REF: ACCESS PERMIT TO COLLECT DATA IN KIMAKIA FOREST: REQUEST for RESEARCH ACCESS FEE.
Reference is made to your letter of 1st August 2018 in which you request for access to Kimakia forest to collect data for your Master's Thesis.

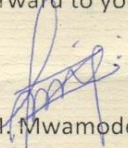
In order to process your request, the following is required;

1. A copy of your approved research proposal, and
2. Payment research fee of **Kshs. 5,000.**

Please deposit or transfer this amount to the account details provided below and forward the deposit/transfer slip to the undersigned for necessary action.

Account number: 1106770021
Account Name: KENYA FOREST SERVICE
KENYA COMMERCIAL BANK
Swift Code: KCBLKENX

I look forward to your action.


James M. Mwamodenyi
For: Chief Conservator of Forests

Trees for better lives
Tel: (254) 020-3754904/5/6, (254) 020-2014663, (254) 020-2020285, Fax: (254) 020-2385374
Email: info@kenyaforestservice.org Website: www.kenyaforestservice.org



REPUBLIC OF KENYA



NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 371523

Date of Issue: 18/March/2021

RESEARCH LICENSE



This is to Certify that Ms. FLORENCE Michere MURIITHI of Kenyatta University, has been licensed to conduct research in Muranga on the topic: EFFECTS OF HUMAN ENCROACHMENT ON NATURAL REGENERATION OF INDIGENOUS TREES SEEDLINGS IN KIMAKIA FOREST, MURANG'A COUNTY KENYA. for the period ending : 18/March/2022.

License No: NACOSTI/P/21/9483

371523

Applicant Identification Number

Walttembo

Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code



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THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing)

Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies
5. The License does not give authority to transfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one year of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke
Website: www.nacosti.go.ke

APPENDIX 7: APPROVAL LETTER FROM GRADUATE SCHOOL



KENYATTA UNIVERSITY GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Website: www.ku.ac.ke

Internal Memo

FROM: Dean, Graduate School **DATE:** 13th March, 2019
TO: Ms. Muriithi Michere Florence **REF:** N50/37672/2016
C/o Department of Environmental Sciences
& Education

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that Graduate School Board, at its meeting on 6th March, 2019, approved your Research Proposal for the M.Env.Science Degree entitled, "Effects Human Encroachment on Natural Regeneration of Indigenous Trees Seedlings in Kimakia Forest, Murang'a County Kenya.

You may now proceed with your Data collection, subject to clearance with the Director General, National Commission for Science, Technology & Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking Forms per semester. The form has been developed to replace the Progress Report Forms. The Supervision Tracking Forms are available at the University's Website under Graduate School webpage downloads.

Thank you.


HARRIET ISABOKE
FOR: DEAN, GRADUATE SCHOOL



CC. Chairman, Department of Environmental Sciences & Education

Supervisors:

1. Prof. James Kung'u
C/o Department of Environmental Sciences & Education
Kenyatta University
2. Dr. Benson Mburu
C/o Department of Environmental Sciences & Education
Kenyatta University

APPENDIX 8: RESEARCH AUTHORISATION FROM GRADUATE SCHOOL



**KENYATTA UNIVERSITY
GRADUATE SCHOOL**

E-mail: dean-graduate@ku.ac.ke

Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Our Ref: N50/37672/2016

DATE: 13th March, 2019

Director General,
National Commission for Science, Technology
and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

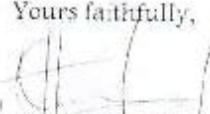
**RE: RESEARCH AUTHORIZATION FOR MS. MURIITHI MICHERE FLORENCE
- REG. NO. N50/37672/16**

I write to introduce Ms. Muriithi Michere Florence who is a Postgraduate Student of this University. She is registered for M.Env. Science degree programme in the Department of Environmental Sciences & Education.

Ms. Muriithi intends to conduct research for a M.Env.Science thesis Proposal entitled, "Effects Human Encroachment on Natural Regeneration of Indigenous Trees Seedlings in Kimakia Forest, Murang'a County Kenya."

Any assistance given will be highly appreciated.

Yours faithfully,


**PROF. ELISHIBA KIMANI
DEAN, GRADUATE SCHOOL**

