ECOSYSTEM RESTORATION METHODS AND LIVELIHOODS DEVELOPMENT IN MACHAKOS COUNTY, KENYA

BENJAMIN MUNUVE KYALO

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DECLARATION

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Signature ……..... Date …….....……

BENJAMIN MUNUVE KYALO

N50/CTY/PT/33094/2015

SUPERVISORS

We confirm that the work reported in this project was carried out by the candidate under our supervision as the approved University Supervisors

Signature …… Date……

Dr. Felix Ming'ate
Kenyatta University

Signature …… Date…….

Dr. Joseph K. Muriithi
Kenyatta University

DEDICATION

I dedicate the thesis to my wife Esther, my son Oliver and parents, Ven. Canon and Mrs. Patrick Kyalo Munuve, for their selfless support in my education journey.

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LIST OF ABBREVIATIONS AND ACRONYMNS

ASALs - Arid and Semi-Arid Lands

CIDP- County Integrated Development Plan

IPCC - Intergovernmental Panel on Climate Change

JNCC - Joint Nature Conservation Committee

NEMA - National Environment Management Authority

MCF- Mully Children's Family

SSA - Sub Saharan Africa

SD- Standard Deviation

UNEP - United Nations Environmental Programme

WASH - Water, Sanitation and Hygiene

WHO - World Health Organization

WRI - World Resources Institute

ABSTRACT

Among the highly degraded environments in the world are the arid and the semi-arid areas hence mostly vulnerable to Global warming, climate change, soil erosion and other environmental challenges. Understanding ecosystem restoration Methods and the local adaptive capacities is critical for livelihood development. This study's main objective was to examine ecosystem restoration methods and livelihoods development in Kithimani sub-location, Machakos County, Kenya. The research determined the effect of ecosystem structure and functioning on livelihood development and ecosystem resilience, examined ecosystem restoration methods used, challenges to ecosystem restoration and the moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County. The study hypotheses were that ecosystem structure and function do not have significant effect on livelihood development and ecosystem resilience, there are no significant ecosystem restoration Methods used, there are no significant challenges to ecosystem restoration and finally, there is no significant moderating influence of ecosystem restoration methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County. This study adopted descriptive research design because it helped in describing the ecosystem structure, observing the ecosystem restoration Methods and outlining the livelihood development methods in the study area. Primary data collection tools included questionnaires and in-depth interviews. The sample size included 384 households which were purposively and randomly selected. Data from questionnaires was first cleaned through editing, coding and tabulation for the detection of any anomalies in the responses. Specific numerical values were assigned for the analysis. Data from the key informants was reviewed to ensure that the interview schedule was well done and analysis done using the Framework Based Approach. Both qualitative and quantitative data were then analyzed using Statistical Package for Social Sciences. Mann Whitney U and Kruskal-Wallis H tests were also conducted to test if medians between comparison groups were different. Results showed that 56.3% and 61.1% of the household heads and key informants were male while 37.7% and 38.9% of the household heads and key informants were aged 40-49 years. There was a significant positive effect of structure and function, challenges to ecosystem restoration and ecosystem restoration Methods used and a significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. All the null hypotheses were rejected and the alternative hypotheses accepted. The study concludes that ecosystem structure and functioning, challenges to ecosystem restoration and restoration Methods used are significant variables affecting livelihood development and ecosystem resilience and recommends that specific ecosystem-based restoration measures like planting of drought tolerant crops and trees need to be adopted in Kithimani to decrease the vulnerability of the communities.

CHAPTER ONE: INTRODUCTION

1.1 Study Background

Human welfare significantly depend on the ecosystems in the earth which gives diverse goods and services like food and water (Oroda, 2011). The ecosystem has a function of meeting the needs of man spiritually, recreationally and educationally and helping in the stabilization of soils and climate in the global and local context (WRI, 2000). Unsustainable use of ecosystems in the world makes them to be unsophisticated structurally and less in biological variation hence degradation of the environment (Oroda, 2011). This lowers their ability to provide essential services, like food and clean water, climate regulation, carbon storage, crop pollination, and wildlife habitat (FAO, 2009). The Intergovernmental Panel on Climate Change (IPCC) affirms that degradation has occurred worldwide (IPCC, 2014) with impacts such as dwindling agricultural production, social-economic impacts in livelihoods and poverty (IPCC, 2014; Brody *et al*., 2008). Therefore, any change in the environment will definitely pose impacts on livelihoods (Amsalu & Wana, 2013). Ecosystem and livelihoods challenges are connected thus need a holistic approach (Beintema & Stads, 2011).

According to Hagen *et al*. (2013), ecosystem restoration is the remedy to the global environmental degradation like pollution, water, land and soil degradation through adoption of techniques that control or reduce the degradation. Peh *et al*., (2014) denotes that well calculated fitting restoration in comparison to ecosystem services loss bestows benefit/cost ratios of 3-75% investments return and an internal rate of return of 7-79%. This is dependent on the ecosystem that has been restored and its economic setting thus provides valuable public investments inclusive of direct or

indirect generation of jobs linked to improved health and environment. Therefore, restoration acts as an economic engine and green employment source (Beintema & Stads, 2011).

Ecosystem services such as the provision of water and soil fertility are important components of livelihoods since they provide a variety of resources and livelihood options at different spatial and temporal scales. Restoration methods like habitat enhancement, remediation and forest landscape restoration using natural forest species and reintroducing plants to the area which had largely disappeared are important in ecosystem restoration and livelihood development (Honadia, Sawadogo, Wandja & Shepherd, 2010). A degraded ecosystem can be considered to have been restored when it regains sufficient biotic and abiotic resources to sustain its structure, ecological processes and functions with minimal external assistance or subsidy (Aronson & Sasha, 2013).

Globally, restoration is recognized in most multilateral agreements and international laws which include the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the United Nations Convention to Combat Desertification (IPCC, 2014). In practical levels, restoration has a highly valuable, low cost investment for the maintenance of ecosystem services (Cortina *et al*., 2011). A study done on restoration in India on the Kannur Kandal Restoration Project revealed that restored mangroves on the coastal areas serve as barriers to storms reducing household losses from 155 to 30 USD /household depending on the intactness of the vegetation (Pereira, 2010). Further, the mangroves serve as home to birds and fish, thereby an empowerment to the fish folks whom were struggling for a reliable source of income (Peh *et al.*, 2014). Restoration of wetlands, peat lands,

catchments and waste water management does improve the health and labor productivity of individuals affected by waterborne diseases thus affecting livelihoods of households and nations (Munang *et al.*, 2013).

Agroforestry has been found to be among the best approaches to combat ecosystem challenges and cause livelihood development in Africa (ICRAF, 2013). Restoration of wetland forests and ASALs treats large amounts of wastewater, controls climate change, sinks great amounts of carbon and promotes sustainable agricultural practices (Kimani *et al*., 2015). These in turn strengthens the natural pest control, soil fertility and food security (ICRAF, 2013). Research is needed to take stock of the successful instances where landscape has been restored, expansion of communications and outreach and support the realization of far-reaching Methods and specific plans to elicit the extensive taking up of ecosystem restoration practices (Harvey *et al*., 2013).

The top section of Kithimani in Yatta plateau is flat and the slopes are typically steep (Wichura, 2011). Increase in the population, development actions that are unplanned and land use variation are threatening sustainable development (Mwamati, 2017). These activities have led to land degradation and loss of livelihoods (CIDP, 2014). A number of conservation programmes have been instigated by the local communities and NGOs in the study area like the water harvesting and conservation by the Mully Children's Family (MCF) although there is much that needs to be done. It is worth noting that there have been very limited studies on ecosystem restoration and livelihoods development. There is need to study the status of the ecosystem restoration and the current impact of livelihoods in Machakos.

1.2 Statement of the problem

Ecosystem restoration is now globally recognized as a key component in conservation programs and essential to the quest for the long-term sustainability of the human-dominated planet (Aronson & Sasha, 2013). In fact, most of the world's ecosystems have undergone significant degradation with negative impacts on biological diversity and peoples' livelihoods. Ecosystem restoration therefore becomes a fundamental element of ecosystem management given that many people are dependent on what have become degraded ecosystems to sustain their livelihoods (Crossman *et al*., 2017).

There has been a high dependence on the ecosystems by human beings for a variation of services important to their well-being. The diminuendos of this relationship are characterized by a global increase in urbanization, swift technological advances and increase in population (Fangli *et al*., 2018). These dynamics are associated with substantial environmental costs, rendering ecosystems that are increasingly transformed and mostly mismanaged and degraded which is the exact situation in Kithimani area. Nthambi and Orodho (2015) further denoted that environmental degradation comes about as a result of dynamic relations between institutional and technological activities thus a direct result of human activities. Environmental change has contributed to people's mobility and migration which affects the ecosystem directly and indirectly (Ratha *et al*., 2010). Population increase in Kangundo and Makueni caused migration in Kithimani sub location (Kithiia, 2008) resulting to ecosystem degradation (Mwamati, 2017). It is important to note that like other parts of the globe, the area is highly degraded whilst the dwellers are committed to earn a living and restoration of the ecosystem (Kithiia, 2008).

In the semi-arid regions, the problems faced by populations arise from the environment, economic and social limitations. Environmental degradation as a result of insufficient and erratic seasonal rainfall, high mean annual temperatures and high evaporative demand greatly constrains supply of water for agricultural use contributing to low and declining agricultural productivity which worsens people's welfare (Kirui & Mirzabaev, 2014). There is therefore need for ecosystem restoration Methods which are geared towards livelihood development and improvement of people's welfare (Crossman *et al*., 2017; Fangli *et al*., 2018). The study sought to explore the status of the ecosystem of Kithimani sub location and how the community developed and sustained livelihoods at the same time restoring the degraded ecosystem in the increasing arid conditions. The study further examined the most sustainable ways that livelihoods can be enhanced and ecosystems restored exploring the relationship therein, with a specific focus of the research area.

1.3 Objectives of the study

1.3.1 General Objective

The general objective of the study was to examine ecosystem restoration Methods and livelihoods development in Kithimani sub-location, Machakos County, Kenya

1.3.2 Specific Objectives

i. To examine the effect of ecosystem structure and function on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.
ii. To assess the ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

iii. To determine the challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

iv. To establish the moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County.

1.4 Research questions

i. How does ecosystem structure and function affect livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya?

ii. What are the ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya?

iii. What are the challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya?

iv. Does ecosystem restoration Methods have a moderating impact on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County?

1.5 Hypotheses of the Study

H_{01}: Ecosystem structure and function does not have significant effect on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

H_{02}: There are no significant ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

H_{03}: There are no significant challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

H_{04}: There is no significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County.

1.6 Rationale of the Study

Many traditional norms, taboos and practices affect either directly or unintentionally in the ecosystems restoration, livelihood development and ecosystem resilience. Cultural practices performed by the communities and the social functions can significantly help in reducing their vulnerability and improving the ecosystems. This provides an entry point for biodiversity conservation and ecosystem Methods that can reduce vulnerability. This study generates information on the ecosystem status and the activities of the people geared towards restoration of the ecosystem in Kithimani. The information adds to existing knowledge on ecosystems and livelihood development highlighting the specific action in the study area. This brings understanding of the challenges and opportunities in arid and semi-arid ecosystem restoration and its relationship to livelihood development which is important to organizations and institutions in the region like NEMA, Ministry of Environment and World Vision. The study findings are useful to policy makers in the department of environment in their decision making. Further, the findings of this research are

valuable in equipping the policy making process at the ministry of environment at the County level to improve the methods of ecosystem restoration and livelihood development.

1.7 Conceptual Framework

It represents the relationship between the study variables. In this study, the independent variables include structure and functioning and challenges to restoration, the moderating variable is restoration Methods while the dependent variables are livelihood development and ecosystem resilience. Despite the fact that the framework was adopted from (FAO, 2015 & Heal *et al*., 2005) in the research concerning economics of smallholder farmers in the semi-arids and valuing of ecosystems services in Washington, it is relevant to the study because the variables proposed in the framework are capable of addressing the study objectives since this research intended to determine the restoration challenges and restoration Methods in relation to livelihoods development which are well captured by the framework. Thus the framework was useful for this kind of study.

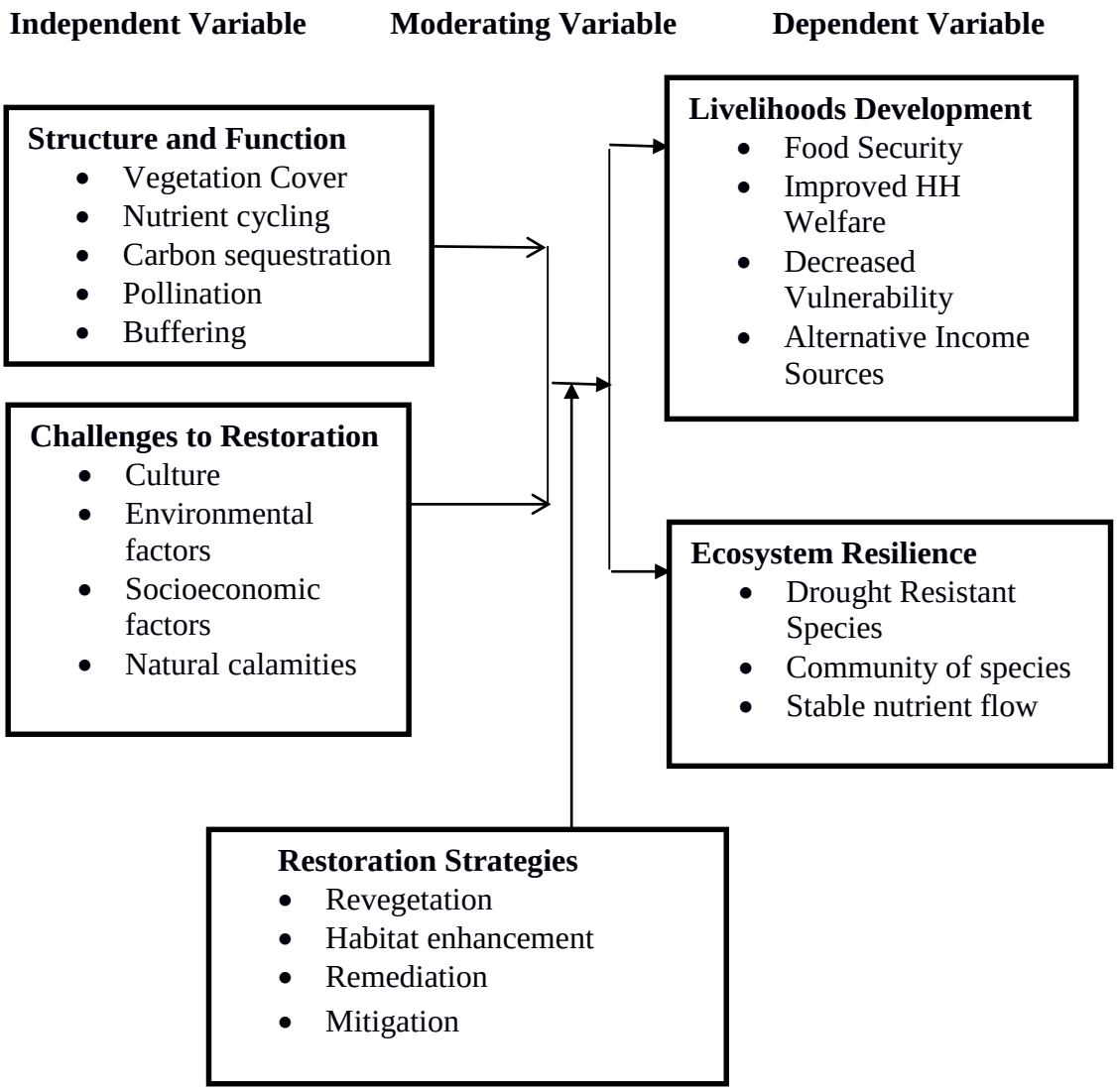

Figure 1.1: Conceptual Framework modified from FAO (2015) and Heal et al. (2005)

1.8 Definition of Operational Terms

Ecosystem Function- a process resulting from the relations of plants, animals and other organisms in the ecosystem with each other or their setting (Heal *et al*., 2005)

Ecosystem resilience- the inherent ability to absorb various disturbances and reorganize while undergoing state changes to maintain critical functions (Brand, 2005)

Ecosystem restoration - process of aiding the reclamation of a degraded, damaged or destroyed ecosystem (Bowers, 2016)

Livelihood development is the provision of better chances so as to earn a living (Majale, 2002).

Resilience - the amount of disruption that a system can take up without varying stability domains (Lance, 2000).

Structure- both the composition of the ecosystem and the physical and biological configuration defining the organization of those parts (Heal *et al*., 2005)

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviewed empirical literature whereby earlier studies carried out by other scholars both at international and local scale related to the research objectives were reviewed with the aim of coming up with research gaps. Pointing the weaknesses and gaps of past studies helped in supporting the present study with a view of suggesting probable ways of filling them. The chapter is arranged as: ecosystem structure and function, ecosystem based restoration Methods, challenges to ecosystem restoration, ecosystem resilience and livelihood development, relationship between ecosystem restoration Methods and livelihood development and lastly, literature gaps on ecosystem restoration and livelihoods development

2.1 Ecosystem Structure and Function

Lavelle and Spain (2001) denoted that nutrient cycling is the locomotion inside and among the several biotic or abiotic bodies where nutrients occur in the global setting. These entities can be mined from their mineral or atmospheric sources or recycling done from their organic formations through conversion to the ionic form thus enhancing their absorption to take place and eventually getting them back to the atmosphere. It is made possible by a highly diverse number of organisms leading to the creation of several physical structures and procedures which are involved in regulation of the fluxes of nutrients between the partitions. These structures and processes helps in buffering thus limiting losses and transfers to other ecosystems. Certain ecosystems are involved in the distribution of the nutrients.

Weber and Flannigan (1997) did a study on the Canadian boreal forest ecosystem structure and functioning in a varying climate focusing on their impact on fire

regimes. Anticipated climatic/atmospheric effect on plant physiological, communal, ecosystem and landscape-level connections with fire were reviewed (Weber & Flannigan, 1997). Rampant food insecurity in ASALs is as a result of droughts and unpredictable weather patterns, unfavorable policies and environmental degradation affecting household incomes through reduced livestock and/or crop productivity and development of appropriate environmental policies will help avert this (Julius, 2013; FAO, 2015).

Eldridge *et al*., (2011) did a research on the effects of shrub encroachment on ecosystem structure and function. They used univariate analyses, meta-analysis and structural equation modeling to examine the suggestions that encroachment of shrub and qualities affect the functional aftermath of encroachment. It revealed that encroachment had mixed impacts on ecosystem structure and functioning at international scales and that shrub qualities affected the functional aftermath of encroachment (Eldridge *et al*., 2011).

Vitousek *et al.* (2002) in their study highlighted that human actions have led to large-scale variations in nutrient cycles since the 1800s and the variations have taken place at an increased rate since the mid-1900s. There have been changes in land use arrangements, increased use of fertilizers linked with high-yielding crops and lateral removal of nutrients in the ecosystems limits which have intensely varied the rate, pathways and efficacy of nutrient cycling. The outdated small-scale, low-input agricultural techniques usually resulted to reduction of nutrients especially when uncultivated seasons were reduced. Further still, sustaining soil fertility when large-scale, high-input intensive agriculture is practiced is still a challenge since the practice began a few decades ago (Smil, 2000; Falkow-ski *et al*., 2000)

IPCC (2007) report indicated that internationally, an approximately 0.2-0.8 gigatonnes of carbon dioxide annually can be confiscated in grassland soils by the year 2030 since the cost for carbon dioxide of USD 20–50/tonne. Fertilization and management of fires are contributors of carbon sequestration but the probable sequestration in non-degraded regions is mostly caused by variation in grazing management systems. Approximate carbon sequestration rates per unit are less than those for sequestration on agricultural lands but sequestration possibility is equivalent to that of croplands since grasslands cover large portions of the global surface.

Nair *et al.* (2009) found out that agroforestry increases uptake of carbon by broadening the growing season, enlarging the fortes where drawing of water and soil nutrients takes place and to the nitrogen (N)-fixing species, improving fertility of the soil. Introducing agroforestry systems in appropriate localities leads to carbon sequestration in the tree biomass and there is a tendency of it being sequestered also in the soil (Jose, 2009). Enhanced management in the prevailing agroforestry systems leads to sequestration of 0.012gigatonne of carbon per year while converting 630 million ha of croplands and grasslands that are not productive or degraded to agroforestry will result in sequestration of about 0.59 Tg C per year by 2040 (IPCC, 2000), which will be complemented by modest upsurges in N_2O emissions as more circulation of N happens in the system.

Neely and Bunning (2008) denoted that good grassland management involves managing grazing within equilibrium and non-equilibrium systems and needs an understanding of using grazing as a stimulant such that there is aggressive growth of grasses and healthy rooting systems, using the grazing process in the feeding of domestic animals and soil biota- through maintenance of soil cover and managing

plant spp components thus maintaining feed quality and provision of sufficient break from grazing (Jose, 2009) and comprehending effects of and adaptation to climate variation like plant community variations. Productivity of grasslands depends on the domestic animals' movement (Niamir-Fuller, 1999).

FAO (1995) indicated that pollinators assist in the perpetuation of plants by enhancing successful sexual reproduction. Conserving pollinators means conserving plant species and vice-versa is also true. Conserving both the plants and pollinators supports species variation in the ecosystem and thus means conserving the ecosystem. A stable ecosystem is the one having high species variation and thus a species-rich ecosystem which is the norm in the tropics.

2.2 Ecosystem Restoration Methods

Procedures stimulating ecological restoration can either be financial or nonfinancial or both (Stringer *et al*., 2007). Financial procedures steer restoration projects through provision of economic incentives like arrangements of private market, voluntary private non-market funding systems and financial incentives (de Groot *et al*., 2007). Nonfinancial procedures comprise of indirect incentives like intervention by government through laws and regulation, charitable activities of organizations, other charitable ecological restoration activities stemming from local happenings and restoration activities based on artistic values, beliefs or faith (McGhee *et al*., 2007).

Wang *et al.*, (2005) did a report where they collected the most effectual methods that Chinese and Mongolian researchers executed on degraded ecosystem restoration and desertification control. Their findings indicated that the most lucrative techniques were an innovative procedure of producing sand stabilization material using lignin extracted from the black liquor of straw paper mills and a silvo-pastoral procedure

that encouraged ban on grazing and fence-closure stockbreeding policy, a practicable scheme to substitute over-cultivating with forest /wetland conservation and eco-tourism development.

Restoration of ecosystems is ideal for the conservation of the endangered and exceptional dry land biodiversity. Ecological restoration is considered as an effectual way for the improvement of both biodiversity and providing ecosystem services and subsequently promotes sustainable development (Schiappacasse *et al*., 2012). Further, restoration of dry lands improves the adaptive capability and resilience of local communities and ecosystems (Yirdaw *et al*., 2014).

Restoration of highly degraded rangelands is possible through active restoration methods like reseeding grass species, controlling and reducing encroachment of woody species, cultivating fodder trees, improving grazing system and aiding natural regeneration of native species. Grass reseeding technology has been in use effectively as a method of rehabilitating rangelands that have been degraded in Eastern Africa (Tebeje *et al.,* 2014). The rehabilitation success depends on the kind of species cultivated and on enhancing of site circumstances by soil scarification, mulching and addition of manure. Rangelands that are highly degraded are usually low in soil nutrition to back quick formation and growth after seeding (Danano, 2011).

Protection of the soil from erosion is possible when vegetation cover and litter is placed on soil surface since there is reduction of runoff and increased water infiltration into the soil matrix (Liao *et al.,* 2014). Planting of trees using species that are salt-tolerant can amend saline soils making them productive since they produce litter that surges the content of soil organic matter and N (Mishra *et al.,* 2003) and lowers the water table. Revegetation is a significant tool important for replenishing the fertility

of soil and as such enhances productivity of land and food security (Erdmann, 2005). Revegetating rangelands using leguminous trees greatly contributes to soil fertility since atmospheric N is fixed and input into the soil, nutrients that are below the rooting zone of the crops are retrieved and losses of nutrients from leaching and erosion is reduced (Pinho *et al.*, 2012). The woody constituents can also give probabilities for using the green and animal manure for the soil amendment (Marques *et al*., 2016).

Restoration Methods for degraded lands should be site-specific and dependent upon closeness to the seed sources and soil seed banks especially previous disturbance systems (Elliot *et al*., 2013; Hoffman *et al*., 2015). The restoration Methods established for the wet areas are not mostly applicable in the ASALs. The high quantities of species that are small-seeded and wind dispersed, high sprouting capability and the comparatively simple structure and low variation of ASALs compared to wet areas need to be considered when selecting restoration Methods (Vieira & Scariot, 2006; Marques *et al*., 2016). Contigent on the location circumstances and the aims either one or more varying restoration Methods can be used (Yirdaw *et al*., 2014).

Methods for restoration of ecosystems vary among countries and this difference can partly be described by the varying environmental circumstances of the ecosystems (Hagen & Evju, 2013). Resemblances in the environmental challenges and rates at which particular habitat kinds can regrow inside these ecosystems can describe why similar approaches or procedures are used in particular habitats irrespective of the nation (Bruvoll *et al*., 2011). Other descriptions are that habitats have previously been used in the same ways thus providing normal difficulties for restoration over the nations. Resemblances in the habitats, regardless of the region show that the

restoration approach is directed by the kind of habitat being restored (Martinsen & Hagen, 2010).

In regions where there is a long cultural memoire, such targets are mostly not realized and not regarded. Natural successional routes are usually unaccepted in cultural landscapes and restoring the ecology needs continuous management to sustain their norms. Therefore, restoration in most cases aims at recreating past cultural situations with suitable norms. Such restoration in most cases needs continuous management to favor particular biodiversity (Norderhaug & Johansen, 2011)

2.3 Challenges to Ecosystem Restoration

Diversity biologically, culturally, environmentally and socioeconomically in situations over regions require diverse approaches to ecosystems restoration and sustainable farming thus experience varied challenges. In vegetation restoration, genetic mismatch of plant materials to specific target areas may result to reduced viability of restoration projects (Evert *et al*., 2014). Unbalanced genetic diversity during restoration of endangered species can hinder proper mating between remnant plants (Young *et al.*, 2000). Identifying restoration threshold and prescribing effectual ecotechnological tools improves the achievement and probability of restoration programs thus call for research before any restoration projects (Cortina *et al.*, 2011).

According to Capistrano and Clyde (1995), promoting consumption and transformation of resources and recognizing minimal importance of restoration globally is shaped by the structures put in place economically, politically, socially and culturally. Resource manipulation is contributed through widely accepting involving in activities like logging, mining and agricultural enlargement to development and rarely recognizing the probable contribution of natural habitations and biodiversity.

Socioeconomic forces and situations mostly create motivations for actions which place pressure on ecosystems and create hindrances to deviations in behavior which would decrease the pressures and contribute to restoration and thus conservation efforts are struggling in many countries (Capistrano & Clyde, 1995).

Culture and cultural management objectives do not necessarily connect with restoration of ecosystem. Cultural approaches may include the removal of natives, introduction of exotics and simplifying of the ecosystems (O'Neill, 2000). When there is re-establishment of past approaches by ecologists like burning, it is mostly for varied aims from the traditional people. Dwyer (1994) denoted that with the wide-ranging traditional ecological knowledge (TEK) of the indigenous people about the environment do not mostly engage in approaches that can be regarded conservation-oriented by the criteria of ecological sciences. It is worth noting that many traditional groups have convictions based on ideas of harmony and balance with nature but these do not necessarily become exemplified as ecologically-sustainable approaches (Hames, 2007).

According to Hagen *et al.* (2013), up to date ecosystem management approaches are based on scientific or conservation ethics. This has resulted in some instances to rivalry between culture and conservation although in the recent past, there has been a strong acknowledgement that effectual ecosystem management is only achievable via a better comprehension and integrating relationships between households and nature. Most households regard and manage ecosystems via a prism determined by long deemed cultural convictions sustaining the society. The difficulty in ecosystem management is that, in a varying global setting most of these long deemed approaches can result to degradation of the ecosystem while others playing a very important

function in the promotion of biodiversity conservation and in assisting households to deal with the effects of climate variation (Hagen *et al.*, 2013).

Natural calamities and human influences like fires in forests where fire is not a natural commotion but a human making impacting the species negatively (Kinnaird & O'Brien, 1998). Fire on forests directly affects animals through killing them and indirectly affects are great and have longer term which are habitat loss, territories loss, shelter and food loss. Forest fires can result to movement of territorial birds and mammals upsetting the local, balance and eventually lead to the loss of wildlife. Losing food trees minimizes the carrying ability of the forest which causes overall reduction of species relying on fruits for food (Kinnaird & O'Brien, 1998). Losing the main organisms in forest ecosystems like pollinators and decomposers can considerably reduce the recovery rate of the forest ecosystems (Boer, 1989).

Uncontrolled, human-induced fires negatively affect the ecosystems. From an ecological stand-point, any positive effect depends utterly on location, timing, strength and regularity of fires. From a human stand-point, if individuals have been using fire in a landscape for a number of years to maintain particular norms and there happens an uncontrolled, human-induced fire, the intentions of the individuals may happen and be unswerving with what the individuals intended. Opportunistic, short-term advantages for individuals may be available but in circumstances where fire did not occur naturally, there are neutral or negative effects. Nevertheless, fire-induced variation is not certainly negative to all things and all individuals, though the positive features may be paricular to sub-groups of fauna or flora (Shvidenko & Goldammer, 2001).

According to Death *et al.* (2015), natural calamities like flooding directly affects the organisms that live in rivers, ousting or killing freshwater fauna. Further, they indirectly affect ecosystems through variations to the shape and form of the river. The structure of a river is a determinant on the value and amount of habitation available to fresh water organisms. Thus, the structural variation brought about by intense flooding could affect river ecology more than the direct effect of the flood itself via variation to habitat availability. Putting infrastructure in place for the protection of humans from intense flooding can also vary the rivers' geomorphology, habitat value and ecology (Death *et al.*, 2015).

2.4 Ecosystem Resilience and Livelihood Development

Resilience in ecological systems is the amount of disruption that a system can take up without varying stability domains (Lance, 2000). It lies in the essential various functional groups and the accumulated capital providing recovery sources. Most human actions reduce ecological resilience by trying to control changes in the main ecosystem processes. The loss of resilience is mostly complemented by a variation in system state denoted by crisis in the resources. When a system has changed into an unfavourable stability domain, the management options are to restore the system to a favourable domain, allowing the system to resume to a favourable domain by itself or adapting to the varied system since variations cannot be reversed (Lance, 2000).

According to Berkes and Folke (1998), maintaining resilience is possible through focusing on keystone structuring processes which cross gauges, on the renewal and reformation sources and on numerous capital and skills sources. No single approach can warrant maintenance of resilience. Methods addressing essential variety of functions and concentrating on renewal greatly contributes to resilience. There is need

for institutions to focus on learning and comprehending main cross-gauge interactions. Learning, confidence and engagement are significant constituents of social resilience. Learning socially is made possible through acknowledgement of uncertainties, monitoring and determination by participants. Dealing with challenging issues whose effect will be felt after 10 to 50 years in the days to come over-broadens gauges (Berkes & Folke, 1998).

When there is appropriate management of ecosystem services, there is reduction on the susceptibility of humans, communities and economies. Ecosystem services have a contribution on the reduction exposure, sensitivity or adaptive competence of human–environmental systems in different ways. The ecosystems play a role in providing a natural boundary against vulnerabilities to minimize exposure of the social systems (Locatelli, 2008). Supporting services greatly contributes to the adaptive capacity of an ecosystem since nutrient cycling and primary production are key constituents of the functioning, endurance and resilience of the ecosystem (Locatelli, 2008).

Protected or non-protected ecosystems have a contribution to water, food, energy, and livelihood security. Landscapes that have prominent ecological integrity assist in the protection of water supplies, maintaining and improving the water quality thus aiding in food production and resource harvesting actions (Villanueva, 2011). Ecosystems are complicated and interrelate with social and environmental systems across a variety of scales (UNEP, 2011) and therefore when designing the adaptation Methods and comprehending vulnerability, there is need of including the variety of drivers affecting the delivery of ecosystem services (Brooks *et al.*, 2011). There is a likelihood of having an efficient adaptation strategy when the fundamental reasons for vulnerability

are understood. This enhances a deeper comprehension of the adaptation strategy to be involved or not, to what degree and why (UNEP, 2012).

Livelihoods strengthen food security and are the channels that individuals gain access to resources and assets in their settings so as to meet the household requirements. When scrutinizing the livelihoods of households and people, the starting point is determining the five livelihood assets which are the physical, financial, natural, social and human capital that are available in the surveyed region then the various livelihood Methods into which people translate them. One of the consequences of an effective livelihood strategy is food security. Vulnerability, risk and capacity to cope are the main conceptions defining a probable livelihood consequence and food security of a household (Jaspars & Maxwell, 2009).

In the rural areas, there is a lot of interest by the researchers on how the welfare of farmers can be improved and how the ecosystem can be protected (Scoones & Borras, 2009). The method of a household's efforts in improving its own welfare is a reflection of livelihood that involves ability, capital and actions for survival. Achievement of a sustainable livelihood increases a household's capability in managing stress and maintaining and enhancing the abilities of households and capital without obliterating natural resources (Chambers & Conway, 1992). Communities in varying natural settings and social structures have differing livelihood Methods depending on their own livelihood capital. They deal with risks and their effects by merging various capitals, and maintaining their livelihood security through converting adaptably between several livelihood Methods so as to obtain a sustainable livelihood (Koczberski & Curry, 2005).

2.5 Relationship between Ecosystem Restoration Methods and Livelihood Development

Food security and livelihoods in local communities of Africa's dry lands are negatively affected by land degradation, desertification and drought (FAO, 2014). Kimani *et al*., (2015) studied improvement of livelihoods in semi-arid areas of Africa through reduction of vulnerability to climate change and climate resilience promotion. The areas highly vulnerable are the health sector, food production, biodiversity, water resources, and rangelands. Communities have turned to their immediate surrounding environments to meet their needs. People have turned to charcoal burning, sand harvesting and fishing along the Athi river to meet their needs thus deriving their raw materials from the natural resource base (Kithiia, 2008). Therefore, restoring a degraded environment impacts directly or indirectly the people dependent to its products and services.

Revegetation of the forests and planting of trees plays a key role in sustaining food production and contributes to food security and nutrition in different dimensions. The impact of revegetation on forests and trees and the considerable landscape changes driven by agricultural expansion also enhance the ecosystem restoration that sustain agricultural production itself, with potential impacts on the food security and nutrition status of local populations as well as on global food availability and food security (Sunderland *et al.,* 2019).

According to FAO (2015), mitigating against climate change is important since climate change impacts may reduce income level and stability, through effects on productivity, production costs or prices leading to searching of alternative income sources by individuals. Such variations can drive sales of productive capital like

livestock, which reduces long-term household productive capacity. Exposure to risks lowers incentives to invest in production systems, often with negative impacts on long-term productivity, returns and sustainability thus increasing vulnerability of people. Evidence from recent analyses of the impacts of various types of weather anomalies on farm income indicates that the impacts are greatest for the poorest farmers (FAO, 2015)

2.6 Literature Gaps on Ecosystem Restoration and Livelihoods Development

Reviewed literature in this study involves the empirical review and the conceptual framework. Scholarly past studies on the study variables was done to help in coming up with the knowledge gaps that needs to be filled. The conclusion that was drawn from the past scholarly studies is that the available information in the area of ecosystem restoration methods and livelihoods development in the ASAL regions is not consistent and the results are mixed thereby presenting a research gap which this study attempted to fill. Weber and Flannigan (1997), Eldridge *et al*., (2011), Lavelle and Spain (2001), Vitousek *et al.* (2002) and Nair *et al.* (2009) have looked at the relationship between ecosystem structure and functioning and livelihood development and ecosystem resilience but the results have shown significant, insignificant or no relationship. Further, the challenges to ecosystem restoration and the ecosystem restoration Methods used for livelihood development and ecosystem resilience, very little has been done specifically in the semi-arid regions. Additionally, the moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience is an area that has received very little attention from researchers. There is thus a need to continue with research undertaking, specifically in the semi-arids regions with an effort to get tangible evidence on the effect of ecosystem

restoration Methods and livelihoods development in the ASAL regions. Review of related literature showed that most scholars have concentrated on forests and water ecosystems in developed nations whose restoration Methods and household needs are varied compared to those in ASALs, Kenya thus limited knowledge on ASALs restoration. This study looked at the gaps expecting to make a contribution on livelihood development and ecosystem resilience in the ASAL areas.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the methodology used in obtaining the data required for the study. The chapter has the study area, research design, sample size and sampling procedure, data collection, data analysis and ethical considerations.

3.1 Study Area

The research was carried out in Kithimani sub location, Machakos County. The area is located at 36.660^0N, 1.270^0E. The county covers approximately 6,208km^2 and it's inhabited by agricultural Kamba community. Maize and drought-resistant crops are cultivated. Cattle, goats, sheep, donkeys and poultry are livestock that are reared. Studies have shown that agriculture contributes to approximately 70% of the household income (GoK, 2002-2008; CIDP, 2014; FAO, 2015). There are high evaporation rates which affects the ground water levels (water in the springs and wells) since it is in ASALs. Total population is over 1,098,584 and 264,500 households with a population density of 177 persons per square kilometer (KBS, 2010)

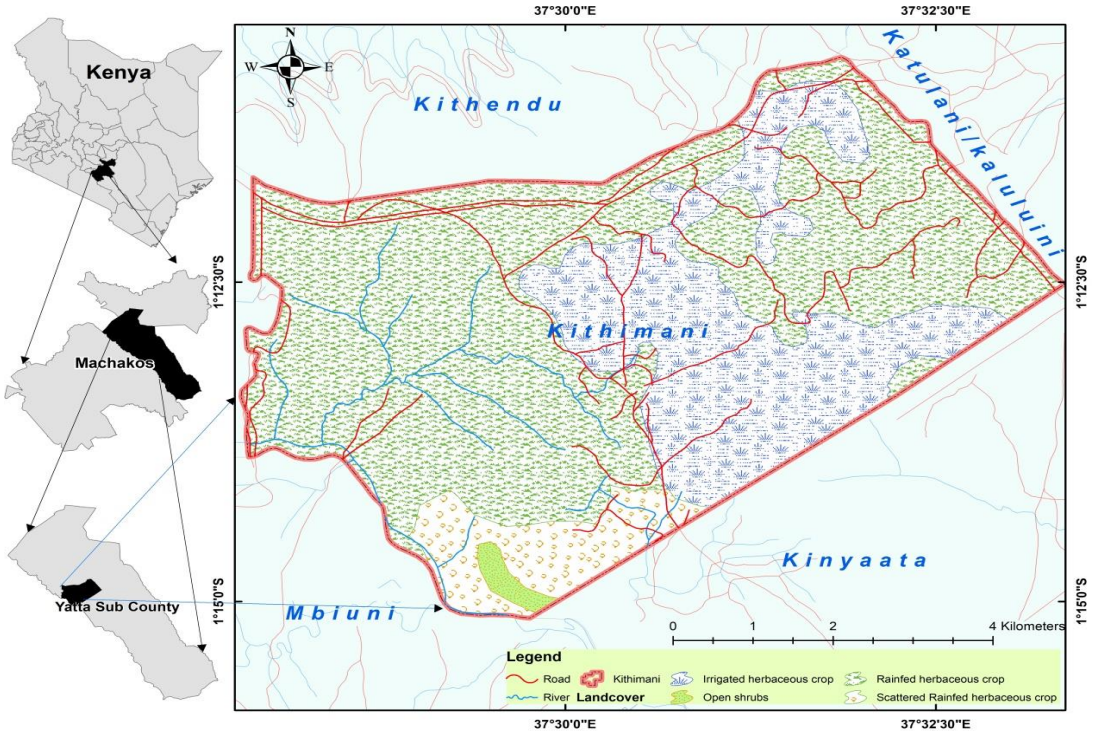

Figure 3.1: Kithimani Sub location, Machakos County

3.2 Research design

This research used descriptive research design which is a scientific approach which involves making observations and descriptions of the behavior of a subject without impacting it in any way (Gall, & Borg, 2007). Further, this design is concerned with circumstances, practices, configurations, differences or connections that exist, views held and on-going processes or apparent trends. Descriptive research examines an occurrence which is happening at a specific place and time (Babbie, 2012). This design was useful in that it helped in describing the ecosystem structure, observing the ecosystem restoration Methods and giving the trends in the livelihood development methods in the research area thus achieving the objectives of the research. However, this design has disadvantages in that majority of studies are not repeatable due to their observational nature and that they are not helpful in identifying cause behind described phenomenon.

3.3 Sample Size and Sampling Procedure

In this research, the households' heads, NGOs in the study area, area sub-chief and village headmen were the target population. Selection of projects coordinators in the NGOs, area sub-chief and the village headmen was done using purposive sampling. The household heads sample size was estimated using Cochran formula (Cochran, 1977). A total of 384 respondents (household heads) were randomly selected in Kithimani sub location to participate in the survey. They were useful in the provision of information of what the specific households were doing to restore the ecosystem and earn their incomes.

$$n_0 = \frac{z^2 \times p(1-p)}{e^2}$$

Where,

n_0	-	?
z^2	-	95% confidence level (The value of (1-α) in Standard Normal Distribution **z**-table, which is 1.96 for 95%)
p	-	50% variability of the population (which is maximum)
e	-	5% margin of error

Therefore

$$n_0 = \frac{(1.96)^2 \times 0.5(1-0.5)}{(0.05)^2} = 384.16$$

The sample size of **384** respondents was used.

Further, the study involved NGOs operating in the area involved in livelihood development and ecosystem restoration namely, Yatta Community Development Assistance Program, Plan international, World Vision, AIC Matuu and MCF Mully Children's Family. The projects coordinators in the NGOs were purposively targeted since they had the information on the projects on ecosystem restoration implemented. The 5 NGOs were involved in the study since they have been operational in the research area for many years dealing with ecosystem restoration and livelihood improvement and therefore were conversant about the issues the researcher was examining and had a high level of knowledge on the issues in question. Further, the area sub chief, government officials and 5 village head men (Nyumba Kumi) were also interviewed. They helped in the provision of information on what the government had done so far in the protection and restoration of the environment.

Table 3.1: Sample Size

Sampled respondents	Numbers
Household heads	384
Key informants	
NGOs + Village heads	10
Government officials	10

3.4 Data collection

The research used different tools to gather information on various variables. First, the researcher administered structured questionnaires since questionnaires ensures that the information sought is related to the research objectives, standard and focuses the research on collection of the information instead of thinking about what information to collect (Bulmer, 2004). The questionnaire also gives the data on the daily

experiences, activities and attitudes of the people in the households (Bulmer, 2004). Questionnaires were used to collect data from the household heads in the study area. The questionnaires were physically delivered to the homesteads of the households.

Key Informants included NGOs project coordinators and 10 government officials (area chief, sub-chief, NEMA, Agriculture, Environment, Forestry, Land, Labor, Devolution and Education) and 5 village head men were interviewed using the interview schedule. This is because the personal approach usually produces more satisfactory results than a questionnaire and also the need to elucidate additional information for the study (Bulmer, 2004). There were physical meetings through appointments for interviewing the key informants. Qualitative data was collected which was aimed at complimenting the data from the household heads. In depth information on the ecosystem restoration Methods and livelihood development in Kithimani area was provided.

A pilot study was undertaken before the main study to evaluate the consistency and any flaws in designing and development of the questionnaire and the interview schedule. The pilot study helped in disclosing significant information within the data sets. The questionnaire was piloted using nineteen (19) respondents selected from the household heads and interview schedule was piloted using two village heads from the neighboring Kithendu Sublocation. This presented 10% of the actual sample as recommended by Mugenda and Mugenda (2008).

Validity shows whether an instrument gives measurement of what it intends to measure. This research used content validity which determines the degree to which the research tool gives sufficient coverage of the research questions that guides the research (Cooper & Schindler, 2006). Content validity was done through discussions

on the questions in the questionnaire with the supervisor to ensure they captured the objectives of the study.

Reliability indicates the consistency with which the research tool determines a concept and assists in the assessment of the goodness of a measure (Bryman, 2008). Sekaran and Bougie (2010) argued that Cronbach's Alpha ranges between 0-1 and the higher the coefficient, the more reliable the research instrument. Reliability was determined via Cronbach's Coefficient Alpha and a Coefficient (α) value of 0.7 was considered sufficient for the study. The independent variables comprised of ecosystem structure and functioning and challenges to ecosystem restoration, moderating variable comprised of ecosystem based restoration Methods while the dependent variables were livelihood development and ecosystem resilience.

Table 3.2: Reliability Statistics

Variable	Cronbach's Coefficient	Items
Ecosystem structure and functioning	0.758	5
Challenges to ecosystem restoration	0.702	4
Ecosystem based restoration Methods	0.764	4
Livelihood development	0.752	4
Ecosystem resilience	0.722	4

Source; Researcher (2020)

The findings shown in Table 3.2 indicates that ecosystem structure and functioning had a coefficient of 0.758, challenges to ecosystem restoration, a coefficient of 0.702, ecosystem based restoration Methods, a coefficient of 0.764, livelihood development,

a coefficient of 0.752 while ecosystem resilience, a coefficient of 0.722. The coefficients had a range from 0.70 to 0.76 and thus the research instruments were considered reliable. Sekaran and Bougie (2010) suggested that reliability value of 0.7 and above is recommended for social sciences.

3.5 Data Analysis

Data from the questionnaires was taken through data analysis stages. Data was cleaned where editing, coding and tabulation so as to detect any anomalies in the responses and giving particular numerical values to the responses for further analysis was done. Entry of the data using the proper codes and specified variables then took place in the Statistical Package for Social Sciences (SPSS) version 25.0 computer software then counter checking took place.

Data from the key informants was first reviewed to make sure that the interview schedule was well done. Analysis was done using the Framework Based Approach proposed by Ritchie *et al*. (2003) since it is a systematic and flexible method to analyzing qualitative data (Gale et al., 2013). The framework also helps in the identification of issues that were raised by the key informants to be clearly and thoroughly deliberated in the analysis and further facilitate adequate flexibility in detecting and characterizing issues emerging from the data (Ritchie & Spencer, 1994). The data was classified and organized into a thematic framework based on the main themes, concepts and categories and later entered in SPSS for analysis.

Analysis of data involved using descriptive and inferential statistics. This assisted in streamlining large data sets and thus allowed for comprehension of the particular set of observations in the study. It involved generating summary statistics; means,

standard deviations and percentages. Linear regression was done to test the significance of the independent variables on the dependent variables.

3.6 Ethical Considerations

Conducting research needs expertise, hard work, honesty and integrity and thus, the right to anonymity, confidentiality and informed consensus was observed. Respondents' consent was obtained before administering the questionnaires. University introductory letter was also obtained and research permit from National Council for Science, Technology and Innovation (NACOSTI). References from all sources were fully acknowledged using APA referencing system.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter gives the findings and their discussion. The results are presented based on the four specific objectives. Specifically, the study examined the effect of ecosystem structure and function, ecosystem restoration Methods used, challenges to ecosystem restoration for livelihood development and ecosystem resilience and finally, the moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County. Questionnaires and interview schedule were the data collection tools. Results are presented below.

4.1 Profiles of the Household Heads and Key Informants

The study looked onto the demographic characteristics of the household heads and key informants. These were gender, age, highest education level and years lived in Kithimani area of the household heads and key informants. Gender was an important factor since men and women have different mindsets due to community gender roles thus varying in their view of the environmental resources around them. Therefore, they would have varying views in regard to the aims of the research thereby enriching the data. Age on the other hand was significant in that the varying perceptions of the young and older respondents on the variables this research was examining would complement each other. Education level affects the understanding of the respondents on the issues being investigated and can influence the outcome of the research. The more an individual stays in an area, the more they are conversant with the ecosystem and therefore this was a key factor in this research since the variables in question needed respondents conversant with them.

4.1.1 Gender of the Household Heads and Key Informants

The gender of the household heads and key informants was evaluated (Table 4.1). Results from the household heads indicated that 56.3% were male while 43.7% were female. Results from the key informants indicated that 61.1% were male while 38.9% were female.

Table 4.1: Household heads and Key Informants' Gender

	Household Heads		**Key informants**	
Gender	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Male	170	56.3	7	61.1
Female	132	43.7	11	38.9
Total	**302**	**100.0**	**18**	**100**

Results showed that there were more male household heads and key informants compared to the female household heads and key informants. This contradicts the 2019 census results which showed prevalence of more women than men. However, the disparity was around 12% for the household heads which could be explained by the fact that most households are male headed and therefore, when data was being collected, the house hold head was responsible for giving the data required.

4.1.2 Age of the Respondents

The research asked for the age of the household heads and key informants (Figure 4.1). Thirty-seven point seven percent (37.7%) and 38.9% of the household heads and key informants respectively were aged 40-49 years. Further, 34.4% and 27.8% of the household heads and key informants respectively were 30-39 years old. Also,

household heads and key informants aged above 50 years and 20-29 years were 15.9% and 11.9% and 22.2% and 11.1% respectively.

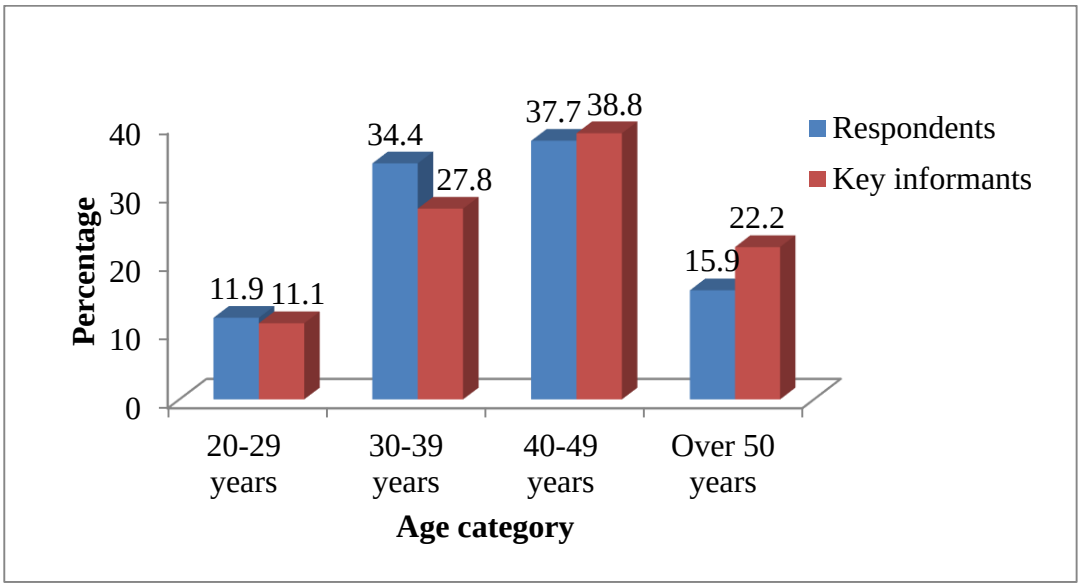

Figure 4.1: Household heads and Key Informants' Age

Studies have shown that productivity of individuals goes up to 50 years from which decline begins. Results from this study showed that most household heads and key informants were in the productive stage which energy that can be effectively utilized in restoration Methods thus advancing the communities' livelihoods in Kithimani area. Household heads close to 45% were below 40 years.

4.1.3 Highest Education Level of the Household heads and Key Informants

The study asked for the highest education level of household heads and key informants (Table 4.2). Household heads who were diploma holders were 37.4%, 27.8% had education level up to secondary school level while 14.9% had bachelor's degree and 10.9% had primary school as their highest level of education. Postgraduate degree holders were the least with 8.9%. On the other hand, results showed that majority of the key informants had bachelor's degree with 38.9%. Further, 22.2% had education

level up to postgraduate level while 22.2% had diploma level and 16.7% had secondary school as their highest education level.

Table 4.2: Highest Education Level of the Household heads and Key informants

	Household Heads		Key informants	
Education Level	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Primary	33	10.9	0	0
Secondary	84	27.8	3	16.7
Diploma	113	37.4	4	22.2
Bachelor's degree	45	14.9	7	38.9
Postgraduate degree	27	8.9	4	22.2
Total	**302**	**100.0**	**18**	**100**

Results indicated that the education levels of most household heads were basic. In fact, 75% of them were either primary, secondary or diploma holders. Lack of education is a great contributor to environmental degradation due to lack of exposure, employment and high levels of ignorance. A lot therefore needs to be done to ensure the people of Kithimani area are educated on the importance of protecting the ecosystem which will eventually lead to conservation.

4.1.4 Years lived in Kithimani Area

The study asked the household heads and key informants to indicate the length of time they had lived in Kithimani area (Table 4.3). Most household heads and key informants had lived in Kithimani area for more than 10 years. 42.5% and 44.4 % of the household heads and key informants and 32.5% and 16.7% of the household heads

and key informants had lived in Kithimani area for 11-15 years and over 15 years respectively, 11.6% and 11.1% of the household heads and key informants had lived in Kithimani area for 3-5 years while 8.2% and 16.7% of the household heads and key informants had lived in Kithimani area for 6-10 years and 5.0% and 11.1% of the household heads and key informants were residents of Kithimani area for 2 years or less.

Table 4.3: Years lived in Kithimani

	Household Heads		**Key informants**	
Years	**Frequency**	**Percentage**	**Frequency**	**Percentage**
0-2 years	15	5.0	2	11.1
3-5 years	35	11.6	2	11.1
6-10 years	25	8.2	3	16.7
11-15 years	129	42.7	8	44.4
Over 15 years	98	32.5	3	16.7
Total	**302**	**100.0**	**18**	**100.0**

Results showed that more than 60% of the household heads and key informants had lived in Kithimani area for more than 10 years. This shows that the information given was truthful since most of the respondents had a better insight concerning the area.

4.2 Ecosystem Structure and Function

The study examined the effect of ecosystem structure and function on livelihood development and ecosystem resilience. The indicators that were being measured included vegetation cover, nutrient cycling, carbon sequestration, pollination and

buffering. The indicators had means of 3.51 to 4.11 as shown in Table 4.4 meaning that ecosystem structure and function affected livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a great extent.

Findings showed that 32% and 28% of the respondents agreed to a great extent and to a very great extent respectively that the vegetation cover in Kithimani area has been on the decrease with time due to charcoal burning. According to Dekker *et al.* (2007), the general vegetation cover in the semi-arids is a product of the rainfall received while the distribution and amount of rainfall affects the development and distribution of vegetation. Further, practices like charcoal burning are major contributors to decreasing vegetation cover. Respondents agreed that in Kithimani area, charcoal burning has greatly contributed to decrease on the vegetation cover.

Findings also showed that the different land preparation methods used in Kithimani area has led to nutrient cycling as agreed by 30% of the respondents to a great extent. All living organisms in the ecosystems are dependent on one another and nutrient cycling is important for their survival. The organisms are connected by the flow of the nutrients which is driven by the nutrient cycles. The ecosystem requires the state of equilibrium for it to function appropriately and restoration to the equilibrium state normally takes place through the nutrient cycles (Lavelle & Spain, 2001). Use of manure has been a boost in the nutrient cycling in the area.

Findings denoted that 39% of the respondents agreed that the ecosystem available in the area have been assisting in carbon sequestration to a very great extent. Terrestrial ecosystems act as carbon sinks through carbon sequestration. Changes in the carbon in the atmosphere can be accelerated through changes in land use and agricultural practices like conversion of crop and livestock grazing land or forested land into bare

land through charcoal burning (Balvanera, 2006) which has been happening in Kithimani area. This has resulted in changes in the weather patterns which have affected agricultural production.

Findings also showed that 38% of the respondents agreed to a very great extent that pollination has greatly been affected since land degradation has deteriorated in Kithimani area. People and animals rely on pollinators in the production of crops and fruits that are significant components of a healthy diet for their survival (Klein *et al.*, 2007). Land degradation in Kithimani area has led to destruction of habitat that sustains existence of insects that pollinates the plant species. Drought has also limited the effectiveness of the pollinators which results in their migration

Results shown in percentages in Table 4.4 showed that the highest proportions of 39% and 38% were all responses of very great extent, indicating that generally the respondents were of the view that livelihood development and ecosystem resilience are to a very great extent affected by ecosystem structure and function. Further, very few respondents agreed to a small extent that ecosystem structure and function affected livelihood development and ecosystem resilience (least being 0% and the highest 14%). A good number of respondents disagreed (not at all) that ecosystem structure and function affected livelihood development and ecosystem resilience.

Mean summaries in Table 4.4 showed that pollination has greatly been affected since land degradation has deteriorated had a mean of 4.11 (great extent) with standard deviation (SD) of 0.81, median of 4 (great extent) and a mode of 5 (very great extent). This was followed by vegetation cover available is not enough to buffer ecosystem destruction which had a mean of 4.00 (great extent) with SD of 0.91, median of 4 (great extent) and a mode of 4 (great extent). The ecosystem available in the area have

been assisting in carbon sequestration had a mean of 3.65 (great extent) with SD of 1.38, median of 4 (great extent) and a mode of 5 (very great extent), in Kithimani, there has been a decrease in the vegetation cover with time had a mean of 3.61(great extent) with SD of 1.25, median of 4 (great extent) and a mode of 4 (great extent) while the different land preparation methods used in this area has led to nutrient cycling had a mean of 3.51(great extent) with SD of 1.35, median of 4 (great extent) and a mode of 5 (very great extent). The composite mean was 3.78 (great extent).

NGOs working in the area denoted that land and soil productivity in Kithimani has been on the decline with time. They indicated that soils have been exposed due to tree cutting for charcoal burning making them vulnerable to both wind and water erosion. Further, the vegetation cover is dispersed with vegetation as shrubs which are usually used as forage for livestock (goats and cattle). Poor rainfall has been also a factor of poor vegetation cover in the area. They suggested a need for educating the people on the importance of reclaiming the vegetation cover for the protection of the land surface from rainfall splashes and for the increase of soil organic matter. It will also help in retarding and reduction of surface water runoff. This greatly concurred with the sentiments of the respondents (household heads).

Table 4.4: Ecosystem Structure and Functioning

Statement	Frequency and Percentages						Mean	SD	Median	Mode	Interquartile		
	NA	SE	ME	GE	VGE	n					25	50	57
The vegetation cover in this area has been on the decrease with time due to charcoal burning	32	18	70	97	85	302	3.61	1.25	4	4	3	4	5
	11%	6%	23%	32%	28%	100%							
The different land preparation methods used in this area has led to nutrient cycling	42	21	70	79	90	302	3.51	1.35	4	5	3	4	5
	14%	7%	23%	26%	30%	100%							
The ecosystem available in the area have been assisting in carbon sequestration	31	42	46	65	118	302	3.65	1.38	4	5	3	4	5
	10%	14%	15%	22%	39%	100%							
Pollination has greatly been affected since land degradation has deteriorated	3	0	75	109	115	302	4.11	0.81	4	5	3	4	5
	1%	0%	25%	36%	38%	100%							
Vegetation cover available is not enough to buffer ecosystem destruction	0	17	70	110	105	302	4.00	0.91	4	4	3	4	5
	0%	6%	23%	36%	35%	100%							
Composite mean							**3.78**	**1.14**					

NA=Not at All, SE= Small Extent, ME= Moderate Extent, GE= Great Extent,
VGE= Very Great Extent, n= sample size, SD= Standard deviation

The findings of this study indicated that land degradation has deteriorated and that the vegetation cover may not buffer ecosystem destruction. The findings are supported by studies by Asner *et al.* (2004) and Andersson *et al.* (2011) which indicated that vegetation clearing processes linked with land-use variations include deforestation and other natural and semi-natural ecosystems like grasslands and shrub lands (mostly found in semi-arids), giving rise to croplands, pastures or just barren land. The processes have been fast-tracked since the mid-1800s globally (Van der Ven & Cashore, 2018) due to the need for more land for cultivation due to population increase. Variation in plant components of natural or semi-natural ecosystems without having noteworthy vegetation structural variations will bring about degradation which will affect rangelands and forested areas (Andersson *et al.*, 2011).

4.2.2 Mann Whitney U and Kruskal-Wallis H tests for Ecosystem Structure and Function

A comparison of the mean of the distribution of the variable ecosystem structure and function was desired for GENDER categories; Female and Male where a Mann Whitney test was done. Gender category Female (N= 132) had a larger mean rank (156) than male (N= 170) with mean rank (148) and thus had larger values (Table 4.5). A statistically insignificant difference was obtained ($U = 10625.5$, $p < 0.427$). The results denoted that female respondents had a tendency to engage more in ecosystem structure and function' activities than male respondents, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable ecosystem structure and function was desired for AGE categories; 20-29 years, 30-39 years, 40-49 years and above 50 years where a Kruskal-Wallis H test was carried out. Age category; 30-39

years (N= 104) had a larger mean rank (159.01) than 20-29 years (N= 36) with mean rank (150.07), 40-49 years (N= 154) with mean rank (147.47), above 50 years (N= 8) with mean rank (137.81) and thus had larger values. A statistically insignificant difference was found ($K = 1.318$, $p < 0.725$). The results denoted that respondents aged 30-39 years had a tendency to engage more in ecosystem structure and function' activities than respondents in other age categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable ecosystem structure and function was desired for EDUCATION LEVEL categories; primary, secondary, diploma, bachelors and postgraduate level where a Kruskal-Wallis H test was carried out. Education level category; postgraduate (N= 27) had a larger mean rank (173.31) than diploma (N= 113) with mean rank (153.49), primary (N= 33) with mean rank (150.44), secondary (N= 84) with mean rank (149.31), bachelors (N= 45) with mean rank (138.29) and thus had larger values. A statistically insignificant difference was found ($K = 2.861$, $p < 0.581$). The results denoted that respondents with postgraduate level of education had a tendency to engage more in ecosystem structure and function' activities than respondents in other education level categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable ecosystem structure and function was desired for YEARS LIVED IN KITHIMANI categories where a Kruskal-Wallis H test was carried out. Years lived in Kithimani category; 3-5 years (N= 35) had a larger mean rank (159.13) than above 15 years (N= 98) with mean rank (158.64), 0-2 years (N= 15) with mean rank (157.21), 6-10 years (N= 25) with mean rank (152.45), 11-15 years (N= 129) with mean rank (142.23) and thus had larger

values. A statistically insignificant difference was found (K = 2.573, p < 0.462). The results denoted that respondents who had lived in Kithimani for 3-5 years had a tendency to engage more in ecosystem structure and function' activities than respondents in other years lived in Kithimani categories, a difference that was statistically insignificant.

Table 4.5: Mann Whitney and Kruskal-Wallis H tests for Ecosystem Structure and Function

		N	Mean rank	Mann whitney U/Kruskal-Wallis H	df	Sig
Gender	Male	170	148	10625.5	1	0.427
	Female	132	156			
Age	20-29 yrs	36	150.07	1.318	3	0.725
	30-39 yrs	104	159.01			
	40-49 yrs	154	147.47			
	Above 50 yrs	8	137.81			
Education level	Primary	33	150.44	2.861	4	0.581
	Secondary	27	173.31			
	Diploma	113	153.49			
	Bachelors	84	149.31			
	Postgraduate	45	138.29			
Years lived in Kithimani	0-2 yrs	15	157.21	2.573	4	0.462
	3-5 yrs	35	159.13			
	6-10 yrs	25	152.45			
	11-15 yrs	129	142.23			
	>15 yrs	98	158.64			

4.2.3 Hypothesis Testing for Ecosystem Structure and Function

The hypothesis aimed at establishing whether there is significant effect of ecosystem structure and function on livelihood development and ecosystem resilience in

Kithimani Sub location, Machakos County, Kenya. A composite index of livelihood development and ecosystem resilience was the dependent variable.

$Y= \beta_o+ \beta_1X_1 + \varepsilon o$ was the model used for testing the hypothesis

Where: Y = Livelihood development and ecosystem resilience

β_0 = Constant

β_1 = Coefficients

X_1 = Structure and functioning

ε_o = Error term

r of 0.755 indicated that the effect of structure and function on livelihood development and ecosystem resilience was positive (Table 4.6). The adjusted R^2 of 0.569 implied that structure and function explained 56.9% of livelihood development and ecosystem resilience while 43.1% was explained by other factors other than structure and functioning.

Table 4.6: Table of Coefficients of Structure and Function

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.475	0.124		11.906	0.000
Structure and functioning	0.643	0.032	0.755	19.948	0.000

a. Dependent Variable: Livelihood development and ecosystem resilience

b. Predictors: (Constant), structure and functioning

F (1,301) = 397.916** [p=0.000<0.05], r= 0.755, R^2= 0.570, Adjusted R^2= 0.569

** 5% level of significance

The F value = 397.916 with a significant p value= 0.000 that was below 0.05, which means rejecting the null hypothesis and the conclusion was the existence of a significant effect of ecosystem structure and function on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

The beta coefficient of the model showed that the constant = 1.475 was different from 0, since the p value= 0.000 was less than 0.05. The t value for the constant was 11.906, while the t value for the ecosystem structure and function was 19.948, an indication that they were significant. The implication was rejecting the null hypothesis and accepting the alternative hypothesis which indicated that the model Y= 1.475 + 0.643 (ecosystem structure and function), was significant. Further, the beta value of 0.643 implied that a unit change in ecosystem structure and function would lead to 0.643 units change in livelihood development and ecosystem resilience. This confirmed the existence of a significant positive effect of ecosystem structure and function on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

4.3 Challenges to Ecosystem Restoration

The study examined the challenges to ecosystem restoration. The indicators that were being measured included culture, environmental factors, socio-economic factors and natural calamities. The indicators had means of 3.27 to 4.01 (Table 4.7) meaning that the challenges to ecosystem restoration affected livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a moderate and great extent.

Findings in Table 4.7 showed that 31% of the respondents agreed to a very great extent that the culture in Kithimani area encourages more land productivity and deforestation

which leads to desertification. Some of the negative practices in the area include wood carving, charcoal burning, crop production and overgrazing all of which lead to ecosystem degradation limiting the restoration efforts. On the other hand, there are many NGOs working in the area who have greatly influenced the culture of restoration of ecosystems like the terracing of the land which has been done by almost all households and it is very effective in controlling soil erosion. Further, households have been encouraged to plant crops like pigeon peas which help in improving the nutrition value of the soils thus more land productivity.

Findings also showed that the changes in the rainfall patterns, winds (environmental factors) in Kithimani area have greatly contributed to worsening land productivity as agreed by 51% of the respondents to a great and very great extent. In Kithimani area being a semi- arid, availability of water in such settings is highly pulsed and discrete rainfall events are usually combined with drought periods which forms the constituents of the yearly supply of water (Miranda *et al.*, 2011). Further, Omoyo *et al*. (2015) denoted that the impact of rainfall patterns through climate change and variability is more remarkable in the Arid and Semi-Arid Lands (ASALs) in Kenya which is negatively affecting land productivity and revegetation work.

Findings further showed that 77% of the respondents agreed to a great and very great extent that the community's poverty level in Kithimani area hindered restoration of the land productivity and soils (Table 4.7). Poverty level in Kithimani area has resulted in activities like charcoal burning and sand harvesting by the youth which leads to loss of ecosystem thus negatively affecting land productivity. According to Suich *et al.* (2015), effective management and conservation of ecosystems are key to poverty reduction especially in the semi-arids like Kithimani area.

Results showing percentages in Table 4.7 showed that the highest proportions of 41% and 34% were all responses of very great extent, indicating that on a general note the respondents were of the opinion that livelihood development and ecosystem resilience are to a very great extent affected by challenges to ecosystem restoration. Further, a number of respondents agreed to a great extent that challenges to ecosystem restoration affected livelihood development and ecosystem resilience (33%, 26% and 25%). Further, very few respondents disagreed (Not at all) that challenges to ecosystem restoration affected livelihood development and ecosystem resilience (least being 0% and the highest 10%).

Mean summaries in Table 4.7 showed that the community's poverty level hinders restoration of the land productivity and soils had a mean of 4.01(great extent) with SD of 0.84, median of 4 (great extent) and a mode of 5 (very great extent). This was followed by there has been frequent occurrence of natural calamities affecting ecosystem restoration which had a mean of 3.96 (great extent) with SD of 1.04, median of 4 (great extent) and a mode of 5 (very great extent). The culture in the area encourages more land productivity and restoration of soil fertility had a mean of 3.55 (great extent) with SD of 1.29, median of 4 (great extent) and a mode of 5 (very great extent) while the changes in the rainfall patterns, winds are greatly contributed to worsening land productivity had a mean of 3.27 (moderate extent) with SD of 1.47, median of 4 (great extent) and a mode of 4 (great extent). The composite mean was 3.69 which showed that the respondents agreed to a great extent that challenges to ecosystem restoration affected livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

Change in weather patterns is an issue that has affected the soils and land productivity in the area. This was reported by the key informants especially the chiefs and the village headmen who have lived in the area for many years. They noted that rainfall has been very erratic, poor and mostly does not fall when expected. Further, they noted that poverty has been on the rise and thus most people have indulged in practices like charcoal burning which has affected the soils.

Table 4.7: Challenges to ecosystem restoration

Statement	Frequency and Percentages						Mean	SD	Median	Mode	Interquartile		
	NA	SE	ME	GE	VGE						25	50	75
The culture in the area encourages more land productivity and restoration of soil fertility	31	28	79	72	92	302	3.55	1.29	4	5	3	4	5
	10%	9%	26%	24%	31%	100%							
The changes in the rainfall patterns, winds have greatly contributed to worsening land productivity	16	68	61	80	77	302	3.27	1.47	4	4	2	4	5
	5%	23%	21%	26%	25%	100%							
The community's poverty level hinders restoration of the land productivity and soils	0	3	96	99	104	302	4.01	0.84	4	5	3	4	5
	0%	1%	32%	33%	34%	100%							
There has been frequent occurrence of natural calamities affecting ecosystem restoration	0	32	70	76	124	302	3.96	1.04	4	5	3	4	5
	0%	11%	23%	25%	41%	100%							
Composite mean							**3.69**	**1.16**					

NA=Not at All, SE= Small Extent, ME= Moderate Extent, GE= Great Extent, VGE= Very Great Extent, n= sample size, SD= Standard deviation

According to a report by FAO (2015), smallholder farmers and most especially those in semi-arids work on their lands and a range of jobs off-farm, earning them a differentiated income. An average smallholding family in Kenya makes a gross income of approximately $2527 annually which is a clear indication of the poverty levels in the areas. Further, looking at the setting of the rural economy, the smallholder livelihoods have to make decisions depending on the allocation of the labour and few assets across farm and non-farm undertakings and generation of the probable highest income putting in mind the challenges faced (FAO, 2015). Due to the low incomes, most of the community members opt for the available cheap options like charcoal burning which has led to increased natural calamities. A report by the UNDP (2019) also indicated that the growing population has led to an increased emission in greenhouse gas, natural ecosystems loss, biodiversity decline and climate change.

4.3.2 Mann Whitney U and Kruskal-Wallis H tests for Challenges to Ecosystem Restoration

Comparing the mean of the distribution of the variable challenges to ecosystem restoration was needed for GENDER categories; Female and Male where a Mann Whitney test was conducted. Gender category Female (N= 132) had a smaller mean rank (148.86) than male (N= 170) with mean rank (153.55) and thus had smaller values (Table 4.8). A statistically insignificant difference was found ($U = 10871.0$, $p < 0.641$). The results denoted that male respondents had a tendency to engage more in challenges to ecosystem restoration variables than female respondents, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable challenges to ecosystem restoration was desired for AGE categories; 20-29 years, 30-39 years, 40-49 years and

above 50 years where a Kruskal-Wallis H test was carried out. Age category; above 50 years (N= 8) had a larger mean rank (193.81) than 40-49 years (N= 154) with mean rank (156.29), 20-29 years (N= 36) with mean rank (148.01), 30-39 years (N= 104) with mean rank (142.37) and therefore had larger values. A statistically insignificant difference was obtained ($K = 3.581$, $p < 0.310$). The results denoted that respondents aged above 50 years had a tendency to engage more in challenges to ecosystem restoration variables than respondents in other age categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable challenges to ecosystem restoration was desired for EDUCATION LEVEL categories; primary, secondary, diploma, bachelors and postgraduate level where a Kruskal-Wallis H test was carried out. Education level category; bachelors (N= 45) had a larger mean rank (163.64) than postgraduate (N= 27) with mean rank (161.56), primary (N= 33) with mean rank (153.95), diploma (N= 113) with mean rank (149.08), secondary (N= 84) with mean rank (144.05) and thus had larger values. A statistically insignificant difference was obtained ($K = 1.978$, $p < 0.740$). The results denoted that respondents with bachelors' level of education had a tendency to engage more in challenges to ecosystem restoration variables than respondents in other education level categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable challenges to ecosystem restoration was desired for YEARS LIVED IN KITHIMANI categories where a Kruskal-Wallis H test was carried out. Years lived in Kithimani category; 11-15 years (N= 129) had a larger mean rank (154.26) than 3-5 years (N= 35) with mean rank (154.07), 0-2 years (N= 15) with mean rank (152.23), 6-10 years (N= 25) with mean

rank (151.83), above 15 years (N= 98) with mean rank (146.65) and thus had larger values. A statistically insignificant difference was found (K = 0.471, p < 0.925). The results denoted that respondents who had lived in Kithimani for 11-15 years had a tendency to engage more in challenges to ecosystem restoration variables than respondents in other years lived in Kithimani categories, a difference that was statistically insignificant.

Table 4.8: Mann Whitney and Kruskal-Wallis H tests for challenges to ecosystem restoration

		N	Mean rank	Mann whitney U/Kruskal-Wallis H	df	Sig
Gender	Male	170	153.55	10871.0	1	0.641
	Female	132	148.86			
Age	20-29 yrs	36	148.01	3.581	3	0.310
	30-39 yrs	104	142.37			
	40-49 yrs	154	156.29			
	Above 50 yrs	8	193.81			
Education level	Primary	33	153.95	1.978	4	0.740
	Secondary	27	161.56			
	Diploma	113	149.08			
	Bachelors	84	144.05			
	Postgraduate	45	163.64			
Years lived in Kithimani	0-2 yrs	15	152.23	2.573	3	0.471
	3-5 yrs	35	154.07			
	6-10 yrs	25	153.45			
	11-15 yrs	129	154.26			
	>15 yrs	98	146.65			

4.3.3 Hypothesis Testing for Challenges to Ecosystem Restoration

The hypothesis aimed at establishing whether there are significant challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. A composite index of livelihood development and ecosystem resilience was the dependent variable.

$Y= \beta_o+ \beta_2X_2 + \varepsilon o$ was the model used in testing the hypothesis

Where: Y = Livelihood development and ecosystem resilience

β_0 = Constant

β_2 = Coefficients

X_2 = Challenges to ecosystem restoration

ε_o = Error term

r of 0.363 indicated a very positive effect of challenges to ecosystem restoration on livelihood development and ecosystem resilience (Table 4.9). The adjusted R^2 of 0.129 implied that challenges to ecosystem restoration explained 12.9% of the level of livelihood development and ecosystem resilience while 87.1% was explained by other factors other than challenges to ecosystem restoration.

Table 4.9: Table of Coefficients of Challenges to Ecosystem Restoration

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.698	0.181		14.878	0.000
Challenges to ecosystem restoration	0.326	0.048	0.363	6.756	0.000

a. Dependent Variable: Livelihood development and ecosystem resilience

b. Predictors: (Constant), Challenges to ecosystem restoration

F (1,301) = 45.640** [p=0.000<0.05], r= 0.363, R^2= 0.132, Adjusted R^2= 0.129

** 5% level of significance

The F value = 45.640 with a significant p value= 0.000 that was below 0.05, which means rejecting the null hypothesis and the conclusion was that there are significant challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

The beta coefficient of the model showed that the constant = 2.698 varied from 0, since the p value= 0.000 was less than 0.05. The t value for the constant was 14.878, while the t value for the challenges to ecosystem restoration was 6.756, an indication that they were significant. The implication was rejecting the null hypothesis and accepting the alternative hypothesis which indicated that the model Y= 2.698 + 0.326 (challenges to ecosystem restoration), was significant. Further, the beta value of 0.326 implied that a unit change in challenges to ecosystem restoration would lead to 0.326units change in livelihood development and ecosystem resilience. This confirmed the existence of a significant positive effect of challenges to ecosystem restoration on livelihood

development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

4.4 Ecosystem Restoration Methods

The study examined the ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County. The indicators measured included; revegetation, habitat enhancement, remediation and mitigation. The indicators had means of 3.19 to 4.03 (Table 4.10) meaning that the ecosystem based restoration Methods used affected livelihood development and ecosystem resilience to a moderate and great extent.

According to the results, 33% and 32% of the respondents agreed to a great extent and very great extent respectively that the community has been doing revegetation to restore ecosystem. Production, selling and planting of fruit seedlings has been a local strategy for to enhance vegetation cover and still create food and income for livelihood development in the area. Remediation via cultivating indigenous tree species and other vegetation has been taking place to combat desertification and curb soil erosion. This shows that the community has seen the adverse effects that have resulted from activities like tree felling for both firewood and charcoal burning. Further, through the NGOs working in the area and NEMA, communities have been sensitized on the need for planting more trees and the need of abandoning traditional activities that have harmed the ecosystems.

According to the results, 51% of the respondents agreed to a great and very great extent that there has been improvement in Kithimani area by controlling soil erosion and taking care of the ecosystem to encourage soil fertility. There has been intense cultivation and inadequate soil management by the community in the study area which

has led to very poor soils. Interview results with the officials from the agriculture and forestry offices showed that they have been training the community on soil and water conservation Methods and encouraging their implementation.

Further results showed that 76% of the respondents agreed to a great and very great extent that there have been mitigation measures put in place to avoid further destruction in Kithimani area. According to Brown (2010), mitigation measures in the semi-arids are imperative to increase the resilience of ecosystems. NGOs have supplied some community members with indigenous tree seedlings for planting for habitat enhancement in the area. This is expected to boost the population of the pollinators and mammals in the area by restoring their encroached habitats. The community needs to recognize the need to adopt the mitigation measures, they should be willing to undertake the adaptation and resources should be available. In Kithimani area, there has been support from all the key players and the mitigation measures adopted to avoid further destruction of the ecosystem.

Results showing percentages in Table 4.10 showed that the highest proportions of 43% (great extent) and 34% (very great extent), indicating that the respondents opinionated that livelihood development and ecosystem resilience are to a great extent affected by ecosystem restoration Methods used. Respondents also agreed to a great extent that ecosystem restoration Methods used affected livelihood development and ecosystem resilience. Further, there were responses of very great extent at 34%, 33% and 32% that ecosystem restoration Methods used affected livelihood development and ecosystem resilience. Moreover, very few respondents disagreed (Not at all) that ecosystem restoration Methods used affected livelihood development and ecosystem resilience (least being 1% and the highest 9%).

Mean summaries in Table 4.10 showed that there have been mitigation measures put in place to avoid further destruction had a mean of 4.03(great extent) with SD of 0.88, median of 4 (great extent) and a mode of 4 (great extent). This was followed by the community has been doing revegetation to restore ecosystem which had a mean of 3.92 (great extent) with SD of 0.93, median of 4 (great extent) and a mode of 4 (great extent). There has been planting of trees and vegetation that have been depleted with time had a mean of 3.66 (great extent) with SD of 1.34, median of 4 (great extent) and a mode of 5 (very great extent) while improvement of the area by controlling soil erosion and taking care of the ecosystem has been taking place to encourage habitat enhancement had a mean of 3.19(moderate extent) with SD of 1.50, median of 4 (great extent) and a mode of 4 (great extent). The composite mean was 3.7 which showed that the respondents agreed to a great extent that ecosystem restoration Methods used affected livelihood development and ecosystem resilience.

Key informants suggested that planting of indigenous trees will go a long way in restoring the ecosystem in Kithimani area. Indigenous trees are drought tolerant and mainly adapted to the prevailing climatic conditions. Poverty eradication through coming up with opportunities that will ensure that the people are economically empowered to cut on charcoal burning. They also suggested that coming up with sustainable programs among the residents on annual tree planting where trainings, rewards and such can be done to encourage them on the importance of healthy ecosystems.

Table 4.10: Ecosystem Based Restoration Methods

Statement	Frequency and Percentages						Mean	SD	Median	Mode	Interquartile		
	NA	SE	ME	GE	VGE	n					25	50	75
The community has been doing revegetation to restore ecosystem	6	5	94	100	97	302	3.92	0.93	4	4	3	4	5
	2%	2%	31%	33%	32%	100%							
Improvement of the area by controlling soil erosion and taking care of the ecosystem has been taking place to encourage habitat enhancement	27	72	48	82	73	302	3.19	1.50	4	4	2	4	4
	9%	24%	16%	27%	24%	100%							
There has been planting of trees and vegetation that have been depleted with time	19	38	54	87	104	302	3.66	1.34	4	5	3	4	5
	6%	13%	18%	29%	34%	100%							
There has been mitigation measures put in place to avoid further destruction	3	13	56	130	100	302	4.03	0.88	4	4	4	4	5
	1%	4%	19%	43%	33%	100%							
Composite mean							**3.7**	**1.16**					

NA=Not at All, SE= Small Extent, ME= Moderate Extent, GE= Great Extent, VGE= Very Great Extent, n= sample size, SD= Standard deviation

A study by Nuraddeen *et al*. (2014) showed that the natural environment is being progressively destroyed and therefore a need for sustainable mitigation measures as supported by the findings of this study to minimize rising environmental degradation. Since mid1970s, humans have considerably intensified the rate at which globe's forest cover and soils are damaged (Nuraddeen *et al.*, 2014). Moreover, since the 1900s there has been development claiming almost all the borders of key towns especially in Africa. There is also need to consider hybrid alternatives that combines indigenous and contemporary developed methods which are compatible with the settings and cultures in the semi arids to combat degradation in Kithimani area.

4.4.2 Mann Whitney U and Kruskal-Wallis H tests for Ecosystem Restoration Methods

Comparing the mean of the distribution of the variable ecosystem restoration Methods was needed for GENDER categories; Female and Male where a Mann Whitney test was conducted. Gender category Female (N= 132) had a larger mean rank (159.82) than male (N= 170) with mean rank (145.04) and therefore had larger values (Table 4.11). A statistically insignificant difference was obtained ($U = 10121.5$, $p < 0.141$). The results denoted that female respondents had a tendency to engage more in ecosystem restoration Methods than male respondents, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable ecosystem restoration Methods was needed for AGE categories; 20-29 years, 30-39 years, 40-49 years and above 50 years where a Kruskal-Wallis H test was carried out. Age category; 30-39 years (N= 104) had a larger mean rank (160.57) than 20-29 years (N= 36) with mean rank (151.54), 40-49 years (N= 154) with mean rank (146.31), above 50 years (N= 8) with

mean rank (133.38) and thus had larger values. A statistically insignificant difference was found (K = 2.040, p < 0.564). The results denoted that respondents aged 30-39 years had a tendency to engage more in ecosystem restoration Methods than respondents in other age categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable challenges to ecosystem restoration was desired for EDUCATION LEVEL categories; primary, secondary, diploma, bachelors and postgraduate level where a Kruskal-Wallis H test was carried out. Education level category; bachelors (N= 45) had a larger mean rank (178.83) than primary (N= 33) with mean rank (153.39), postgraduate (N= 27) with mean rank (152.48), diploma (N= 113) with mean rank (145.88), secondary (N= 84) with mean rank (143.35) and thus had larger values. A statistically insignificant difference was found (K = 5.711, p < 0.222). The results denoted that respondents with bachelors' level of education had a tendency to engage more in ecosystem restoration Methods than respondents in other education level categories, a difference that was statistically insignificant.

A comparison of the mean of the distribution of the variable challenges to ecosystem restoration was desired for YEARS LIVED IN KITHIMANI categories where a Kruskal-Wallis H test was carried out. Years lived in Kithimani category; 0-2 years (N= 15) had a larger mean rank (160.61) than 6-10 years (N= 25) with mean rank (156.32), above 15 years (N= 98) with mean rank (154.64), 3-5 years (N= 35) with mean rank (149.77), 11-15 years (N= 129) with mean rank (146.76) and thus had larger values. A statistically insignificant difference was found (K = 0.971, p < 0.808). The results denoted that respondents who had lived in Kithimani for 0-2 years had a

tendency to engage more in ecosystem restoration Methods than respondents in other years lived in Kithimani categories, a difference that was statistically insignificant.

Table 4.11: Mann Whitney and Kruskal-Wallis H tests for Ecosystem Restoration Methods

		N	Mean rank	Mann whitney U/Kruskal-Wallis H	Df	Sig
Gender	Male	170	145.04	10121.5	1	0.141
	Female	132	159.82			
Age	20-29 yrs	36	151.54	2.040	3	0.564
	30-39 yrs	104	160.57			
	40-49 yrs	154	146.31			
	Above 50 yrs	8	133.38			
Education level	Primary	33	153.39	5.711	4	0.222
	Secondary	27	152.48			
	Diploma	113	145.88			
	Bachelors	84	143.35			
	Postgraduate	45	178.83			
Years lived in Kithimani	0-5 yrs	40	160.61	0.971	3	0.808
	5-10 yrs	35	149.77			
	11-15 yrs	129	146.76			
	>15 yrs	98	154.64			

4.4.3 Hypothesis Testing for Ecosystem Restoration Methods

The hypothesis aimed at establishing whether there are significant ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. A composite index of livelihood development and ecosystem resilience was the dependent variable.

$Y= \beta_o + \beta_3 X_3 + \varepsilon o$ was the model used in testing hypothesis

Where: Y = Livelihood development and ecosystem resilience

β_0 = Constant

β_3 = Coefficients

X_3 = Ecosystem restoration Methods used

ε_o = Error term

The results as shown in Table 4.12 indicated that the r of 0.480 indicated a very positive effect of ecosystem based restoration Methods used for livelihood development and ecosystem resilience. The adjusted R^2 of 0.228 implied that ecosystem based restoration Methods used explained 22.8 % of livelihood development and ecosystem resilience while 77.2% was explained by other factors other than ecosystem restoration Methods used.

Table 4.12: Table of Coefficients of Restoration Methods Used

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.293	0.173		13.281	0.000
Ecosystem restoration Methods used	0.435	0.046	0.480	9.479	0.000

a. Dependent Variable: Livelihood development and ecosystem resilience

b. Predictors: (Constant), Ecosystem based restoration Methods used

F (1,301) = 89.845** [p=0.000<0.05], r= 0.480, R^2= 0.230, Adjusted R^2= 0.228

** 5% level of significance

The F value = 89.845 with a significant p value= 0.000 that was below 0.05, which means rejecting the null hypothesis and the conclusion was that there are significant ecosystem based restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

The beta coefficient of the model showed that the constant = 2.293 varied from 0, since the p value= 0.000 was less than 0.05. The t value for the constant was 13.281, while the t value for the ecosystem restoration Methods used was 9.479, an indication that they were significant. The implication was rejecting the null hypothesis and accepting the alternative hypothesis which indicated that the model Y= 2.293 + 0.435(ecosystem restoration Methods used), was significant. Further, the beta value of 0.435 implied that a unit change in ecosystem restoration Methods used would lead to 0.435 units change in livelihood development and ecosystem resilience. This confirmed the existence of a significant positive effect of ecosystem restoration Methods used for livelihood development and ecosystem resilience on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

4.5 Livelihood Development in Kithimani Sub location, Machakos County

The study examined livelihood development in Kithimani Sub location, Machakos County. The indicators that were being measured included food security improved HH Welfare, decreased vulnerability and alternative income sources. The indicators had means that ranged from 3.43 to 4.25 (Table 4.13) meaning that there was livelihood development in Kithimani Sub location, Machakos County, Kenya to a moderate and great extent.

According to the results in Table 4.13, 42% of the respondents agreed to a great extent while 30% agreed to a very great extent that planting of trees will lead to more rainfall

thus more harvest from the crops planted leading to food security in Kithimani area. The current food insecurity problems in the semi-arids in Kenya are attributable to numerous factors that includes the recurrent droughts and low rainfall, increased costs of domestic food production caused by high inputs costs specifically fertilizer, high food prices globally and since there are high levels of poverty, there is low purchasing power for the larger percentage of the population (FSR, 2012). Due to this situation in Kithimani, there has been campaigns in the community to plant more trees that would lead to more rainfall increasing harvest from the lands.

Results further showed that increased incidences of diseases will reduce when indigenous trees are planted improving their HH welfare as denoted to a great extent by 50% of the respondents (Table 4.13). Climate variability in the semi-arids has been found to lead to increased incidences of pests and diseases (Skoufias *et al*., 2011) which affect the HH welfare of the communities. Destruction of the crops by the pests and the diseases leads to reduced harvest and with planting of the indigenous trees in Kithimani area, pests and diseases would be controlled leading to increased harvest meaning extra would be sold improving their HH welfare.

According to the results in Table 4.13, 28% and 30% of the respondents agreed to a great extent and very great extent that planting of trees will reduce instances of flooding and loss of lives and eventually lead to decreased vulnerability. In Kithimani area like any other semi-arid areas globally, the effect of deforestation and destroyed ecosystems has increased vulnerability for the communities. Production of fruits, indigenous food sources such as honey from pollinators, cassava and arrow roots used as cover crops against soil erosions is used as an alternative source of income in Kithimani area.

Planting of trees to act as a buffer against drought and extreme rains leading to flooding thus tragedies associated with flooding like loss of lives will reduce in Kithimani.

Most of the respondents (with the least being 0% and the highest 50%) agreed to a great extent that there was livelihood development in Kithimani Sub location, Machakos County, Kenya. Notably, the highest proportions of 50% and 42% were responses of great extent, indicating that the respondents were of the view that there was livelihood development (Food security, improved HH Welfare, decreased Vulnerability and alternative income sources). Moreover, very few respondents disagreed (Not at all) that there was livelihood development (least being 0% and the highest 13%) in Kithimani Sub location, Machakos County, Kenya.

The mean summaries results in Table 4.13 showed increased incidences of diseases will reduce when indigenous trees are planted improving their HH welfare had a mean of 4.25 (great extent) with SD of 0.79, median of 4 (great extent) and a mode of 4 (great extent). This was followed by planting of trees will lead to more rainfall thus more harvest from the crops planted leading to food security which had a mean of 3.97 (great extent) with SD of 0.85, median of 4 (great extent) and a mode of 4 (great extent). Planting of trees will reduce instances of flooding and loss of lives had a mean of 3.50 (great extent) with SD of 1.38, median of 4 (great extent) and a mode of 5 (very great extent) while when more crops are harvested and trees planted, some will be sold for income had a mean of 3.43 (moderate extent) with SD of 1.36, median of 4 (great extent) and a mode of 5 (very great extent). The composite mean was 3.78 which showed that the respondents agreed to a great extent that there was livelihood development in Kithimani Sub location, Machakos County, Kenya.

Table 4.13: Livelihoods Development

Statements	Frequency and Percentages						Mean	SD	Median	Mode	Interquartile		
	NA	SE	ME	GE	VGE	n					25	50	75
Planting of trees will lead to more rainfall thus more harvest from the crops planted leading to food security	2 1%	10 3%	7 24%	129 42%	89 30%	302 100%	3.97	0.85	4	4	3	4	5
Increased incidences of diseases will reduce when indigenous trees are planted improving their HH welfare	0 0%	10 4%	20 6%	152 50%	120 40%	302 100%	4.25	0.79	4	4	4	4	5
Planting of trees will reduce instances of flooding and loss of lives	35 12%	51 17%	38 13%	85 28%	93 30%	302 100%	3.50	1.38	4	5	2	4	5
When more crops are harvested and trees planted, some will be sold for income	38 13%	43 14%	56 19%	81 26%	84 28%	302 100%	3.43	1.36	4	5	2	4	5
Composite mean							**3.78**	**1.10**					

NA=Not at All, SE= Small Extent, ME= Moderate Extent, GE= Great Extent, VGE= Very Great Extent, n= sample size, SD= Standard deviation

The results of this study supports those of FAO (2014) which indicated that trees planted on farms provides a source of food and cash income directly for approximately a billion of the poorest individuals globally through provision of both staple foods and supplemental foods like fruits, edible leaves and nuts (FAO, 2014; Njuguna, 2010).

4.5.2 Mann Whitney U and Kruskal-Wallis H tests for Livelihood Development

Comparing the mean of the distribution of the variable livelihood development was desired for GENDER categories; Female and Male where a Mann Whitney test was conducted. Gender category Female (N= 132) had a larger mean rank (156.02) than male (N= 170) with mean rank (147.99) and thus had larger values (Table 4.14). A statistically insignificant difference was obtained ($U = 10624.0$, $p < 0.426$). The results denoted that female respondents had a tendency to engage more in livelihood development than male respondents, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable livelihood development was needed for AGE categories; 20-29 years, 30-39 years, 40-49 years and above 50 years where a Kruskal-Wallis H test was carried out. Age category; 30-39 years (N= 104) had a larger mean rank (154.33) than 20-29 years (N= 36) with mean rank (153.47), 40-49 years (N= 154) with mean rank (149.74), above 50 years (N= 8) with mean rank (139.69) and thus had larger values. A statistically insignificant difference was found ($K = 0.340$, $p < 0.952$). The results denoted that respondents aged 30-39 years had a tendency to engage more in livelihood development than respondents in other age categories, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable livelihood development was desired for EDUCATION LEVEL categories; primary, secondary, diploma, bachelors and postgraduate level where a Kruskal-Wallis H test was carried out. Education level

category; postgraduate (N= 27) had a larger mean rank (175.81) than diploma (N= 113) with mean rank (154.65), secondary (N= 84) with mean rank (146.36), bachelors' (N= 45) with mean rank (144.98), primary (N= 33) with mean rank (142.80) and thus had larger values. A statistically insignificant difference was found ($K = 3.144$, $p < 0.534$). The results denoted that respondents with postgraduate level of education had a tendency to engage more in livelihood development than respondents in other education level categories, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable livelihood development was desired for YEARS LIVED IN KITHIMANI categories where a Kruskal-Wallis H test was carried out. Years lived in Kithimani category; 3-5 years (N= 35) had a larger mean rank (158.90) than 0-2 years (N= 15) with mean rank (158.13), 6-10 years (N= 25) with mean rank (156.52), above 15 years (N= 98) with mean rank (154.39), 11-15 years (N= 129) with mean rank (145.24) and thus had larger values. A statistically insignificant difference was found ($K = 1.265$, $p < 0.737$). The results denoted that respondents who had lived in Kithimani for 3-5 years had a tendency to engage more in livelihood development than respondents in other years lived in Kithimani categories, a difference that was statistically insignificant.

Table 4.14: Mann Whitney and Kruskal-Wallis H tests for Livelihood Development

		N	Mean rank	Mann whitney U/Kruskal-Wallis H	df	Sig
Gender	Male	170	147.99	10624.0	1	0.426
	Female	132	156.02			
Age	20-29 yrs	36	153.47	0.340	3	0.952
	30-39 yrs	104	154.33			
	40-49 yrs	154	149.74			
	Above 50 yrs	8	139.69			
Education level	Primary	33	142.80	3.144	4	0.534
	Secondary	27	175.81			
	Diploma	113	154.65			
	Bachelors	84	146.36			
	Postgraduate	45	144.98			
Years lived in Kithimani	0-5 yrs	40	158.13	1.264	3	0.737
	3-5 yrs	35	158.90			
	6-10 yrs	25	156.52			
	11-15 yrs	129	145.24			
	>15 yrs	98	154.39			

4.6 Ecosystem Resilience

The study examined ecosystem resilience in Kithimani Sub location, Machakos County. The indicators that were being measured included drought resistant species, community of species and stable nutrient flow. The indicators had means that ranged from 3.82 to 4.12 as shown in Table 4.15 meaning there was ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a great extent.

Percentages in Table 4.15 showed that the majority of the respondents (with the least being 0% and the highest 38%) agreed to a very great extent the existence of ecosystem

resilience in Kithimani Sub location, Machakos County, Kenya. Notably, the highest proportions of 38% and 37% were responses of very great extent, indicating that the respondents were of the view that ecosystem resilience existed to a very great extent. Further, a good number of the respondents (37%, 32% and 28%) agreed to a great extent that there was ecosystem resilience. The basis of the view was on the increased revegetation and alternative food and income sources by the people. Moreover, very few respondents disagreed (Not at all) that there was ecosystem resilience (least being 0% and the highest 1%) due to drought and the varied rain patterns experienced in Kithimani Sub location, Machakos County, Kenya.

Mean summaries in Table 4.15 showed community of species had a mean of 4.12 (great extent) with SD of 0.85, median of 4 (great extent) and a mode of 5 (very great extent). Stable nutrient flow had a mean of 4.02 (great extent) with SD of 0.93, median of 4 (great extent) and a mode of 5 (very great extent) while drought resistant species had a mean of 3.82 (great extent) with SD of 1.14, median of 4 (great extent) and a mode of 5 (very great extent). The composite mean was 3.99 showing there was ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a great extent.

Table 4.15: Ecosystem Resilience

Statement	Frequency and Percentages						Mean	SD	Median	Mode	Interquartile		
	NA	SE	ME	GE	VGE	n					25	50	75
Drought Resistant Species	2	55	50	84	111	302	3.82	1.14	4	5	3	4	5
	1%	18%	16%	28%	37%	100%							
Community of species	2	5	65	113	117	302	4.12	0.85	4	5	4	4	5
	1%	2%	22%	37%	38%	100%							
Stable nutrient flow	0	19	71	96	116	302	4.02	0.93	4	5	4	4	5
	0%	6%	24%	32%	38%	100%							
Composite mean							**3.99**	**0.97**					

NA=Not at All, SE= Small Extent, ME= Moderate Extent, GE= Great Extent, VGE= Very Great Extent, n= sample size, SD= Standard deviation

Research has shown that more varied ecosystems means more resources useful in helping the recovery from dearth, famine, diseases or the extinction of species. There is need for a sustainable system via supply of mineral fertilizer centered on expected plant nutrient uptake, return of crop residues in well-defined growth stages, use of fertility-building crops and crop rotations (Deligios*et al.*, 2017). The findings of this study support the research therein.

4.6.2 Mann Whitney U and Kruskal-Wallis H tests for Ecosystem Resilience

Comparing the mean of the distribution of the variable ecosystem resilience was needed for GENDER categories; Female and Male where a Mann Whitney test was conducted. Gender category Female (N= 132) had a larger mean rank (154.63) than male (N= 170) with mean rank (149.07) and thus had larger values (Table 4.16). A statistically insignificant difference was obtained ($U = 10807.0$, $p < 0.581$). The results denoted that female respondents had a tendency to engage more in ecosystem resilience than male respondents, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable ecosystem resilience was needed for AGE categories; 20-29 years, 30-39 years, 40-49 years and above 50 years where a Kruskal-Wallis H test was carried out. Age category; 40-49 years (N= 154) had a larger mean rank (166.27) than 30-99 years (N= 104) with mean rank (142.19), 20-29 years (N= 36) with mean rank (123.18), above 50 years (N= 8) with mean rank (115.56) and thus had larger values. A statistically significant difference was found ($K = 10.880$, $p < 0.012$). The results denoted that respondents aged 40-49 years had a tendency to engage more in ecosystem resilience than respondents in other age categories, a difference that was statistically significant.

Comparing the mean of the distribution of the variable ecosystem resilience was needed for EDUCATION LEVEL categories; primary, secondary, diploma, bachelors and postgraduate level where a Kruskal-Wallis H test was carried out. Education level category; postgraduate (N= 27) had a larger mean rank (171.61) than bachelors' (N= 45) with mean rank (159.07), primary (N= 33) with mean rank (150.41), diploma (N= 113) with mean rank (148.84), secondary (N= 84) with mean rank (144.99), and thus had larger values. A statistically insignificant difference was found ($K = 2.380$, $p < 0.666$). The results denoted that respondents with postgraduate level of education had a tendency to engage more in ecosystem resilience than respondents in other education level categories, a difference that was statistically insignificant.

Comparing the mean of the distribution of the variable ecosystem resilience was needed for YEARS LIVED IN KITHIMANI categories where a Kruskal-Wallis H test was carried out. Years lived in Kithimani category; 3-5 years (N= 35) had a larger mean rank (152.77) than 11-15 years (N= 129) with mean rank (151.77), 0-2 years (N= 15) with mean rank (151.28), above 15 years (N= 98) with mean rank (150.79), 6-10 years (N= 25) with mean rank (149.35), and thus had larger values. A statistically insignificant difference was found ($K = 0.016$, $p < 0.999$). The results denoted that respondents who had lived in Kithimani for 3-5 years had a tendency to engage more in ecosystem resilience than respondents in other years lived in Kithimani categories, a difference that was statistically insignificant.

Table 4.16: Mann Whitney and Kruskal-Wallis H tests for Ecosystem Resilience

		N	Mean rank	Mann whitney U/Kruskal-Wallis H	df	Sig
Gender	Male	170	149.09			
	Female	132	154.63	10807.0	1	0.581
Age	20-29 yrs	36	123.18			
	30-39 yrs	104	142.19	10.880	3	0.012
	40-49 yrs	154	166.27			
	Above 50 yrs	8	115.56			
Education level	Primary	33	150.41			
	Secondary	27	171.61			
	Diploma	113	148.84	2.380	4	0.666
	Bachelors	84	144.99			
	Postgraduate	45	159.07			
Years lived in Kithimani	0-5 yrs	15	151.28			
	3-5 yrs	35	152.77			
	6-10	25	149.35	0.016	3	0.999
	11-15 yrs	129	151.77			
	>15 yrs	98	150.79			

4.7 Moderating Influence of Ecosystem Restoration Methods

The hypothesis aimed at establishing whether there is a significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. A composite index of livelihood development and ecosystem resilience was the dependent variable.

$Y= \beta_o + \beta_1X_1+ \beta_2X_2 + \beta_3X_3 + \varepsilon o$ was the model used for testing the hypothesis

Where: Y = Livelihood development and ecosystem resilience

β_0 = Constant

$\beta_1 - \beta_2$ = Coefficients

$X_1 - X_3$ = Structure and functioning, challenges to ecosystem restoration, restoration Methods used

ε_o = Error term

The results as shown in Table 4.17 indicated that the r of 0.771 indicated a very positive effect of structure and functioning, challenges to ecosystem restoration, restoration Methods used for livelihood development and ecosystem resilience. The adjusted R^2 of 0.591 implied that structure and functioning, challenges to ecosystem restoration, restoration Methods used explained 59.1% of livelihood development and ecosystem resilience while 40.9% was explained by other factors other than structure and functioning, challenges to ecosystem restoration, restoration Methods used.

Table 4.17: Table of Coefficients Moderating Influence

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.079	0.154		7.013	0.000
Structure and functioning	0.574	0.035	0.674	16.195	0.000
challenges to ecosystem restoration	0.064	0.042	0.071	1.532	0.127
Restoration Methods used	0.113	0.045	0.125	2.522	0.012

a. Dependent Variable: Livelihood development and ecosystem resilience

b. Predictors: (Constant), structure and functioning, challenges to ecosystem restoration, restoration Methods used

F (3,298) = 146.002** [p=0.000<0.05], r= 0.771, R^2= 0.595, Adjusted R^2= 0.591

** 5% level of significance

The F value = 146.002 with a significant p value= 0.000 that was below 0.05, which means rejecting the null hypothesis and the conclusion was a significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

Livelihood development and ecosystem resilience = 1.079 + 0.574 (0.035) + 0.064 (0.042) + 0.113 (0.045)

Where; Livelihood development and ecosystem resilience = Constant + structure and functioning + challenges to ecosystem restoration + restoration Methods used

The relationship between livelihood development and ecosystem resilience and structure and functioning was positive and statistically significant (Table 4.17) (β=0.574, p=0.000). Livelihood development and ecosystem resilience and challenges to ecosystem restoration relationship was positive and statistically insignificant (β= 0.064, p=0.127) while livelihood development and ecosystem resilience and restoration Methods used relationship was positive and significant at the 95% confidence level (β= 0.113, p=0.012).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter summarizes the findings, conclusions and the recommendations that are related to the research objectives. Areas for further studies are suggested. The study was to establish ecosystem restoration methods and livelihoods development in the arid and semi-arid regions of Kithimani sub-location, Machakos County, Kenya.

5.1 Summary of Findings

The study had four specific objectives which examined the effect of ecosystem structure and function, challenges to ecosystem restoration, ecosystem restoration Methods used on livelihood development and ecosystem resilience and finally examined the moderating influence of ecosystem restoration on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County. There were four hypotheses which were to be tested. They were; Ecosystem structure and function does not have significant effect livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, there are no significant challenges to ecosystem restoration for, there are no significant ecosystem based restoration Methods used for and that here is no significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County.

5.1.1 Ecosystem structure and functioning on livelihood development and ecosystem resilience

The first objective examined the effect of ecosystem structure and functioning on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. Ecosystem structure and function affected livelihood development and

ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a great extent as the indicators had means that ranged from 3.51 to 4.11. There was a significant positive effect of ecosystem structure and function on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

5.1.2 Challenges to ecosystem restoration for livelihood development and ecosystem resilience

The second objective examined the challenges to ecosystem restoration for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. Challenges to ecosystem restoration affected livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a moderate and great extent since the indicators had percentages and means that ranged from 24% to 38% and 3.27 to 4.01 respectively. There was a significant positive effect of challenges to ecosystem restoration on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya

5.1.3 Ecosystem based restoration Methods used for livelihood development and ecosystem resilience

The third objective was to examine the ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya. Ecosystem based restoration Methods used affected livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya to a moderate and great extent as the indicators had means that ranged from 3.19 to 4.03. There was a significant positive effect of ecosystem restoration Methods used for livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

5.1.4 Moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience

The moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County was examined. There was a significant moderating influence of ecosystem restoration Methods on livelihood development and ecosystem resilience in Kithimani Sub location, Machakos County, Kenya.

5.2 Conclusions

This study concludes that

1. Pollination and vegetation cover in the study area were significant variables as they were found to lead to food security and decreased vulnerability significantly.
2. Culture and socioeconomic factors affecting communities in the study area were challenges to ecosystem restoration resulting to food insecurity and decreased household welfare.
3. Habitat enhancement through planting drought resistant trees and species are significant ecosystem based restoration Methods for adoption in the study area.
4. Land degradation through charcoal burning has been heightened in the study area and therefore need to be critically looked into and mitigation measures put in place to avoid further destruction of the entire ecosystem structure.

5.3 Recommendations

1. There is need to educate communities on the significance and the connection of the ecosystem thus lead to healthy structures and well-functioning systems like the trees enhancing pollination and carbon sinking for a healthy ecosystem.

2. Alternative income sources and improved HH welfare is achievable through empowerment of the communities in the study area. This should be prioritized to improve the living standards and their welfare since the poverty level was found to hinder restoration of the land productivity and soils.
3. Specific ecosystem based restoration measures like planting of drought tolerant trees need to be adopted in Kithimani to decrease people's vulnerability.
4. Mitigation measures and revegetation on the lands that ecosystem has been depleted should be put in place to avoid further destruction.

5.4 Areas for Further Research

There are other variables which need to be evaluated since the variables in the current study had 58.4% of livelihood development and ecosystem resilience. This research saw a gap in plant succession as a possible area to study and use for ecosystem restoration. Further, a research study should be carried in other areas since the exposure levels depicted by the level of education in the study area were low. The study was also limited to data collection using questionnaires and interview schedules and therefore a comparative study should be done using other data collection tools.

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APPENDICES

Appendix I: Introduction Letter

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/CTY/PT/33094/2015 DATE: 9th September, 2019

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

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR MR. BENJAMIN MUNUVE KYALO – REG. NO. N50/CTY/PT/33094/15

I write to introduce Mr. Benjamin Munuve Kyalo who is a Postgraduate Student of this University. He is registered for M.Env. Studies degree programme in the **Department of Environmental Studies & Community Development.**

Mr. Kyalo intends to conduct research for a M.Env. Studies thesis Proposal entitled, **"Ecosystem Restoration Methods and Livelihoods Development in Machakos County, Kenya."**

Any assistance given will be highly appreciated.

Yours faithfully,

KENYATTA UNIVERSITY OFFICE OF DEAN 17 SEP 2019 GRADUATE SCHOOL P.O. Box 43844-00100 NAIROBI

PROF. ELISHIBA KIMANI
DEAN, GRADUATE SCHOOL

Appendix II: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 506442

Date of Issue: 28/March/2020

RESEARCH LICENSE

This is to Certify that Mr.. Benjamin Munuve of Kenyatta University, has been licensed to conduct research in Machakos on the topic: ECOSYSTEM RESTORATION METHODS AND LIVELIHOODS DEVELOPMENT IN KITHIMANI SUB-LOCATION, MACHAKOS COUNTY, KENYA for the period ending : 28/March/2021.

License No: NACOSTI/P/20/4514

506442

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

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Appendix III: Questionnaire

Instructions: Please tick where appropriate

Section 1: Demographics

1. Gender

   i. Male [ ]

   ii. Female [ ]

2. Age Bracket (Choose one)

   i. 20-29 years [ ] iii. 40-49 years [ ]

   ii. 30-39 years [ ] iv. Over 50 years [ ]

3. Highest education level attained

   i. Primary [ ] iv. Diploma [ ]

   ii. Secondary [ ] v. Bachelor's degree [ ]

   iii. Certificate [ ] vi. Postgraduate degree [ ]

4. Number of years lived in Kithimani area (Choose one)

   i. 0-2 years [ ]

   ii. 3-5 years [ ]

   iii. 6-10 years [ ]

   iv. 11-15 years [ ]

   v. Over 15 years [ ]

Section B: ASAL Ecosystem Restoration and Livelihoods Development

On a scale of one to five where 5 is very great extent, 4 is great extent, 3 is moderate extent, 2 small extent and 1 is not at all, please show your level of agreement with the statements in this section

Ecosystem Structure and Functioning

		1	**2**	**3**	**4**	**5**
5	The vegetation cover in this area has been on the decrease with time					
6	The different land preparation methods used in this area has led to nutrient cycling					
7	The ecosystem available in the area have been assisting in carbon sequestration					
8	Pollination has greatly been affected since land degradation has deteriorated					
9	Vegetation cover available is not enough to buffer ecosystem destruction					

Challenges to Ecosystem Restoration

		1	**2**	**3**	**4**	**5**
10	The culture in the area encourages more land productivity and restoration of soil fertility					
11	The changes in the rainfall patterns, winds are greatly contributed to worsening land productivity					
12	The community's poverty level hinders restoration of the land productivity and soils					

13	There has been frequent occurrence of natural calamities affecting ecosystem restoration					

Ecosystem Based Restoration Methods

		1	**2**	**3**	**4**	**5**
14	The community has been doing revegetation to restore ecosystem					
15	Improvement of the area by controlling soil erosion and taking care of the ecosystem has been taking place to encourage habitat enhancement					
16	There has been planting of trees and vegetation that have been depleted with time					
17	There has been mitigation measures put in place to avoid further destruction					

Livelihoods Development

		1	**2**	**3**	**4**	**5**
18	Planting of trees will lead to more rainfall thus more harvest from the crops planted leading to food security					

19	Increased incidences of diseases will reduce when indigenous trees are planted improving their HH welfare					
20	Planting of trees will reduce instances of flooding and loss of lives					
21	When more crops are harvested and trees planted, some will be sold for income					

Ecosystem Resilience

Please indicate the extent you agree that Kithimani sub location will experience improved soils and land productivity if the following indicators are adopted

		1	**2**	**3**	**4**	**5**
22	Drought Resistant Species					
23	Community of species					
24	Stable nutrient flow					

Appendix IV: Interview Schedule

General Information

Hello, my name is Benjamin Kyalo. I am carrying out research on Ecosystem Restoration and Livelihoods Development in Arid and Semi Arids in Kithimani sub location, Machakos County, Kenya. You have been selected because you are important key stakeholder in this sector. I would like to ask you some questions related

1. Gender

i. Male [ ] ii. Female [ ]

2. Age

i. 20-29 years [ ] iii. 40-49 years [ ]

ii. 30-39 years [ ] iv. Over 50 years [ ]

3. Highest education level

i. Primary [ ]

ii. Secondary [ ]

iii. Certificate [ ]

iv. Diploma [ ]

v. Bachelor's degree [ ]

vi. Postgraduate degree [ ]

4. Number of years lived in Kithimani area (Choose one)

i. 0-2 years [ ]

ii. 3-5 years [ ]

iii. 6-10 years [ ]

iv. 11-15 years [ ]

v. Over 15 years [ ]

5. Kindly share with me the status of the land and soils productivity in this area

……

……

……

……

6. How is the vegetation cover in this area?

……

……

……

7. What are the challenges for land and soils productivity in this area?

……

……

……

……

8. What are some of the restoration Methods (for improved land and soils productivity, vegetation cover) that you would recommend for adaptation in this area?

……

……

……

……