IMPACT OF AGRO-FORESTRY PRACTICES ON RESILIENCE TO CLIMATE VARIABILITY AMONG FARMERS IN VIHIGA SUB-COUNTY, KENYA

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A Thesis submitted in partial fulfillment of the requirements for the award of Master of Science degree in Disaster Management and Sustainable Development of Masinde Muliro University of Science and Technology.

AUGUST, 2018

DECLARATION AND CERTIFICATION

DECLARATION AND CERTIFICATION

Declaration

This is my original work and has not been submitted elsewhere for a degree or any other award.

Sign:.. Date: 28/8/18

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Certification

The undersigned supervisors approve that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology a Thesis entitled **"Impact of Agro-forestry practices on resilience to Climate Variability among farmers in Vihiga sub County, Kenya".**

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DEDICATION

This thesis is dedicated to my beloved Mother Rhasoa Imbwaga for working tirelessly to enable me get education. Not forgetting my beloved wife Lydia Asena and children Victor Namema, Ian Tsisaga and Alvin Lomosi for their encouragement and prayers during the entire period of my study.

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ABSTRACT

Climate variability which is a reality in Kenya is manifested by fluctuations in climatic parameters, low agricultural production, land fragmentation, soil degradation, and loss of biodiversity. Addressing climate variability requires the use of ecologically based traditional climate smart agriculture systems such as agro forestry. In the past decade human lives, crops and livestock worth millions of shillings have been destroyed by increased intensity of extreme weather events in Kenya. This study therefore intended to examine the impact of agro forestry practices as a resilient mechanism for farmers against the effects of climate variability in Vihiga Sub County, Kenya. The specific objectives were to: (i) determine the agro forestry techniques practiced by farmers in Vihiga Sub County; (ii) examine the rainfall and temperature variability trends in Vihiga Sub County from 1985 to 2015 and (iii) evaluate the contribution of agro forestry practices and products to households' income as farmers' resilience to Climate Variability in Vihiga Sub County. Evaluation research design was used in this study. The sample size involved 418 respondents. Stratified random sampling was used to get farmer households by using the five locations in the sub county as strata. All the strata had a target population of about 4184. Purposive sampling was used to sample relevant organizations which included: ministry of agriculture, Kenya Agricultural and Livestock Research Organization, International center for research and agro forestry, Kenya meteorological department, Kenya sugar research foundation and District Agricultural office staff. Quota sampling was used to identify respondents for focus group discussions; the study used interview schedules to collect data from officers attached to these organizations. Secondary data was collected from documentary analysis obtained from these offices. Information on different trends in temperature, rainfall, agricultural outputs and potential yields was obtained from these organizations. Data collected was subjected to Analysis of Variance using Statistical Analysis Systems software version 8.0 to determine if agro forestry practices had significant effects on climate variability and correlation-regression analyses were done to establish relationship(s) between key variables on climate variability and agro-forestry practices. The results revealed that multiple agro forestry practices have been adopted in the study area, they include mixing trees with agricultural crops (7.7%), fruit trees with agricultural crops (6.7%), trees and agricultural crops with animals (20.6%) and agricultural crops with pasture (44.8%) and other agro forestry practices (20.2%) respectively. The chi square test at 0.01 gave a p-value of (0.006) indicating that there was statistically no significant difference between agro forestry techniques and climate variability. Agro forestry has contributed to the moderate climatic conditions experienced in the sub county while the increase in temperature is attributed to global warming. The benefits of agro forestry in Vihiga sub county range from planting trees as windbreaks (90.7%) to diversifying agricultural products (17.4%) respectively. These results are useful in understanding the role of agro forestry systems in enhancing farmers' resilience to climate variability and thereby reducing the level of vulnerability. The results will further assist policy makers in formulating sound policies in matters pertaining to climate variability resilience.

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ABBREVIATIONS AND ACRONYMS

SDMHA School of Disaster Management and Humanitarian Assistance

CSA Climate Smart Agriculture

FAO Food and Agriculture Organization

FGD Focus group discussions

GDP Gross domestic product

GHG Greenhouse gases

ICRAF International centre for research and agro forestry

IFAD International Fund for Agricultural Development

ILRI International livestock research institute

IPCC Intergovernmental Panel on Climate Change

KALRO Kenya Agricultural and Livestock Research Organization

KARI Kenya Agricultural Research Institute

KESREF Kenya Sugar Research Foundation

KMD Kenya meteorological department

MDGs Millennium Development Goals

NCCAS National climate change adaptation strategy

NGOs Non-Governmental Organization

SCS Soil carbon sequestration

SLM Sustainable land management

SASS Statistical Analysis Systems software

SSA Sub-Saharan Africa

UNFCCC United Nations Framework Convention on Climate Change

DEFINITION OF OPERATIONAL TERMS

Adaptation: In this study Adaptation will be used in the context of the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities, human intervention may facilitate adjustment to the expected climate effects.

Adaptive capacity: Refers to the ability or potential of a human or natural system to respond successfully to climate variability and change so as to moderate potential risks or cope with consequences of extreme events (floods, heavy hail/snow events, heavy wind and dust storms, droughts and dry spells, heat waves and warm spells, cold spells etc)

Agro forestry: ICRAF (2013) defines agro forestry as an agricultural system that integrates trees, shrubs and animals in a farm that results to multiple benefits. These benefits are multiple include making available fodder for animals, timber for fuel wood, enrichment of soil as well as medicinal products

Agro forestry Technologies: Farming systems that integrate trees, forage, livestock and other Components in combination with new conservation techniques such as Contour hedgerows, alley cropping and enrich fallows (Faulkner *et al.*, 2014). This denotes the farming system combination with integration of trees and livestock by farmers in the study area.

Climate variability: This is the departure from normal or the difference in magnitude between climatic episodes.

Climate change: It is the alteration in the composition of the global atmosphere and which is in addition to natural variability observed over comparable time periods due to human activities.

Climatic parameters: refers to elements of weather and climate, such as rainfall, temperature etc.

Ecosystem: Refers to a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system. These biotic and a biotic component are regarded as linked together through nutrient cycles and energy flows. Ecosystems are defined by the network of interactions among organisms, and between organisms and their environment.

Land degradation: It is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. It is viewed as any change or disturbance to the land perceived to be deleterious or undesirable.

Mitigation: The lessening or minimizing of the adverse impacts of a hazardous event (UNISDR 2017).

Resilience: In the context of this study, according to Hughes et al. (2005); Lin (2011) and Thomas *et al.* (2011), resilience refers to the ability of a system to maintain key functions and processes in the face of stresses or pressures by resisting, adapting or mitigating change. It refers to the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Sustainability: This is the capacity to endure; it is how biological systems remain diverse and productive indefinitely. In more general terms, sustainability is the endurance of systems and processes.

Vulnerability: Vulnerability to climate change is defined by the Intergovernmental Panel on Climate Change (IPCC) as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and its extremes.

CHAPTER ONE

INTRODUCTION

1.1 Preamble

This chapter presents the background information of the study, statement of the problem, Objectives of the study, research questions, justification, significance and scope of the study.

1.2 Background

Climate variability refers to the departure from the normal or the difference in magnitude between climatic episodes bringing about intense and extreme weather events that can be destructive and uncontrollable causing loss of lives, destruction of crops and death of livestock (Parry *et al*., 2007). Agriculture is a human enterprise that is most vulnerable to climate variability. Tropical agriculture, particularly subsistence farming is vulnerable because smallholder farmers do not have adequate resources and capacity to adapt to extreme weather events. While agro-forestry may play a significant role in mitigating the atmospheric accumulation of greenhouse gases (GHG), it also has a role to play in helping smallholder farmers adapt to climate variability through carbon sequestration (Verchot *et al.*, 2007). This indeed is the resilience aspect of Agro forestry against climate variability.

Temperature fluctuations, as well as seasonal shifts, can have large effects on crop growth, production and quality (FAO, 2010). In order to stabilize output, ecosystem and income, production systems must become more resilient, i.e. more capable of performing well in the face of destructive events and perturbation (Roy *et al.*, 2011). Agro forestry practices are an example of socio-ecological systems that increase resilience and boost carbon dioxide removals (Zomer *et al*., 2009; Ajayi *et al*., 2011). Agro forestry systems protect crops and animals from extreme weather events such as heavy rains, drought and wind storms, in which high rainfall intensity and hurricane winds can cause landslides, flooding and premature fruit drop from crop plants (Nair 2008; Smith 2010; Berrang *et al.,* 2011).

The frequency and magnitude of climate change induced incidences are increasing in scale across the world, creating serious threats to lives and livelihood in recent years (Field *et al*., 2012). In 2011, the world faced the worst drought-induced famine which plunged 13.3 million people into crisis in the region, the risks are generally believed to be more acute in developing countries, because they rely heavily on climate-sensitive sectors, such as agriculture which have low gross domestic product; high levels of poverty; low levels of literacy; and limited human, institutional, economic, technical, and financial capacities, as cited by (Tesso *et al.,* 2012). This means that the vulnerability of countries and societies to the effects of climate variability depends not only on the magnitude of climatic stress but also on the sensitivity and capacity of affected societies to adapt to or cope with such stress.

It is in response to such climate variability-induced risks that the world has focused on resilience. There is currently a wave of enthusiasm for "building resilience." For many humanitarian and development actors, resilient households and communities are those that are effectively working out of poverty for the long run, in spite of any immediate setbacks they may face (Oxfam, 2013). Indeed, it is hoped that, through the undertaking of such efforts, the negative impacts of disasters will be less severe, as resilience is understood to go beyond simply helping poor people to "bounce back."

The international community faces great challenges in the coming decades including increased global climate variability, ensuring food security for the growing population, and promoting sustainable development (FAO, 2010). Changes in the agriculture sector are therefore essential to meeting these challenges. Globally, agriculture provides the main source of livelihood for the poor especially in developing countries and therefore improving agricultural productivity is critical to achieving food security as well as most of the targets specified under the Millennium Development Goals (Roose *et al.,* 2006). This explains the need to improve agricultural productivity with a view to sustaining the current productivity through adoption of agroforestry.

In particular, parts of South Asia and Sub-Saharan Africa are expected to be hardest hit, with decreases in agricultural productivity between 15-35 percent because of climate variability (Fisher *et al.*, 2002; IPCC, 2007). Wakhungu *et al.* (2013) observes that these are precisely the same regions that already exhibit high vulnerability to weather shocks, meaning that increasing the adaptive capacity of agricultural systems of these regions is required not only to meet Millennium Development Goals (MDGs) in the near future, but also to ensure that such gains are not lost where negative climate variability impacts increases in the future. IPCC, 2007 predicts that Africa will be the region most affected by climate variability, due to both changes in mean temperatures and rainfall, as well as increased variability associated with both. This explains why agro forestry is being used widely as a resilient mechanism against climate variability.

According to (ICRAF, 2011), over the years, forests and natural vegetation have been cleared as demand for land for agriculture and industrial development increases. The destruction of forests and natural vegetation and development of industries that emit dangerous gases are the main causes of increased climate variability. Phiri *et al*. (2004), believes that to cope with this situation, farmers in Nigeria, Ethiopia and Tanzania are now increasingly being encouraged to plant more trees to meet the ever increasing demands and enjoy other benefits from trees such as food, fodder, medicine, water conservation and soil fertility. Adger *et al*. (2003) indicates that Agro-forestry enhances climate-smart agriculture, increases food security, alleviates rural poverty and therefore facilitates achievement of truly sustainable development.

Agro forestry systems enhance smallholder farmers' resilience to climate variability by supporting them with the diversity of products or benefits (Bucagu *et al*., 2012) such as: food (arable crops, vegetables, animal products, fruit, mushrooms, oils, nuts, and leaves; fuel-charcoal and fire wood). Others include fodder and forage, fibre, timber (construction and furniture making), gums and resins, thatching and hedging materials (binders and stakes), gardening materials (pea sticks, beans poles, fencing, hurdles), medicinal products, craft products (natural dyes, floral arrangements) and ecological services (Ndayambanje , 2011; de Souza *et al*., 2012).

Unsustainable farming practices by small-scale farmers in Lake Victoria basin have been a contributing factor to land degradation, greenhouse gas emissions and farmers' vulnerability to climate variability (Guthiga, 2007). Maragoli hills forest in Vihiga Sub County consists of 469.3 ha of exotic tree species. However, the forest has since been destroyed through human activities as a result of population pressure, leading to deforestation. Due to this human encroachment, most indigenous forest species have been destroyed leaving ground bare and rocky, this has had an impact on the climate of the area. Alternative farming methods have been explored in Vihiga Sub County but the key to addressing climate variability requires the use and expansion of agro-forestry which is an ecologically based ,this potential has not been explored in this sub county. This study therefore purposed to examine how farmer household agro forestry practices could be used to create resilience among farmers against extreme weather events in this sub County.

The existing research gaps therefore indicate where hard data is required to provide a predictive understanding of resilience, profitability and sustainability aspects of agro-forestry and its implications on climate variability among farmers in Vihiga sub-county.

1.3 Statement of the problem

Climate variability and change could have serious effects on agricultural production worldwide. A number of technologies and agronomic techniques have been developed in various parts of the world to reduce these effects. However these methods have not been able to enhance resilience to climate variability. The key to addressing climate variability in Vihiga Sub County requires wide use and expansion of agro-forestry practices as a resilient mechanism. Use of agro forestry technologies is well covered in the previous studies but little information is available on these practices and their resilience to climate variability in Vihiga Sub County.

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) points at increased evidence indicating that the current climate variability and change is to a large extent due to human activities and this will alter the living conditions for all humans, flora, fauna, and ecosystems. According to Nyandiko *et al*. (2013), a decrease in annual rainfall results in lowering of soil moisture, which if combined with high evapo-transpiration, promotes desertification as vegetation cover reduces.

Many African countries lose significant proportions of their GDP to recurrent droughts, floods, landslides, epidemics, and other climate shocks. The 2015–2016 El Niño provides recent evidence of how Africa is thought to be the region most vulnerable to these impacts. Drought and floods have increased in frequency and intensity over the past decade. Severe droughts occurred in 2010 and 2011, with 4 million people requiring food assistance (IFAD, 2013). Residents of Vihiga Sub County were also affected by this drought.

Rural poverty in Kenya is strongly linked to environmental concerns especially deforestation, poor water management, soil erosion, declining soil fertility and land degradation (IFAD, 2013). The high population density of 1,073 persons per Km^2 in Vihiga Sub County has put pressure on the land leading to uneconomical sub-divisions of land, rampant land degradation, deforestation, threats of food insecurity and frequent land disputes. Most people in the sub county own land however, 3 % of the total population are landless. Some of the landless have invaded Maragoli hills forest for settlement while others have immigrated to neighboring counties like Siaya, Nandi, Kakamega, Trans Nzoia and Bungoma.

With this high rate of population growth rate, most of the existing forests reserves have been destroyed in search of land for farming and settlement for instance the destruction of Maragoli hills forest which now largely remains bare rocks. The high population growth rate and destruction of forest reserves has led to negative impacts on the environment such as extreme weather events, frequent occurrence of landslides and food insecurity. This study therefore purposed to provide key knowledge on resilience of agro forestry practices on climate variability among farmers in Vihiga Sub County.

1.4 Research objectives

1.4.1 Overall objective

The overall objective of the study was to examine the impact of agro forestry practices on resilience to climate variability among farmers in Vihiga sub County.

1.4.2 Specific objectives

The specific objectives of this study were to:-

i. Determine agro forestry technologies practiced by farmers in Vihiga sub County, Kenya.
ii. Examine rainfall and temperature variability trends in Vihiga Sub County between 1985 and 2015.
iii. Evaluate the contribution of agro forestry practices and products to households' income as farmers' resilience to climate variability in Vihiga Sub County.

1.5 Research questions

The results of this study was achieved through the use of the following research questions

i. What are some of the agro forestry technologies adopted by farmers in Vihiga sub County?
ii. What were the trends in rainfall and temperature between the period 1985 and 2015 in Vihiga Sub County?
iii. How do Agro forestry practices and products to household's income contribute to resilience on Climate variability among farmers in Vihiga Sub County?

1.6. Justification and Significance

1.6.1 Justification

The potential for building resilience and adapting to climate variability through agro forestry is particularly promising for smallholder farmers in the developing world who are most vulnerable to the effects of climate variability. On the basis of this background, this study has explored the various strategic choices of agro forestry practices on increasing farmers' resilience on climate variability. This study was necessary in order to understand the adaptation, resilience and mitigation functions of agro forestry systems examine the concept of sustainability and explore the impact of agro forestry systems in moderating climate variability in Vihiga Sub County.

According to (Lundberg and Moberg, 2003; Lin 2011; Nakashima *et al*., 2012), a system with high adaptive capacity has the ability to sustain the combined system of human and nature in a desirable state, along a desirable trajectory, in response to changing weather events. Loss of resilience means vulnerability of agricultural structures and functions that are crucial for buffering disturbance, mitigating change and maintaining the capacity of agriculture to produce goods and services (FAO, 2010; Lin, 2011; Roy *et al*., 2011).

Climate is a major driving factor for most economic activities in Kenya (GoK, 2010), with climate change and variability being a major threat to National Development. Evidence of climate change include irregular and un-predictable rainfall, intense downpours, rising temperature and generally extreme and harsh weather (G.O.K, 2010). The agricultural system in Kenya is mainly rain fed and at high risk of crop failure due to increased frequency of dry spells and uneven rainfall distribution. In many regions of Kenya, where economic fortunes are often tied to the availability of rainfall, the relationship between climate change/variability and crop failures is not a new phenomenon, but in areas where infrastructure is limited, poor people are often vulnerable to climate induced hazards (Ziervogel *et al.,* 2006).

In Kenya, more than three quarters of the population lives in rural areas, and rural households rely on agriculture for their income and livelihood development. The rural economy depends mainly on smallholder farming, which produces the majority of Kenya's agricultural output (IFAD, 2013). However, they are faced with low production as a result of climate change and variability which is undermining the resource base and contributing to decline agricultural yields (Molua *et al*., 2010). Droughts and floods have increased in frequency and intensity over the past decade.

Agro forestry as a Climate Smart Agriculture choice therefore seeks to enhance the capacity of the agricultural sector in Kenya, to sustainably support food demands, incorporating the need for resilience into development strategies. Agriculture is highly dependent on the prevailing weather conditions and is therefore highly sensitive to climate variability. Internationally, Climate Smart Agriculture (CSA) choices address the challenges of building synergies among climate variability, resilience, and food security that are closely related within agriculture and minimizing their potential negative trade-offs. Most studies have been done on Agro forestry practices that results in mitigation against soil and water erosions, improvement of water management and increased carbon sequestration. Studies elsewhere ((Bucagu *et al*., 2012), also reveal that Agro forestry practices also provide a particular example of a set of innovative practices that are designed to enhance productivity in a way that often contributes to climate variability resilience through a variety of tradeoffs, and that can also strengthen the system's ability to cope with adverse impacts of varying climate conditions and therefore the need to triangulate the same to Vihiga sub county.

1.6.2 Significance

The impact of Agro forestry practices and their resilience to climate variability will provide key knowledge to farmers, meteorological department and agricultural officers, and this can be used in buffering smallholder farmers against climate related shocks and therefore reduce the risk associated with climate variability. The findings of this study are also expected to promote the recognition of the roles played by agro forestry practices; resilience to climate variability, contribution to the achievement of the adaptation programme of action, strategies on deforestation and forest degradation, sustainable development goals (SDGs) and National Poverty Reduction by 2030 respectively.

1.7 Scope of the study

The study was conducted in Vihiga Sub County using farmer households as a unit of analysis. Information on agro forestry practices was obtained from farmer household heads and forest officers; information on rainfall and temperature trends was obtained from Kenya meteorological department (KMD) and district agricultural office, and Kenya sugar research. Contributions of agro forestry practices and products to household income on resilience to climate variability was obtained from farmer households, Kenya Agricultural and Livestock Research Organization, and International center for research and agro forestry. Vihiga Sub County was selected due to its high population growth rate and density and its impact on land and forest resources that triangulates to extreme weather events. Other aspects considered were the long history of deforestation of the only forest resource in the region (Maragoli hills forest), the long term effects that have been experienced in the region as a result of the deforestation, such as extreme weather events(e.g. draught), land degradation, landslides and unpredictable fluctuations in temperature and rainfall.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of relevant literature in the context of the study problem formulated. The main themes discussed included; Agro forestry practices, rainfall and temperature variability trends and the contribution of agro forestry practices and products on household income as farmers resilience to climate variability. All these are reviewed in context to the study objectives.

2.2 Agro Forestry Practices

Agro forestry systems are a key to agriculture that allow for a high level of progressive adaptation from simply increasing structural and temporal diversity of the production system to selling ecosystem services for increased economic diversification. There are many types of agro forestry systems that are employed in a number of regions of the world and at different levels of complexity. Verchot *et al.,*(2006) describe the different types of agro forestry technologies; Silvopasture systems are agricultural systems where trees are planted within a pasture field to provide shade to pasture and animals as well as provide food and fuel for the farmer. McCarthy *et al.,* (2001) point out another type of agro forestry within agriculture, which is the intercropping of trees within row-crops systems to provide windbreaks/shelterbelts for the crops and increase the soil stability of the region. Mixed-use forests is another type of agro forestry that allows for multiple crops to be produced in a small physical area, increasing the temporal and structural diversity of the ecosystem, and the net benefits or negatives are largely based on the design of the system. The range of agro forestry systems possible can potentially allow for many different types of adaptation to occur under a range of conditions (Franzel &

Scherr, 2002). However the levels of co-benefits depend on the amount of diversity integrated into the system, as more diversity within the agro forestry system will lead to greater co-benefits e.g. alley cropping, windbreaks, Silvopasture, traditional forest farming etc. The way agro forestry works and the benefits of agro forestry to smallholder farmers has been highlighted (Verchot *et al.,* 2006; McCarthy *et al*., 2001; Franzel and Scherr, 2002). However, the focal point which is resilience to climate variability has not been captured

In many African countries including Nigeria, Tanzania, Ethiopia and Malawi, Agro-forestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and in reducing crop output variability (Ajayi *et al*., 2006; Franzel & Scherr, 2002). Trees and bushes may also yield products that can either be used for food consumption (fruits), fodder, fuel, building materials, firewood, or sold for cash, leading to greater average household income, and contributing to household risk management via reduced income variability (Ajayi *et al.,* 2006; Franzel *et al.,* 2004). Planting trees and bushes also increases carbon sequestered both above and below ground, thereby contributing to GHG mitigation (Verchot *et al*., 2007) According to this revelation, the impacts established are for the purpose of mitigating climate variability in many African countries in general. The level of resilience on climate variability in Vihiga Sub County is not well established.

Agro forestry is therefore important for both climate change mitigation as well as adaptation through reducing farmers` vulnerability, diversifying income sources and building the capacity of smallholders to adapt to climate change (FAO, 2010). The risk of losses from environmental hazards is spread among many species and varied land use practices (Lin, 2011; Smith 2010); argued that agro forestry systems are more resilient and less risky than other agricultural options because of the effective and efficient use of natural resources for production. However, efforts and strategies are needed for intensifying management and governance efforts to generate products and services in agro forestry systems, through integrating trees in agricultural landscapes, cultural landscapes, watersheds and adjacent natural forests in order to restore ecosystems (Smith, 2010; Angelsen *et al*., 2012).

In Kenya, agro forestry focuses on a wide range of working trees grown on farms and in rural landscapes. Among these are fertilizer trees for land regeneration, soil health and food security; fruit trees for nutrition; fodder trees that improve smallholder livestock production; timber and fuel wood trees for shelter and energy; medicinal trees to combat disease; and trees that produce gums, resins or latex products. Many of these trees are multipurpose, providing a range of benefits (Verchot *et al.,* 2006). All this gives little on the benefits of agro forestry practices that are known, however this study wants to extend and get more information on the benefits that are realized by farmers particularly on resilience to variability in climate in Vihiga Sub County, apart from the earlier mentioned.

Agro forestry practices that are common are: intercropping, multiple cropping, bush and tree fallows, shelterbelts and riparian zones/buffer strips. According to (Ajayi *et al*., 2006) assertion, highlights on individual outcome on agro forestry but have minimum revelation on resilience to climate variability. Further discussions on types of agro forestry that are employed in a number of regions of the world have been brought up. Farmers in Vihiga Sub County are engaged in several forms of agro forestry but the benefits and levels of resilience to climate variability have not been discussed and documented, majorly resilience to climate variability that is being investigated. Therefore the researcher found it prudent to pursue this path.

2.2.1 Indigenous and Traditional Knowledge of Forests and Agriculture

Scientific modeling and projections about the impacts of climate change provide key insights about what a warmer world would look like, and how different regions, sectors, and communities must plan to adapt. Supporters of smallholder agriculture in the developing world will inevitably utilize modern science to deliver critical knowledge to farmers about projected climatic impacts and necessary resilience building measures. However, there is much to be said about existing practices that are indigenous and traditional in nature, and developed from the ground by agricultural communities over time. Some of these methods may have been used for many years to adapt agricultural systems to local climate variability, even before long term climate change was a topic of discussion.

This concept is of particular relevance at the intersection between forestry and agriculture. As (Parrotta and Agnoletti 2012) explains, "The holders and users of traditional forest related knowledge are on the front lines of global efforts to deal with climate change and its impacts. Because of their close connection with, and high dependence on, forest ecosystems and landscapes, indigenous and local communities are among the first to witness, understand, and experience the impacts of climate change on forests and woodlands as well as on their livelihoods and cultures. The history of forest and agricultural landscape management practices of indigenous and local communities based on their traditional knowledge offer insights into principles and approaches that may be effective in coping with, and adapting to, climate change in the years ahead.

Global, regional, national and local efforts to mitigate and adapt to climate change, however, have not yet given adequate attention either to the forest related knowledge and practices of traditional communities, or to the interests, needs and rights of local and indigenous communities in the formulation of policies and programmes to combat climate change. Due consideration of, and a more prominent role for, traditional forest related knowledge and its practitioners could lead to the development of more effective and equitable approaches for facing the challenges posed by climate change while enhancing prospects for sustainable management of forest resources. The importance of connecting with those who are closest to the land when addressing land use in general especially in the context of climate change and variability cannot be underestimated. This point brings the concept of agro forestry back to its traditional roots, and reminds us that at the heart of agro forestry there is a close relationship between the forest and humans.

It was traditional knowledge and regard for forest ecosystems that enabled the joint practice of forestry and agriculture long before agro forestry could be touted by donors and institutions as a tool for addressing the effects of climate change and variability. Because of the traditional and indigenous nature of agro forestry in the context of humans' relationship with the land and its resources, this level of knowledge should remain at the center of agro forestry practices in today's scientific discussion. The literature highlights the importance of community led, location,specific adaptation measures that harness the extensive indigenous knowledge and adaptation techniques of local farmers. At the same time, fail to seek better interdisciplinary evaluations that highlight practices that can improve farmers' ability to cope with climate related hazards thereby resilience. Therefore the researcher found it necessary to pursue this path in Vihiga Sub County.

2.3 Climatic Variability Trends Globally

Recent studies of climate variability trends indicate that the global-mean annual surface air temperature has increased by about 0.6°C since the late 19th century with about 0.4°C of this warming occurring since the 1970s (Folland *et al.,*2001). The warmest year in the 142 years of instrumental record was 1998, while 2001 was the third warmest. In many regions, it is the daily minimum (night-time temperature) that has increased at a greater rate than the daily maximum (day-time temperature). The warming temperature has led to longer frost-free seasons and growing seasons in many regions of the Northern Hemisphere (Folland *et al.,* 2001). This is also consistent with long-term significant decreases in spring snow cover over Eurasia. Global precipitation over land has increased by only 1%; however, more intense precipitation events have been observed in many mid-to-high latitude regions. Considerable spatial and temporal variations have occurred over the past 100 years, and these tendencies of warming, increased precipitation and lesser snow cover have not been uniform all around the world. From (Folland *et al*., 2001) accounts, it points to the fact that all these variations are attributed to destruction of the ground cover including forests. Therefore the need for agro forestry and the ground for this study in Vihiga sub county.

Even though people are fairly perceptive of climate variability, it is not as noticeable as weather variability because it happens over seasons and years. Evidence includes statements like: “the last few winters have seemed so short,” or “there seem to be more heavy downpours in recent years.” Scientists think of climate variability as the way climate fluctuates yearly above or below a long-term average value. You can think of it as a story with two parts: average and range. These parts complement each other; understanding the range gives context to the average and vice versa. Climate isn’t defined by any particular timeframe; however Most of these climate changes are caused by human activities, majorly deforestation. However available literature is limited to giving the mitigation and intervention ways in controlling these causes. Therefore the need to examine resilience and how agro forestry may provide this with specific bias in Vihiga sub county. Agro forestry practices as emphasized by the researcher and this may be the probable intervention remedy for these climate variability trends in Vihiga Sub County, the country and the whole world as a whole.

2.3.1 Temperature Trends in Canada

According to (Vincent, 2007).During the 20th century, the annual mean temperature has increased by an average of 0.9°C over southern Canada (Zhang *et al.,* 2000). The warming is consistent from coast to coast and the largest increase occurs in the west during the winter and spring. As is observed in the global record, the warming is greater in the night-time temperature as opposed to the day-time temperature, especially prior to the 1950s. The second half of the century is associated with distinct regional differences, including significant and strong warming in the west and south and significant cooling in the north-east. This pattern is more evident in winter and spring where trends have been as high as+2.5°C in the Mackenzie Basin over the last 50 years, and as low as -1.0°C on Baffin Island during the same period. Summer displays slight increasing trends and autumn is generally associated with a small cooling.

Trends and variability were also examined in daily minimum and maximum temperatures with emphasis on the extremes (Thornton *et al.*, 2002). For both periods, there are fewer days with extreme low temperature during winter, spring and summer, and there are more days with extreme high temperature during winter and spring. No consistent trends, however, are found in the higher percentiles during the summer indicating little change in the frequency of extreme hot days. Thornton *et al*. (2002) do not display either mitigation or the cause of varied trends of climate. This is now how agro forestry practices should be investigated to find out if they help in maintaining, adapting and coping up with adverse effects of varied climatic conditions in Vihiga Sub County.

2.3.2 Temperature and rainfall trends in Asia

Past and present climate trends and variability in Asia are generally characterized by increasing surface air temperature which is more pronounced during winter than in summer. Increasing trends have been observed across the seven sub-regions of Asia. The observed increases in temperature in some parts of Asia during recent decades ranged between less than 1°C to 3°C per century. Increases in surface temperature are most pronounced in North Asia (Savelieva *et al.,* 2000; Izrael *et al.,* 2001; Gruza and Rankova, 2004).

Interseasonal, interannual and spatial variability in rainfall trend has been observed during the past few decades all across Asia. (Gruza and Rankova, 2004) indicates that decreasing trends in annual mean rainfall are observed in Russia, North-East and North China, coastal belts and arid plains of Pakistan, parts of North-East India, Indonesia, Philippines and some areas in Japan.

Annual mean rainfall exhibits increasing trends in Western China, Changjiang Valley and the South-Eastern coast of China, Arabian Peninsula, Bangladesh and along the western coasts of the Philippines. More details are observed on characteristics in surface air temperature and rainfall in Asian sub-regions. A collection of data (Savelieva *et al.,* 2000; Izrael *et al.,* 2001; Gruza and Rankova, 2004) indicates accounts of such temperature trends in Asia. However, they are short of explaining the cause and possible effects of these trends.

Climate change impacts in Sri Lanka involve the increasing variability of rainfall intensity and regimes, increasing frequency of storms, increasing mean ambient temperature and sea level rise. The World Bank Group (2011) predicts further increases of climate variability and extreme events across Sri Lanka in the future. The country's mean air temperature increases by 0.016˚C per year during the period of 1961-1990 (Chandrapala, 1996), and it is predicted that the mean temperature may increase by approximately 0.9˚C to 4˚C by the year 2100 (Basnayake *et al*., 2007). The annual average rainfall in Sri Lanka decreased by 144 mm from 1961 to 1990; this is a decrease of approximately 7% compared with the period of 1931 to 1960 (Baba, 2010).

According to the World Bank Group (2011), historical records from 1974-2004 indicate that floods and droughts are increasing. The rainfall intensity, amount of rainfall per rainy day and the average rainfall per spell have increased in most parts of the country (Ratnayake & Herath, 2005). El Nino events caused severe drought in Sri Lanka from January to March 1983. Approximately 55% of the land area, mostly in the dry and intermediate zones, received less than 10% of the normal rainfall (Yamane, 2009). A flood triggered by 730 mm of rain was an extreme event and severe climate anomaly in the southern province of Sri Lanka on 17 May 2003 (Cruz *et al.*, 2007).

Sri Lanka is considered as a vulnerable small island nation that is under serious threat from various climate change impacts according to the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). The impacts of climate change are manifested in all socioeconomic sectors, including agriculture, forest resources, biodiversity, health, energy, and human settlements.

The Sri Lankan government ratified the UNFCCC in 1993 and the Kyoto Protocol in 2002. The Ministry of Environment has developed the National Climate Change Adaptation Strategy (NCCAS) for a climate-change-resilient future. The concept of adaptation is closely associated with vulnerability. The UNFCCC and the IPCC have considered the vulnerability and adaptation to climate change as integral components (Yamane, 2009). Farming and forestry have been threatened by the complexity and magnitude of weather-related phenomena (www.Copa-Cogeca.eu). Strengthening adaptation mechanisms by combining agriculture and forestry through sustainable agro forestry management reduces the impacts of climate change.

Agro forestry has an important role in climate change adaptation through diversified land-use practices, protected livelihoods and sources of income, enhanced agricultural productivity, and mitigated weather-related production losses, which enhance a region's resilience to climate impacts on farming systems (www.fao.org/forestry 2010). Sri Lanka has a long history of integrating trees into land use systems, and many diverse agro forestry systems are in use due to the cultural, climatic and topographic variations of the country.

2.3.3 Temperature trends in Scandinavian countries

Although these hot summer days can be truly spectacular, especially along the Norwegian coast or by a Swedish lake, it can be difficult to plan a trip. Simply put, these days can occur at any point from May to August, and predicting exactly when this can occur is more art than science. In Norway, the area around Røros close to the Swedish border and the inland parts of Finnmark such as Kautokeino and Karasjok are normally the coldest regions (Israeli *et al*., 1992). Temperatures here can drop below -30°C several times during the winter, and can remain below freezing for weeks or even months at a time. The coldest temperature ever recorded in Sweden was below -50°C (-58°F) although the temperatures haven't got that low since the turn of the century, and only then in the remote Arctic region. Normally in the north, temperatures of below -20°C (-4°F) are considered cold days, while temperatures in the bigger cities tend to drop below -10°C (14°F) a couple of times each winter..

Denmark's lowest temperature ever recorded was “only” -31.2°C (-24.2°F), in Hørsted in the north-west of the country in January, 1982. Climate of northern Europe is known to be cold, but the temperatures are not as low as its northerly latitude might suggest. However, there is no indication of how these areas have used agro forestry in these regions to mitigate climatic changes (Savelieva *et al*., 2000)

Given the northerly latitudes, much of the Scandinavian peninsular, people often expect the region to be bitterly cold for much of the year. While snow is commonplace in the winters, temperatures can be surprisingly mild. Temperature and weather varies massively across the region. The distance between the cycle paths of the Danish countryside and the cross-country skiing tracks of Arctic Norway is massive. To give you a feel for the climate in general, let us look at the Norwegian capital city, Oslo. The hottest month is July with an average temperature of 18°C (64°F), while the coldest month is January with an average temperature of -3°C (27°F). The wettest months tend to be August and September (Savelieva *et al*., 2000) and there is no indication of this temperature being caused by destruction of forests.

Although the climate can vary massively, it doesn't necessarily follow that the farther north you travel, the colder it gets. It all comes down to the geography of Scandinavia.

For example, Norway's Lofoten archipelago has incredibly mild winters considering its latitude equals that of northern Canada. As such, the real difference between mild and cold occurs not from north to south, but from coast to inland. Heat generated by the Gulf Stream and its extension into the Norwegian Sea is the most important reason why Norway experiences a milder climate than Sweden.

The warm current on the clean surface is balanced by a colder, southbound returning current in the Atlantic Ocean (Izrael *et al*., 2001). The source of the heat that the Gulf Stream brings to the north is the sun. This must be in balance with the strength of the current for the system to remain stable. Because of this, some experts are predicting trouble ahead due to climate change. Many parts of Norway and Sweden are guaranteed snow for months every year, most notably the areas farthest from the coast. In the case of Sweden, this means the majority of the central and northern parts of the country.

Temperatures in most parts of both countries can dip below freezing point for weeks at a time. The Danish winter is more temperate, but frost and snow are still to be expected. January and February are the coldest months, with temperatures averaging around 0°C (32°F). Although living farther south than many of their fellow Scandis, Danes still suffer from lack of light due to the cloudy skies. While winters can surprise people with their mildness, other seasons are equally surprising. Scandinavian summers can be incredibly warm, although the inconsistency is frustrating.

Temperatures in the capitals can reach 30°C, although an average temperature of 15°-20°C is more common. In Norway, the area around Røros close to the Swedish border and the inland parts of Finnmark such as Kautokeino and Karasjok are normally the coldest regions. Temperatures here can drop below -30°C several times during the winter, and can remain below freezing for weeks or even months at a time. (Thornton *et* *al.,* 2002). The coldest temperature ever recorded in Sweden was below -50°C (-58°F) although the temperatures haven't got that low since the turn of the century, and only then in the remote Arctic region.

2.3.4 Temperature and rainfall trends in Africa

The climate of Africa is warmer than it was 100 years ago and model-based predictions of future GHG-induced climate change for the continent clearly suggest that this warming will continue and, in most scenarios, accelerate (Hulme *et al*., 2001). Observational records show that during the 20th century the continent of Africa has been warming at a rate of about 0.05°C per decade with slightly larger warming in the June–November seasons than in December–May (Hulme *et al.,* 2001). By 2000, the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years.

This rate of warming is not similar to that experienced globally, and the periods of most rapid warming, the 1910s to 1930s and the post-1970s occur simultaneously in Africa and the rest of the world (IPCC, 2007). The cause of these warming has been attributed to change in vegetation cover. Agro forestry should be brought into focus to help buffering the rising global warming.

The projections for rainfall are less uniform. Hulme *et al.,* 2001 illustrated the large regional differences that exist in rainfall variability. East Africa appears to have a relatively stable rainfall regime, although there is some evidence of long-term wetting. There is likely to be an increase in annual mean precipitation in many of the countries, impacts of climate change will materialize through changes in extreme events such as droughts and flood extremes (Place and Dewees, 1999). Such weather events result in severe human suffering, and hamper economic development and efforts at poverty reduction. Unfortunately, assessments of climate change are often limited to mean temperature and precipitation. Knowledge of extreme changes in climate is sparse, particularly for Africa. In some regions, different models project different trends in wet and dry extremes. In other regions, however, models show clear trends such as increasing drought in the Kalahari and increasing floods in East Africa (Guthiga, 2007). Generally, major impacts are not highlighted fully and resilience methods are not full discussed in this report. This gives a veiled view of any considerable value of agro forestry and its practices (Lobell, 2008).

The challenges climate change poses for development are considerable (Thornton *et al.,* 2002). Despite the uncertainties that exist in long-term climate predictions, it is necessary to explore the sensitivity of the environmental and social systems, and economically valuable assets to climate change (Hulme *et al*., 2001). High levels of vulnerability and low adaptive capacity in areas of Africa have been linked to factors such as limited ability to adapt financially and institutionally, low per capita gross domestic product (GDP) and high poverty rates, and a lack of safety nets. For example, sub-Saharan Africa (SSA) is predicted to be particularly hard hit by global warming because it already experiences high temperatures and low (and highly variable) precipitation, the economies are highly dependent on agriculture, and adoption of modern technology is low (Kurukulasuriya *et al*., 2006).

Current climatic variation has significant impacts on agricultural production, constraining agricultural income and forcing farmers to adopt new agricultural practices in response to altered conditions (Molua *et al*., 2010). According to projections by Intergovernmental Panel on Climate Change (IPCC), Kenya is expected to observe a mean annual temperature increase of about 0.8 - 0.9 °C across the country by the year 2030 and from 1.5 to 1.6 °C by the year 2050. Annual precipitation is also expected to be between 7.0 - 9.7 % and 13.3 - 18.8 % by the year 2030 and 2050 respectively. For countries with significant proportion of agrarian economies like Kenya, climate change is expected to have significant economic consequences on them (Deressa*et al.*, 2005; Gbetibouo and Hassan, 2005). Given the pressing concern over food security in the next 20 years, due to increased population and at least locally decreased food supply resulting from climate stresses (Lobell*et al.*, 2008). Agro forestry systems must be a key focus of resilience strategies to climate change (Cook, 2009; Nair and Garrity 2012) and this must begin from local levels like Vihiga sub county.

A study carried out by (Nyandiko *et al., 2013)* in lower eastern part of Kenya Makueni, Machakos, Kitui and Mwingi districts revealed that high variability exist in seasonal and annual rainfall amounts in all the weather stations with some years receiving over 1000 mm and others receiving below 250 mm. According to the study, the rate of rainfall decline in the selected weather stations had been dramatic.

Climate change has been felt in Vihiga Sub County as high temperatures are experienced with heavy and erratic rainfall. More dry spells that interfere with the soil and crop productivity and natural disasters like hailstorms, landslides have become common phenomena during rainy seasons and they do interfere with crop production. Wetlands in Vihiga Sub County are fast diminishing in size due to deforestation, siltation as a result of soil erosion and human livelihood activities including increased settlements. Sources of water such as rivers, springs and wells suffer reduced sizes and low water volumes with obvious pollution from car wash, refuse, raw sewage and garbage from homes, roads and plants. This is attributed to population pressure and poverty that have led to destruction of forest land. Agricultural land is scarce in Vihiga Sub County. This has led to continued encroachment of crop farming on forest reserves as is the case of Maragoli hills forest, with severe deforestation having taken place in 1989 to 1993.

Therefore the key to addressing climate variability in this sub county requires wide use and expansion of agro-forestry practices as a resilient measure. Trees play important roles in reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risks.

2.4 Contribution of Agro forestry practices and products on resilience to climate variability

In this study, resilience is used in the context of farmer households and climate variability, and for a system to be resilient, it must be able to continue to thrive and reproduce, and compete for space and resources in face of perturbation. According to (Hughes *et al*., 2005; Lin, 2011 and Thomas *et al*., 2011), resilience refers to the ability of a system to maintain key functions and processes in the face of stresses or pressures by resisting, adapting or mitigating change.

Agro forestry systems enhance smallholder farmers' resilience to climate variability by supporting them with the diversity of products or benefits such as food, fuel, and fodder items that are produced by the smallholder farmer (Mendez *et al*., 2010). There are other naturally occurring co-benefits that occur in agro forestry systems including enhanced nutrient cycling, integrated pest management, and increased resistance to diseases, which will additionally protect farm production.

In many regions of the world Agro forestry involves land use practices in which woody perennials are deliberately integrated with agricultural crops, varying from simple and sparse to very complex and dense systems. It embraces a wide range of practices (for example, farming with trees on contours, intercropping, multiple cropping, bush and tree fallows, established shelter belts and riparian zones/buffer strips with woody species, etc.) which can improve land productivity providing a favorable micro-climate, permanent plant cover, improved soil structure and organic carbon content, increased infiltration and soil fertility and therefore reducing the need for mineral fertilizers (Ajayi *et al*., 2006)

In many African countries including Nigeria, Tanzania, Ethiopia and Malawi, Agro-forestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and in reducing crop output variability (Ajayi *et al*., 2006; Franzel.& Scherr, 2002) Trees and bushes may also yield products that can either be used for food consumption (fruits), fodder, fuel, building materials, firewood, or sold for cash, leading to greater average household income, and contributing to household risk management via reduced income variability (Ajayi *et al.,* 2006; Franzel *et al.,* 2004). Planting trees and bushes also increases carbon sequestered both above and below ground, thereby contributing to GHG mitigation (Verchot *et al*., 2007).

According to Agro forestry Research Trust (2010), various studies have noted the benefits of integrated farming systems in comparison to monoculture systems as they increase diversity in areas of food production and livelihoods mainly through sale of farm produce. Without doubt agro forestry is an agricultural system which is promising in solving numerous challenges of our time. A number of factors motivate farmers to plant trees, although the factors varied from site to site based on ecological and socio-economic circumstances (Kumar, 2006; Abebe *et al*., 2010; Moges, 2010; Fifanou *et al*., 2011). For example, in Ethiopia it has been reported that most common factors for planting *Eucalyptus* species are wood scarcity both for construction and fuel wood and thus the need to satisfy household subsistence demand and to generate income. Another important contribution of this tree has been security of tenure. For example, tree based systems have proved to be the most important guarantors for farmers who wanted to maintain ownership of their rural land while living in urban areas. For example, (Bucagu *et al*., 2012) reported that farmers preferred *Grevellia robusta* due to its fast growing and being less competitive and may be grown with other crops, while *Eucalyptus* planting in Rwanda was preferred as collateral for loans .

Many agriculturally based economies have few other livelihood strategies (Altieri, 1999), and small family farms have little financial capital to invest in expensive adaptation strategies, thereby increasing the vulnerability of rural, agricultural communities to a changing environment (Tillman *et al*., 2002). Management options that reduce the risks of climate variability to production and increase resilience for small farmers should be actively documented and promoted. One such strategy is the implementation of agro forestry systems which can help systems adapt to greater climate variability as well as mitigate greenhouse gases through sequestration (Tillman *et al.,* 2002). Further asserts that by improving production and financial stability, agro forestry systems provide many benefits for smallholder farmers vulnerable to the effects of climate variability and may prove to be especially important in rural, agriculturally based economies with few other livelihood options.

Thorlaksen (2011) describes field research conducted in the Nyando District of Nyanza Province, in Western Kenya, that examines the use of agro forestry as a method of building resilience against climate-related shocks such as floods, drought and variability in rainfall. His study examines farmers practicing agro forestry compared with a nearby control group, and concludes that agro forestry creates more resilience to Climate-related shocks (Verchot *et al.,* 2007). Several studies have proved the potential of trees in increasing resilience of subsistence farmers against environmental extremes by modifying temperatures, providing shade, shelter and by acting as alternative feed resources during periods of drought (Rao *et al*., 2007; Abebe *et al*., 2010).

Trees can reduce surface runoff, increase infiltration and soil water holding capacity. Furthermore, agro forestry reduces the risk of flash flooding following periods of heavy rainfall, with the tree roots. Thus, diversifying the production system to include a significant tree component may buffer farmers against income risks associated with climatic variability. There are positive links between agro forestry and adaptation to climate variability, which means agro forestry option, may provide a means for diversifying production, increasing resilience of subsistence farmers and buffering against production risk associated with climate.

The literature zeros on the effects of agro forestry on climate change in Nyando district but leaves out the contribution of agro forestry on farmer households' pieces of farms as a resilient measure to climate variability a case study of Vihiga Sub County. This Sub County is one of the most densely-populated sub counties in Kenya. Pressure on land is so much such that farm lands have been subdivided into uneconomical parcels. Farmers in the sub county have small-woodlots and trees dotted all over their farmlands where they generate small incomes from the farm forest products such as timber, poles, firewood and to some extend charcoal, thus the need for this study.

2.4.1 Agricultural Adaptations for Smallholder Farmers

There are many ways in which smallholder farmers in the developing world can reduce their vulnerability to climate variability and change, the broadest of which is to improve the overall strength of their farms and households. As described by Thorlaksen (2011), this can more specifically include: Diversifying and expanding crop varieties; Increasing off farm income opportunities; Improving access to markets; Accessing improved agricultural training; Improved modes of transport for agricultural products; Improved communication systems and community organizing; Access to better forecasting of weather events and drought patterns; Improved water storage facilities; Short term migration; and, Planting of trees to improve vegetation cover and water filtration of soils, reduce soil erosion and runoff, and improve soil water retention (i.e. agro forestry).

The methods of adaptation on this list range from complex and reliant on outside sources of funding or support, to relatively simple and easy to implement at the farm level with limited financial or institutional support. The more complex adaptations, such as improving access to markets, may be difficult to pursue for a poor, rural farmer due to institutional, financial, legal or other barriers.

According to Thorlaksen (2011) the barriers to the adoption of these adaptation measures include poverty, lack of access to credit and lack of information". Studies have proven that farmers with more agricultural knowledge and skills, better access to credit, more secure property rights, higher levels of wealth, access to off farm employment and higher educational levels are more likely to invest in adaptation measures. But what about farmers who remain poor and uneducated, with little or no access to credit, and may not have sufficiently secure property rights. These are the farmers who are the most vulnerable to the impacts of climate change, and who nevertheless need to seek ways to adapt to new challenges brought by increasing rainfall variability, warmer temperatures and longer droughts. For these farmers to adapt to climate change in a timely manner and within their own means that is, not relying on outside institutional or financial support they will have to look at the options that are most readily available to them such as diversified crop varieties and agro forestry.

Access to information about climate smart farming techniques and weather patterns is also critical for poor farmers adapting to climate change. In theory information does not cost anything. However, someone needs to transfer the information, and it needs to be available in the appropriate language; farmers who are illiterate will require more attention in information transfers. But in some cases traditional knowledge already comprises sustainable agricultural techniques such as agro forestry that can build resilience to climatic impacts. These traditional forms of agricultural resilience and adaptation can be shared and built upon at the community level, requiring minimal outside investment or involvement.

Many agriculturally based economies have few other livelihood strategies (Altieri, 1999), and small family farms have little financial capital to invest in expensive adaptation strategies, thereby increasing the vulnerability of rural, agricultural communities to a changing environment (Tillman *et al*., 2002; Smith *et al*., 2010). Management options that reduce the risks of climate variability to production and increase resilience for small farmers should be actively documented and promoted. One such strategy is the implementation of agro forestry systems which can help systems adapt to greater climate variability as well as mitigate greenhouse gases through sequestration. (Tillman *et al*., 2002). Further asserts that by improving production and financial stability, agro forestry systems provide many benefits for smallholder farmers vulnerable to the effects of climate variability and may prove to be especially important in rural, agriculturally based economies with few other livelihood options.(Verchot *et al*., 2007) describe four reasons why agro forestry can provide resilience for smallholder farmers, their deep root systems are able to explore a larger soil volume for water and nutrients, which will help during droughts. Increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years. Tree-based systems have higher evapo-transpiration rates than row crops or pastures and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems.

Bank (2010) asserts that tree-based production systems often produce crops of higher value than row crops. Thus, diversifying the production system to include a significant tree component may buffer against income risks associated with climatic variability. The four reasons why agro forestry can provide resilience to climate related shocks as fronted by (Verchot *et al.* 2007) have to take time as climate changes take time because they are caused naturally or by human activities. Time taken to realize any change in climate is great that the planting of trees and bushes alongside other crops is seasonal to change the effectiveness of the reasons. A lot is been noted about using agro forestry in resilience to climate related shocks but less is talked of the magnitude of the impact.

In many African countries including Nigeria, Tanzania, Ethiopia and Malawi, Agro-forestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and in reducing crop output variability (Ajayi et al. 2006; Franzel and Scherr, 2002) Trees and bushes may also yield products that can either be used for food consumption (fruits), fodder, fuel, building materials, firewood, or sold for cash, leading to greater average household income, and contributing to household risk management via reduced income variability (Ajayi et al. 2006) (Franzel et al. 2004). Planting trees and bushes also increases carbon sequestered both above and below ground, thereby contributing to GHG mitigation (Verchot *et al.,* 2007).However, there is little on how resilience to climate variability is measured.

In many regions of Kenya, where economic fortunes are often tied to the availability of rainfall, the relationship between climate change/variability and crop failures is not a new phenomenon, but in areas where infrastructure is limited, poor people are often vulnerable to climate hazard (Ziervogel *et al*. 2006). To summarize this, in terms of benefits, empirical evidence suggests that where gains to farmers from reducing soil and water erosion are high (e.g. hillsides), where gains from water management are high (for example, semi-arid and arid regions) and where climate variability is high, agro-forestry options are more likely to be adopted. Also, agro-forestry options that yield multiple benefits in the form of food, fodder and fuel are usually more attractive. This is the option for Vihiga Sub County

Furthermore, there are positive links between agro forestry and adaptation to climate variability, which means agro forestry option, may provide a means for diversifying production, increasing resilience of subsistence farmers and buffering against production risks associated with climate change.

2.4.2 Agro forestry as a buffer to climate related shocks

As a method of adapting agriculture to climate variability, agro forestry systems have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms.(Niggli *et al*., 2008).In coffee farms agro forestry systems, crops grown under heavy shade (60-80%) are kept 2-3°C cooler during the hottest times of the day than crops under light shading (10-30%) (Lin, 2007) and lose 41% less water through soil evaporation and 32% less water through plant transpiration (Lin, 2010).

Windbreaks planted in citrus groves have been shown to reduce wind speeds by 80-95%, reducing wind damage up to two times the distance of windbreak height (Tamang *et al.,* 2010).

Trees in agro forestry systems increase farmer`s resilience to climate variability by modifying microclimatic conditions including temperature, humidity and wind speed (Rao *et al*., 2007). A study from India revealed that during the monsoon season, the soil temperature just beneath the tree cover were lower by as much as 10°C to 16°C in the top soil zone and 4°C to 5°C at 30 cm depth when compared to open field conditions, thereby indicating better soil-thermal regime (Roy *et al*., 2011). While wind speed reduction prevented crop loss due to flower or fruits drop. Several studies have proved the potential of trees in increasing resilience of subsistence farmers against environmental extremes by modifying temperatures, providing shade, shelter and by acting as alternative feed resources during periods of drought (Rao *et al*., 2007; Abebe *et al*., 2010). Trees can reduce surface runoff, increase infiltration and soil water holding capacity. According to (Nair *et al*., 2009; Akinnifesi *et al*., 2010 and FAO, 2010), the use of trees and shrubs in agricultural systems help to tackle the triple challenge of food security, mitigation and reducing vulnerability and increasing adaptive capacity of agricultural systems to climate changes

Farmer household systems in the tropics are expected to experience decreased precipitation and increased temperatures in future predicted climate scenarios, creating problems in production stability for many of the world's most economically unstable farmers. Research has shown that many crops are sensitive to changes in temperature and precipitation and have a narrow threshold for production success, such that threshold events that occur during key developmental stages of the crop can lead to production failure (Gregory and Ingram 2000).This particular literature does not give more details of how extreme temperature and precipitation protect crops. A lot more needs to be put across on how these theories may protect crops from failure. Therefore there is need to establish how agro forestry is of help in crop production and protection from changes in temperature and rainfall in Vihiga sub county.

2.4.3 Agro forestry for biodiversity and climate change

Many trees and shrubs planted through agro forestry can increase plant and ecosystems biodiversity; trees are also helpful in ameliorating global climate change by sequestering vast amounts of carbon. The physical presence of trees on farm boundaries serve as living fences and protect home gardens from free grazing livestock.. Trees on farm can increase farm incomes and serve to diversify production and thus spread risk against agricultural production or market failures. Agro forestry is therefore important for both climate change mitigation as well as adaptation through reducing farmers` vulnerability, diversifying income sources and building the capacity of smallholders to adapt to climate change (FAO, 2010). The risk of losses from environmental hazards is spread among many species and varied land use practices (Lin, 2011; Smith, 2010; Kabebew and Urgessa, 2011) argued that Agro forestry systems are more resilient and less risky than other agricultural options.

Agro forestry systems enhance smallholder farmers' resilience to climate variability by supporting them with the diversity of products or benefits: food (arable crops, vegetables, animal products, fruit, mushrooms, oils, nuts, and leaves), fuel (charcoal and fire wood) (Bucagu *et al*., 2012). Others include fodder and forage, fibre, timber (construction and furniture making), gums and resins, thatching and hedging materials (binders and stakes), gardening materials (pea sticks, beans poles, fencing, hurdles), medicinal products, craft products (natural dyes, floral arrangements) and ecological services (Ndayambanje and Mohren, 2011; de Souza *et al*., 2012)

.As the key economic sector of most low income in Kenya, improving the resilience and adaptation of agricultural systems is essential for climate variability adaptation (Conant 2009); (Paustian et al.2009) indicates that improvements in agricultural production systems offers the potential to provide a significant source of mitigation by increasing carbon stocks in terrestrial systems, as well as emissions reductions through increased efficiency in agro forestry. Individual farmer households may not understand how agro forestry richness in biodiversity may provide resilience to climate change. Therefore a lot of information in this area is required and that gives the purpose for this study in Vihiga Sub County.

2.4.4 Contributions of fertilizer trees/shrubs to ecosystems services and climate change

Fertilizer trees/shrubs increase maize yield (staple food in southern Africa) about two times compared with farmers' *de facto* practice in which maize was cultivated continuously without external fertilization (Kwesiga et al., 2003; Akinnifesi et al., 2008). A recent meta-analysis demonstrated that the superior maize yield performance under fertilizer trees/shrubs technology is consistent across most of sub-Saharan Africa (Sileshi *et al.,* 2008). An assessment of the impact of fertilizer trees/shrubs in eastern Zambia shows that it enhances household food security and can reduce seasonal household hunger period by 2-4 months per year depending on the type of tree or shrub species planted (Ajayi *et al.,* 2007c). Agro forestry-based land use practices enhance household food security through higher yields resulting from soil fertility improvement and provision of services such as source of energy and fodder and, ultimately improving local livelihoods. At the same time, Agro forestry-based land use practices provide ecosystem services such as carbon sequestration and storage, biodiversity conservation and protection of watershed among other services that help to adapt to and mitigate climate change effects. Fertilizer trees/shrubs improve the physical properties of soils. In particular, soil aggregation is higher in fields where fertilizer trees are being grown, and this enhances water infiltration and water holding capacity of soils thereby reducing water runoff and soil erosion (Phiri *et al*., 2003). As a result, fertilizer trees/shrubs have the potential to help reduce the impact of droughts, a common seasonal phenomenon in southern Africa where agriculture is mainly rain-fed.

The repeated application of tree biomass increases the soil organic matter that leads to important increases in soil water retention capacity. The tree biomass and roots also provide favourable environment for soil microbes and fauna which in turn break down the biomass and release plant nutrients. Fertilizer trees/shrubs enhance soil activity of soil fauna and flora that perform important ecosystem functions (Sileshi and Mafongoya, 2006). In some cases, fertilizer tree systems harbour about the same diversity and abundance of soil invertebrates as the miombo woodland. This diversity can, in time, provide ecological resilience and contribute to the maintenance of beneficial ecological functions such as pest suppression. Fertilizer trees also help to reduce incidence of noxious weeds such as *Striga* and termite problems (Sileshi *et al.,* 2005) which become more serious under conditions of low soil fertility. This literature provides information on the benefits of fertilizer trees/shrubs. However, this is a viable agro forestry system that the benefits should now be used in addressing the many adaptation strategies that can enhance farmers' resilience to climate variability and this purpose this study in Vihiga sub county.

2.4.5 Carbon sequestration services and its influence on climate change mitigation

One of the most important contributions of agro forestry in general is to respond to climatic change through sequestration of carbon in above-ground plant biomass and the soil (Unruh *et al*., 1993; Kaonga, 2005; Verchot *et al.,* 2007). The analysis of Carbon stocks from various parts of the world shows that 1.1–2.2x1015 g carbon could be removed from the atmosphere over the next 50 years if Agro forestry systems are implemented on a global scale (Albrecht and Kandji, 2003). Average carbon storage by Agro forestry practices, of which fertilizer trees is an integral part has been estimated as 9, 21, 50, and 63 Mg C ha-1 in semiarid, sub humid, humid, and temperate regions respectively (Montagnini and Nair, 2004).

Based on assessments of national and global terrestrial carbon sinks, two primary beneficial attributes of agro forestry have been identified (Wise and Cacho, 2005). The first is direct near-term carbon storage in trees and soils through accumulation of carbon stocks in the form of live tree biomass, wood products, soil organic matter and protection of existing products. The second involves potential to offset greenhouse gas emissions through energy substitution (e.g. fuel wood from woodlots) and fertilizer substitution (through biological nitrogen fixation and biomass production).

Agro forestry can also have an indirect effect on carbon sequestration when it helps decrease pressure on natural forests, which are the natural sinks of terrestrial carbon. Although pure forests sequester higher amounts of carbon per unit land area and contribute more to improved climate change, the opportunity cost in terms of food production of initiatives that take land out completely for forestation for many years may be high in some southern African countries that experience seasonal food deficit. Such initiatives may also not be attractive to smallholder farmers in countries such as Malawi where the average land holding per household is less than 1 hectare. However, there is insufficient literature on the potential of agro forestry in combating impacts of climate change in Vihiga sub county.

2.4.6 Agro forestry and fodder trees

Agro forestry practices such as the planting of fodder trees and shrubs along farm borders and grazing lands can provide fodder for livestock. Fodder trees and shrubs supply much needed fodder for livestock, especially during feed shortages. Fodder banks are also a source of forage legumes, established and managed by pastoralists near their homesteads, as a means of providing additional protein for cattle during the dry season. Well-fed livestock will provide not only milk and meat, but also significant amounts of manure that can go into improving soil fertility.

In order to realize the full potential of agro forestry in Ethiopia and Kenya, it has to be supported by research results from the National Institute of Agricultural Research, regional research institutions, institutions of higher learning, the World Agro forestry Centre and the International Livestock Research Institute. Such existing data can provide a good background for future research and development activities, including scaling up of successful experiences.

Vihiga Sub County suffers from different forms of land degradation. It exhibits a high growing population which has put a lot of pressure on forest resources, agricultural farm resources and water systems (ICRAF, 2007 and KARI, 2012). The farming systems are becoming unsustainable as population increases and the amount of agricultural land available also decreases (ICRAF, 2007 and KARI, 2012). Vihiga Sub County is characterized by erratic droughts, famine and climatic variations which affect both the community's livelihood and livestock. According to ICRAF (2007) the community was aware of this land degradation and its impacts as a result of depletion of Maragoli forest between 1988-1993. Therefore, for a long time farmers practiced indigenous agro forestry particularly intercropping as an intervention measure to climate variability and increase farm produce with an objective of creating resilience to these extreme weather events. Sustainable land use practices offer opportunities for smallholder farmers to adapt to climate change and related risks, but the challenge is that the adoption of such practices by farmers is low due to policy and institutional constraints, among other key reasons. Literature showed that while men focus on timber productivity, women often preferred trees with multiple uses because these trees offer more domestic and supplementary value such as fuel, fodder, fruits and shade (Djoudi and Brockhaus, 2011).

This difference is relevant in managing s as Agro forestry systems resilience to climate change (Ajayi *et al.*, 2011). Women‟s activities are strongly interlinked with the services provided by local ecological systems. The reliance on natural resources increases women‟s ability to acquire and disseminate knowledge, information about ecosystems, sustainable practices and conservation techniques (Snelder *et al.*, 2007).

2.5 Contributions of agro forestry products to households income as Farmers' resilience to climate variability

Agricultural production depends on climate variables, such as temperature, precipitation, and light. Farmers' households' ability to grow enough food to feed themselves and their animals is determined to a large extent by the weather. Examining the effects of an altered weather on agriculture dependent households, (Downing, 1992) asserted that change in global climate variables may present risks to future livelihoods. Agro ecosystem farming practices, as proposed by (Schutter, 2010), should mimic nature as much as possible through a range of simple techniques that increase crop yield by promoting naturally beneficial interactions among soil, nutrients, crops, pollinators, trees, and livestock. Agro forestry systems that achieve one or several of these interactions can contribute toward "climate-smart agriculture" that can increase sustainable productivity, strengthen the resilience of farmers' livelihoods, and increase carbon sequestration.

Farmers with mature trees are able to sell seedlings, timber, and firewood, and consume fruit from their trees Farmers explain that the most effective way to reduce their vulnerability to the climate-related hazards is to diversify income, including off-farm income activities. Higher farm productivity also contributes to reducing the overall climate risk. In order to overcome some of their vulnerabilities, poor farmers often rely on social safeguard systems, as opposed to financial safeguards (Chaudhury *et al.*, 2011).

Agro ecosystem farming practices, as proposed by (Schutter, 2010), should mimic nature as much as possible through a range of simple techniques that increase crop yield by promoting naturally beneficial interactions among soil, nutrients, crops, pollinators, trees, and livestock. Agro forestry systems that achieve one or several of these interactions can contribute toward "climate-smart agriculture" that can increase sustainable productivity, strengthen the resilience of farmers' livelihoods, and increase carbon sequestration.

Climate is a major driving factor for most of economic activities (Agriculture) in Kenya (GoK, 2010) with climate change and variability being a major threat to National Development. Evidence of the change include irregular and un-predictable rainfall, intense downpours, rising temperature and generally extreme and harsh weather (G.O.K, 2010) The agricultural system in Kenya is mainly rain fed and at high risk of crop failure due to increased frequency of dry spells and uneven rainfall distribution. Food security thus faces serious threats from climate change and weather variability (Gichuki, 2000).A study on Analysis of maize yield responses to climate in the arid and semi-arid lands of lower eastern Kenya by (Nyandiko *et al.,* 2013) revealed that from climate variability analysis, there is adverse effects on maize production and thus food security. There is enormous negative impact of climate on maize yields in the four ASAL districts of lower Eastern Kenya. Trend analysis revealed that maize yields are alarmingly declining at high levels in Machakos district (22.5 Kg/acre pa) followed by Kitui (12.0Kg/acre pa), Mwingi (7.3 Kgs/acre pa) and lastly Makueni 8.7 Kg/acre pa) (Nyandiko *et al*., 2013). The maize yields Z-values were predominately negative in the period 1994-2008.In western Kenya, the shrubs have been intermixed with maize and other crops such as sorghum with remarkable increase in cereal yields. ICRAF has in the past demonstrated that the leaves and stems of a local shrub - *Tithonia diversifolia* when incorporated with a rock phosphate-common in western Kenya - can improve food production and reduce over-reliance on chemical fertilizers. The impact is well seen on the soil but little is said of the ever changing climate.

Agro forestry systems are multifunctional in provisioning of services to animals like provision of shelter from rain, wind, shade, feed and fodder, cover from predators and a diversity of foraging resources. Farm animals such as chicken and ducks have forest-dwelling ancestors and therefore prefer to range in tree and thicket cover (Ulsrud *et al*., 2008);(Smith, 2010) argued that if livelihoods including feeding of animals, depend more on bushes and trees and less on grasses and annual grain crops, the risk of losses during floods and drought becomes less, because trees are more resilient to such weather than other plants.

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Jerneck and Olsson (2014) found that agro forestry fails to be taken up by many poor farmers whose main priority is to get food on the table and do not invest time and labour in technologies. Use of agro forestry practices is as well highlighted in the reviewed literature but little attention is seen on the impact of these practices and their adaptability to climate changes. Therefore, the study focuses on providing key knowledge on resilience to climate variability among farmers in Vihiga to the world of knowledge, which can be used in controlling climate variability and reduce the risks associated with it.

2.6 Tree Products in Increasing Farmer's Resilience to Climate Variability

Several studies have proved the potential of trees in increasing resilience of subsistence farmers against environmental extremes by modifying temperatures, providing shade, shelter and by acting as alternative feed resources during periods of drought (Rao *et al*., 2007; Abebe *et al*., 2010). Trees can reduce surface runoff, increase infiltration and soil water holding capacity. Furthermore, AFs reduce the risk of flash flooding following periods of heavy rainfall, with the tree roots and trunks acting as permeable barriers to reduce sediment and debris loading into rivers following floods (Snelder *et al*., 2007; Zomer *et al*.,2009; Nair *et al*., 2009). In semi-arid climates, soil water content under tree canopies was reported to be higher than in open pasture due to reduced evapotranspiration under the tree shade out-weighing water uptake by plants (Smith, 2010).

A number of factors motivate farmers to plant trees, although the factors varied from site to site based on ecological and socio-economic circumstances (Kumar, 2006); (Abebe *et al*., 2010);(Moges, 2010);(Fifanou *et al*., 2011). For example, in Ethiopia it has been reported that most common factors for planting Eucalyptus species are wood scarcity both for construction and fuel wood and thus the need to satisfy household subsistence demand and to generate income. Another important contribution of this tree has been security of tenure. For example, tree based systems have proved to be the most important guarantors for farmers who wanted to maintain ownership of their rural land while living in urban areas. For example, (Bucagu *et al*.,2012) reported that farmers preferred *Grevellia robusta* due to its fast growing and being less competitive and may be grown with other crops, while Eucalyptus planting in Rwanda was preferred as collateral for loans.

However, trees preferences differ between individuals, groups, institutions, societies and cultures due to socio-economic need, management and environmental factors (Snelder *et al*., 2007; Abebe *et al*., 2010; Ajayi et al., 2011; de Souza *et al*., 2012; Bucagu *et al*., 2012). In Benin, tree density was directly related to the size of land holding and local perception of the species abundance in the wild. Small land holdings and inherited farm supported more tree species (Fifanou *et al*., 2011). Further tree preference and use played an important role in responding to climate change, both in terms of mitigation of GHGs emissions such as CO2 sequestration and resilience to changing climate conditions.
Literature showed that while men focus on timber productivity, women often preferred trees with multiple uses because these trees offer more domestic and supplementary

value such as fuel, fodder, fruits and shade (Djoudi and Brockhaus, 2011). This difference is relevant in managing AFs as resilience to climate change (Ajayi *et al.*, 2011). Women's activities are strongly interlinked with the services provided by local ecological systems. The reliance on natural resources increases women's ability to acquire and disseminate knowledge, information about ecosystems, sustainable practices and conservation techniques (*Snelder et al.*, 2007).

2.7 Conceptual Framework

The theoretical framework for this study was based on the systems theory. A theory is a set of systematically interrelated concepts and propositions that are advanced to explain or predict a phenomenon. Mugenda and Mugenda (2003) define a theory as a set of concepts or and the interrelations that are assumed to be among them. Lesniewski (2006) defines a system as a collection of objects joined in a constitutive relationship of interactions that forms a whole .The systems theory was proposed by Ludwig Von Bertalanffy in 1928 who emphasized that systems are open to and interact with their environments. Heylighen and Josyln (1992) notes that, the theory focuses on the arrangements of and relationships between the parts, which connect them into the whole.

The developments of the systems theory are diverse. According to Heylighen and Josyln (1992), Systems analysis has been developed to aid a decision maker into identifying, reconstructing, optimizing, and controlling a system while taking into consideration multiple objectives, constraints and resources. It aims at specifying possible courses of action, together with their risks, costs and benefits Izac (2003) concurs with these views: A basic rule is that systems theory is that systems at a certain level x are constrained and controlled by systems at another level y and in turn they constrain the systems at level w. Social scientists who have analyzed farmers decision making in the tropics have shown that farmers think in a systematic fashion. Decisions regarding agro forestry and resilience to climate variability are made within the context of the whole farm and the totality of the resources available.

The farmers operating at the farming system level have to take climate variability at the village level as a constraint in their decision to practice agro forestry. Consequently, farmers integrate a wide range of ecological, social and economic parameters belonging to levels higher than the farming systems in their decision to adopt resilience mechanisms (coping and adaptation strategies) through agro forestry practices. The systems theory was appropriate for this study because climate variability in Vihiga Sub County is a constraint for the farmer who is determined to improve the quality of life and has no option but to take up agro forestry as the most appropriate and sustainable land use practice to enhance resilience. At the same time, the size of the land is limited for those farmers whose access to land is through inheritance. Which is the most common phenomena in the sub county.

Human activities and natural phenomena are both drivers of climate inconsistency and variability. However, adaptation of sustainable and appropriate agricultural practices such as agro forestry will significantly reduce and alleviate (coping and adaptation strategies) not only the causes of climate variability and change but also the associated impacts. For instance, reduction of greenhouse gases (GHG's) while at the same time providing other products such as food, timber, fodder, windbreak, microclimate, wood fuel which can also be traded with resultant effect of resilience. Therefore, the dependent variable in the conceptual framework below is Resilience. The independent variables are agro forestry practices and products as well as livelihood options.

Intervening variables are Government policies such as Forest Act, Agriculture Act and the Role of County and National governments as displayed in Figure 2.1

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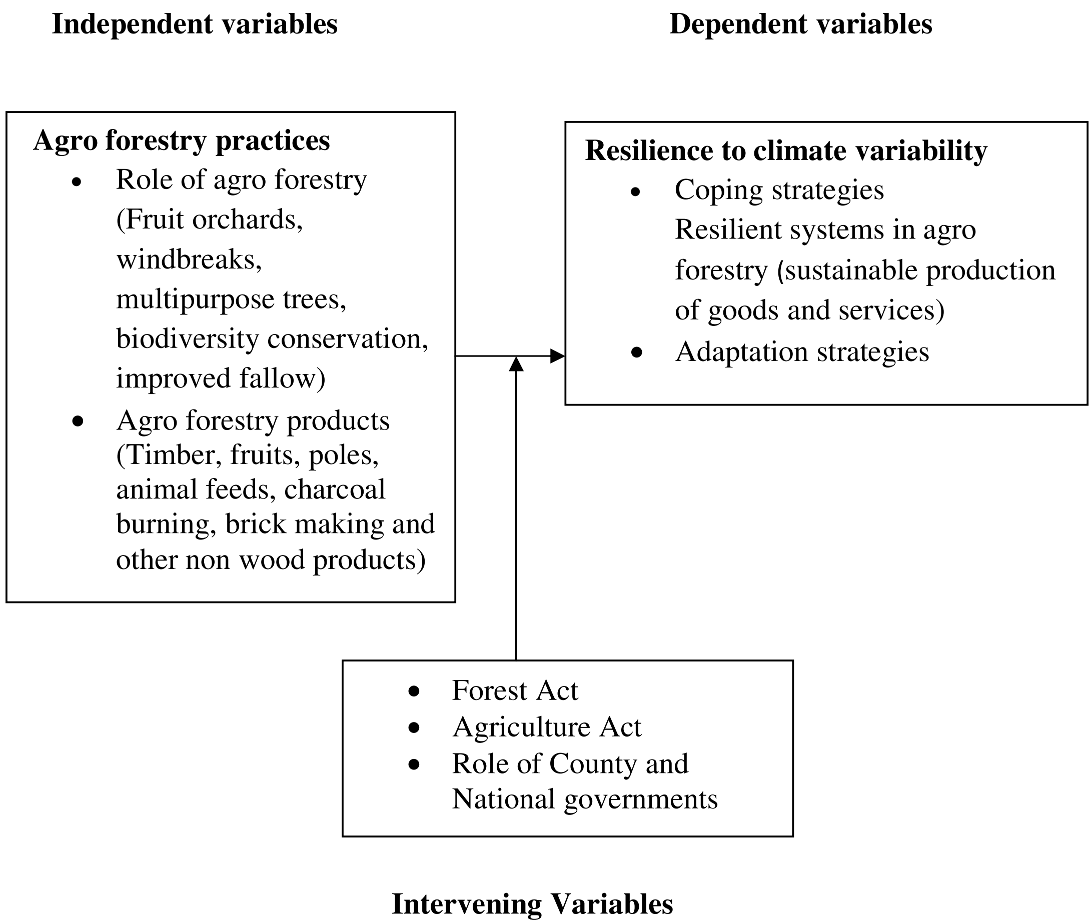


Figure 2.1: Conceptual Framework
Source: Author (2017)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the methods used to analyze data. It presents a description of the study area, study population, research design, and sampling strategy, instruments of data collection, analysis and presentation. This chapter also discusses the limitations, assumptions and ethical considerations of the study.

3.2 Study Site.

This study was carried out in Vihiga Sub County, Vihiga County, Kenya. It is located in western part of Kenya. It lies north of the Equator between latitudes 0°0'00"N and 0^0 3'20"N and longitudes 34°40'00"E and 34^o43'20"E. It borders Sabatia Sub County to the north, Hamisi Sub County to the east, Kisumu east Sub County to the south and Emuhaya Sub County to the west (Figure 3.1). Its administrative headquarters and largest town is Mbale. The predominant inhabitants of this sub county are maragoli ethnic community. It is divided into five locations namely; Lugaga, Wamuluma, Central Maragoli, Mungoma and South Maragoli (Figure 3.1).

3.2.1 Climate and topography

Vihiga Sub County experiences equatorial type of climate with fairly well distributed rainfall throughout the year with an average annual precipitation of 1900 mm. The rainfall ranges from 1800 – 2000 mm. Temperatures range from 14 ^{0}C – 32 ^{0}C with a mean annual temperature of 23^0C. Rains are experienced in the months of March, April and May which are the wettest months, while short rains are experienced in the months of September, October and November. The driest and hottest months are December, January and February with an average humidity of 41.75%.

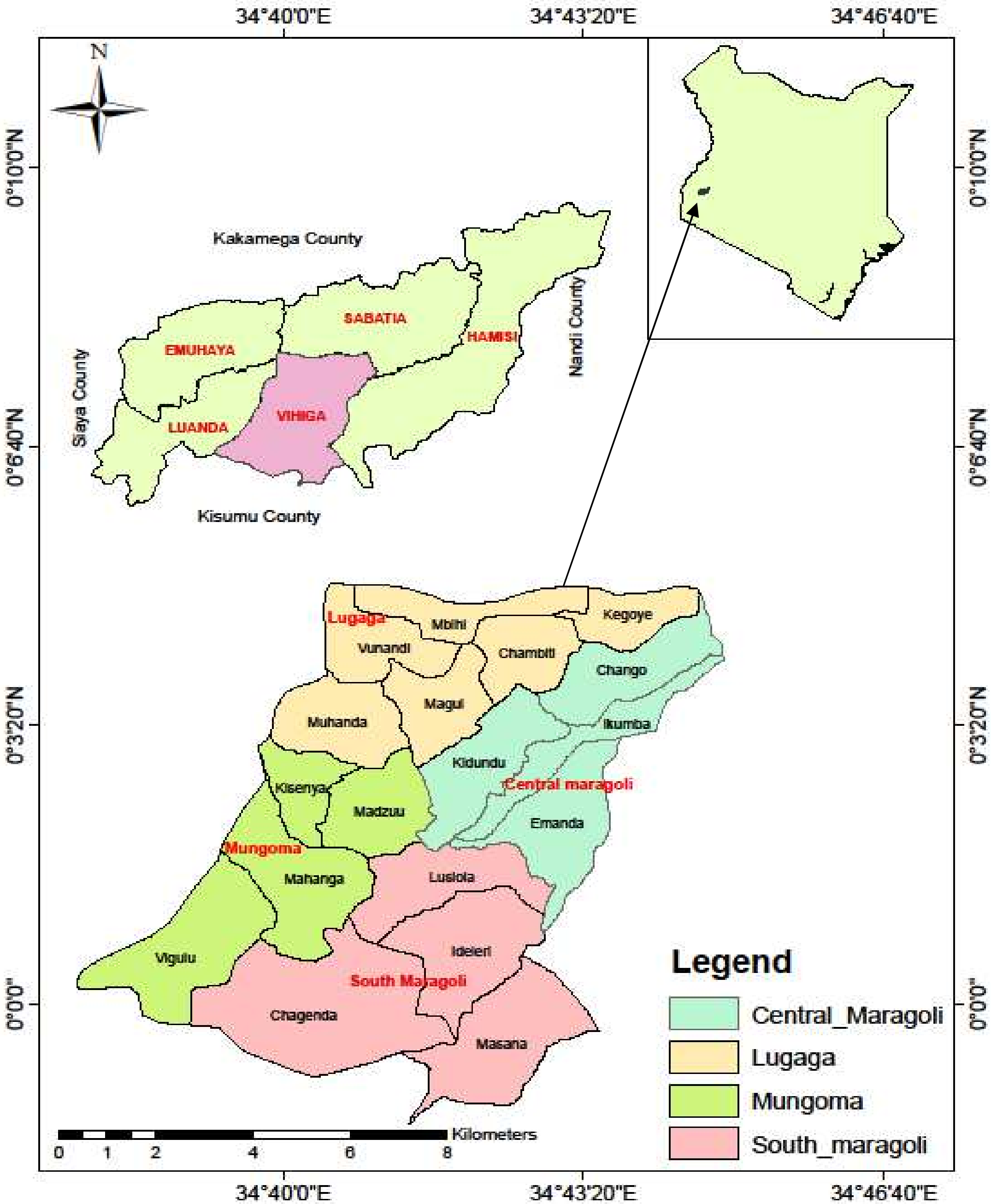


Figure 3.1: Map of Vihiga Sub County in Vihiga County, Kenya

Source: Author (2017)

This climate supports a variety of crop farming such as coffee, tea, and horticultural crops and rearing of livestock. The Sub County's altitude ranges between 1300 m and 1800 m above sea level. It slopes gently from East to West with undulating hills and valleys. The estimate terrain elevation above sea level is 1591 meters. The streams flow from northeast to southwest draining into Lake Victoria.

3.2.2 Population density and geology

Vihiga Sub County has a population of approximately 91,616 people (KNBS 2009) with a population density of 1,073 persons per Km^2. It covers an area of 90.20 Km^2. The high population density has put pressure on the land in the sub county leading to uneconomical sub-divisions of land, rampant land degradation, deforestation, threats of food insecurity and frequent land disputes. Vihiga Sub County has been selected due to its high population density, land fragmentation, the deforestation of Maragoli hills forest resource and its implications on climate variability and the need for coping up and adaptation strategies such as exploration on the use of agro forestry as a resilient mechanism.

The geographical formation of the sub county is composed of Kavirondian and Nyanzian rocks. The soils in the county are mainly sedimentary in nature and support various farming activities which include cash crops like tea and coffee. The abundant rain in the county enables rearing of livestock, crop farming, fruits and other horticultural crops vital for sustainability of agro based industries. The types of soils and climate favour two planting seasons in the year. During long rains, crops such as maize, sweet potatoes, sorghum and beans are grown for subsistence use in most parts of the sub county. Rocky hills dot many parts of the county notably in South Maragoli, Jepkoyai, and Gamoi and around Kima. The main river in Vihiga Sub County is river Esalwa.

3.3 Study population

The study population included farmer households, foresters, agriculturalists, seed companies, livestock specialists, research stations such as KALRO, County and sub county Government Authorities, Non-Governmental Organization (NGOs) such as KESREF, and ICRAF and the Kenya Meteorological department (KMD).

3.4 Research design

The study employed evaluation research design. Evaluation research design is normally carried out to determine judgment of worth or merit, to improve programmes and to generate knowledge (Earl, 2001). This research design was used to address the three objectives. The study was done in line with the study variables and specific objectives as outlined in the summary matrix in Table 3.1

Table 3.1: Research Designs for Vihiga County, Kenya

Specific Objectives	Variables/Indicators	Research design
i. Determine agro forestry practices adopted in Vihiga sub County	Agro forestry practices, quality and quantity of trees	Evaluation
ii. Examine the rainfall and temperature variability trends in Vihiga sub county between 1985 and 2015.	Weather patterns, rainfall distribution and intensity, temperatures trends	Evaluation
iii. Evaluate the contribution of Agro forestry practices and products on resilience to Climate Variability among farmers in Vihiga sub County	Windbreak, soil conservation, soil fertility, Timber, fruits, poles, animal, feeds, charcoal burning, brick making,	Evaluation

Source: Research (2017)

3.5 Sampling strategy

This study employed purposive, quota and stratified random sampling techniques as outlined in the summary matrix in Table 3.2. The study used purposive sampling to pick on the study site because it had the desired characteristics for the study. Mugenda, (2008) postulates that purposive sampling is useful when there is need to limit the sample to cases that are likely to be "information rich "with respect to the study. Stratified random sampling was done to get farmer households by holding the five locations in the sub county as strata, this was to minimize the differences among the sampling units within the strata and maximize differences among the strata (Gupta 2002). All the strata have a target population of about 4184 as outlined in table 3.2. of which 10% of the target population was used to come up with a desired sample size of 418 in this category. Akpa and Angahar (1999) assert that 10% is an appropriate portion that reduces the chance variation between a sample and the population it represents.

Other organizations were sampled out using purposive sampling because they were the only ones with the relevant information for this study. These organizations include: ministry of agriculture, KARI, ICRAF, KMD, KESREF and, District Agricultural office staff. Quota sampling was used to identify participants of FGDs; the study used interview schedules to collect data from officers attached to these organizations. Secondary data was collected through documentary analysis. Information on different trends in temperature, rainfall and agricultural outputs to mitigate climatic changes and potential yields was obtained from relevant organizations while advisory guides on agro forestry came from KESREF and ICRAF.

Table 3.2: Allocation of sample size to every stratum in Vihiga sub county, Kenya.

Location (Strata)	Study Population	Target population (Farmers household)	Sample size $n_{h=}(N_h/N)$x n
South Maragoli	19,293	987	99
Central Maragoli	23,370	1005	100
Mungoma	19,800	940	94
Lugaga	14,699	610	61
Wamuluma	14454	636	64
Total	91,616	4184	418

Source: Researcher (2017)

If the strata differ in size, allocation of sample sizes to strata is done proportionately to the stratum sizes (Barreiro and Albandoz, 2001). The formula below was used to establish the sample size(s) for every stratum as shown.

$n_{h=} (N_h/N)$x n

Where n_h is the sample size for stratum,

N_h is the population size for stratum h,

N is total population size and

n is total sample size.

Therefore the sample size for the study was 418 households based on the sampling strategies used at every category of the respondents that participated in this study. Table 3.3 displays a Summary of the sample sizes.

Table 3.3: Summary of Sample Size for Vihiga Sub County, Kenya.

Study population	Sampling method	Sample size
Study site	Purposive	1
Farmer households	Stratified random	418
Ministry of agriculture	Purposive	6
KARI	Purposive	4
ICRAF	Purposive	3
KMD	Purposive	3
KESREF	Purposive	3
FGDs (3)	Quota	Each having 8-12 members
District Agricultural office staff	Purposive	3

Source: Researcher (2017)

3.6 Instruments of Data collection

Tools for data collection were based on indicators to be assessed, the research objectives and research questions. The tools included questionnaires, interview schedules and observation checklist. This study relied on primary and secondary sources of data. Table 3.4 gives the data schedule that includes the population units and the research instruments that was used to collect data.

Table 3.4: Data schedule for Vihiga Sub County, Kenya.

Study population	Instruments for data collection	Appendix
Study site	Observation checklist	Appendix iii
Farmer households	Questionnaire/Observation checklist	Appendix i
Ministry of agriculture	Document analysis/Interview schedule	Appendix ii
KALRO	Document analysis/Interview schedules	Appendix ii
ICRAF	Document analysis/Interview schedules	Appendix ii
KMD	Document analysis/Interview schedules	Appendix ii
KESREF	Document analysis/Interview schedules	Appendix ii
FGDs	FGD guide	Appendix
District agricultural office staff	Document analysis/Interview schedules	Appendix ii

Source: Researcher (2017)

3.6.1 Questionnaires

This was the main instrument used for collecting primary data. The questionnaire has the advantages of confidentiality, saves on time and allows information to be collected from a large sample and from diverse regions (Kombo and Tromp, 2007). The questionnaires used were divided into specific sections that adequately captured all the study variables as presented in the conceptual framework. It consisted of both open ended and closed ended questions. They were administered to the smallholder farmer households in Vihiga Sub County. The study employed the drop and pick method when administering the questionnaire. The technique was adopted because it was good for measuring attitudes and eliciting other contents from the research participants and that the instrument was relatively cheaper (Appendix I).

3.6.2 Interview Schedule

Qualitative interview schedules were administered by the researcher with the main target being ministry of agriculture, KARI, ICRAF, KMD, KESREF and, District Agricultural office staff. This method is time saving as respondents answer what has been asked by the researcher, it is reliable since the questions are similar and is also comprehensive and systematic since the questions are formulated before the interview (Kombo & Tromp , 2007). The interview schedules allowed probing and posing of follow-up questions and provided information about respondents" internal meanings and ways of thinking about the study constructs". The responses and observations from interview schedules were recorded through hand written notes using key words and phrases. Detailed notes from interviewees were written by the researcher for easy compilation and coding with other study results (Appendix ii). The researcher sought permission from the national commission for science, technology and innovation (Appendix vii). The research further sought permission from relevant authorities to carry out the study (Appendix v).

3.6.3 Documents Analysis

The researcher sought relevant information from documents in the Ministry of Agriculture, KALRO, ICRAF, KMD, KESREF, FGDs and Sub county agricultural officers. These documents provided secondary data that were relevant to this study because they were used to support the other instruments of data collection.

3.6.4 Observation checklist

The study used this to ascertain the real situation on the ground with a view to Confirming information given or that may arise from the other research instruments. This instrument was used to gather information on the following: Types of trees, agro forestry practices, livestock types, pasture types, presence/absence of water source e.g. dams, shallow wells, Stage of crops in the fields, their condition and husbandry practices, weather conditions of Vihiga sub county etc. Table 3.4 gives the data schedule that includes the population units and the research instruments that was used to collect data.

3.7 Reliability and Validity of Research Instruments

The researcher measured the quality of the research instruments through testing their reliability and validity. These were very pertinent for this quantitative type of research.

3.7.1 Validity

Validity of the instruments is concerned with the extent to which an instrument actually measures what it is intended to measure (Wellington, 2000). This study limited itself to content validity and face validity. Content validity pertains to the degree to which the instrument fully assesses or measures the content of interest. Face validity is a component of content validity. It is established when an individual reviewing the instrument concludes that it measures the characteristic or trait of interest. This was done by conducting a pilot study. According to Rodgers & Hrovat, (1997) a pilot or pretest study is a small experiment designed to test logistics and gather general information prior to a larger study in order to improve the latter's quality and efficiency. The rationale behind the pilot survey was to explore issues that may potentially have an antagonistic effect on the survey results. These issues included the appropriateness of questions to the target population. It also tested the correctness of the instructions to be measured and whether all the respondents in the pilot sample would be able to follow the directions as indicated. Additionally, the pilot survey pre-tested and worked out modalities of identifying all stakeholders for the main study and also ensures identification of research assistants and potential respondents who were basically agro forestry farmers, it can therefore reveal deficiencies in the design of a proposed questionnaire or procedure which can then be addressed before embarking on large scale studies.

This study conducted a pilot study on twenty farmer households, four from each of the five locations counties of Vihiga sub County. The population subjected to the pilot study was not used as part of the study sample. The questionnaires of the pilot study were assessed by professionals especially the supervisors to identify weaknesses such as inaccurate responses and any other inconsistencies so as to ensure content validity. The instrument was modified accordingly. Thus, attempts to ensure the validity of study results was taken into consideration by controlling extraneous variables that may have affected the sampled farmer households and put them into consideration when interpreting results.

3.7.2 Reliability

Reliability is a measure of the degree to which a research instrument yields consistent data or results or data after reported trials (Mugenda & Mugenda 1999) to test the reliability of instruments, the researcher used the test–retest method. Test-retest reliability was used to establish the correlation coefficient. A pilot study population was subjected to data collection instrument within a period of four weeks. The inadequate variables were modified or discarded to improve the consistency of the items.

For purposes of the pilot study, fifteen farmer households, three from each of the five locations in the Sub County, were represented in the target population. Reliability of instruments was ascertained using results of the pre-test study from respondents who were involved in the pilot study but were not included in the study sample. The results from the pre-test study were used to calculate Pearson Product Moment Correlation Coefficient. Pearson Product Moment Correlation Coefficient of 0.5 was used for the purpose of calculating the reliability score. The formula given below was used.

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

R is the sample correlation coefficient, $\sum$ denotes the summation of the items indicated $\sum X$ denotes the sum of all X scores $\sum X^2$ indicates that each X score should be squared and then those squares summed $(\sum X)^2$ indicates that the X scores should be summed and the total squared. [avoid confusing $\sum X^2$ (the sum of the X squared scores) and $(\sum X)^2$ (the square of the sum of the X scores] $\sum Y$ denotes the sum of all y-scores $\sum Y^2$ indicates that each Y score should be squared and then those squares summed $(\sum Y)^2$ indicates that the Y scores should be summed and the total squared. If $r \geq 0.5$, then the instruments will be reliable for use and if the correlation coefficient $r<0.5$ then the instruments will not be the correct tools for data collection and thus the need to modify them to improve on their reliability. Reliability of instruments was ascertained using results of the pre-test study from respondents who were involved in the pilot study but were not included in the study sample. The results from the pre-test study were used to calculate Pearson Product Moment Correlation Coefficient. Pearson Product Moment Correlation Coefficient of 0.5 was used for the purpose of calculating the reliability score. From the pre-test study a correlation coefficient of 0.741 was arrived at revealing that the instruments were reliable.

3.8 Data Analysis and Presentation

Data analysis was done in respect to specific objectives, and respective measurable variables. This involved examining what had been collected and making deductions and inferences. The study followed the procedure of editing, coding, classification and tabulation of raw data (Kothari, 2009). Data Analysis involved a variety of methods that were used to analyze specific data as indicated in Table 3.5. Frequency distributions and percentages were used to organize, describe and summarize the data. The analyzed data was presented in form of tables, graphs and pie charts.

Table 3. 5: Data Analysis for Vihiga Sub County, Kenya.

Specific objectives	Measurable variable/indicators	Methods of data analysis
i. Determine the agro forestry techniques practiced among farmers in Vihiga sub County	Agro forestry practices, Quality and Quantity trees.	Descriptive analysis, Regression and Chi square test.
ii. Examine the rainfall and temperature variability trends in Vihiga sub county between 1995and 2015	Weather patterns,, Rainfall distribution and intensity, temperatures variations	Descriptive analysis, Regression and time series analysis
iii. Evaluate the contribution of agro forestry practices and products as farmer's resilience to Climate Variability in Vihiga sub County	Windbreak, soil conservation, soil fertility, nitrogen fixation, shade, rainfall patterns, temperature regulation, and soil erosion control.	Descriptive analysis and Chi square test.

Source: Researcher (2017)

3.9 Limitations of the study

Vihiga Sub County has five locations and over 50,000 farmer households. The Sub County has a population of 91,616 (KNBS 2009).

As such the following were the study limitations:

i. It was difficult to isolate the impact of climate variability related hazards from the impact of other socioeconomic events and natural threats. Therefore, the study took in consideration the interrelationship between climatic, socioeconomic and natural factors.

ii. It was not possible to entirely exclude biases of communities and other stakeholders while collecting information about agro forestry practices and their potential impacts on climate variability as a resilience strategy. There were too many perspectives and opinions. Therefore, the study used several methods to triangulate the given information.

3.9.1 Assumptions of the study

The basic assumption of this study was that causes of climate variability are human and natural phenomenon and the effects are adverse and felt mainly by farmers in Vihiga sub- county, therefore there was need to adopt farmer households' agro forestry practices as a resilient mechanism against these adverse climatic effects.

3.10 Ethical Considerations

According to Mugenda and Mugenda (1999) ethical considerations are important for any research issues including proper conduct of the researcher during the research process, avoidance of plagiarism and fraud. Confidentiality and privacy of the information obtained from the respondent was crucial. Volunteer and informed consent from the respondents and dissemination of the findings was adhered to during the study. Thus, the study was carried out and conducted with ethical requirements as stipulated by all relevant Government Ministries. Authorization was sought from the National Council of Science and Technology (NACOSTI). A consideration such as non-intrusive methods at various levels either by question or procedure that were likely to embarrass the respondents was avoided. Personal data was collected, handled and stored with confidentiality and was only used for this study.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results and discussion of the findings according to each objective of the study. The results are reported in the following order: Response rate of the respondents, Demographic information of the respondents, agro forestry technologies practiced by farmers in Vihiga Sub County, rainfall and temperature variability trends in Vihiga sub county between 1985 and 2015 and contribution of agro forestry practices and products to households' income as farmers' resilience to Climate Variability in Vihiga Sub County.

4.2 Response Rate

The researcher used drop and pick method of distribution of questionnaire. The sample population constituted 418 farmers household in Vihiga sub county, Vihiga County. 108 of them did not return the completed questionnaires, giving a 74.2% response rate. This made the researcher to use 310 as the possible respondent's rate for this study. The high percentage of participation enhanced the findings as this would be perceived to be more representative of the population under study. According to Mugenda and Mugenda (2003), a questionnaire return rate of 50% is adequate for analysis and reporting. Therefore this study questionnaire return rate of over 70% was very good therefore adequate for this analysis.

4.3 Demographic Information

This study sought to identify the farmers' gender, age, level of education and the length of time they had stayed in the sub county. This was important because before one undertakes a study on a given population, certain facts must be known about the respondents. The demographic profile of the respondents would determine how they complete the research instruments and their understanding of the study topic.

4.3.1 Farmer Household heads by gender

The study sought to find out the gender distribution and agro forestry practices among the sampled household heads. Table 4.1 gives a summary of the findings. Out of the 310 household heads 72.3% were males and 27.7% were females. The finding showed that most households in the region were male headed, as noted during the focus group discussions, according to the Luhya community, traditionally and culturally men are supposed to head the family. This also agrees with (Mathu, 2005) who recorded that households in the sub-Saharan Africa are male headed. This means that there were fewer females making decisions related to role of agro forestry on climate variability among farmers in Vihiga sub-county.

Table 4.1: Farmer Household heads by gender

Gender	Frequency	Percent
Male	224	72.3
Female	86	27.7
Total	310	100.0 %

Source: Field data (2017)

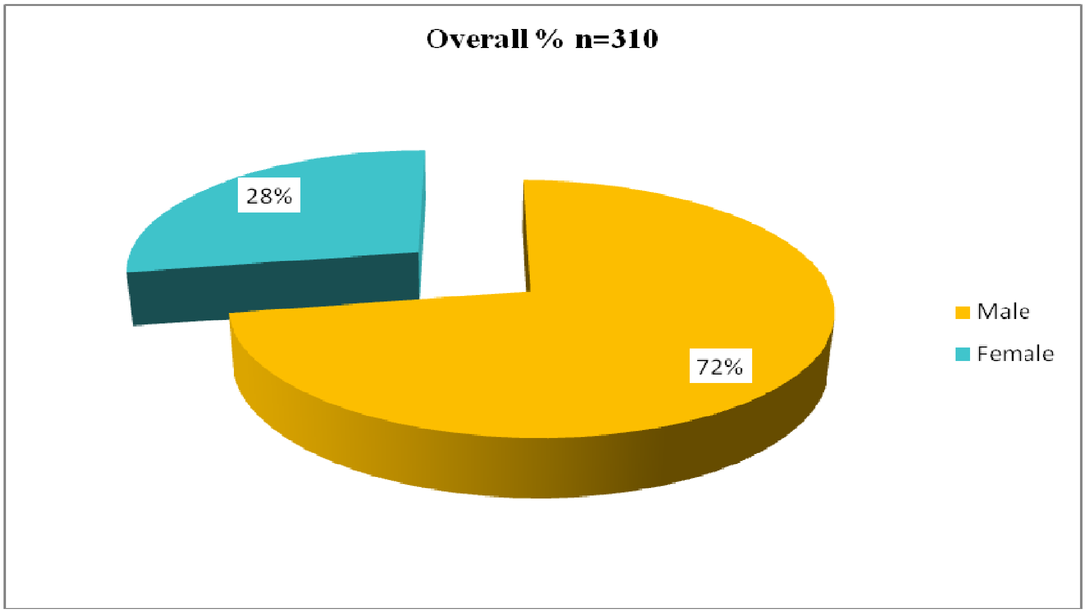


Figure 4.1: Farmer Household heads by gender

Source: Field data (2017)

The findings in Figure 4.1 reveal that majority of the households who own pieces of land are male. The female who own land and practice agro forestry are widows who were left those pieces of land after the death of their husbands. The results of studies elsewhere showed that while men focus on timber productivity, widows often preferred trees with multiple uses because these trees offer more domestic and supplementary value such as fuel, fodder, fruits and shade (Djoudi and Brockhaus, 2011). This difference in gender perceptions is relevant in managing agro forestry systems that are resilient to climate change (Ajayi *et al*., 2011). This agrees with findings of this study in Vihiga Sub County.

4.3.2 Age and land ownership

This study sought to find out the age bracket of the respondents. The respondents were led through establishing their age. This was to help determine the age distribution for the sampled households. Table 4.2 and Figure 4.2 show that majority of household heads 57.4% lie in the age bracket of above 50 yrs and above, followed by 33.5% under 40-

50yrs, 7.4% under 30-40 yrs, 1.3% under 20-30 yrs, 0.3% below 20 yrs. It is noteworthy that the age group above 50 years in the context of the farmers formed the bulk of agro forestry practitioners who would be key in building capacity in agro forestry and who would significantly impact its uptake. The age range above 50 years constituted the majority of Farmers (57.4 percent), and they have significant level of education, a factor that would increase the success of new agro forestry interventions to be introduced in the area. Findings in this study were in line with previous studies conducted by Paxton *et al.,* (2010); Roberts *et al.,* (2004); Velandia *et al.,* (2010); and Walton *et al.*, (2010) which revealed that age influenced adoption decisions on technological invention.

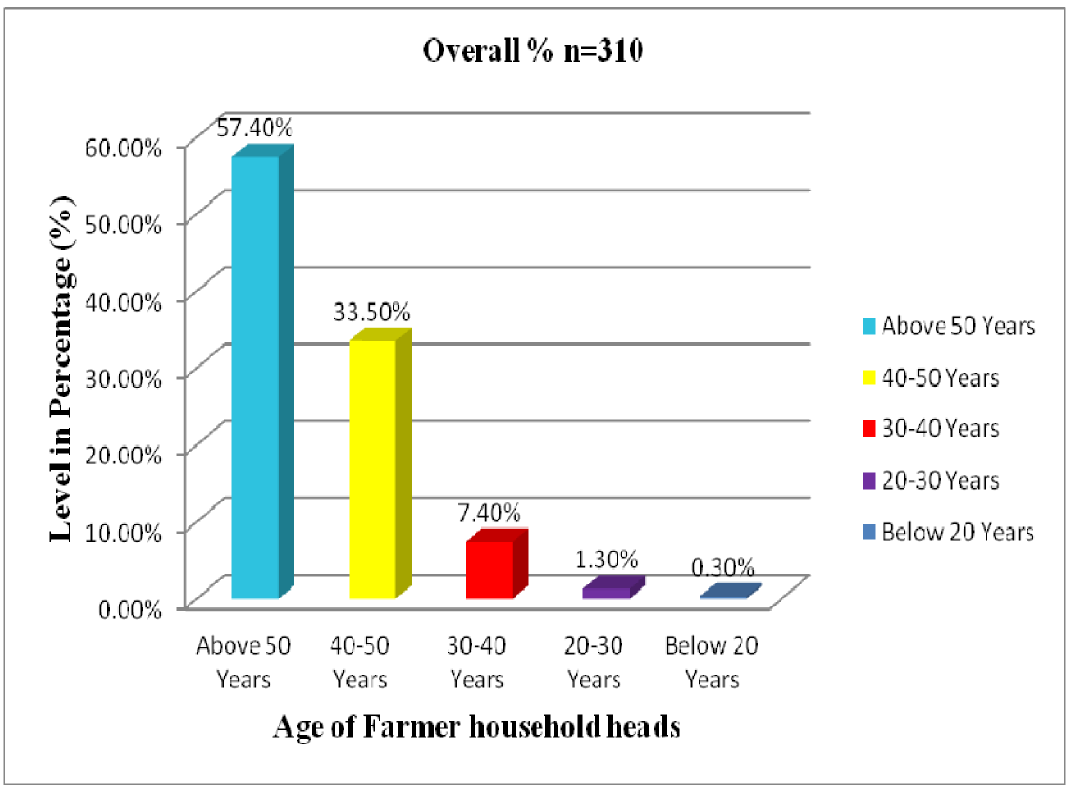


Figure 4.2: Farmer household heads by age

Source: Field data (2017)

4.3.3 Levels of education

The study sought to find out levels of education of household heads. Figure 4.3 gives a summary of the findings where the revelations are, the highest level of education for the majority was tertiary 38.7% followed by secondary level certificate holders 26.5%, Degree certificate holders 11.9%, primary level .8% and those who have not gone to school 6.8%.This agrees with observations made in the field, interviews with key informants and focus group discussions. Given that the majorities of the residents in the study area have formal education and therefore can read and write, it is easier for them to comprehend the causes of extreme weather events in the sub county and therefore the importance and integration of agro forestry into farming as form of resilience to this extreme weather shocks.

These findings confirm the work done by Rogers (1995) and Haggblade *et al*. (2004). Who observed that educated farmers are more innovative. This is because educated Farmers can access more information sources, comprehend and benefit more from extension service and usually they are more aware about environmental problems. This was found to be the case in Vihiga Sub County, primarily because of learning through apprenticeship, where farmers learn from each other. Normally, farmers' level of education has a positive relationship with adoption of any new innovation, especially on the decision making process. This is because farmers with higher levels of education are expected to understand the benefits of agro forestry more since school curriculum cover the general principles of agriculture and agro forestry practices and hence would impact positively on its adoption as compared to those with lower education levels.

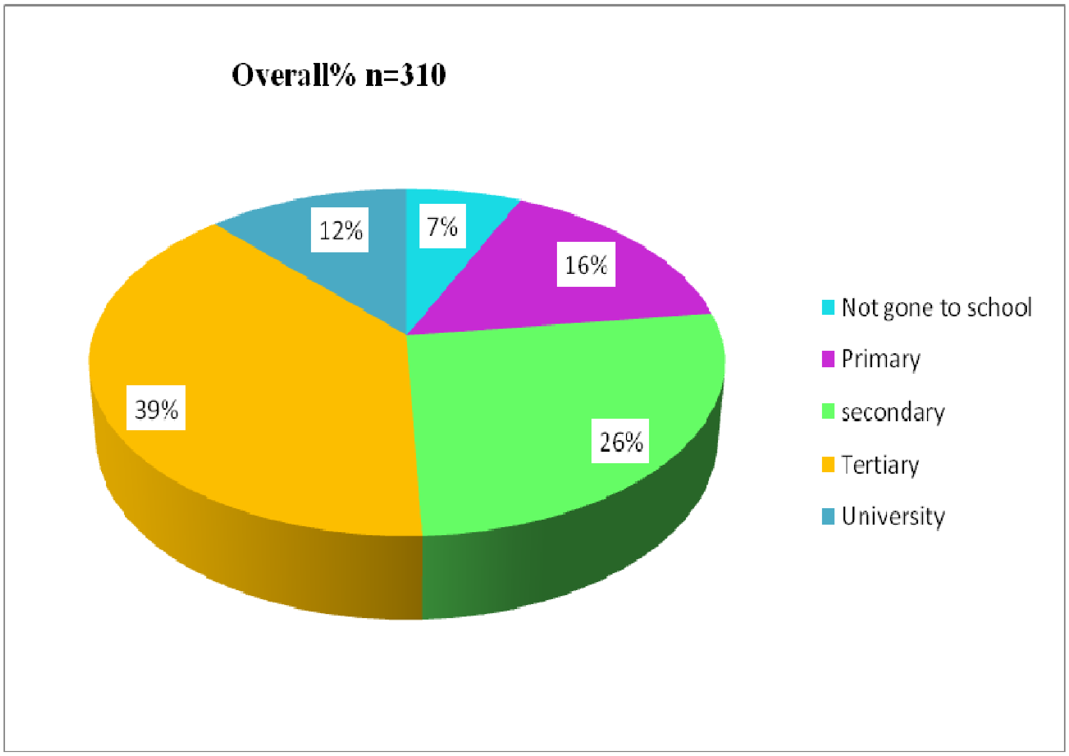


Figure 4.3: Level of education of farmers

Source: Field data (2017)

4.3.4 Number of years the respondents had lived in Vihiga Sub County

Studies carried out elsewhere reveal that farmers progressively move from traditional technologies to more appealing technologies that address their needs with time. This happens as a result of the experiences they accumulate through practice over time (Feder*et al.,* 1985). This is consistent with results of findings in Vihiga sub county where a majority (32.25%) of farmers interviewed had lived between 50-59 years in the County while a few (6.45%) had lived between 0 -9 years in the sub county, this means a majority of the farmers can attest to the adoption of agro forestry technology as a resilient mechanism against extreme weather events in Vihiga Sub County (Figure 4.4)

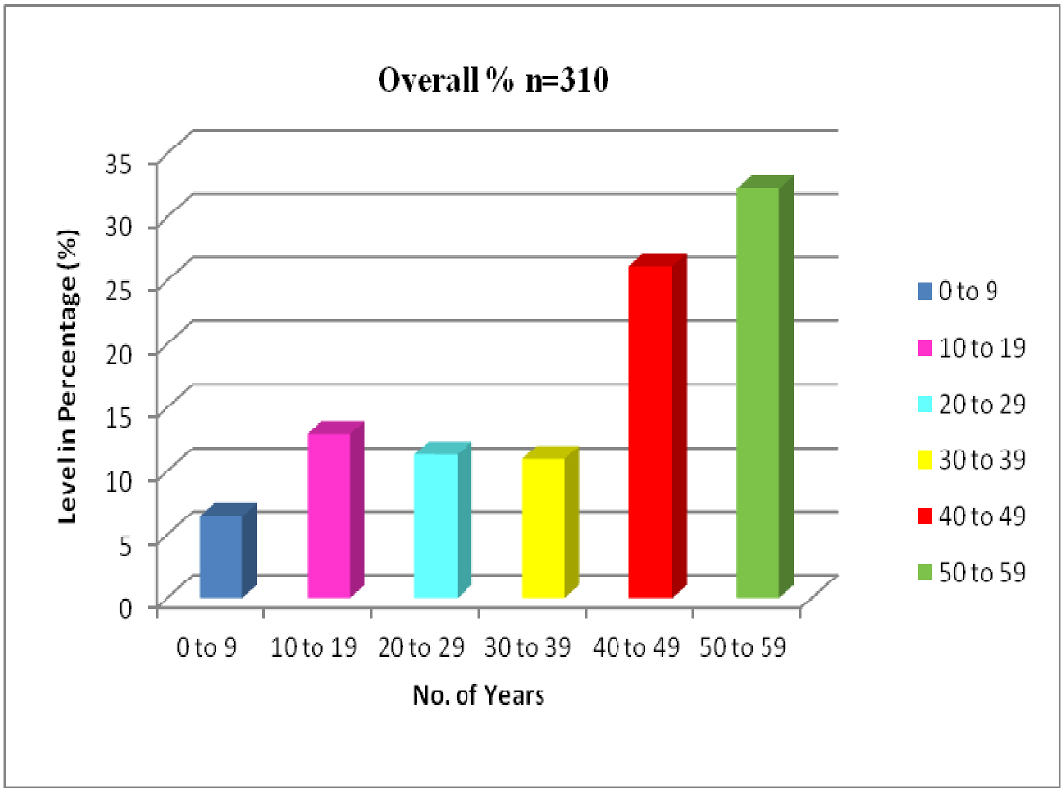


Figure 4. 4: Number of years the Household heads had lived in Vihiga Sub County

Source: Field data (2017)

4.3.5 Occupation of farmer households

The study sought to find out occupation of farmer household heads besides farming and how they help the farmers in agro forestry as a resilience mechanism. Table 4.5 displays the Primary occupation of farmers and their main sources of income. Farming was the main livelihood occupation for a majority of household heads compared to off-farm activities (Table 4.5). Results in figure 4.5 show that farmers had diverse sources of income. At least a third of all farmers mainly sold tree products to generate household income. This finding clearly shows that improvement in agro forestry and marketing it products as envisaged can benefit most farmers thereby cushioning them against extreme weather shocks.

Table 4. 2: Primary occupation of farmers and their main sources of income (Overall % n=310)

Primary occupation	Proportion (%) of farmers by gender	
	Male (n=202)	**Female (n=108)**
Farming activities	85.3	86.7
Off-farm activities	14.7	13.3
Total	**100**	**100**

Source: Field data (2017)

These findings collaborate with those of Kuwornu, Ohene-Ntow, & Asuming-Brempong, (2012) which showed that farming was not a guarantee of household food security. In their study, Kuwornu *et al,*. (2012), in Central Ghana found that the majority (68.8%) of food crop producers were food insecure. The findings showed that respondents in the study area obtaining their income from nonfarm activities were the least food secure do not concur with studies by Alem, (2007) in Ethiopia.

His study found out that a large proportion of households (84.8%) engaged in off-farm income earning activities were food secure. This collaborates with findings in Vihiga Sub County which showed that at least two thirds of all farmers mainly sold tree products to generate household income. Selling of Firewood is an important source of household income for about 30% of the respondents. Income from firewood sales was cited by a relatively higher proportion of female (30%) than male (28%) farmers (Figure 4.5). To supplement farm income, one in every ten farmers earned wages from salaried employment. Disaggregated by gender, income from petty business source involved mostly female (2.1%) than male (1.5%) farmers. Other sources of income such as selling seedlings and selling herbal medicine were reported in less than 10% of all responses.

(Figure 4.5).This off the farm income has made the farmers more food secure and therefore more resilient to climate variability.

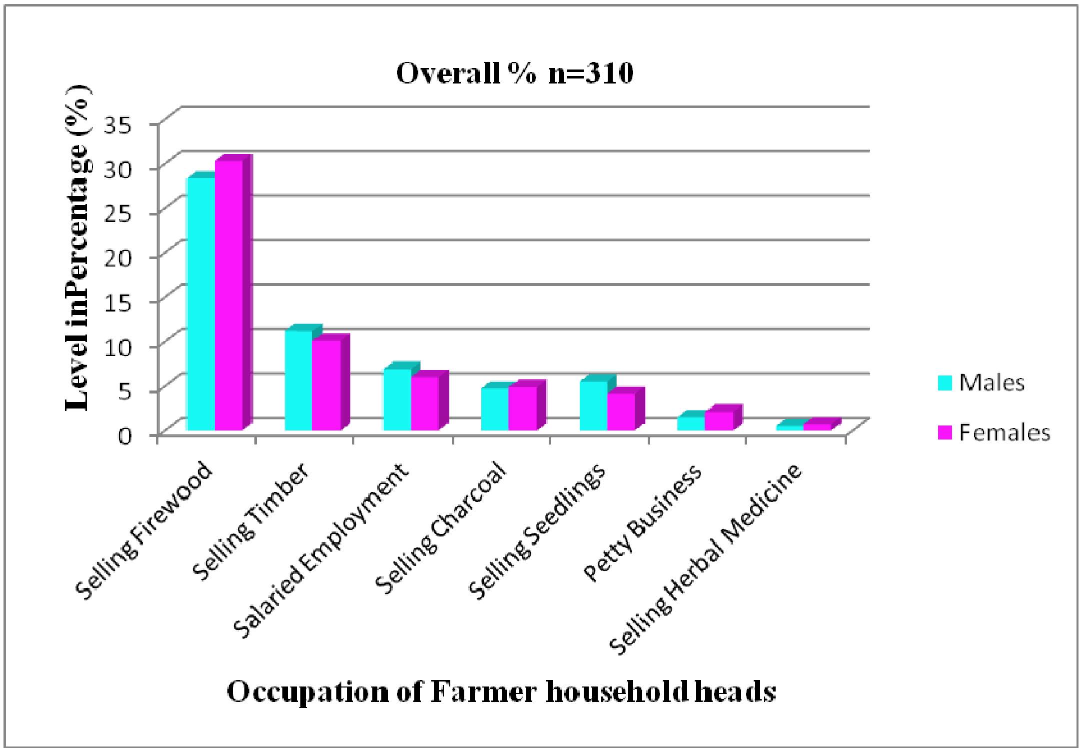


Figure 4. 5: primary occupation of farmers and their main source of income

Source: Field data (2017)

4.3.6 Land ownership

Agro forestry production systems that involve local farmers will directly be related to the flexibility of the land tenure system. Secure land tenure provides for proper incentives for farmers to make investments in the long-term productivity of their land. The findings on land ownership in Vihiga sub county points to small average land holdings that may require the application of intensive and sustainable practices in order to support the increasing needs of farming households with rising population. Most of the households owned land with title deeds (81%) on which mixed crop-livestock farming is practiced by almost all households which is at (98%). This indicates that a majority of households have secure land tenure, which could serve as security for investment into longer term improved practices such as planting agro-forestry and fodder trees as well as acceptable collateral to secure affordable credit to do so.

With the ownership of a title deed the farmer is assured of the trees he/she plants on that particular piece of land. (Table 4.7) This agrees with the results of a study by Tengnas (1994), who found out that in Kenya most farmers find it unacceptable and unattractive to invest in tree production on land that is not legally theirs. This was also supported by results from a study by Busienei (1991), who found out that the low participation in Agro forestry activities in Ainabkoi Division of Uasin Gishu District was due to lack of title deeds. A farmer's ownership of land with all due legal rights that includes title deed is important to a farmer's investment on the farm since he/she knows that whatever is invested on such land is fully owned.

Table 4. 3: Land ownership and farming

Ownership and Farming	Frequency	Percentage
Own title deeds	251	81
No title deeds	59	19
Mixed crop and livestock farming	304	98
No mixed crop and livestock farming	6	2

Source : Field data (2017)

4.4 Agro forestry technologies practiced by farmers

The study sought to find out agro forestry technologies practiced by farmers in Vihiga Sub County.

The variables analyzed included establishing the farm size of every individual respondent, their response on whether they plant trees alongside crops, technologies used in planting crops with trees and the relationship between trees planted and climate variability and usefulness of all these to their resilience to climate variability.

4.4.1 Farm Acreage

The study established that 37.4% of the household heads had only 1 acre of land, 37.1% had 2 acres, and 13.9% had 3 acres while 11.6% had above 4 acres. This is an indicator that most people had small pieces of land. About 75% of the respondents had less than 2 acres of land while 25% of all the respondents had more than 2 acres and more (Figure 4.6). Studies carried out in many parts of Kenya reveal that the high rate of increase in population in Kenya has led to fragmentation of land (Aboud, 1992). For example in the coffee subsistence zones of Kenya, the land parcels are small and shared by too many people; so that after planting cash and food crops, there is limited space for planting of trees (Bradley, 1991).

Many Agro forestry technologies require reasonable farm size (Ragland and Lal, 1993). A study in Bangladesh found out that tree planting increased with the amount of homestead land owned and the farmers whose main source of income was non-agricultural were more likely to decide to plant trees in their homestead (Salam *et al,* 2000).This agrees with the findings of the study in Vihiga sub county that the size of land will most of the time determine the type of land use practices to be put on it therefore influence Agro forestry.

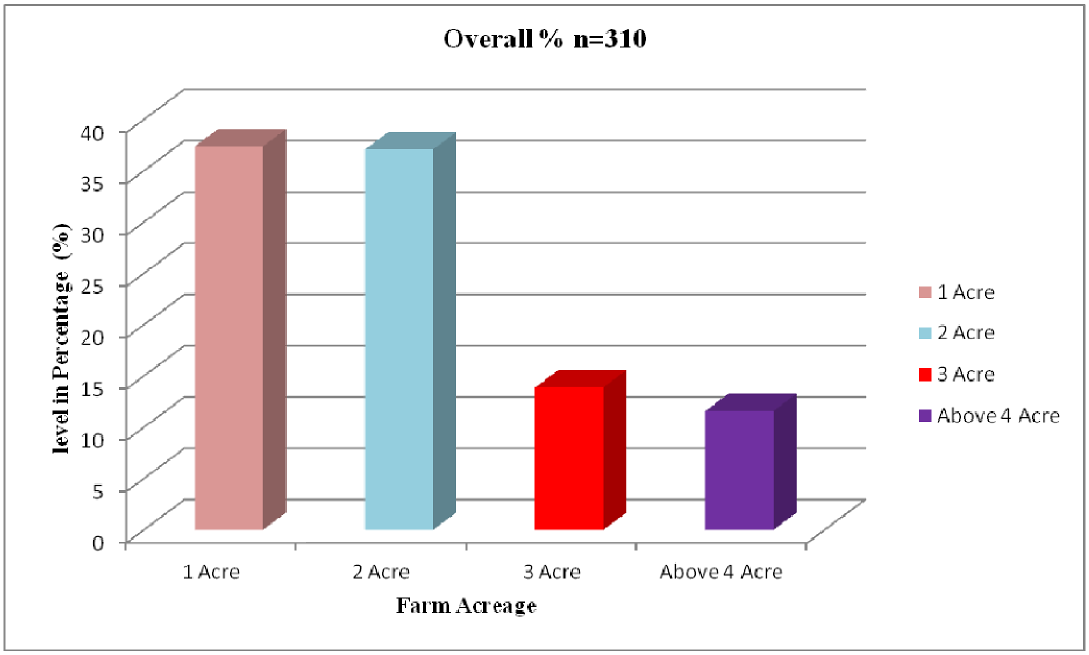


Figure 4.6: Farm acreage

Source: Field data (2017)

4.4.2 Crops grown alongside trees

The study interviewed KARI and the Sub county agricultural staff on the type of cereals planted by the smallholder farmer households in the sub county (Table 4.8).The staff revealed that majority of the households planted maize, millet, peas and beans for subsistence. They indicated that the climatic conditions favor the kind of farming practiced by the smallholder farmer households in the sub county. This agrees with results from studies elsewhere by Nair (2008) and Smith (2010) confirmed that Agro forestry systems are useful in maintaining production during wetter and drier years.

A central hypothesis in Agro forestry is that productivity is higher in Agro forestry systems compared to monoculture systems due to complementarities in resource-capture i.e. trees acquire resources that the crops alone would not. Based on the ecological theory of niche differentiation; different species obtain resources from different parts of the environment, such as, *Grevellia robusta* are fast growing and less competitive, while tree roots of *Persea americana* and *Syzigium species* are reported to extend deeper than crop roots and are therefore able to access soil nutrients and water available to crops, as well as absorbing nutrients leached from the crop rhizosphere (Pandey, 2007; Smith, 2010; Bucagu *et al*., 2012).

This also agrees with several other studies that confirmed that in drought-prone environments, such as Rajasthan, as a risk aversion and coping strategy, farmers maintain AFs to avoid long-term vulnerability by keeping trees as an insurance against drought, insect pest outbreaks and other threats, instead of a yield-maximizing strategy aiming at short-term monetary benefits (Singh and Pandey, 2011; Rigueiro-Rodríguez *et al*., 2011).

Table 4. 4: Crops grown alongside trees

`Response	Crops Grown with trees						Total
	Maize	Beans	Cassava	Tea	Vegetables	Fruits	
Yes	64	5	3	199	7	4	282
No	1	0	0	17	9	1	28
Total	**65**	**5**	**3**	**216**	**16**	**5**	**310**

Source: Field data (2017)

The information in Table 4.8 was further subjected to chi square tests. This was to check the association of those who plant trees and the crops grown alongside various tree species. According to the chi square analysis 7 cells (58.3%) have the expected count of less than 5. The minimum expected count is 27. So if the chi square is ($x^2 = 22.081$), the predetermined alpha level of significance is (0.05), and the degrees of freedom (df = 1) on entering the Chi square distribution Table with 1 degree of freedom and reading along the row the value of $x^2 = (22.081)$ does not fit in the chi square distribution table.

Table 4.5: Chi-Square Tests for Crops grown with trees

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	49.739[a]	5	.000
Likelihood Ratio	31.713	5	.000
Linear-by-Linear Association	22.081	1	.000
No. of Valid Cases	310		

Source: Field data (2017)

That means that the p-value is 0.00 since a p-value of 0 is less than the conventionally accepted significance level of 0.05 (i.e. $p > 0.05$). Therefore we conclude that there is statistically no significant difference in the proportion of association between respondents who plant trees and crops and trees planted.

4.4.3 Agro forestry and fodder trees

The study sought to find out, the types of agro forestry fodder trees planted by farmers in Vihiga Sub County. The findings revealed that almost all (93%) of the homesteads had some fodder trees. Male headed households had (93%) while female headed had (87%), they planted agro forestry trees on their farms possibly due to socio-cultural factors such as land tenure and customs that limit women from planting trees. Common agro forestry trees found on farms were Croton (83%) and Grevillia (69%). Fodder trees adopted by farmers included Calliandra (24%), Sesbania sesban (13%) and Leucaena (5%). Adoption of these types of trees was generally higher among male headed than female headed households. (Figure 4.7). Tree Lucerne was the least adopted by less than 1% of famers and only reported in female headed households.

This agrees with results from studies by Smith (2010) and Bucagu *et al*. (2012) who reported the multifunctional role of trees in their provision of resources for animals‟ on Elm Farm. Other studies also revealed that if fodder for livestock will depend more on bushes or trees and less on grasses and annual grain crops, the risk of losses during floods, drought and landslides would be less, because trees are more resilient to such weather conditions than non perennial plants (Ulsrud *et al*., 2008).

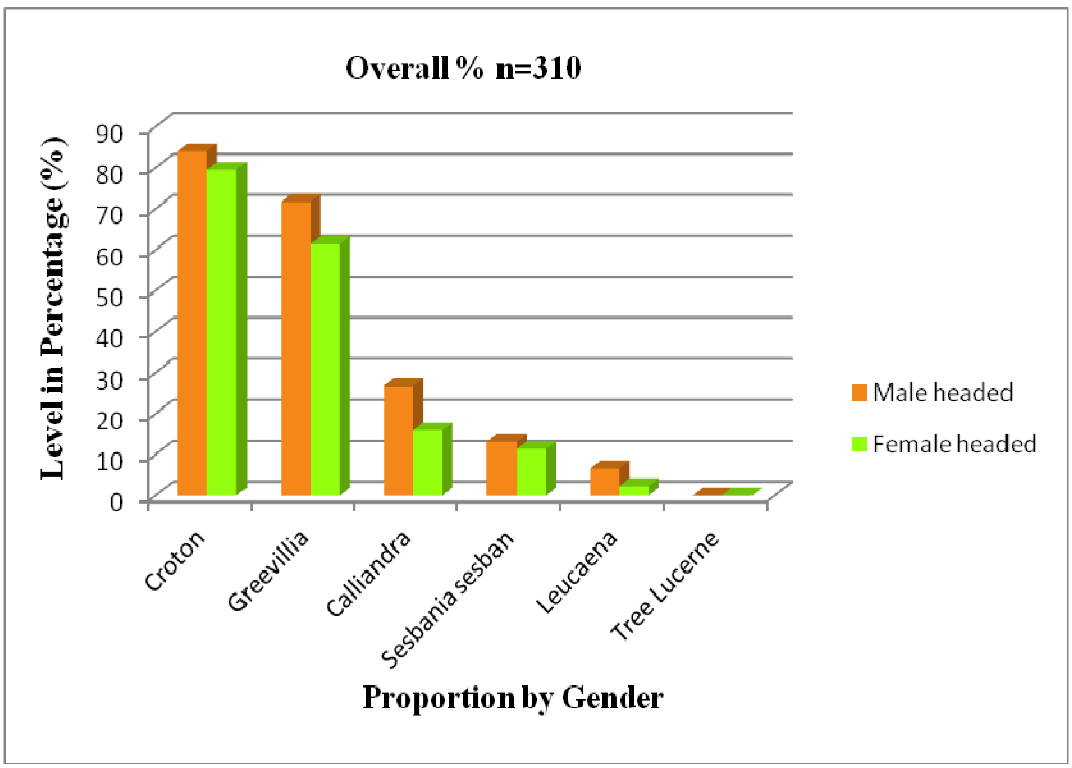


Figure 4.7: Types of agro forestry and fodder trees planted on farms

Source: Field data (2017)

Studies in Tanzania for example revealed that, the Chagga farmers are self sufficient in fodder produced primarily from the trees and shrubs grown in home gardens (Fernandes *et al*, 1984). And in Namable division of Busia district (Kenya), farmers have planted *Sesbania sesban* on terraces to control soil erosion, to provide fuel wood and green manure (ICRAF 1992). There is therefore, need to establish the perceived benefits of Agro-forestry in Vihiga Sub County to allow for better decision making on resilience to climate variability through Agro forestry

4.4.4 Tree nursery establishment and challenges

To enhance adoption of agro forestry, there was need for farmers to have tree seedlings for planting .The results from this study showed that about 28 % of the farmers had established their own or group tree nurseries, 72% would buy the seedlings from other farmers or institutions, this was because of various challenges that emerged during the study. The main challenges faced in tree nursery management are presented in Table 4.11. The main challenges were unreliable rainfall (63%), damage by pests and diseases (63%) and unavailability of preferred seeds (60%). Other hardships encountered revolve around poor markets for tree seedlings (48%), poor germination of seeds (40%) and theft of seedlings from nurseries (5%). Effective promotion of tree nurseries for enhancement of household agro forestry requires proper integration of practical solutions to these problems.

Table 4.6: Challenges faced in the management of tree nurseries

Challenges	Frequency	Percentage (%)
Unreliable rainfall	72	80
Damage by pests/diseases	67	74
Unavailability of seeds	25	27
Lack of market for seedlings	80	88
Poor germination of seeds	21	23
Theft of seedlings	30	33

Source: Field data (2017)

4.5 Agro forestry technologies in relation to climate variability

The study sought to find out the various technologies employed by the respondents in practicing agro forestry and how they influence climate of Vihiga Sub County.

4.5.1 Agro forestry technologies used to cope with climate variability

The findings revealed that several techniques have been employed by farmers as the best practices within the study area. These were: trees with agricultural crops; trees with pasture; trees, agricultural crops with animals; fruit trees with agricultural crops; trees with fruit trees; agricultural crops with fruit trees; fruit trees with pasture; agricultural crops with pasture; Trees with bee keeping. The study further revealed that 279 (90%) of the respondents confirmed that they practice the listed agro forestry techniques and that the techniques gave the required results while 31(10%) reported that they use none of the listed agro forestry techniques. Table 4.12, shows the agro forestry techniques in relation to climate variability.

Table 4.7: Agro forestry Technologies in relation to climate variability

Techniques	Agro forestry relation to climate		Total
	YES	NO	
Trees with agricultural crops	24	19	43
Trees with pasture	13	0	13
Trees, Agricultural crops with Animals	64	0	64
Trees, Fruit trees with agricultural crops	21	0	21
Trees with fruit trees	6	0	6
Agricultural crops with Fruit trees	8	0	8
Trees, Fruit trees with pasture	2	0	2
Fruit trees with pasture	1	0	1
Agricultural crops with pasture	139	5	144
Trees with Bee keeping	1	7	8
Total	**279**	**31**	**310**

Source: Field data (2017)

A chi square test was carried out to check the degree of association between the agro forestry techniques and climate variability. The results for the test are given in Table 4.13. This chi square analysis gives a chi square statistic as (x^2 = 7.594), the predetermined alpha level of significance as (0.05), and the degrees of freedom as

(df = 1). This chi square corresponds to probability of 0.006 probability levels. That means that the p-value is below 0.01 (it is actually 0.006) meaning that there is a statistically significant difference in the proportion of association and relationship between techniques and agro forestry in relation to climate variability.

Table 4.8: Chi-Square tests on Agro forestry techniques in relation to climate variability

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	128.822[a]	9	.000
Likelihood Ratio	93.067	9	.000
Linear-by-Linear Association	7.594	1	.006
No. of Valid Cases	**310**		

Source: Field data (2017)

These results agrees with the findings of Tengnas (1994), who observed that in small scale farming areas, boundary planting reduces wind speed and that trees on boundaries which are regularly pollarded can meet most of a family's needs for firewood while ensuring a properly demarcated boundary. Here, *G. robusta* and *C. lusitanica* were common sources of firewood.

This also agrees with studies conducted elsewhere by Sharma (1995) which indicated that farmers in most cases tend to accept multipurpose and fast growing tree species that yield benefits early rather than those that take long maturity periods. Lionberger (1960) explained this habit by stating that different farmers prefer different technologies based on farm size and the direct benefits to their well being. So farmers will also strive to adopt technologies that give them more benefits, boundary planting, provides poles, timber, fuel wood, marks property rights and protects farmer's crops against strong winds hence was highly adopted.

This study also revealed that trees help to buffer subsistence farmers against environmental extremes by modifying temperatures, providing shade and shelter and acting as alternative sources of food and feed during the period of drought. This observation is consistent with other studies on the multifunctional role of trees by sustaining production during wetter and dry season (Smith, 2010; Fifanou *et al*., 2011; Folega *et al*., 2011 This agrees with the observations made in the field in Vihiga county that there is a significant variation in temperatures and rainfall in the sub county and this could be attributed to deforestation and therefore the need to intensify agro forestry to buffer this variations.

4.5.2 Agro forestry practices and farmers resilience to climate variability

The group was further subjected to more questioning to check how agro forestry practices have helped in resilience to climate variability. Table 4.14 summarizes the findings of agro forestry practices and their adaptation to climate variability.

From the findings in Table 4.14, 28 (9%) of the respondents did not practice agro forestry. Majority of those who plant trees believe that most indigenous trees rejuvenate and that 102 (33%) believe that these species help in providing shade to crops and animals against direct sunlight and they do not prefer cutting them for sell, while 180 (58%) plant exotic trees which they use for firewood, building material, charcoal and timber.

Table 4.9: Agro forestry practices and farmers resilience to climate variability

Respondents	Plant type	Species	Frequency	Percentage
Practice AF	Tress	Exotic,	180	58
		Indigenous	102	33
Don't practice			28	9
Practice AF	Cash Crops	Tea	278	89
		Coffee	6	2
Don't practice			28	9
Practice AF	Food Crops	Maize	230	74
		Beans	40	13
		Potatoes	10	3
		Cassava	2	1
Don't practice			28	9
Practice AF	Horticultural Crops	Vegetables	270	87
		Fruits	6	2
		Flower	6	2
Don't practice			28	9
Practice AF	Animal Feeds	Grass	45	15
		Napier	237	76
Don't practice			28	9

Source: Field data (2017)

Further interviews revealed that farmers use the proceeds from agro forestry in tilling the land for the next seasons. The category of cash crops reveal that majority of the respondents, 278(89%) have planted tea and believe that tea assists in controlling soil erosion by providing ground cover to the land surface while the proceeds help in sustaining other crops by buying fertilizer and food. A small group of only 6 (2%) still have coffee plants on their farms. Further inquiry revealed that low prices and lack of collecting centers made farmers to uproot coffee for tea. Those who plant food crops believe that maize is the main stable food in Vihiga sub county of which 230 (74%) plant maize, 40 (13%) plant beans, 10 (3%) plant potatoes, and 2 (1%) plant cassava.

Those interviewed agreed to plant these crops mainly for food and thereby saving the money to buy food. Further inquiry revealed that these crops have made farmers to adapt well to climatic changes since they are planted throughout the year. It was revealed that maize is planted twice a year. On horticultural crops, vegetables and fruits like paw paws, avocadoes; guavas are planted for domestic consumption and for sale. The proceeds are used in maintaining and planting more trees. Farmers interviewed revealed that they water their vegetable gardens during dry seasons to maintain vegetables throughout the year. Majority of farmers 270 (87%) plant vegetables while 12 (4%) plant flowers and fruits. Flowers planted are found in the homesteads for beautification, providing shade to the residents and as live fences. These flowers also help bees in collection of nectar for honey thus farmers resilience. From the field observations, many farmers 237 (76%) have small portions of Napier grass on their farms. Majority have planted Napier on strips of terraces of their farms. This group admitted that Napier is food for their animals but where there is excess they sell to get money for the fertilizers to maintain the Napier. It was also revealed that Napier is used to control soil erosion on the terraces therefore mitigating the effects of climate variability.

These results are consistent with results from studies according to (COSEPUP, 1992), where it emerges that there are several strategies – including technologies that will increase the potential of agro forestry systems as adaptive strategies. They note the importance of capacity building to farmers that will enable them understand and evaluate potential systems for adoption based on their ecological zones that will enhance the communities resilience and adaptive capacity to climate change.

For agro forestry practices to cushion against negative impacts of climate change, it is prudent for relevant structures to critically examine the climatic characteristics, farming systems and their adaptive capacity to climatic stress, assessment of infrastructure that will forge links to markets, evaluate policies in an attempt to bridge any gaps that would exacerbate inadequate coping mechanisms.

4.6 Rainfall and temperature variability trends in Vihiga sub county between1985 and 2015

Trees in Agro forestry systems increase farmer`s resilience to climate variability by modifying microclimatic conditions including temperature, humidity and wind speed (Rao *et al*., 2007).This study interrogated the respondents on rainfall and temperature trends of Vihiga sub county. Interviews were carried out and documents analyzed from different institutions including: the Ministry of Agriculture, KALRO, ICRAF, KMD, KESREF, and Sub county agricultural offices which revealed that there has been variation in temperature and rainfall trends in the sub county.

4.6.1 Climate of Vihiga sub county

The study purposed to find out the nature of climate experienced in the sub county. The respondents were asked to describe the climate of their area of which 5.56% said that rainfall had become so unpredictable, 22.22% said that temperatures were higher than usual, 44.44% said that temperatures are cooler while the remaining 27.78% said that rainfall and temperatures had not changed as such. This indicated that the climate of Vihiga Sub County has had variable trends (Table 4.15).

A majority of the respondents 60% felt that the climate has not always been like it is currently while the remaining 40% were of the opinion that the climate has always been as it is today (Table 4.15) presents this response. This is collaborated by work done by Lukuyu *et al* (2009) which found out that the rainfall level in Namayumba area of Uganda are generally adequate to support cropping activities; however, rainfall unreliability is increasingly becoming common. Other studies by the Kenya National Climate Change Response strategy (GOK, 2010) indicate that climate variability and change have resulted into frequent droughts and emergency of vector-borne parasites that affect milk production; this is due to increased seasonal variability within the year and also a decline of the long rainy season. Several studies have therefore proved that trees have the potential of increasing resilience of subsistence farmers against environmental extremes by modifying temperatures, providing shade, shelter and by acting as alternative feed resources during periods of drought (Rao *et al*., 2007; Abebe *et al*., 2010).This agrees in totality with the findings of the study carried out in Vihiga sub county.

Table 4.10: Climatic change in Vihiga sub county

Response	No. of farmers	Percentage
Climate has not always been as it is	186	60
The climate has changed	124	40
Total	**310**	100

4.6.2 Temperature changes due to agro forestry

This study was set to analyze temperature variation due to agro forestry. The findings established that out of the 310 respondents, almost 50% of the respondents affirmed that temperatures were moderate, while the other 50% of the respondents disagreed citing global warming as the reason for high temperature trends. Table 4.16 gives a summary of the findings.

Table 4.11: Temperature changes due to agro forestry

Responses	Frequency	Percent (%)
Cool temperatures	43	13.9
Warm temperatures	110	35.5
High temperatures	141	45.5
Very high temperatures	16	5.2

Source: Field data (2017)

Implication from the results of these findings indicate that we have drastic temperature variations and therefore there is need for adaptations of climatic resilient technologies to buffer smallholder farmer households against this variations, thus need for agro forestry. This collaborated with results from studies according to projections by IPCC, (2012) which reveal that Kenya is expected to observe a mean annual temperature increase of about 0.8 - 0.9 °C across the country by the year 2030 and from 1.5 to 1.6 °C by the year 2050. Annual precipitation is also expected to be between 7.0 - 9.7 % and 13.3 - 18.8 % by the year 2030 and 2050 respectively.

Other studies also revealed that for countries with significant proportion of agrarian economies like Kenya, climate change is expected to have significant economic consequences on them (Deressa *et al*., 2005; Gbetibouo and Hassan, 2005). Given the pressing concern over food security in the next 20 years, due to increased population and at least locally decreased food supply resulting from climate stresses (Lobell*et al*., 2008). Agro forestry systems must therefore be a key focus of resilience strategies to climate change (Cook, 2009; Nair and Garrity 2012). This agrees with study findings in Vihiga Sub County.

4.6.3 Rainfall variations due to agro forestry

The study analyzed rainfall patterns and trends in Vihiga Sub County. The findings established that out of the 310 respondents, 80% of the respondents agreed that rainfall amounts and distribution in the sub county had reduced drastically, while about 6 % did not agree with this inference, about 11% were not sure whether rainfall received in the sub county had reduced or not (Table 4.17),(Figure 4.8). Conclusion from these findings was that rainfall amount and intensity had reduced drastically and therefore there was need for resilience mechanisms to combat this extreme climatic event. This collaborated with several studies that revealed that the projections of rainfall amounts and distribution are less uniform all over the world. Hulme *et al.,* (2001) illustrated the large regional differences that exist in rainfall variability which explained that,

Table 4.12: Rainfall variations due to agro forestry

Responses	Frequency	Percentage (%)
Reduced drastically	105	33.9
Reduced moderately	168	54.2
Not sure of any reduction	35	11.3
Not reduced at all	2	6
Total	**310**	**100.0**

Source: Field data (2017)

Several other studies revealed that Kenya, similarly to most of other African countries, is dependent on rain-fed agriculture as well as reliance on agricultural export for its economic growth. According to the National Climate Change Response Strategy (GOK, 2010), indicate that current annual rainfall patterns are much lower than those observed in the early 1960's.

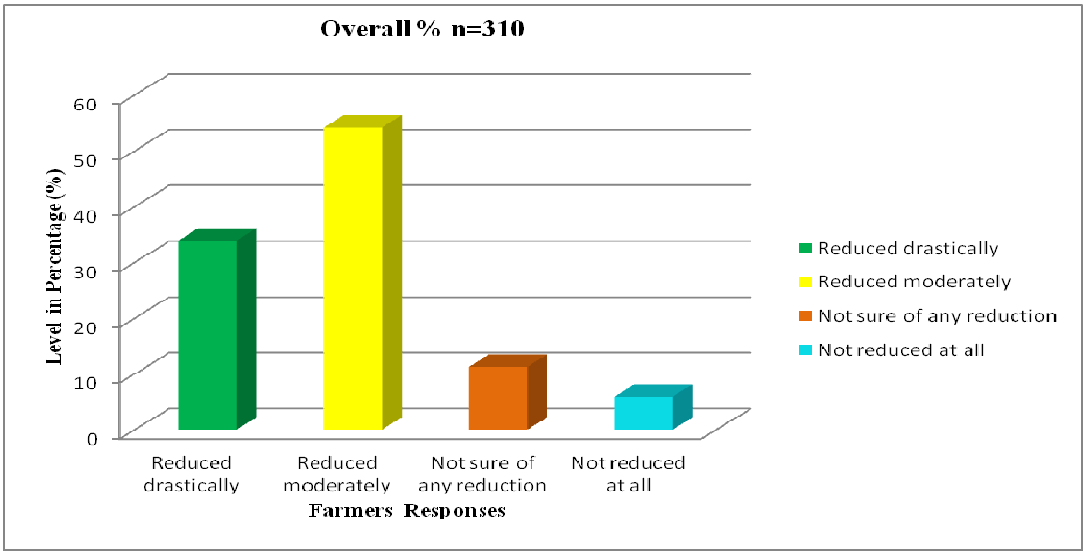


Figure 4.8: Rainfall variations due to agro forestry

Source: Field data (2017)

Climate change has resulted to shifts in rainfall patterns as well as trickling effects such as soil degradation. The result has been a decline in food production with unwanted effects on livelihoods – income, food security and employment

4.6.4 Rainfall and temperature trends

The information obtained from Vihiga county meteorological department on climate included temperature and rainfall data for a period of 30 year. The data was analyzed using time series analysis to establish the trends of climatic variables in Vihiga sub county and establish the role of agro forestry. The findings are as shown in the Figure 4.9 and Figure 4.10. Scrutiny of seasonal, monthly and inter-annual temporal and spatial variability of rainfall and temperature in a changing climate is vital to assess climate-induced changes and suggest adequate future resilience strategies for vulnerable communities.

This study focused on temporal trends analysis of in-situ rainfall and temperature records for Vihiga sub county, Kenya using time series analysis. The data sets used were rainfall and temperature for the period between (1985 and 2015). The findings revealed that the highest rainfall amount of (2786.0 mm) was recorded in the year 2000 with temperatures of (16^0C minimum, 31^0C maximum) while in 2001 rainfall of (2789.0 mm) and temperatures of (18^0C minimum, 32^0C maximum) were recorded The lowest annual rainfall recorded was in 1989 and in 2002 with (1039.5 mm) and (1197.2 mm).

Figure 4.9, shows the time series analysis of minimum and maximum temperatures for Vihiga sub-county. The horizontal axis has the period of time which ran from 1985 to 2015. The vertical axis had temperature in degrees Celsius. The graphs show annual temperature variation over time. From the graph, it is evident that in 15 years' time the maximum temperature has been steady at 25^0C while the minimum has been at 15^0C this can be verified by the equation y=0.1004x-184.35, with a slope of 0.2508, there is significant linear trend, an indication that agro forestry has kept the temperatures steady) respectively (Appendix IV).

Figure 4.10, shows the annual rainfall trend of Vihiga Sub County with varying rainfall patterns. By use of the equation y=13.973x-25946, it is revealed that the rainfall in a period of 15 years had steadily increased to a level of over 2500 mm. The trend line is found to be leaning on the right and rising up. Further results revealed that among the seasons, a noticeable increase in rainfall was observed in the year 1999 based on the trends analysis, overall findings demonstrated that a significant rise in both maximum and minimum temperatures occurred between 1998 and 2015 and this is in line with recent trends of global warming as reported by the latest Intergovernmental Panel on Climate Change (IPCC, 2011) report

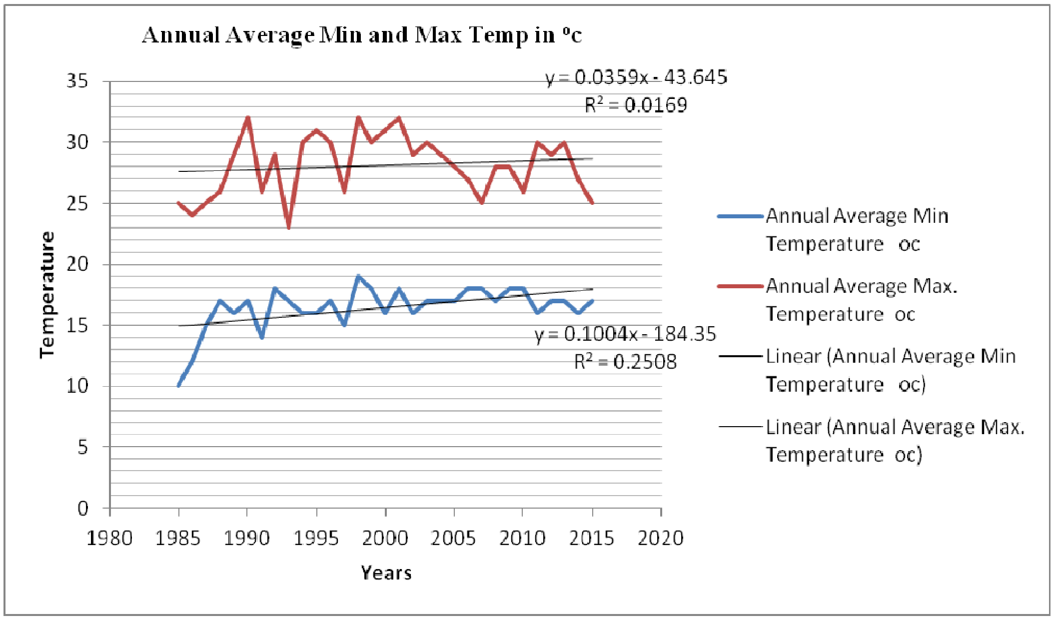


Figure 4.9: Temperature trends-for Vihiga Sub-county

Source: Field data (2017)

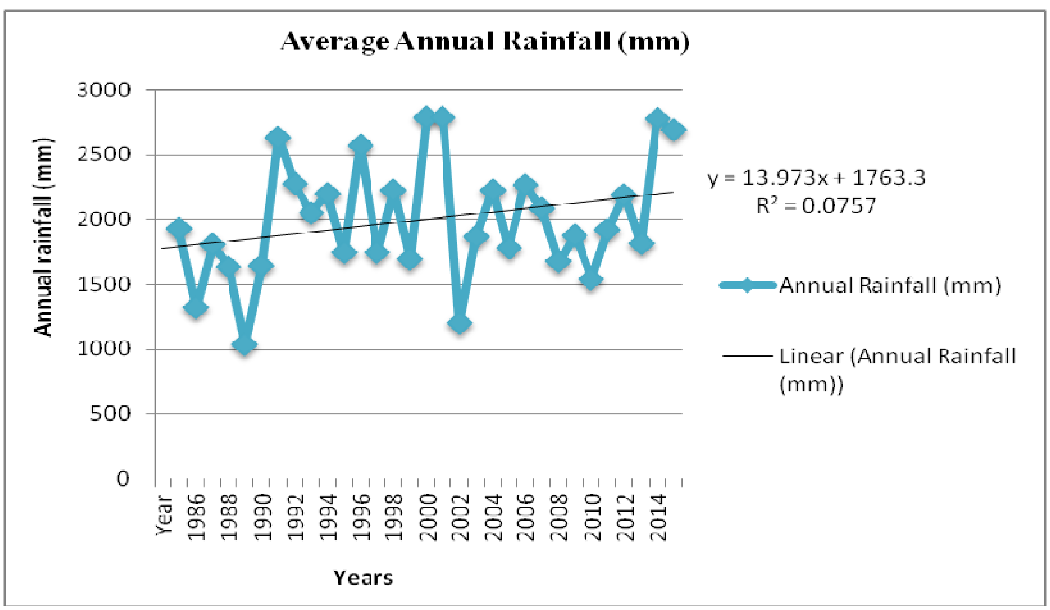


Figure 4.10: Annual Rainfall trends for Vihiga sub-county

Source: Field data (2017)

The significance of these findings is that it could support various policy makers and development partners working in Kenya on issues of climate change adaptation and resilience.

The study further interviewed the Kenya Meteorological department staff on the number of seasons experienced in the sub county, the dates of the onset and cessation of the rains and the overall trends in temperature, precipitation and rainfall. Information obtained from KMD (Appendix iv) revealed moderate climatic conditions with constant temperatures that are favorable for farming. They confirmed that the onset of long rains is experienced in the month of March to August while short rains start from September to December. This confirms that Vihiga sub county has two planting seasons. It further revealed that the worst years with the worst climatic conditions were in 1987 to 1989 that threatened food security in the region. They rated 2000 to 2002 as the best years that the sub county produced better yields due to sufficient rainfall. Respondents were further asked to state how climate changes have shaped farmers adaptability to climate variability and the results are indicated (Table 4.18).

Table 4.13: Climate patterns enhancing resilience to Climate Variability

	Climate pattern Adaptability			
	Varying temperature		**Varrying rainfall**	
Responces	**Frequency**	**%**	**Frequency**	**%**
Yes	237	76.5	275	88.7
No	73	23.5	35	11.3
Total	**310**	**100**	**310**	**100**

Source: Field data (2017)

The findings in Table 4.18 reveal that majority of the farmers agree that varying climate patterns have shaped farmers adaptability to climate variability. The findings reveal that 237(76.5%) agree that varying temperature patterns and 275(88.7%) agree that varying rainfall patterns have led to farmers resilience to climate variability while 73(23.5) and 35(11.3) respectively do not agree with this statement.

This agrees with studies conducted in Asia that reveal Increasing trends that have been observed across the seven sub-regions of Asia. The observed increases in temperature in some parts of Asia during recent decades ranged between less than 1°C to 3°C per century. Increases in surface temperature are most pronounced in North Asia (Savelieva *et al.,* 2000; Izrael *et al.,* 2002; Gruza and Rankova, 2004). Interseasonal, interannual and spatial variability in rainfall trends have been observed during the past few decades all across Asia. Gruza and Rankova, (2004) indicates that decreasing trends in annual mean rainfall are observed in Russia, North-East and North China, coastal belts and arid plains of Pakistan, parts of North-East India, Indonesia, Philippines and some areas in Japan.

4.7 Agro forestry practices and products to households' income as farmers' resilience to Climate Variability

The study sought the farmer household heads' views on agro forestry practices and products to household income as farmers resilience to climate variability. This was done to establish how agro forestry practices and products contribute to resilience to climate variability among farmers in Vihiga Sub County. The byproducts and income from agro forestry are the zeal that drives most households to practice agro forestry; in return the practice contributes to resilience on climate variability. Most of the farmers believed that the best way of coping with climate threats and stresses involved improving their standards of living. Agro forestry therefore helps farmers do this by raising productivity and income through diversification, and thus providing farmers with greater resilience to climatic related hazards.

4.7.1 Agro forestry techniques and number of trees planted

The study sought to establish the number of households who practice agro forestry, the number of trees grown on their farms and the kind of agro forestry techniques practiced by farmer households (Table 4.19). The findings from this Table 4.19, reveal that farmer households practiced agro forestry and planted up to 10 trees on the farm, 117 household heads who answered the questionnaires revealed that they practiced agro forestry and planted between 10 to 20 trees, while 14 households in this category did not practice agro forestry but planted 10 to 20 trees, 79 household heads practiced agro forestry and planted between 20 to 30 trees while 27 household heads did not practice agro forestry but planted between 20 to 30 trees- in another category, 70 household heads practiced agro forestry and planted over 40 tree while 2 do not practice agro forestry but planted over 40 trees.

Table 4.14: Agro forestry techniques and number of trees planted

No. of trees planted	**Agro forestry practice**		**Total**
	YES	**NO**	
1-10 Trees	1	0	1
10-20 Trees	117	14	131
20-30 Tress	79	27	106
OVER 40 Trees	70	2	72
Total	267	43	310

Source: Field data (2017)

Generally 282 farmer household heads out of the 310 farmer household heads practiced agro forestry and planted trees while 43 did not practice agro forestry but planted trees. Further inquiry revealed that apart from planting of trees, most households practiced other techniques of agro forestry. The study established that based on the majority of the farmers it is generalized that Vihiga sub county farmer households practiced agro forestry where planting of trees is the key element for resilience against climate variability.

This collaborated with studies carried out elsewhere which revealed that trees preferences differ between individuals, groups, institutions, societies and cultures due to socio-economic needs, management and environmental factors (Snelder *et al*., 2007; Abebe *et al*., 2010; Ajayi *et al*., 2011; de Souza *et al*., 2012; Bucagu *et al*., 2012). In Benin, tree density was directly related to the size of land holding and local perception of the species abundance in the wild. Small land holdings and inherited farms supported more tree species (Fifanou *et al*., 2011). Further tree preference and use played an important role in responding to climate change, both in terms of mitigation of GHGs emissions such as CO2 sequestration and resilience to changing climate conditions.

4.7.2 Types of trees planted

The study further sought to establish the types of trees planted by farmer household heads. The types of trees planted in the study area included; fruits, indigenous trees, exotic trees, shrubs and flowers (Figure 4.11). The study established that farmer household heads who planted fruit trees accounted for 29.7%, for indigenous trees were 41%, for exotic trees were 23.9%, for shrubs and flowers were 2.5% and 2.9 % respectively. The study established that majority of the farmer household heads planted exotic, indigenous and fruit trees. Apparently, majority of the farmers planted indigenous trees, fruit trees and exotic trees an indication that they practice agro forestry.

Results from the FGDs showed that 43 species trees are important to farmers in Vihiga Sub County, and that 77% of these provided multiple benefits (Figure 4.11). The results demonstrated the multi functionality of trees in Vihiga sub county area and their contribution to farmers' livelihoods. The main CSA practices demonstrated include, improved fodder production (Napier grass, Columbus grass, forage sorghums), and agro forestry and fodder trees (Calliandra, Leucaena, Trichandra, tree Lucerne, Sesbania sesban, Grevillia and Croton); These are resilient tradeoffs of agro forestry against climate variability in the sub county. This result collaborated with other studies carried out which confirmed that Proximity to town favored trees with higher returns such as fruits trees, timber and poles. Competition with other crops discouraged farmers from planting *Cedrella odorata* and *Acrocarpus fraxinifolius* (Zomer *et al*., 2009; Irshad *et al*., 2011; Roy *et al*., 2011). Experience has shown that avocado (*Persea americana*) and mango trees do well during drought, hence people depended on their fruits during drought periods as a climate resilient strategy. The aforementioned studies indicated that tree based systems are important sources of carbon sinks which are targeted by REDD+ (Angelsen *et al*., 2012). even if variations of carbon stock in AFs as described above depended upon several factors (Albrecht and Kandji, 2003; Nair, 2008; Brakas and Aune, 2011; Nair, 2011; Singh and Pandey, 2011). Similarly, higher carbon accumulation rate from agro forestry with high diversity facilitated a better nutrient use and therefore increased C sequestration compared with non-agroforest systems (Nair *et al*., 2009; Howlett *et al*., 2011; Singh and Pandey, 2011)

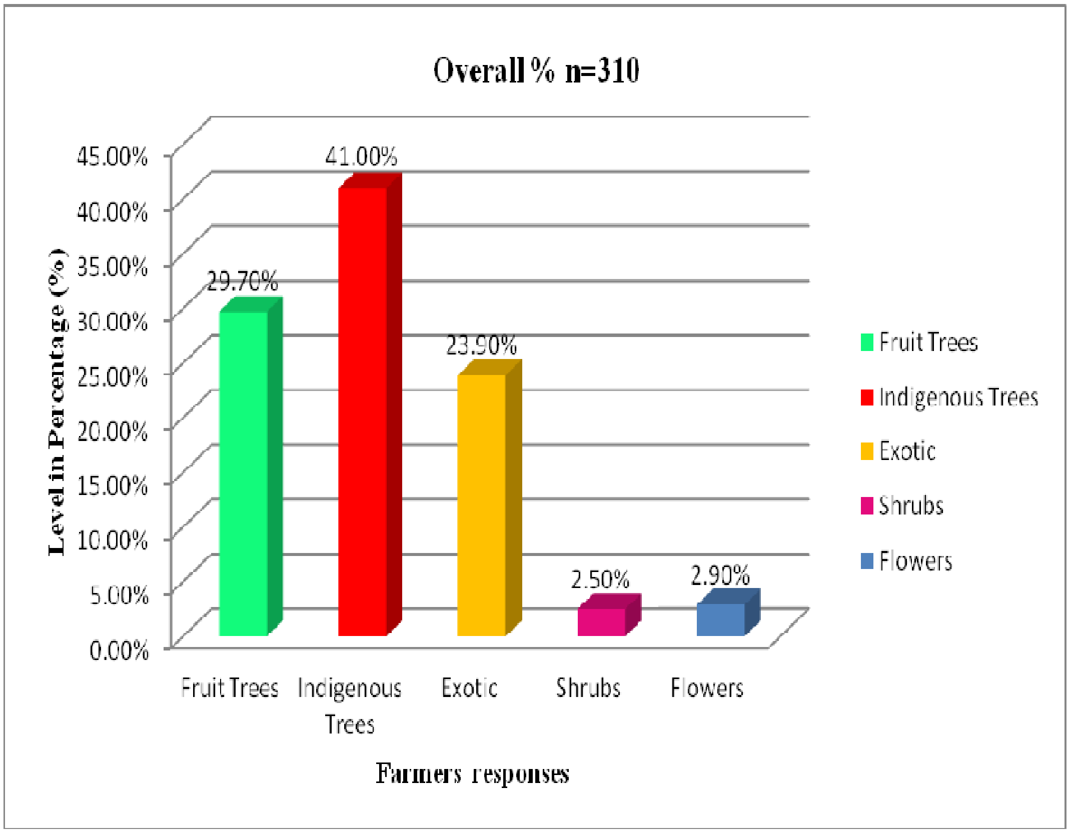


Figure 4.11: Tree types

Source: Field data (2017)

4.8 Benefits of agro forestry practices

Agricultural production depends on climate variables, such as temperature, precipitation, and light. This study examined the benefits of agro forestry resulting from planting trees alongside crops and rearing of animals by Vihiga sub county farmer households.

4.8.1 Buffering crops from high temperatures

The study revealed that, out of 310 farmer households 27.1% indicated that planted trees buffer crops from extreme heat, 25.2% were undecided while 47.7 % disagreed. Those who disagreed said that they did not plant crops under shade to protect them from extreme heat. This was attributed to absence of extreme high temperatures in the sub county that would favor that kind of system. However, they agreed that they could plant crops under shade to buffer them from extreme heat if future weather changes persisted. Figure 4.12 gives a summary of the findings.

This agrees with findings from other studies which revealed that as a method of adapting agriculture to climate variability, agro forestry systems have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms. (Niggli *et al.*, 2008). In coffee farms agro forestry systems, crops grown under heavy shade (60-80%) are kept 2-3°C cooler during the hottest times of the day than crops under light shading (10-30%) (Lin, 2007) and lose 41% less water through soil evaporation and 32% less water through plant transpiration (Lin, 2010).

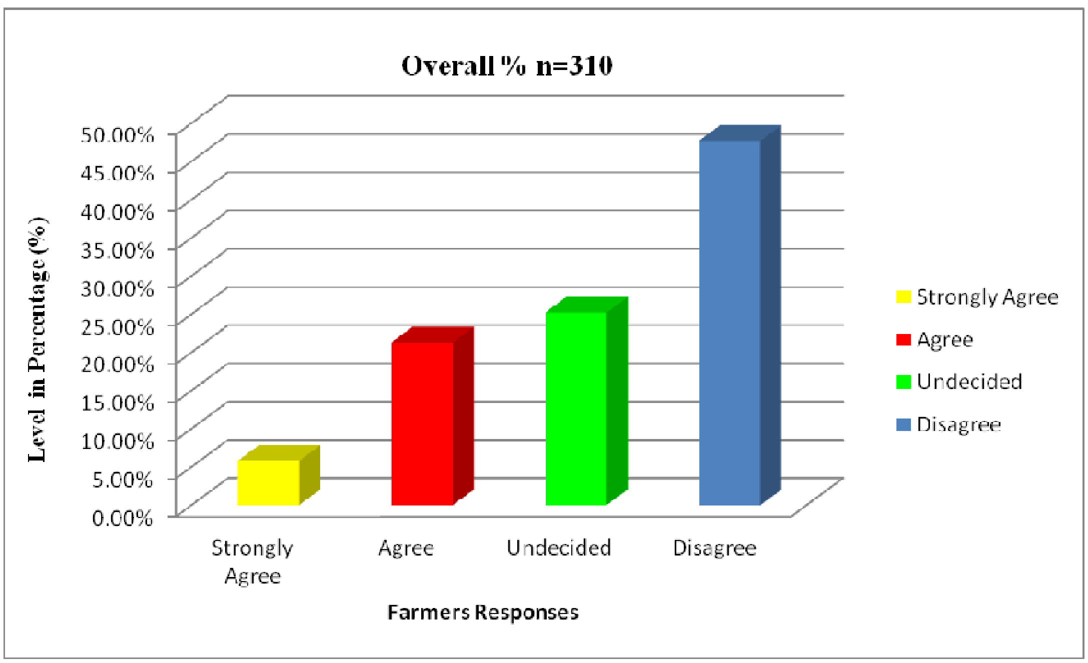


Figure 4.12: Buffering crops from high temperatures

Source: Field data (2017).

4.8.2 Buffering crops from heavy downpour

The study further interrogated the farmer household heads on agro forestry practices buffering crops from heavy downpour, most farmers agreed to the fact that agro forestry helps in buffering crops from heavy downpour. Figure 4.12 gives a summary of the findings. The findings shown in Figure 4.12 reveal that 46.1% of the farmer household heads agree to the fact that agro forestry practices buffer crops from heavy downpour while 18.1% were undecided and 35.8% of the respondents disagreed that agro forestry practices buffer crops. Most respondents who disagreed confirmed that Vihiga sub county does not experience very heavy downpours that destroy crops however there are isolated incidences of heavy hailstones that occur. This agrees with several studies conducted elsewhere which revealed that rain water is a scarce resource and the impact of climate change is expected to make the situation worse. Climate change has both direct and indirect impacts on Rain water availability.

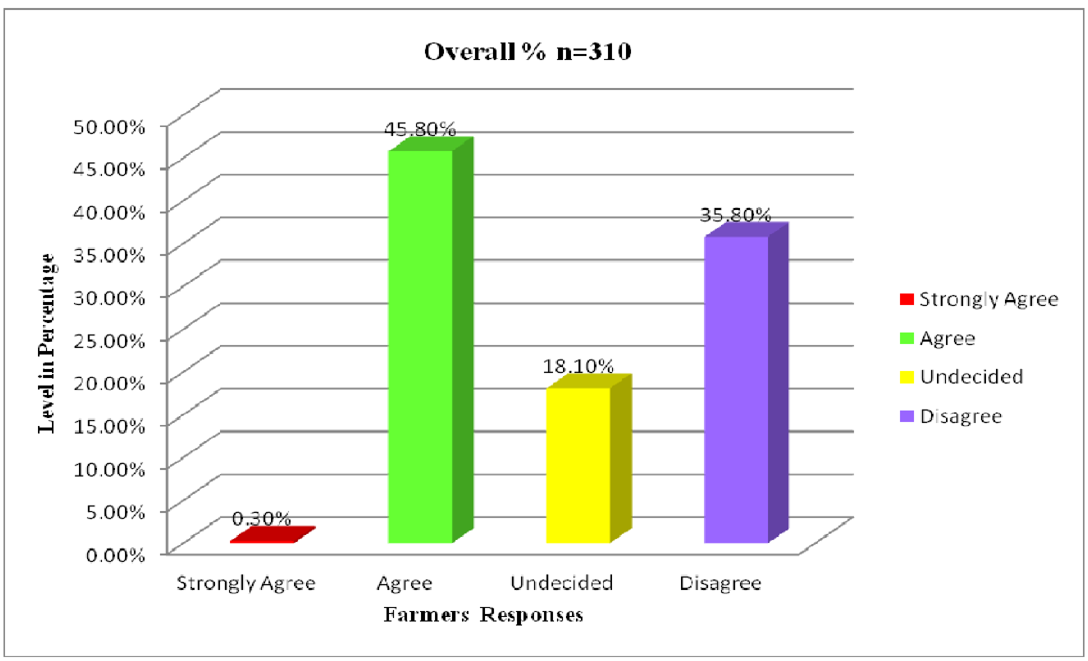


Figure 4.12: Buffering crops from heavy downpour

Source: Field data (2017)

The direct impacts include changes in precipitation pattern, while indirect ones are increase in losses through runoff and evapotranspiration (Roy *et al*., 2011). There are several mechanisms whereby AF may use available water more effectively than monoculture. First, agro forestry increase productivity of rain water by capturing large proportion of the annual rainfall by reducing runoff and by using water stored in deep layers. Secondly, changes in microclimate reduce the evaporative demand and make more water available for transpiration (Smith, 2010). Other studies also revealed that rainfall interception is positively correlated with canopy cover (Roy *et al*., 2011), and the percentage of annual runoff and soil erosion is very low in AFs in comparison to non-AF. Thus, the presence of woody species in AFs improved farmers‟ resilience to climate variability .This collaborated with the purpose of this study in Vihiga Sub County.

4.8.3 Planting trees for wind breaks

The study further investigated the usefulness of agro forestry practices acting as wind breaks (Figure 4.13). This study revealed that, trees planted alongside food crops have always acted as wind breaks in homes and the whole county at large. The results from the respondents revealed that 90.7% of the respondents confirmed that trees have always helped them during times of strong winds, especially during heavy rainfall. They protect crops from being blown off or flattened leading to breakages, further in depth investigation revealed that trees protect buildings and other structures on the farms during strong winds.

This collaborated with studies carried out in India which revealed that while wind speed reduction prevented crop loss due to flower or fruits drop, the resultant decline in wind erosion effects had multiple benefits for crops including increased growth rate and quality, due to moisture management and soil protection (Smith, 2010; Roy *et al*., 2011). In a system where trees are planted in single or multiple rows along the edge of a field to reduce wind effects on crops or livestock, Windbreaks have been shown to reduce wind impact over a horizontal distance equaling at least ten times the height of the trees (Beetz, 2010).

The wind break system therefore minimizes wind erosion, adverse damage of crops and creates a suitable micro-environment for favorable for crop growth

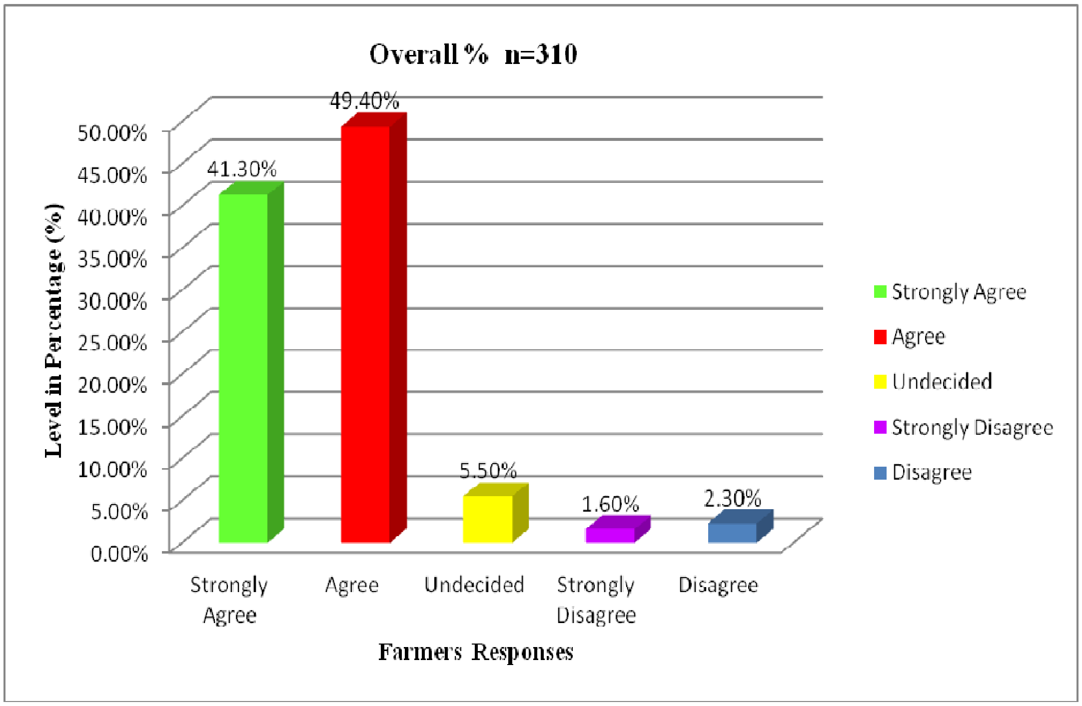


Figure 4.13: Planting trees for wind breaks

Source: Field data (2017

4.8.4 Trees as a source of food for animals and people

The same respondents were asked about the usefulness of trees in providing food and medicines for animals and humans. The study established that people use fruits from the fruit trees while pastures grown within crops are used as fodder for animals. This is common where farmers practice agro forestry technologies involving mixing crops and pasture. Some tree leaves are also used as fodder for animals as well as medicines for both animals and people (Figure 4.14). Out of the 310 farmer household heads, 69.3%

agreed and confirmed that some tree parts are used as food and medicines for both animals and people while 23.2% did not agree to this. Only 7.4 % were undecided.

Those who agreed cite various benefits of trees such as provision of fruits, medicines, food and flowers for bees that collect nectar for honey.

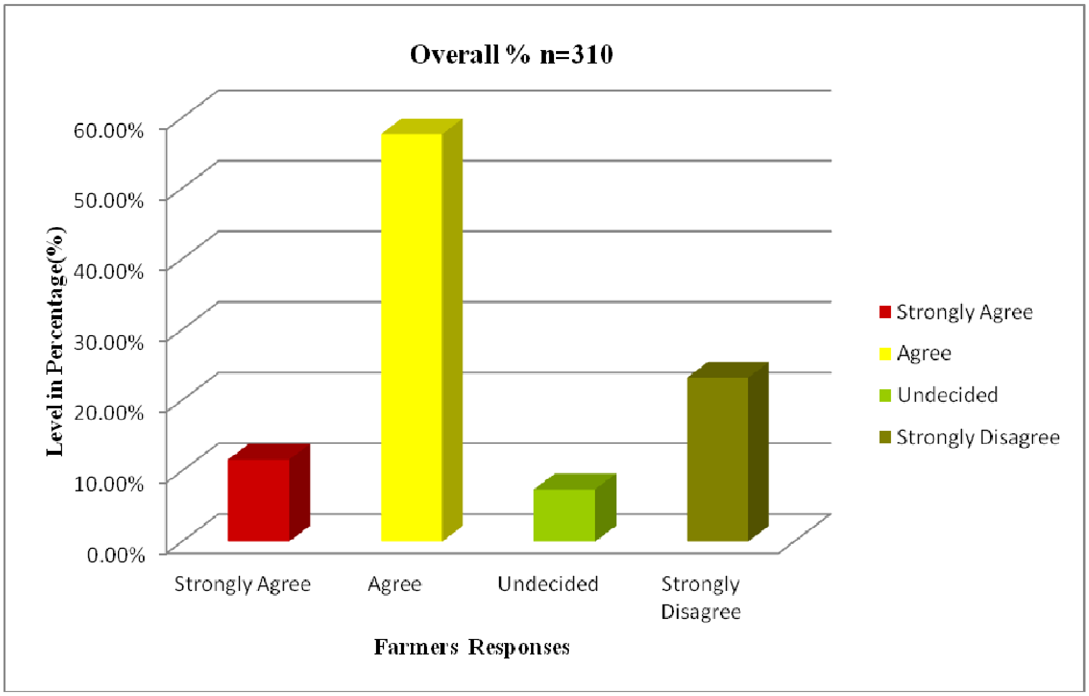


Figure 4.14: Trees as sources of food for animals and people

Source: Field data (2017)

This agrees with the study conducted in Muwanga district of Tanzania that revealed that Agro forestry systems are multifunctional in provisioning of services to animals like provision of shelter from rain, wind, shade, feed and fodder, cover from predators and a diversity of foraging resources. Ulsrud *et al.* (2008) argued that if livelihoods including feeding of animals, depend more on bushes and trees and less on grasses and annual grain crops, the risk of losses during floods and drought becomes less, because trees are more resilient to such weather than other plants.

4.8.5: Agro forestry practices, products and benefits enhancing resilience to Climate Variability

According to Kalaba *et al*. (2010); Smith (2010) and Folega *et al*. (2011), integrating trees into the agricultural landscape had potential to affect the local economy through increasing economic stability, diversification of local products and economies, diversification of rural skills, improving food and fuel security, improvements to the environment, landscape diversification and thus increasing farmers resilience to climate variability.

This study interrogated farmer household heads on Agro forestry practices, products and benefits in enhancing the adaptability to Climate Variability. The benefits were; buffering crops from high temperatures, planting trees as wind breaks, trees as sources of food for animals and people, control of soil erosion and diversification of agricultural products. Table 4.20 gives the findings of agro forestry practices products and benefits in enhancing resilience to climate variability.

The findings revealed that 120 (37.7%) agree that buffering crops from high temperatures had made farmers adapt to climate variability while 90 (62.3%) disagreed. Planting trees as wind breaks was attested to by 285 (91.9%) respondents, trees as sources of food for animals and people 280 (90.3%) respondents, control of soil erosion 250 (80.6%) had the highest no of respondents who agreed to trees acting as windbreaks and assisting farmers in resilience to climate variability as well as acting as a source of food for animals and people. This has made farmers cut on cost of feeding animals.

Table 4. 15: Agro forestry practices, products and benefits enhancing resilience to Climate Variability

Agro forestry Benefits	Agree		Disagree	
	Frequency	%	Frequency	%
Buffering crops from high temperatures,	120	37.7	90	62.3
Planting trees as wind breaks	285	91.9	25	8.1
Trees as sources of food for animals and people	280	90.3	30	9.7
Control of soil erosion	250	80.6	60	19.4
Diversification of agricultural products	54	17.4	256	82.6
Tree benefits	300	96.8	10	3.2

Source: Field data (2017)

Tree benefits like providing medicine, food, fuel, timber and income make farmers' plant more trees in Vihiga sub county hence resilience to climate variability.

These findings agree with other studies which proved that a variety of benefits of AF products found in this study are similar to those are reported in other studies (Akinnifesi *et al*., 2010; Ndayambanje and Mohren, 2011; de Souza *et al*., 2012). However, in these studies farmers seemed to put more emphasis on the benefits of shade, livestock manure, food, fodder, ecosystem services and wood products. Sileshi *et al*. (2007) ; Masamha *et al*. (2010); Singh and Pandey (2011) argued that the major role of AF in increasing farmer's resilience to changing climatic conditions was through supporting production of wide range of products including food, fuel wood, fodder and forage, timber, shade, gardening material, medicine, biological control and ecological services.

Agro forestry systems enhance smallholder farmers resilience to climate variability by supporting them with the diversity of products or benefits.

Studies carried out in semi-arid climates reveal that soil water content under tree canopies was reported to be higher than in open pasture due to reduced evapo transpiration under the tree shades out-weighing water uptake by plants which is in agreement with (Smith, 2010). The same information concurs with the findings of the study in Vihiga sub county, where (37.7%) of the respondents agree that trees help plants by buffering them from high temperatures. These finding prove that farmers have fully adopted agro forestry knowing that it has made them adapt to climatic changes which the study purposed to establish.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of the main findings, conclusions and recommendations which if implemented will buffer Vihiga Sub County from extreme weather volatility in climatic parameters.

5.2 Summary

This study revealed that multiple techniques are used to promote agro forestry practices in Vihiga Sub County. The practices used include mixing trees with agricultural crops, trees with pasture and animals, fruit trees with agricultural crops, trees with fruit trees, agricultural crops with fruit trees, fruit trees with pasture, agricultural crops with pasture, and trees with bee keeping. The key informants in this study revealed that a few years back the sub county had suffered in terms of extreme weather conditions and food security. The onset of rains occur in mid-month of March when majority of people in the sub county plant their staple food, maize and beans. However, most respondents revealed that rains were not predictable as before when farmers knew the onset of the rains. Due to changes in weather patterns, dry spells have extended into the month of April while the wet spells occasionally spilt over to the month of January unlike in the past.

It is clear that the crops lasted between 3 to 7 month on the farm before harvest. Short rains started in the month of August to December where people preferred planting crops such as beans, maize and vegetables. Rains ceased in the month of January and February followed by moderate dry spells coupled with dry winds and dust. There were no serious out breaks of diseases due to climate variability. Precautionary measures were taken to cushion farmers on any eventuality. Therefore, agro forestry practices and techniques have had an impact on climate variability in the sub county.

A study on evaluation of the rainfall and temperature variability trends in Vihiga sub-county between 1985 and 2015 revealed that the worst year that recorded the lowest amount of rainfall with annual rainfall of 1039.5 mm and minimum and maximum temperatures of 16^0C and 29^0C respectively was in 1989. The year 2001 was a year with the highest rainfall of 2789.0 mm with minimum and maximum temperatures of 16^0C and 30^0C respectively. Several analyses reveal that agro forestry has strongly contributed to the stability in temperature and rainfall in Vihiga Sub County. However, the study focused on analysis of rainfall and temperature leaving out other climatic parameters that would assist in improving on the accuracy of the climatic trends.

The study further interrogated individuals on contribution of agro forestry products to household's income as farmers' resilience to climate variability in Vihiga sub County. More than 50% of the respondents revealed that they practiced agro forestry sub consciously. Most of them had planted indigenous and exotic trees on their farms alongside crops. They believed that trees in agro forestry help in buffering crops from high temperatures and heavy downpour, they provide windbreaks and food for animals and people, reduce soil erosion and have a way of diversifying agricultural products.

Farmer household systems in the tropics are expected to experience decreased precipitation and increased temperatures in future predicted climate scenarios, creating problems in production stability for many of the world's most economically unstable farmers (Gregory and Ingram 2000). Research has shown that many crops are sensitive to changes in temperature and precipitation and have a narrow threshold for production success however; changes that occur during key developmental stages of the crop can lead to production failure. Vihiga Sub County has hardly experienced adverse scenarios due to climatic changes. This study focused on temporal trends analysis of in-situ rainfall and temperature records for Vihiga sub county, Kenya.

5.3 Conclusion

1. Multiple agro forestry practices have been adopted in the study area. They include mixing trees with agricultural crops, trees with pasture and animals, fruit trees with agricultural crops, trees with fruit trees, agricultural crops with fruit trees, fruit trees with pasture, agricultural crops with pasture, and trees with bee keeping. Information obtained from key informants in this study revealed that there are a few years when the sub county suffered in terms of extreme weather conditions and food security.

2. The study revealed that there has been a significant fluctuation in both maximum and minimum temperatures which occurred between 1998 and 2013 and this is in line with recent trends of global warming as reported by the latest Intergovernmental Panel on Climate Change (IPCC, 2012) report. It is therefore concluded that there has been widespread variability in climate in Vihiga Sub County. From climate variability analysis, the results show climate variability is influenced by agro forestry.These findings can support various policy makers and development partners working in Kenya to appreciate the climatic changes at the local scale and lead to better planning for a changing climate. The study revealed that agro forestry can change the climate trends of a place.

3. Agro forestry systems enhanced diversity in terms of the multiple benefits from trees, crops and livestock integrated in agriculture systems. Agro forestry products seemed to improve resilience of smallholder farmers against climate

change, particularly by improving farm production (food, fodder, timber, fuel wood, and manure), ecosystem services (soil improvement, wind break, erosion control, and disease and pest control) and household income. Agro forestry was found to be significant in enhancing farmer`s resilience to climate variability due to increased income as a result of the diversity of products distributed throughout the year.

5.4 Recommendations

1. The study recommends that farmers be facilitated in promoting agro forestry by providing them with good quality indigenous tree seedlings. This can be achieved in collaboration of the County government of Vihiga. The county government needs to ensure that extension services on agro forestry are made available and easily accessible by all farmers.
2. There is need to continue monitoring the climatic changes in order to establish the influence of agro forestry practices to climatic conditions within the study area. This therefore calls for concerted efforts in investing on climate data collection instruments. Through such efforts, farmers will be able to appreciate the changes and come up with sustainable coping strategies towards climate variability.
3. It is necessary to identify key players in agro forestry from among the farmers who can train others on agro forestry techniques in the study area. The identified farmers will be expected to work closely with relevant organizations including KARI, ICRAF, KMD, and KESREF to promote the agro forestry practices and products. Establishment of farmers' field schools where knowledge on agro forestry products can be shared among experienced farmers is recommended.

This will lead to up scaling of agro forestry practices to other areas within Vihiga County and beyond.

5.5 Suggestions for Further Research

In line with the findings, conclusions and recommendations made in this study, the following areas are suggested for further research in order to create more knowledge on the relationship(s) between agro-forestry practices and resilience to climate variability.

1. Further research should be conducted on the impact of climate variability on food security in Vihiga Sub County.
2. Research on effects of land tenure systems on agro forestry technologies adoption in Vihiga Sub County is vital.
3. The results of this study suggests that research priorities should consider extending agro forestry species that match farmer preferences and include those options that have direct potential for increasing farmers‟ resilience to climate change

REFERENCES

Abebe, T.; Wiersum, K. F. and Bongers, F. (2010). Spatial and temporal variation in crop diversity in Agro forestry homegardens of Southern Ethiopia. *Agro forestry systems* **78**: 309 – 322.

Aboud, A.A. (1992). Population pressure, Environmental Degradation and farmers' Adaptive Strategies in Nakuru District of Kenya, Unpublished PhD, thesis, University of Illinois atUrbana – Champaign, 1992, Urbana, Illinois

Adger, N, Lorenzoni,I and Karen O (2003). *Adapting to climate change.* Cambirdge: Cambridge University press. No of pages

Ajayi, O.C., F. K Akinnifesi,G Sileshi & W Kanjipite (2006). Labour inputs and financial profitability of conventional and Agro forestry-based soil fertility management practices in Zambia. *International Forestry review journal* , Vol 48(3) 276-293.

Ajayi, O.C., F.K. Akinnifesi, G. Sileshi, and S. Chakeredza. 2007. Adoption of renewable soil fertility replenishment technologies in the southern African region: Lessons learnt and the way forward. *Natural Resources Forum*, 31(4): 306-317.

Ajayi, C. O., Place, F., Akinnifesi, F.K. and Sileshi, G. W. (2011). Agricultural success from Africa: the case of fertilizer tree systems in southern Africa Malawi, Tanzania, Mozambique, Zambia and Zimbabwe. *International Journal of Agricultural Sustainability* 9(1):126 – 136.

Akinnifesi, F.K., Chirwa, P., Ajayi, O.C., Sileshi, G., Matakala, P., Kwesiga, F., Harawa, R., Makumba, W. 2008 Contributions of Agro forestry research to livelihood of smallholder farmers in southern Africa: Part 1. Taking stock of the adaptation, adoption and impacts of fertilizer tree options *Agricultural Journal* 3(1): 58-75

Akinnifesi, K.F.; Sileshi, G.; daCosta, J.; de Moura, E.G.; da Silva, F.R.; Ajayi, O.; Linhares, J.F.; Akinnifesi, A.I.; Araujo, M. and Rodrigues, M.A. (2010). Floristic Composition and Canopy structure of home-gardens in São Luís city, Maranhão State, Brazil. *Journal of Horticulture and Forestry* 2: 72 – 86.

Akpa A, Angahar P. (1999). Essentials of Research Methodology. A Division of Aboki Holdings Ltd. Ilupeju, Lagos, Nigeria.

Albrecht, A. and Kandji, T. S. (2003). Carbon sequestration in tropical agro forestry systems. *Agriculture Ecosystems and Environment* 99: 15 – 2

Alem, S. (2007). *Determinants of food insecurity in rural households in Tehuludere Woreda, South Wello Zone of the Amhara Region*. University of Adis-Ababa, Ethiopia.

Altieri, M. A. (1999, April 26-30). Enhancing the productivity of Latin American Traditional Peasant Farming Systems through an Agro-ecological Approach. *Confrence on sustainable Agriculture:New paradigms and Old practice?Bellagio confrence center ,Italy* , pp. 230-245.

Amir, J. 2003. An Investigation into the Adoption of Boiler Production / Management Practices by Poultry Farmers In tehsil Samundri. M.Sc. (Hons) Thesis, Dept. of Agri. Ext., Univ. of Agri., Faisalabad

Angelsen, A., Brockhaus, M., Sunderlin. D. and Verchot, V. (Eds.) (2012). *Analysing REDD+: Challenges and Choices*. CIFOR, Bogor, Indonesia. 456pp.

Baba, N. (2010) Sinking the Pearl of the Indian Ocean: Climate Change in Sri Lanka. *Global Majority E-Journal, 1,* 4-16.

Bank, W. (2010). *The cost of Agricultural Adaptation to Climate Change.Development and climate change.Discussion paper No.4.* Newyork: world bank.

Barreiro, P.L & Albandoz, J.P. (2001). Population and sample Sampling techniques. *Management Mathematics for European Schools*. Retrieved 5 March, 2016, from:http://optimierung.mathematik.unikl.de/mamaeusch/veroeffentlichungen/ver_texte/sampling_en.pdf

Basnayake, B. R. S. B., Abjhyasinghe, K. R., Sumathipala, W. L., Punyawardene, B. V. R. P., Perera, N., & Joseph, P. G.(2007). Climate Change in Sri Lanka: Impacts, Adaptation & Mitigation. *Proceedings of the National Conference on ClimateChange*, Centre for Climate Change Studies, and Kobe-Asia-Pacific Network for Global Change Research, Departmentof Meteorology, Colombo, Sri Lanka

Beer, J. R. (1998). Shade management in coffee and cacao palntations. *Agro forestry system* , 38;134-164.

Beetz, A., 2010. Agro forestry Overview, Horticulture System Guide. In National Sustainable Agriculture Information Services. ATTRA Publication http: // attar.ncat.org/attar-pub/PDF/agrofor.pdf

Berrang-Ford, L., Ford, D. J. and Paterson, T. (2011). Are we adapting to climate change. *Global Environmental Change* 21: 25 – 33.

Bonsal, B. R. and Kochtubajda B *2009 An assessment of present and future climate in the Mackenzie Delta and the near shore Beaufort Sea region of Canada* Int. J. Climatol. 29 *1780–95*

Bradley, Phillip N. (1991). Wood fuel, women and woodlots. The Foundations of a wood fuel Development strategy for East Africa. Macmillan Education Limited, London and Basingstoker.

Brakas, GS and Aune, BJ. 2011. Biomass and Carbon accumulation in land use systems of Claveria, the Philippines. In: *Carbon sequestration potential of Agro forestry systems: opportunities and challenges,*ed. Kumar, BM and Nair, PKR, Advances in Agro forestry 8:pp163-175.

Bucagu, C., Van Wijk, T.M. and Giller, E.K. (2012). *Assessing farmers` interest in Agro forestry in two contrasting agro-ecological zones of Rwanda.* [DOI 10.1007/s10457-012-9531-7] site visited on 14/7/2017.

Busienei, R.J.K. (1991). The Potential of Woment's Participation in Agro frestry in Ainabkoi Division, Uasin Gishu. M. PHIL Thesis (Unpublished). Moi University, Eldoret, Kenya.

Chandrapala, L. (1996). Long Term Trends of Rainfall and Temperature in Sri Lanka. In Y. P. Abrol, S. Gadgil, & G. B.Pant (Eds.), *Climate Variability and Agriculture* (pp. 150-152). New Delhi: Narosa Publishing House.

Chaudhury, M., Ajayi, O. C., Hellin, J., Neufelck, H. (2011). *Climate change adaptation and social protection in Agro forestry systems:enhancing adaptive capacity and minimising risk of drought in Zambia and Hondurus.* Nairobi, Kenya: IGRAF.

Conant, R.T., Paustian, K. (2009). Spartial variability of soil organic carbon in grassland:implication for detecting change at different scales. *in environmental pollution*, 116:127-135.

Cook, J. (2009). *Smallholder agriculture and the environment in a changing global Context*. WWFMPO: Macroeconomics for sustainable development program office, Washington, DC. Cruz, R. V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Cruz, R. V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C., & Huu, N. (2007).Asia Climate Change, 2007, Impacts, Adaptation and Vulnerability. In M. L. Parry, O. F. Canziani, & J. P. Palutikof (Eds.), *Contribution of Working Group II to the 4th Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 468). Cambridge: Cambridge University Press.

De Souza, N. H., de Graaf, J. and Pulleman, M. M. (2012). Strategies and economics of farming systems with coffee in the Atlantic Rainforest Biome. *Agro forestry Systems* 84: 227 – 242.

Deressa, T., Hassan R.,&PoonythD.(2005**).** Measuring the Economic Impact of Climate Change on South Africa‟s Sugarcane Growing Regions. In Agrekon 44 (4), 524-542.

Djoudi, H. and Brockhaus, M. (2011). Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. *International Forestry Review* 13: 123 – 135.

Downing, T. E. (1992), ‗Climate change and vulnerable places: global food security and country studies in Zimbabwe, Kenya, Senegal and Chile', Research Paper No.1,Environmental Change Unit,,. Oxford: University of Oxford

Earl, M. (2001). Knowledge management strategies: Toward taxonomy. Journal of Management Information Systems 18(1), 215–233.

FAO (2010). Climate-Smart Agriculture policies,Practices and Financing for Food security,adaptation and mitigation. Rome: FAO.

FAO. (2009). "Climate-Smart" Agriculture policies, Practices and Financing For Food securty,Adaptation and mitigation. Rome: FAO.

Feder, G., Just, R. E., &Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change, 33* (2), 255–298.

Fernandes, E.C.M., Oktingati, A. and Maghembe, J. (1984). The Chagga home gardens. ICRAF, Nairobi, Kenya.

Field, C. B., V. Barros, T. F. Stocker, Q. Dahe, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K.J.Mach, G.-K. Plattner, S. K. Allen, M. Tignor, and P. M. Midgley, eds. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. Special Report of theIntergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Fifanou, V. G., Ousmane, C., Gauthier, B. and Brice, S. (2011). Traditional Agro forestry system and biodiversity conservation in Benin (West Africa). *Agro forestry Systems* 82: 1 – 13.

Fischer, G., Shah, M., and Velthuizen, V. H. (2002), "Climate change and agricultural vulnerability", a special report, prepared by the International Institute for Applied Systems Analysis under United Nations Institutional Contract Agreement No. 1113 as a contribution to the World Summit on Sustainable Development, IIASA Publications Department, Johannesburg 2002.

Folega, F., Gabriel, S., Zhang, Y. C., Hai, X. Z., Wala, K., Batawila, K. and Akpagana, K. (2011). Evaluation of Agro forestry species in potential areas gazetted as protected areas in North-Togo. *African Journal of Agriculture Research* **6(**12): 2828 – 2834.

Folland, C.K., Karl, T.R. (2001). Observed climate variability and change. In The Scientific Basis of Climate Change .Houghton JT, DingY, Naugher M, van der

Linden PJ, Dai X, Maskell K, Johnson CA (eds). Cambridge University Press: Cambridge, UK; 99-181

Franzel, S. G. (2004). Scaling the impact of Agro forestry. *Agr forestry systems journal* , pg 61-62,329-344.

Franzel, S. G., Denning, J. P. B., Lilleso, B, and Mercado, A R. (2004). Scaling up the impact of agro forestry;Lessons from three sites in Africa and Asia. *Agro forestry systems* , pg 329-344.

Franzel, S., Scherr, J. S. (2002). Trees on the Farm:Assessing the adoption potential of Agro forestry practices in Africa. Wallingford UK: CABI.

Garrity, D.P., Akinnifesi,F.K. ,Ajayi,O.C. ,Weldesemayat, S.G., Mowo, J.G., Kalinganire, A.,Larwanou, M., &Bayala, J. (2010). Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security, 2*, 197–214.

Gbetibouo, G., & Hassan, R. (2005). Economic impact of climate change on major South African field crops: A Ricardian approach. *In: Global and Planetary Change, 47* (2): 143-152.

Gichuki, F. N. (2000). *Makueni District profile:Farm Development,1989-1998:Dryland working paper No 1.* Crewkerne,UK: Crewkerne.

Gillies, D. A. (1982). Nursery Management a systems approach. W. B. Saunders Company, 56-74.

GoK (2010). Agriculture sector Development Strategy medium term investment plan 2010-2015. Nairobi: Republic of Kenya.

GoK, 2010: National Climate Change Response Strategy. Nairobi: Government of Kenya

Gruza, G. and Rankova, E., (2004), ‘Detection of Changes in Climate State, Climate

Variability and Climate Extremity', Proc. World Climate Change Conference, Moscow.

Gupta, S.P. (2002). Statistical methods, thirty - first revised edition. Published by Sultan Chand and Sons 23, Daryaganj, New Delhi.

Guthiga, P. (2007). Economic assessment of different management approaches of Kakamega forest in Kenya: cost-benefit and local community satisfaction analysis. Nairobi,Kenya: Institute of Developmental studies.

Haggblade, H., Tembo, G. and Donovan,C. (2004). Household level financial incentives to adoption of conservation agricultural technologies in Africa. *Michigan State University Food Security Research project working paper no. 9*, Lusaka, Zambia.

Heylighen F. And Josly C (1992). The Systems Theory. Retrieved from http://pespmcl.vub.ac.be/systheor.html. on 23rd June 2015.

Howlett, D. S., Mosquera-Losada, M. R., Nair, P. K. R, Nair, V. D., Rigueiro-Rodríguez, A. (2011). Soil C storage in silvopastoral systems and a treeless pasture in north-western Spain. *Journal Environmental Quality* **40**: 1 – 8.

Hughes, P. T., Bellwood, R. D., Folke, C., Steneck, S, R. and Wilson, J. (2005). N.ew paradigms for supporting the resilience of marine ecosystems. *Trend in Ecological Evolution* 20: 1 – 7.

Hulme, M., Doherty,R. M. Ngara, T. New, M.G. & Lister, D. (2001). African climate change: 1900-2100. *Climate Research* , 17,145-168.*Intervention with the advises of Attappady*. Unpublished PhD Thesis,pp24 .

International Centre for Research in Agro forestry. (1992). A Selection of Useful Trees and Shrubs for Kenya. ICRAF, Nairobi, Kenya.

ICRAF (World Agro forestry Centre). 2007. Tackling Global Challenges through Agro forestry Annual Report for 2006. World Agro forestry Centre (ICRAF). Nairobi, Kenya. 64pp.

ICRAF (2011). Occasional Paper No. 25. World Agro forestry Centre, Nairobi, Kenya. [OnlineURL:http:/www.worldAgroforestry.org/downloads/Publications/PDFS /OP16051.pdf

IFAD. (2013).*Rural poverty in Kenya.* Retrieved fromhttp://www.ruralpovertyportal. org/country/home/tags/86enya on: 17th April, 2015

IPCC (2007). Agriculture in climate 2007:mitigation.Working Group III contribution to the Fourth Assessment Report of the IPCC. Cambridge: Cambridge University Press.

IPCC Climate Change (2013). Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (ed) T F Stocker et al (Cambridge: Cambridge University Press).

Irshad, M., Khan, A., Inoue, M., Ashraf, M. and Sher, H. (2011). Identifying factors affecting Agro forestry in Swat, Pakistan. *African Journal of Agricultural Research* **6**(11): 2586 – 2593.

Israel G. A.(1992).Determining sample size. Retrieved from: http://edis.ifas.ufl.edu/pdffiles/PD/PD00600.pdf.

Izac NM A(2003):.Economic Aspects of Soil Fertility Management and Agro forestry. In: Scroth and Sinclair (Eds.),*Trees, Crops and Soil Fertility: Concepts and Research Methods.* Wallinford, Oxon, U.K. :CABI publishers

Izrael, Y.A. and Anokhin, Y.A., 2001, ‘Climate Change Impacts on Russia’, Integrated Environmental Monitoring, Nauka, Moscow.

Jerneck, A., & Olsson, L. (2014). Food first! Theorizing assets and actors in agro forestry: risk evaders, opportunity seekers and „the food imperative" in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *12*(1), 1-22.

Kadir, Tamara, Linda Mazur, Carmen Milanes, and Karen Randles. (2013). Indicators of Climate Change in California. California Environmental Protection Agency (Cal/EPA), Office of Environmental Health Hazard Assessment.

KARI, (2012). Enhancing Agricultural Productivity in the Dryland areas*,* Katumani Research Centre, Kenya (1988). BeLeakey, R.R. B. (1996). Definition of agro forestry revisited. *Agro forestry Today*, 8(1), 5-7.

Kebebew, Z. and Urgessa. K. (2011). Agro forestry perspective in land use pattern and farmers copying strategy: Experience from Southwest Ethiopia. *World Journal of Agricultural Science* 7(1): 73 – 77.

Kalaba, F. K., Chirwa, P., Syampungani, S. and Ajayi, O. C. (2010). Contribution of Agro forestry to biodiversity and livelihoods improvement in rural communities of Southern African regions. [DOI 10 1007/978-3-642-00493-3_22] site visited on 9/3/ 2018.

Kaonga, M., 2005. Understanding carbon dynamics in Agro forestry systems in Eastern Zambia. PhD Thesis, Fitzwilliam College, University of Cambridge, UK.

Kombo, D. K. & Tromp, D. L. A. (2007). proposal and thesis writing. Nairobi,Kenya: *Paulines Publications,* Africa.

Kothari C. R. (2009) "Research Methodology: Methods & Techniques" (Second Revised Edition), New Age International Publishers, New Delhi.

Kuntashula E.O. Ajayi, C., Phiri, D. Mafongoya, P. and Franzel, S. (2002). Factors influencing farmers decision to plant improved fallows:acase of four villages in Eastern province of Zambia. Lusaka: International forest review press.

Kurukulasuriya, P. and Mendelsohn, R.. (2006). , A Ricardian analysis of the impact of climate change on African cropland. *CEEPA Discussion center for Environmental Economics and Policy in Africa* (p. Paper No. 8). Pretoria,SA: University of Pretoria.

Kumar, M. B. (2006). Agro forestry: The new old paradigm for Asian food security. *Journal of Tropical Agriculture* 44:1–14.

Kuwornu, J. K., Ohene-Ntow, I. D., & Asuming-Brempong, S. (2012). Agricultural credit allocation and constraint Analyses of selected maize farmers in Ghana. *Challenge*,*71*, 72.

Kwesiga, (2003). The Effect of Short Rotation Sesbania Sesban Planted Fallows on Maize Yield. Nairobi, Kenya, ICRAF

Lal, R. (2004). Soil carbon sequestration :impact on Global climate change and food security. *science magazine journal on soil carbon* , vol 304 no 5677: pg 1623-1627.

Lesniewski P(2006) Hierarchy Theory:www.uni.-kiel.de/ecology/users/…./2006-06-28-HierarcyTheory.Retrieved on 23rd June 2015

Lionberger, F.H. (1960). Adoption of New Ideas and Practices. Iowa State University Press,Lowa, U.S.A.

Lin, B. B. 2007. "Agro forestry Management as an Adaptive Strategy Against Potential Microclimate Extremes in Coffee Agriculture." *Agricultural and Forest Meteorology* 144 (1–2): 85–94.

Lin, B.B.2010. “The Role of Agro forestry in Reducing Water Loss through Soil Evaporation and Crop Transpiration in Coffee Agroecosystems.” *Agricultural and Forest Meteorology* 150 (4): 510–18.

Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental Change: Bio Science 61(3): 183 – 193

Lin B, Chen Y, Chen Z, Li W and Zhang B *(2013) Variations of temperature and precipitation of snowmelt period and its effect on runoff in the mountainous areas of Northwest* China J. Geogr. Sci. 23 :17–30

Lobell, D. (2008). Priotizing climate change adaptation needs for food security in 2030. *Science and technology on food security* , 319(5863): pg607- 610.

Lukuyu B. A, Kitalyi A, Franzel S, Duncan A and Baltenweck I. 2009: Constraints and optionsto enhancing production of high quality feeds in dairy production in Kenya, Uganda and Rwanda ICRAF Working Paper no. 95. Nairobi, Kenya: World Agro forestry Centre.

Lundberg, J. and Moberg, F. (2003). Mobile link organism and ecosystem functioning: Implications for ecosystem resilience and management. *Ecosystem* 6: 87 – 98.

Maduka, M. S. (2007). Role of Agro forestry products in Household income and poverty reduction in semi-arid areas of Misungwi District, Mwanza Tanzania. Dissertation for Award of MSc Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 93pp.

Mathu, R. (2005). *Towards a praxis model of social work: A Reflexive account of praxis.*

Masamha, B., Gadzirayi, C. T. and Mukutirwa, I. (2010). Efficacy of *Allium sativum* (Garlic) in controlling nematode parasites in Sheep. *International Journal Applied Research Veterinary Medicine* **8**(3): 161 – 169.

McCarthy J J,Canziani O F,Leary N A,Dokken DJ and White K S. (2001). *Climate change:impact adaptation and Vulnerability.* Cambridge: Cambridge University press.

Mendez, V. E, Bacon, C. M., Olson, M., Morris, K. S., Shattuck, A. K. (2010). Agrobiodiversity and shade coffee smallholder livelihoods:areview and synthesis of ten years of research in central America. *Agro forestry systems* , 62,357-376.

Mercer, D. (2004). Adoption of Agro forestry innovations in the topics. *Agro forestry systems journal* , 61(1-2) pg 311-328.

Moges,Y. (2010). Eucalyptus Trees and the Environment: A new perspective in times of climate change. In: *Eucalyptus Species Management, History, Status and Trends in Ethiopia. Proceedings from the Congress. (Edited by Gil, L., Tadesse, W., Tolosana, E and López, R.*), 15 – 17 September 2010, Addis Ababa, Ethopia. pp. 104–113.

Mugenda O & Mugenda A. (1999). Research methods:Quantitative and Qualitative Approaches. Nairobi, Kenya: Acts press. No. of pages.

Mugenda O.M. & Mugenda A.G. (2003). Research Methods Quantitative and qualitative approaches. Nairobi: Acts Press

Mugenda, A. (2008) *Social science Research: Quantitative and Qualitative Approaches.* Applied Research and Training services Press. Nairobi.

Molua, E.L., Benhin, J., Kabubo-Mariara, J., Ouedraogo, M.& El-Marsafawy, S. (2010).Global climate change and vulnerability of African agriculture: implications for resilience and sustained productive capacity. *Quarterly Journal of International Agriculture* 49 (3): 183-21.

Montagnini, F.and Nair, P. K. R. (2004). Carbon sequestration: An underexploited environmental benefit of agro forestry systems. *Agro forestry Systems* 61: 281 – 295. 67

Nair, K. R. (2008). Agro ecosystem management in 21st century: It is time for a paradigm shift. *Journal of Tropical Agro forestry* 46(2): 1 – 12.

Nair, K. R. (2011). Carbon sequestration studies in Agro forestry systems: a reality-check. *Agro forestry Systems* [DOI 10.1007/s10457-011-9434z] site visited on 12/10/2011.

Nair, P.K.R., &Garrity, D. (eds.) (2012).Agro forestry – The Future of Global 105 Land Use. *Advances in Agro forestry*, *9*, DOI 10.1007/978-94-007-4676-3_9.

Nair, K. R., Kumar, M. B. and Nair, D.V. (2009). Agro forestry as a strategy for carbon sequestration. *Journal of Plant Nutrition* 172: 10 – 23.

Nakashima, D. J., Galloway McLean, K., Thulstrup, H. D., Ramos Castillo, A. and Rubis, J. K. (2012). Weathering Uncertainty: Traditional Knowledge for Climate change Assessment and Adaptation Paris. [www.ipmpcc.org] site visited on 21/8/2012.

Ndayambanje, J. D. and Mohren, J. M. G. (2011). Fuel wood demand and supply in Rwanda and the role of agro forestry. *Agro forestry Systems* 83: 303 – 320

Niggli U,A Fliebbach,P Hepperly and N Sciabba. (2008). *Low Greenhouse Gas Agriculture:Mitigation and adaptation potential of sustainable Farming systems.* Rome: FAO.

Nuutinen M, Garcia C and Rioux J (2013) *climate change and mitigation in Agriculture:*Rome:FAO

Nyandiko *et al* (2013) Effects of climate variability on maize yield in the arid and semi-arid lands of lower eastern Kenya, MMUST. Kenya.

Pandey, D. N. (2007). Multifunctional agro forestry systems in India: CIFOR, Bogor, Indonesia. *Current Science* 92(4): 455 – 463

Parrotta, J. A., & Agnoletti, M. (2012). Traditional forest‑related knowledge and Climate change. In *Traditional Forest ‑Related Knowledge* (pp. 491‑533). Springer Netherlands.

Parry, M.L., C. Rosenzweig, A. Iglesias, M. Livermore, and G. Fischere. (2007). Effects of climate change on global food production under SRES emmissions and socio-economic scenarios. *Global environmental change* , 14:53-67.

Paustine K.J,Brenner M.,Easter K.,Killian S.,Ogle C.,Olson j.,Schuler R., Vinning and Williams . (2009). *counting carbon on the farm:Reaping the benefits of carbon offset programs.* London: Oxfarm.Org.

Paxton, K. W., A. K. Mishra, S. Chintawar, J. A. Larson, R. K. Roberts, B. C. English, D. M. Lambert, M. C. Marra, S. L. Larkin, J. M. Reeves, and S. W. Martin. 2010. Precision Agriculture Technology Adoption for Cotton Production. Paper presented at Southern Agricultural Economics Association. Orlando, Florida, 6-9 February.

Phiri, E., Verplancke, H., Kwesiga, F., Mafongoya, P.L. 2003. Water balance and maize yield following improved Sesbania fallow in eastern Zambia. *Agro forestry Systems*, 59, 197-205

Phiri D,Franzel S,Mafongoya P,Jere I,R Katanga and S Phiri. (2004). Who is using new technology?wealth status and gender with the planting of improved tree fallows.acase of eastern province Zambia. *Agricultural systems journal* , V (79),Pg131-144.

Place, F., & Dewees P. (1999). Policies and incentives for adoption of improved fallows. *Agro forestry systems* , 47(1-3)323-343.

Ragland, J. and Lal, R. (1993). Technologies for Sustainable Agriculture in the Tropics. American Society of Agronomy. Winsconsin, U.S.A

Ratnayake, U., & Herath, G. (2005). Changes in Water Cycle: Effect on Natural Disasters and Ecosystems. Sri Lanka National Water Development Report. In N. T. S. Wijesekera, K. A. U. S. Imbulana, & N. B. Paris (Eds.), *World Water Assessment Program.* Paris. www.ircwash.org/…ources/sri-lanka-national-water...

Rao, K. P. C., Verchot, V. L. and Laarman, J. (2007). Adaptation to climate change through sustainable management and development of Agro forestry systems. World Agro forestry Center. *ejournal Icrisat Organization* 4(1):1 – 30.

Rigueiro-Rodríguez, A., López-Díaz, M. L. and Mosquera-Losada, M.R. (2011). Organic matter and chromium evolution in herbage and soil in a *Pinus radiata* silvopastoral system in North-West Spain after sewage sludge and lime application. *Common Soil Science Plant* **12**: 1 – 14.

Roberts, R. K., B. C. English, J. A. Larson, R. L. Cochran, S. L. Larkin, M. C. Marra, S. W. Martin, and J. M. Reeves. 2004b.Factors influencing southeastern cotton farmers to adopt precision farming technologies earlier than later. Proceedings of the 7th International Conference on Precision Agriculture and Other Precision Resources Management, Hyatt Regency, Minneapolis, MN,USA, 25-28 July, 2004: 2103-2114.

Rogers, E.M. (1995). *Diffusion of innovations* (Fifth ed.). New York, USA: The Free Press

Rodgers M & Hrovat K. (1997). *Data analysis and presentation techniques.* Ohio,US: Nasa Lewis Research Center.

Roy, M.M., Tewari, C.J. and Ram, M. (2011). Agro forestry for climate change adaptations and livelihood in India Hot arid Regions. *International Journal of Agriculture Crop Science* 3: 43 – 54.

Roose, E., V.V. Kabore & C. Guenet. (2006). *Fonctionnement,Limites et Amelioration d'une pratique: Traditionelle Africain de Rehabiltation de la Vegetation et de la productivite de Terres Degradees en.* Oegadugu Burkina Faso: Region soudano-sahelienne.

Salam, M.A., Noguchi, T. Koike, M. (2000). Understanding why farmers plant trees in their homestead, Agro forestry in Bangladeshi.Journal of Agro forestry Systems. **50 (1)**. 77 – 93

Savelieva, I.P., Semiletov, L.N., Vasilevskaya and Pugach, S.P., 2000, 'A climate Shift in Seasonal Values Ofmeteorological and Hydrological Parameters for Northeastern Asia', Prog. Oceanogr. 47.

Sharma, R., Sharma, E. and Purohit, A.N. 1995. Dry matter production and nutrient cycling in Agro forestry Systems of mandarin grown in association with Albizia and mixed tree species. Agro forestry Systems29:165-179

Schutter, O. (2010). *Right to Food.* Newyork: UN General Assembly.

Sileshi, G., Mafongoya, P.L., Kwesiga, F., Nkunika, P. 2005. Termite damage to maize grown in Agro forestry systems, traditional fallows and monoculture on Nitrogen-limited soils in eastern Zambia. *Agricultural and Forest Entomology* 7: 61-69.

Sileshi, G. & Mafongoya, P.L. (2006). *Long-term effects of legume-improved fallows on soil invertebrate and maize yield in eastern Zambia.* Journal of Applied Soil Ecology, M Vol.33 (1):49-60.

Sileshi, G., Akinnifesi, K. F., Ajayi, C. O., Chakeredza, S., Kaonga, M. and Matakala, W.P. (2007). Contributions of Agro forestry to ecosystem services in the miombo eco-region of eastern and Southern Africa. *African Journal of Environmental Science and Technology* 4: 68 – 80.

Sileshi, G., Akinnifesi, F.K., Ajayi, O.C., Place, F. 2008. Meta-analysis of maize yield response to woody and herbaceous legumes in sub-saharan Africa. *Plant and Soil* 307 (1&2): 1-19

Singh, V.S. and Pandey, D. N. (2011). *Multifunctional Agro forestry Systems Science-Based Policy Options*. Climate change and CDM Cell Rajasthan State Pollution Control Board, India. 35pp. Smit, B. and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change,* 16: 282 – 292. 70

Smith, J. (2010). *Agro forestry: Reconciling Production with Protection of the Environment*. A synopsis of Research literature. Organic Research Centre, Elm Farm, India. 24pp

Smith P. D., Martino, Z., Cai, D., Gwary, H. H., Janzen, P., Kumar, B., McCarl, S. Ogle, F.O.Mara, C. Rice, R., J, Scholes, O. Sirotenko, M., Howden, T., McAllister, G., Pan, V Romanenkov, U Schneider,S Towprayoon,M Wattenbanch and J U Smith. (2008). Greenhouse gas mitigation in Agriculture. *Transaction of the Royal Society* , 363142):78-813.

Smith, J. (2010). *Agro forestry: Reconciling Production with Protection of the Environment*. A synopsis of Research literature. Organic Research Centre, Elm Farm, India. 24pp.

Snelder, J. D., Klein, M. and Schuren, G. H. S. (2007). Farmers‟ preferences, uncertainties and opportunities in fruit-tree cultivation in Northeast Luzon. *Agro forestry Systems* 71: 1 – 17.

Tamang B, Andreu M G,Rockwood D L. (2010). Micro climate patterns on the leeside of single-row tree windbreaks during different weather conditions in Florida Farms. *Agro Forestry systems* , 79:111-122.

Tengnas, B. (1994). Agro forestry Extension Manual for Kenya. ICRAF, Nairobi, Kenya.

Tesso, G., B. Emana, and M. Ketema. 2012. "Analysis of Vulnerability and Resilience to Climate Change Induced Shocks in North Shewa,Ethiopia."*Agricultural Sciences,* (6):871-888.

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418: 671–677.

Thomas, M., King, D., Keogh, U. D., Apan, A. and Mushtaq, S. (2011). Resilience to climate change impacts: a review of flood mitigation policy in Queensland, Australia. *The Australian Journal of Emergency Management* 26: 1 – 10.

Thorlakson, T. (2011).Reducing Subsistence Farmers` Vulnerability to Climate Change: The potential contributions of agro forestry in Western Kenya, Occasional Paper No. 16. World Agro forestry Centre, Nairobi, Kenya. 76pp

Thornton, P.K., R.L. Kruska, N. Henniger, PM Kristjanson, RS Reid, F Otieno A.N. Odero and T. Nelegwa. (2002). *Mapping poverty and livestock in the developing world.* Nairobi, Kenya: ILRI

Tilman, K, Cassman, P, Matson, R and Polasky, S (2002). Agricultural sustainability and intensive production practices. *Nature,* 418: 671–677..

Ulsrud, K., Sygna, L. and O`Brien, K. (2008). More than Rain: Identifying Sustainable Pathways for Climate Adaptation and Poverty Reduction. Published by Development Fund, Norway. 68pp

Unruh J.D., Houghton R.A., and Lefebvre P.A.: Carbon storage in agro forestry: an estimate for sub-Saharan Africa. Climate Res 1993, 3:39-52. Version with amendments to annexes. Published in November 2005 by UNFCCC Secretariat with supportfrom UNOG. FCCC-Informal-103/ FCCC-Informal-140.

Velandia, M., D. M. Lambert, A. Jenkins, R. K. Roberts, J. A. Larson, B. C. English,and S. W. Martin. 2010. Precision Farming Information Sources Used by Cotton Farmers and Implications for Extension. Journal of extension 48(5): 1-7.

Verchot, L.V., van Noordwijk, M., Kandji, S., Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, C.K., Palm, C., (2006) Climate change: linking adaptation and mitigation through Agro forestry. Mitig. Adapt. Strat. Glob. Change 12 (5), 901–908.

Verchot, I.V.M., Van Noordwijk, S., Kandji, T., Tomich, C., Ong, A., Albrecht, J., Mackensen, C., Bantilan, K.V., Anupama and C. Palm. (2007). Climate change:linking adaptation and mitigation through Agro forestry. *mitigation and adaptation strategies for Global change* , 12(5) pg 901-918.

Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change* 17: 12 – 24.

Von Bertalanffy, L. (1968). *General System Theory: Foundations, Development, Applications*. New York: George Braziller

Wakhungu, J., Volenzo, T., Obiri, J. (2013). Alternative Dairy Feeding Strategies and Climate Change Mitigation: Challenges and Opportunities*: International Journal of Disaster Management and Risk Reduction,* Kenya Pgs 180 – 196.

Walton, J.C., J.A. Larson, R. K. Roberts, D.M. Lambert, B.C. English, S.L. Larkin, M.C.Marra, S. W. Martin, K. W. Paxton, and J.M. Reeves. 2010a. Factors Influencing Farmer Adoption of Portable Computers for Site-Specific Management: A Case Study for Cotton Production.Journal of Agricultural and Applied Economics,42(2): 192-209.

Wellington, J. (2000). *Educatinal research.Contemporary issues and approaches.* London,Uk: Continuum.

Wise, R, Cacho, O. 2005. A bioeconomic analysis of carbon sequestration in farm forestry: a simulation study of Gliricidia sepium *Agro forestry System* 64: 237–250.

World Bank Group (2011). Vulnerability, Risk Reduction, and Adaptation to Climate Change, Sri Lanka. Climate Risk and Adaptation Country Profile April 2011. The World Bank Group, Washington.

Yamane, A. (2009). Climate Change and Hazardscape of Sri Lanka. *Environment and Planning, 41,* 2396-2416 http://dx.doi.org/10.1068/a41213

Zhang, T, Barry, R.G, Gilichinsky D, Bykhovets S.S., Sorokovikov, V.A., and Ye J.P. (2001). An amplified signal of climatic change in soil temperatures during the last century at Irkutsk, Russia *Clim. Change,* 49, 41–76

Ziervogel, G. and R. Calder. (2006). Climate variability and rural livelihood:assessing the impact of seasonal climate forecasts. *climate forecast* , 3 :pg 403-4.

Zomer, R.J., Trabucco, A., Coe, R. and Place, F. (2009). *Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agro forestry*. ICRAF Working Paper No. 89. Nairobi, Kenya. 72pp

APPENDICES

Appendix I: Household Questionnaires for agro forestry practitioners

I am a Master's of Science student in Disaster Management and sustainable development at Masinde Muliro University of Science and Technology. I am undertaking a research study on Impact of agro forestry on resilience to climate variability in Vihiga Sub County. Kindly respond to this questionnaire by filling in the blank spaces or ticking in the preferred answers where there is provision for choices. All the information you give will be treated with the confidentiality it deserves. Please maintain a high level of integrity, you need not indicate your name on the questionnaire.

PART A: Household characterization

1. Gender?

Male [ ]   female [ ]

2. Age?

50 and above years [ ]

40– 49 years [ ]   30 – 39years [ ]

20 – 29 years [ ]   19 and below years [ ]

3. No of Years of residence in the sub county

50 and above [ ]   20 to 29 [ ]

40 to 49 [ ]   10 to 19 [ ]

30 to 39 [ ]   0 to 9 [ ]

4 Education level

Not gone to school [ ] primary [ ] secondary [ ] tertiary [ ] university [ ]

Others specify…………………….

5. Marital status? Single [ ] Married [ ] Widowed [ ] Separated [ ] Divorced [ ]

6. What is the nature of your occupation?

Farming activities [ ]

Off-farm activities [ ]

7. Describe the nature of your occupation.

Selling Firewood [ ]

Selling Timber [ ]

Salaried employment [ ]

Selling charcoal [ ]

Selling seedlings [ ]

Petty business [ ]

6. Land parcel, size and mode of acquisition?

Plot number	Size (acres)	Mode of acquisition

Key: 1.Bought 2.Inherited 3.leased

PART B

I. Agro forestry technologies practiced by farmers in Vihiga Sub County.

a) What is the size of your farm in acres?

1 [ ] 2 [ ] 3 [ ] 4 and above [ ]

b) Do you plant trees on your farm?

Yes [ ] No [ ]

c) Do you cultivate more than one crop 0n your farm? YES/NO

If yes Specify…………………………………………………………

d) Name the crops that you grow along with trees on your farm

Maize [ ], beans [ ], cassava [ ], potatoes [ ], tea [ ],

Coffee [ ], sugarcane [ ], vegetables [ ],

e) Which Agro forestry technologies do You practice among these ?

1.woodlot 2.homegarden 3.mixed intercropping 4.others

f) Which type of tree species do you have on your farm,their uses and ranking

Rank	Tree species(name)	Quantity	Uses
1			
2			

g) Where do you get seedlings for the trees on your farm?

1. Given free 2. Bought 3. Raised seedbed 4. Others

h) For the last 15 years have you experienced any prolonged drought? YES/NO

i) Did the prolonged drought affect you're your crop yields or livestock in your area? YES/NO

j) if yes mention the

a) the crop most affected ………………………………

b) Livestock most affected…………………………….

c)Trees most affected…………………………………..

k)Mention four benefits obtained from your Agro forestry

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………

l)Mention four major challenges or problems you experience in managing agro forestry?

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………

m) Is there any relationship between trees planted and climate changes?

Yes [ ] No [ ]

If yes cite the changes

II. Evaluate the rainfall and temperature variability trends in Vihiga sub county between1985 and 2015.

1. Cite the climatic condition in your area that changes due agro forestry?

Temperature variation [ ] Rainfall amount [ ] wind intensity [ ]

2. Explain your answer in (1) above.

…………………………………………………………………………………………

…………………………………………………………………………………

3.What are the climatic conditions of Vihiga sub county in terms of Rainfall, temperature and moisture due to agro forestry?(please Tick)

Climatic condition	high	moderate	Reduced	Reduced drastically
Rainfall				
Temperature				
Wind intensity				

a) Do trees planted in your area affect climate?

Yes [ ] No [ ]

b) If Yes Explain your answer in (a) above

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……...

III. Contribution of agro forestry products to households income as farmers resilience to Climate Variability in Vihiga sub County

1. (a) Do you practice Agro forestry?

Yes [ ] No [ ]

(b) If Yes, how many trees do you plant on your farm?

1 -10 [ ] 10 - 20 [ ] 20 -30 [ ] 0ver 40 [ ]

2. (a) Which type of trees do you plant along with crops?

Fruit trees [ ] Indigenous trees [ ] Exotic trees [ ] shrubs [ ] Flowers [ ]

Fodder trees [ ]

Others specify………………………………………………………………..

(b) What are the benefits of these trees to you as the farmer?

Income [ ] Food [ ] Shade [ ] Medicines [ ]

Firewood [ ] Fodder [ ]

Others specify ……………………………………………………………….

3. In your own opinion give an account of how agro forestry has benefited you in various areas that include: the farmer, crops, soil and climate

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………

4.What are the climatic conditions of Vihiga sub county in terms of Rainfall, temperature and moisture due to agro forestry?(please Tick)

Climatic condition	high	moderate	Reduced	Reduced drastically
Rainfall				
Temperature				
Wind intensity				
Wind				
Hailstorms				

5. The following are some of the Roles of smallholder Agro forestry practices in increasing farmers' resilience to Climate Variability in Vihiga County. Please respond on the scale: SD-Strongly; Disagree; D- Disagree; U-Undecided; A -Agree; SA-Strongly Agree to show whether they were experienced in Vihiga sub county

STATEMENT	SA	A	U	SD	D
Buffering crops from high temperatures					
Buffering crops from heavy downpour					
Provide windbreaks					
Provide food for animals and people					
Reduce soil erosion					
Diversification of agricultural products					

6. a) Do smallholder Agro forestry practices increase farmers' resilience to Climate Variability in Vihiga County?

Yes [ ] No [ ]

b) How do benefits of smallholder Agro forestry practices increase farmers' resilience to Climate Variability in Vihiga County?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………

7. Name the fodder tress grown on your farm?

Croton [ ]

Grevillia [ ]

Calliandra [ ]

Sesbania sesban [ ]

Leucaena [ ]

Tree Lucerne [ ]

8.Do you raise your own tree nursery for seedlings?

Yes [ ] No [ ]

If Yes, what are the challenges experienced?

Appendix II: interview schedule

Key Informant Interview Guide used in Vihiga sub county .Kenya

I am conducting a research study on 'Impact of Agro-Forestry practices on Resilience to Climate Variability in Vihiga Sub-County'. The purpose of the study is to support me fulfill part of the requirement for my Master studies at MMUST. Your assistance by responding to this interview will be highly appreciated. Please note that responses to this interview will be held with a lot of confidentially. Thank you.

Sub county-------------------

Department--------------

Date-----------------------

1. What is the current trend of adoption in AF practices in the District?.................
2. Which tree species is more preferred by farmer and its uses..............................
3. Where do farmers get planting materials?.......................................
4. What are the existing organization (s) supporting AF in the district?............
5. What do they do to support communities?
6. Are there challenges hinder sustainability of AF? If yes which ones,
7. Is there any changes in AF practices over past 10 years? If Yes Why?..............
8. Where do communities obtain wood fuel? _
9. What is the household expenditure on wood fuel per month? _
10. Is there any changes in the uses or demand of wood fuel ? if so rank...........
11. Is there changes in crops grown in the past 10 years or more? YES/NO?_
12. If yes what are the new crops adopted by the households?...................
13. How have the changes in crops affect households income?
14. Is there been changes in cash crops in the past 10 years or more YES/NO? _

15. If yes name the cash crops? _

16. What are the major livestock types kept in this sub county?

17. How many seasons do you experience in the sub county?

18. Please tell me the month and week/dates when you expect onset and cessation of rains.

19. Since you started working here what has been the general trend in temperature and Precipitation?

20. What effects have these climate variations impacted on your operations and the farmers in general? (Specific operations include: timing of planting season, crop growth, crop yields, livestock production, diseases, water availability, morbidity, deaths of livestock etc

21. Please rate the impacts of climate on agriculture/livestock in the sub county in the last 10 years (on a scale of 1-3 where 1 was the best year and 3 the worst in the last 10 years).

22. Which were the worst years in terms rainfall scarcity and food insecurity?

23. Which were the best years in terms of rainfall availability and food security?

24. Generally what are the challenges facing farmers in the sub county?

Appendix III: Observation guide

Observation check list used in Vihiga Sub County

1. Agro forestry practices, Livestock types, pasture types
2. Presence/absence of water source e.g. dams, shallow wells etc
3. Stages of crops in the fields, their condition and husbandry practices
4. Soil types and soil conservation measures
5. Presence of water sources e.g. dams, Distances to water sources
6. weather conditions of Vihiga sub county
7. Types of crops vis a vis acreage

Type of crops	Acreage	Tick
Maize		
Beans		
Cassava		
Tea leaves		
Coffee		
Potatoes		
Napier grass		
Sorghum		
Vegetables		
Trees		
Other bushes		

Appendix IV: Rainfall and Temperature Data from Vihiga Meteorological Station, Vihiga Sub County, Kenya.

	Annual Rainfall (mm)	Annual Average Min Temperature °c	Annual Average Max. Temperature °c
1985	1929.5	10	25
1986	1319.1	12	24
1987	1808.0	15	25
1988	1633.1	17	26
1989	1039.5	16	29
1990	1642.0	17	32
1991	2636.3	14	26
1992	2274.8	18	29
1993	2051.9	17	23
1994	2198.2	16	30
1995	1745.5	16	31
1996	2574.5	17	30
1997	1751.8	15	26
1998	2222.7	19	32
1999	1696.7	18	30
2000	2786.0	16	31
2001	2789.0	18	32
2002	1197.2	16	29
2003	1866.7	17	30
2004	2227.0	17	29
2005	1782.4	17	28
2006	2268.6	18	27
2007	2088.6	18	25
2008	1674.3	17	28
2009	1880.1	18	28
2010	1543.1	18	26
2011	1916.9	16	30
2012	2192.9	17	29
2013	1814.7	17	30
2014	2783.2	16	27
2015	2692.1	17	25

Appendix V: Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email:dg@nacosti.go.ke
Website: www.nacosti.go.ke
when replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.
NACOSTI/P/17/98949/15699

Date:
8th March, 2017

Cyrus Asena Imbwaga
Masinde Muliro University of
Science and Technology
P.O. Box 190-50100
KAKAMEGA.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Impact of agro-forestry practices on resilience to climate variability among farmers in Vihiga Sub-County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Vihiga County** for the period ending **7th March, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Vihiga County** before embarking on the research project.

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

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Vihiga County.

The County Director of Education
Vihiga County.

National Commission for Science, Technology and Innovation is ISO 9001: 2008 Certified

Appendix VI: Proposal Approval

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

Tel: 056-30870
Fax: 056-30153
E-mail: sgs@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

Office of the Dean (School of Graduate Studies)

Ref: MMU/COR: 509079

Date: 19th September 2016

Cyrus Asena
CDS/G/27/09
P.O. Box 190-50100
KAKAMEGA

Dear Mr. Asena

RE: APPROVAL OF PROPOSAL

Following communication from the Departmental Graduate Studies Committee and the Faculty Graduate Studies Committee, I am pleased to inform you that the Board of the School of Graduate Studies meeting held on 4th September 2016 considered and approved your Master proposal entitled: ***"Impact of Agro-Forestry Practices on Resilience to Climate Variability Among Smallholder farmers in Vihiga Sub-County, Kenya"***andappointed the following as supervisors:

1. Dr. Edward Mugalavai- Department of Disaster Management and Sustainable Development- MMUST
2. Dr. Nicodemus Nyandiko - Department of Disaster Management and Sustainable Development - MMUST

You are required to submit through your supervisor(s) progress reports every three months to the Dean SGS. Such reports should be copied to the following: Chairman, Centre of Disaster Management and Humanitarian Assistance Graduate Studies Committee and Chairman, Disaster Management and Sustainable Development. Kindly adhere to research ethics consideration in conducting research.

It is the policy and regulations of the University that you observe a deadline of two years from the date of registration to complete your Master thesis. Do not hesitate to consult this office in case of any problem encountered in the course of your work.

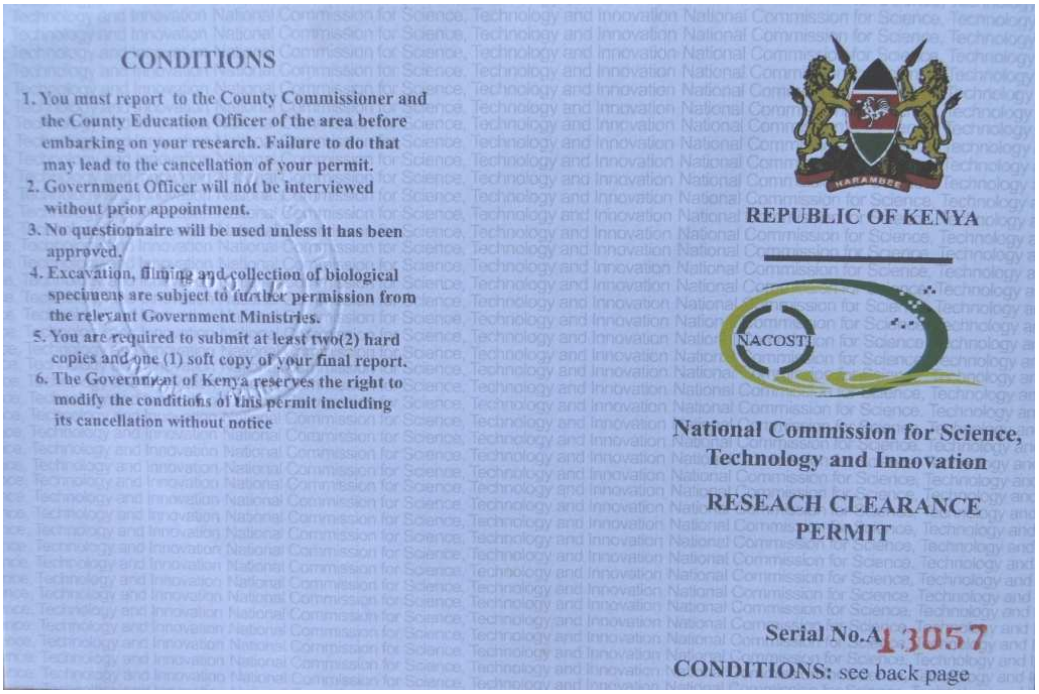
We wish you the best in your research and hope the study will make original contribution to knowledge.

Yours Sincerely,

DEAN
SCHOOL OF GRADUATE STUDIES
MASINDE MULIRO UNIVERSITY
OF SCIENCE & TECHNOLOGY

PROF. HENRY KEMONI
EXECUTIVE DEAN, SCHOOL OF GRADUATE STUDIES

Appendix VII: Research Permit



CONDITIONS

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

REPUBLIC OF KENYA

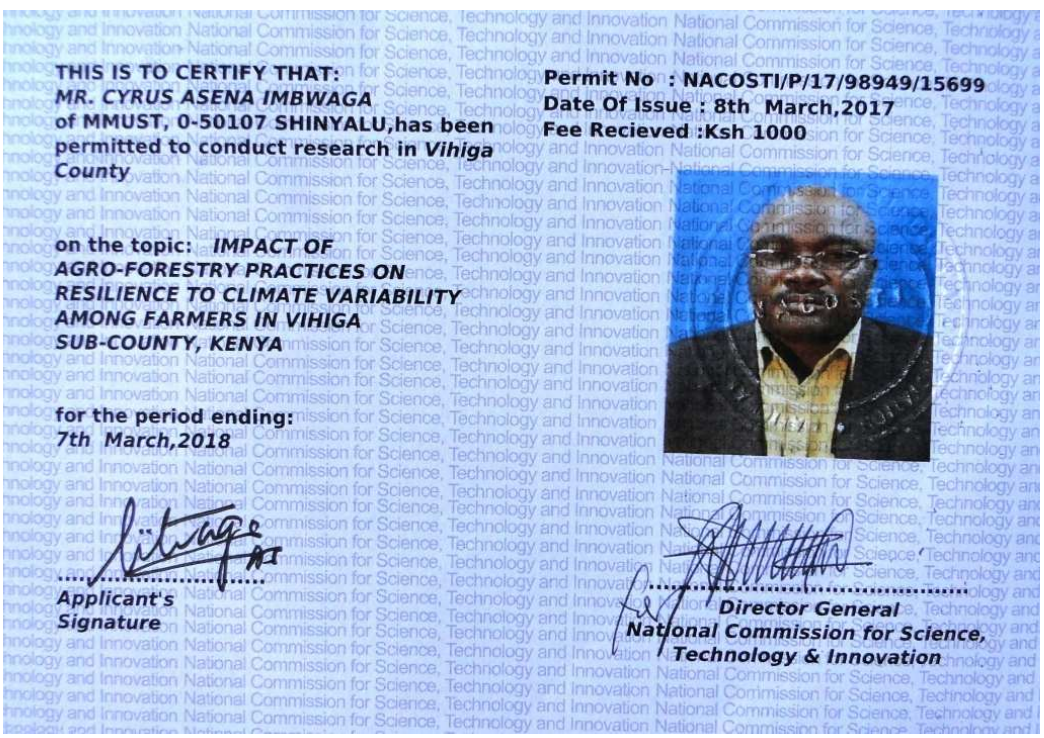
NACOSTI

National Commission for Science, Technology and Innovation

RESEACH CLEARANCE PERMIT

Serial No.A 13057

CONDITIONS: see back page



THIS IS TO CERTIFY THAT:
MR. CYRUS ASENA IMBWAGA
of MMUST, 0-50107 SHINYALU,has been permitted to conduct research in *Vihiga County*

on the topic: *IMPACT OF AGRO-FORESTRY PRACTICES ON RESILIENCE TO CLIMATE VARIABILITY AMONG FARMERS IN VIHIGA SUB-COUNTY, KENYA*

for the period ending:
7th March,2018

Permit No : NACOSTI/P/17/98949/15699
Date Of Issue : 8th March,2017
Fee Recieved :Ksh 1000

Applicant's Signature

Director General
National Commission for Science, Technology & Innovation