IMPACT OF CLIMATE VARIABILITY ON HONEY PRODUCTION: A CASE OF RATAT AND MARIGAT, BARINGO COUNTY, KENYA

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Egerton University

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DECLARATION AND RECOMMENDATION

This thesis is my original work and has not been submitted or presented for examination in any other University, either in part or as a whole.

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DEDICATION

I dedicate this work to Mother Scolastica Gabriel Shayo, my late Father.

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I thank the Almighty God for the gift of life and health during my entire period of study endeavor.

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ABSTRACT

Beekeeping is among the livelihood diversification strategies likely to be affected by climate variability. Changes in climatic variables in varying degrees will affect the productivity of bees because honey production depends on temperature and rainfall. Variation in temperature and rainfall influence the activity of honeybees. The study focused on the relationship between climate variability and honey production for the pastoral communities. Social survey research design was applied and a structured questionnaire administered to 100 household heads who practice beekeeping. Focus group discussion (FGDs) and interviews were used to collect supplementary data. Secondary data was obtained from the relevant institution, journals, books and publication. Rainfall for the period of 2012 to 2016 was analysed using excel. Descriptive and inferential statistics were used to analyse the data: correlation, frequency, percentages, measures of central tendency and dispersion. The results revealed decreasing annual rainfall from the year 2012 (1623.4mm) to 2015 (470mm) with 80% of the respondents reported a decrease in rainfall amount leading to increase in severity and frequency of droughts (90%). The results show a significant positive correlation between rainfall amount and quantity of flowers ($r=0.423$; $p<0.00$), rainfall amount and honey yield ($r=0.369$; $p<0.00$) and duration of rainfall and honey yield ($r=.460$; $p<0.00$). With decreasing rainfall, the prevalence of pest has increased in the past 5 years especially honey badger (70%), ants (66%) which were ranked 1st and 2^{nd,}, respectively. There were new cases of snakes becoming bee pests in the study area. . In conclusion, there was evidence to suggest that climate variability has negative effects on honey production hence affecting the livelihood of the pastoral community who rely on natural resources for their survival. The study recommended for disseminate of meteorological data to the farmers to enhance preparedness.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASALs: Arid and Semi- Arid Lands

FGDs: Focused Group Discussions

GoK: Government of Kenya

IPCC: Intergovernmental Panel on Climate Change

KShs: Kenya Shilling

MRNA: Messenger Ribonucleic Acid

NACOSTI: National Commission for Science, Technology and Innovation

NGO: Non-Governmental Organisation

NCCRS: National Climate Change Response Strategy

UNEP: United Nations Environmental Programme

KARLO: Kenya Agricultural and Livestock Research Organisation

SACCO: Saving and Credit Co-operative

SDGs: Sustainable Development Goals

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Climate change and variability is a global issue of concern and its impacts vary spatially, geographically and temporally. Some areas experience an increase in rainfall whereas others document a decrease (IPCC, 2014; Smith *et al.*, 2014). The global terrestrial temperature has increased by 0.8°C in the past century and 0.6°C in the past three decades because of anthropogenic activities (Hansen *et al.*, 2006). Climate change is encroaching slow but steady with an increase of temperatures of 0.5°C per decade (Hulme *et al.*, 2001). This change has had impacts on people's livelihoods thereby affecting development, economic stability, biodiversity and ecosystems (Thornton *et al.*, 2011)

The impact of climate change and variability is manifested both in developing and developed countries (Simms, 2005). Africa as a continent with limited natural resources is susceptible to impacts of climate variability and change leading to poverty escalation, increase in food price, high inequality, food insecurity, increase in energy price, an impediment to development and high incidences of disasters (Boko *et al.*, 2007; IPCC, 2007). In East Africa, climate variability and change effects are evidenced by increased sea level (IPCC, 2001), rise in water in lakes and change in seasonal migration of wildlife (Thirgood *et al.*, 2004), rainfall uncertainty (Simms, 2005) and other associated effects.

Apiculture is an important element of agriculture as it plays a major role in rural self-employment, economic development and source of food (human nutrition). The key product of beekeeping is honey and wax and is a source of income to many farmers. Honey is used for several purposes such as food, medicine, cultural ceremonies and for religious purposes (Yirga and Teferi, 2010). Seventy three percent of the world crop pollinators are bees. These have an economic significance of €156 billion per year (Gallai *et al.*, 2009). Honey production has grown globally. However, there has been a reduction in the production after the European Union banned the Chinese honey (Dong and Jensen, 2004), where they depend on organic honey from Kenya (Baylis *et al.*, 2010).

In Kenya, beekeeping has been practiced for many years with only about a quarter of honey produced in arid and semi-arid lands of Kenya (Thomas, 2006). In Baringo County, beekeeping is among the top important income generating activities. It is a source of livelihood for many households. Honey production is the third source of income for the County after cash crop farming and livestock keeping (GoK, 2014). The Kenya potential for honey production is over 100,000 metric tons. Baringo county has 176,000 hives and 576 tons of honey is harvested every year that accounts to 1.44 million KSh per month and 5 billion shillings per year (Ngigi, 2013). Approximately, seventy-six percent of the beekeepers sell their honey to middlemen (Gichora, 2003). The honey harvest is at peak between September and December. The farmers sell crude honey at a high price especially during dry season. The products have a long shelf life with high nutritional and medicinal value. This has enhanced poverty reduction, gender equality and extent habitat conservation (Raina *et al.*, 2011).

The County Government of Baringo currently has embarked on how to increase honey production. The decline in honey production has led to indigenous communities of Baringo to engage in charcoal burning and other socio-economic activities (GoK, 2014). This escalates environmental degradation with poor forage production persist in dry conditions and thus a decline in water availability, which are some of the perceived problems in the area (GoK, 2014). According to the Baringo County development plan (2014-2015), the major problems facing Baringo County include environmental degradation due to deforestation, desertification, pollution and climate change. Climate change and variability have led to increased intensity and rate of recurrence of extreme weather conditions, floods, landslides and drought in the area (GoK, 2014).

There has been a decline in natural pollinators because of habitat loss and fragmentation, intensive use of chemicals in agriculture, invasive species, climate change and variability (Potts *et al.*, 2010; GoK, 2014). These impacts of climate variability are experienced highly in medium and low potential zones than in high agricultural areas (Thornton *et al.*, 2011; IPCC, 2014). In low and medium potential areas, most people depend on environmental resources for their livelihood, which include; forage production and construction materials, among others. Therefore, environmental changes has affected people's livelihoods. According to UNEP (2006), African countries had the directive to assess the impacts of climate variability on livelihoods that would help to provide response strategy toward climate variability. This formed the basis of this study that focused on assessment of impacts of climate variability on honey production in Ratat and Marigat areas within Baringo County.

1.2 Statement of the Problem

Honey production a natural resource that complement livestock production activities in ASALs. Current trends in climate warming coupled with the increase in human populations are placing new stresses on the production ability of the fragile ecosystem to sustain the indigenous populations of Baringo. There is need to establish the link between land management in the context of honey production and climate variability. Since climate variability has led to an interruption of the ecosystem services, therefore, the purpose of this study was to assess the relationship between climate variability and honey production in Marigat and Ratat, Baringo County, Kenya.

1.3 Objectives

1.3.1 Broad Objective

The overall aim of the study was to analyze the variation in climate (rainfall and temperature) and assess its implication on honey production in Ratat and Marigat.

1.3.2 Specific Objectives

(i) To determine rainfall variability patterns for the period 2012 to 2016.
(ii) To assess the relationship between rainfall variability and forage phenology.
(iii) To assess the effects of climate variability on honey yield for the period 2012 to 2016.
(iv) To assess the effects of climate variability on bee pest infestation.

1.4 Research Questions

(i) How has rainfall varied for the period 2012 to 2016?
(ii) What is the relationship between rainfall variability and forage phenology?
(iii) What are the effects of climate variability on honey yield for the period 2012-2016?
(iv) How has climate variability influenced bee pest infestation?

1.5 Justification of the Study

Globally, dry area covers about 41% of the entire land. Since climate variability is both a threat and an opportunity, these dry areas are more vulnerable to climatic threat than opportunities. Climate prediction shows that some parts of the world will become hotter and others drier. This will alter societal performance, poverty escalation, hunger, and environmental degradation.

Apiculture is a source of livelihood for the Baringo community and depends on favourable weather condition. Although people have diversified their livelihood in order to cope with unfavourable weather condition, it has been observed that the weather related impacts are manifested in all sectors. The shortage of water, high temperature, and increase net radiation affects plant phenology and pest infestation that affects honey production. Kenya agricultural sector is vulnerable to impacts of climate variability, and the agricultural strategy is inadequate to provide adequate measures to deal with climate variability. The findings of the study provided useful information that will help in the management of ASALs resources and improving the livelihoods of the people through increased honey production. This study enlighten issues being faced by the honey dependent local people because of climate variability. The information is important for adaptive and poverty alleviation strategies among households in Kenyan rangelands and to meet the Sustainable Development Goals 1 (End poverty), 2 (zero hunger) and 13 (climate action) and the Kenyan vision 2030.

1.6 Scope and Limitations

The study focused on impacts of climate variability on honey production in Ratat and Marigat. It focused on establishing the relationship between climate variability and effects on honey production; forage availability for bees, water availability, pest and disease infestation, migration and movement of bees. The study focused on two items: first, assessment of the climate variability based on climatic variable (parameters) i.e. temperature and rainfall. Secondly, to assess the effects of climate variability on forage availability and pest infestation. Rainfall data for the period of 2012 to 2016 was analysed to determine the trend and variation. The baseline rainfall in the study area is 600mm per year.

The limitation of the study was inability to have access to the time series information from the Perkera irrigation scheme and County government. This is because the institutions though were provided with the modern instrument for measuring rainfall and temperature and they were still adopting no how to use them. There was also lack of time series recorded data on honey production among the farmers. It was difficult to deduce the trend in honey production since majority of the farmers did not keep records. Furthermore, the Saving and Credit Cooparative (SACCO) and groups did not have seasonal concise data on honey yield since the buy honey in bulk. Some farmers buy honey from the nearby neighbours and reserve it until the price is high so that they can sell to fetch a high profit. This was mitigated by relying on farmers' perception on honey yield. There was a challenge in answering question among the respondents because of language. This was mitigated by use of the local enumerator to translate some of the question to local language.

1.7 Assumptions of the study

The assumption of the study is that climate variability has led to reduction in honey production affecting the socio-economic status of the people. In addition, it was assumed that the data collected was normally distributed and the sample was representative.

1.7 Operational definitions of terms and concepts

Apiculture - The science and art of bee farming.

Absconding- this is the situation where bees totally leave the beehive because of unfavorable condition.

Climate change: variation and change of weather condition for an extended period of over 35 years of a given area.

Climate variability: The temporal and spatial variation in weather condition beyond the normal weather events of given area.

Food Security- It refers to a household's or country's ability to provide future physical and economic access to sufficient, safe, and nutritious food that fulfills the dietary needs and food preferences for living an active and healthy lifestyle.

Bee migration- The seasonal movements of whole honeybee colonies from one area to another.

Honey yield- Quantity of honey in a single hive

Honey production- Quantity of honey in multiple hives

Swarming- The movement of the bee colony to a new site with a new queen, leaving behind a portion of the colony.

Phenology- The timing, duration and abundance of recurrent biological phenomena, including reproductive events such as flowering, fruiting, seed dispersal and germination.

Pest infestation: Invasion of pest or parasites

Forage type: The type of forage that is bees prefer to collect nectar, propolis and other raw materials

Forage distribution: This spatial and temporal distribution/allocation of forage.

Forage: Raw materials used by bees to make honey

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter consists of the literature review of previous studies related to the study objectives and divided into themes in relation to the information relevant to the study. It also presents policy review and conceptual framework that illustrates the cause-effect relationship between the variables.

2.2 Beekeeping and its contribution to the society

Organisms are adapted to different types of environments because of the differences in climatic conditions. Africa has various types of wild honeybees (Adjare, 1990) with three sub species of *Apis mellifera* that have slightly similar morphology (Crewe *et al.*, 1994). Beekeeping has been a traditional activity among many societies. The African societies have for a long time practiced beekeeping using traditional hives. In the late 1960s, modern technology was introduced in Kenya which has improved management and increase output in honey production (Caroll, 2006). Furthermore, beekeeping does not require an extensive and intensive labour and capital to start as it requires little input but it has a higher output and it is easy to harvest, process, and transport (FAO, 2012). Thus, every individual in the society can practice it. The ASALs communities use honey for traditional ceremonies for the purpose of strengthening social ties and other social activities such as marriage, reconciliation, birth and circumcision ceremony (FAO, 2009). Furthermore, bees are important pollinators in the world and indicators for terrestrial environmental change (Klein *et al.*, 2006).

2.3 Overview of Climate variability

Climate variability is associated with extreme weather condition that affects farmers' output. The impacts varies with the magnitude from and one area to another (Davis and Ali, 2014). Kushnir, and Wallace (1989) and (Trenberth *et al.*, 1998) predicted that regions would experience different weather condition in the late 1990s. Some areas will be drier, whereas other areas will experience warmer and others cooler weather conditions thus unpredictable weather with increasing temperature and change in the onset of rainfall altering the growth of fauna and flora (Roncoli *et al.*, 2010). Therefore, the erratic nature of weather patterns results in reduction in agricultural production thus affecting the socio economic activities of many farmers (Cassman,

1999) impacting on livelihood of people who live in marginal areas because of fragile ecosystems (Maracchi, 2005; IPCC, 2007). These effects vary spatially depending on geographical location and socio-economic status of individuals and groups (McMichael, 2013; IPCC, 2014). According to IPCC (2014), some physical system or ecosystems are at risk of temporal or permanent damage. The effects are manifested more among the farmers who depend on rain-fed agriculture especially in ASALs leading to food insecurity (FAO, 2012; IPCC, 2014), especially in sub-Saharan Africa.

2.4 Climate variability and forage for bees

The abundance of flora differs depending on landscape composition and complexity (Tscharntke *et al.*, 2012; Shackelford *et al.*, 2013). These differences are function of environmental condition, soil and other physical characteristics that influence species richness, density and population performance (Riedinger *et al.*, 2014). Climate variability affects the ecological process that affects the spatial and temporal population and species composition (Stenseth *et al.*, 2003). Plants are more sensitive to the growing season since they have different stages of growth that depends on environmental condition. Therefore, climate anomalies affect the growth at different seasons. For example, variation in temperature induces difference in floral and anthesis development (Hegland *et al.*, 2009) while variation in evapotranspiration determines vegetation cover (Keane *et al.*, 2002). This affect structure and composition of species density in relation to the soil and water content (Gao *et al.*, 2014).

Plants are adapted to different ecological condition based on climatic factor, soil type, moisture, pH and fertility (Robinson and Page 1989). Plants produce nectar and pollen grain and during pollination, the bees are able to collect pollen grain that is essential for honey production (Kirsten *et al.*, 2015). This pollen grain heightens colony growth and increases long life or continued existence, brood production, colony survival, gland development, resistance against disease, increase individual life span, increase immunity and the growth weight of the bee (Paterson, 2006; Lee *et al.*, 2015). Pollen grains contain large protein content and a higher protein content compensates for higher energy and nutrients used by bees (Eischen and Graham, 2008). The flow of nectar and protein decrease the broody adult ratio. The higher the pollen and nectar flow the more the adult that forage for food and water and hence growth of the colony hence bees prefer areas with abundance of flora (Gikungu, 2006).

Although plants and animals live in a mutual relationship, climate change and variability have interfered with this relationship since climate variability poses a threat to pollination (Hegland *et al.*, 2009; Schweiger *et al.*, 2010). For instance, trees flower at different point in a season because temperature influences flowering, pollination, and anthesis. Plants will flower depending on the temperature of the season and the change in the temperature and rainfall alters flowering of the plants (Hegland *et al.*, 2009; Luo, 2011). Depending on environmental condition and the position of the beehive, sometimes pollination will tend to decrease with distance from the beehive (Ricketts *et al.*, 2008).

Species diversity, richness/and abundance vary with landscape composition and complexity. This has an impact on the population of bees that tends to be abundant depending in areas with widespread of the flora (Grundel *et al.*, 2010; Tscharntke *et al.*, 2012). Honey composition also varies geographically depending on plant species except for Phytochemicals composition that depend on climatic conditions (Gemechis, 2012). Therefore, different bees are adapted to different condition in a given geographical area or environment (Ruttner, 1975). As indicated in Table 1, the raw materials for honey production are extracted from the interlinked environmental service. For instance, nectar is converted into honey and pollen into protein and lipids, which are source of food for the bee colony (Crailsheim, 1992).

Table 1: Raw Materials and bee products

		Inside the hive		
Substance	**How bees transport them**	**Processing into….**	**Location**	**Function**
Pollen	In pollen baskets on the hind legs	bee bread	In lower part of combs	Food
		bee milk	In brood cells with	Food
		brood	larvae	
			In center of brood	Food development
	On breast hairs	**-**	Outside the hive	Pollination
Nectar	In honey stomach	Honey	On top and on outer combs of hive	Food Raw material for wax and warmth
		Wax	In the form of comb	Building of combs Nest for brood and food
Water	On honey stomach	Evaporation		Cooling Production of bee milk
Gum Resin Wax	On legs	Propolis		Hive wall putty Heat regulation Cleaning of cells

Source: Marieke *et al.* (2005.)

2.5 Climate variability, water and bees

Variation in weather condition has resulted in change in net radiation, temperature and speed of wind which varies temporally and spatially (Tang *et al.*, 2011; McVicar *et al.*, 2012). Increase in temperature has led to evaporation that is higher than replenish level of surface water and hence the reduction in water (Donohue *et al.*, 2006; Tabari *et al.*, 2011). Areas with a thick cloud cover have less evaporation, whereas sunlight duration affects evapotranspiration (Irmak *et al.*, 2012). Insufficient water affects agriculture and plant growth since plants require water to carry out physiological processes. Some crops are more water demanding, however they wither when rainfall distribution is erratic especially during the season (WRMA, 2013; Recha *et al.*, 2015). The imbalance between water and water supply and erratic rainfall has led to increased frequency of flood, surface runoff, drought, and stream pollution (Wei *et al.*, 2013; WRMA, 2013). Many studies has been conducted in several areas such as China (Shi *et al.*, 2013), Kenya (Mango *et al.*, 2011), USA (Wang and Dickinson, 2012) and other areas in the world which articulate the effects of climate variability on water.

Climate variability affects availability of water resource on the earth. For instance, change in the variation in weather affect both the quantity and quality of water resources accessible for drinking, recreation, irrigation, fish farming, hydroelectric power generation and other uses. Surface and subsurface water is threatened by climate change and variability in the tropics (Ozturk *et al.*, 2015). There is insufficient water access, especially in the ASALs *(*Ozturk *et al.*, 2015*;* Kosonei *et al.*, 2017*)*. The quantity and quality have decreased (IPCC, 2014) affecting flowering thus decrease in pollen and nectar for bees (IPCC, 2007; Inouye, 2008). Water is essential for thermoregulation and honey production (Seeley, 1995) as indicated in Table 2. Therefore, when water is limited, bees use high amount of energy to swarm for long distance to search for water and food. They sprinkle water around the hive to control the temperature on hot days whereas they also fan their wings or move out of the hive to regulate temperature (Heinrich, 1985). Temperature below the optimum level increases the duration for brood development and increases the colony susceptible to disease and pest. Furthermore, water is essential for preparing jelly for feeding brood. The water should have a pH of 5 or 6 (Woyciechowski, 2007).

Table 2: Composition of several bee products

	Concentration and weight in percentage				
Product	Water	Protein	Fat	Carbohydrates	Ash
Honey	17-21	0.4	0	79-83	0.1
Pollen	25=>11	22	5	31	3
Bee bread	20=>14	20	3	24-35	3
Raw jelly	67	11	6	9	1

'=>'; refers moisture content after drying. Source: Marieke *et al.* (2005.)

2.6 Climate variability and pest infestation

In the past century, total world pollinators have declined because of increased outburst, incidences of infectious diseases and degradation of habitats, reduction in resource diversity, and competition with the introduced pollinators, climate change, decline in genetic diversity and pesticide use that causes either direct or indirect effect on them (Ghini and Morandi 2006). These pollinators are vulnerable to pathogens, predators, and parasites (Le Conte and Navajas, 2008). Figure 1 shows how climate change and variability have led to a favourable condition for the pest to bloom, to emerge and re-emergence (Garrett *et al.*, 2006; UNEP, 2014). For example, destruction of natural habitat can reduce the number of natural predators affecting the dominance of certain species and create a favourable condition for pest and disease host. This is also necessitated by human activity which increases incidences of bee diseases and pests (Ratnieks and Carreck, 2010; Henry *et al.*, 2012).

Temperature and humidity alter growth and development of an organism, survival, density and population which may be either positive or negative. This change in weather conditions may provide favourable environment for the pest to increase in population leading to invasion of new pest that is capable of coping and adapting to the current environmental condition (Gunderson 2000; Mijatović *et al.*, 2013). In addition, the condition may favour the emergence of disease pathogen that may be a threat to the bees (Arbetman *et al.*, 2013). A change in abiotic factor increases the dynamics and outbreak of pest by increasing their density, distribution and abundance as temperature above the optimal level reduces reproduction, growth, development and increases mortality of pest and the nonnative species respond better than native species on coping strategies (Betsy *et al.*, 2010; Karuppaiah and Sujayanad, 2012).

The social bond of the bees may enhance spread of pathogens among the hosts particularly through their feeding behaviour to each other using the mandibles (Schmid-Hempel, 2011; Graystock *et al.*, 2013). However, susceptibility increases when the bees are stressed and the infected bees can transfer the pest to other pollinators (Freestone *et al.*, 2008; Goulson and Hughes 2015).

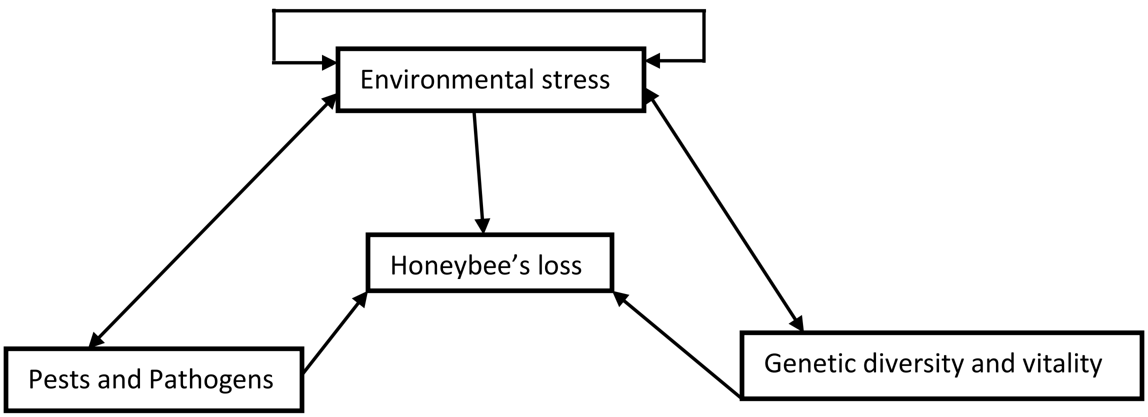

Figure 1: Interaction of drivers that leads to decline in honey.

Source (Potts *et al.*, 2010)

2.7 Policy review

Kenya adopted Vision 2030 with the agriculture sector emerging as one of the major economic sector requiring emphasis since it supports 80% of Kenyan's economy. Among the main aim of the Vision is changing smallholder agriculture from substance to innovative, mass food production and adopt modern agriculture. The Kenya Government launched a National Climate Change Response Strategy (NCCRS) in 2010 based on policy integration on how to respond to climate change vulnerability whose purpose is to increase food production. Nevertheless, the private sector, NGOs and other organization have different interest and goal in response to climate change (GoK, 2010b).

According to GoK (2010b), the Kenya agriculture sector is vulnerable to impacts of climate change and variability since they have a low adaptive strategy. The agriculture strategy is inadequate to provide adequate measures to deal with climate change. The National beekeeping policy of 2009 aims at improving honey production and enhancing awareness through providing extension to farmers, research and training. This will enhance practicing beekeeping especially in areas covered with expansive forests (GoK, 2010a). This will help in poverty reduction and achieve vision 2030. The Policy acknowledges the impacts of climate change, climate variability, pest, predators and disease on beekeeping (GoK, 2010a). According to the Water act of 2002, the Water Resources Management Authority has the mandate to proclaim principles and arrangements for conservation, management and control of water resources. The regulatory board is supposed to gather data and maintain the information on water services and distribution, access and utilization, promote conservation, monitor water services, monitor compliance with terms and condition. This will promote a resilient environment (GoK, 2002).

Sustainable Development Goals number 1, 2 and 13 are geared towards poverty and hunger reduction and strategies to combat climate change and its impacts, respectively. Climate change escalates hunger and poverty especially in communities that have low risk management strategies. Adoption of strategies proposed under the policy of 2014 to combat climate change and reduce hunger and poverty among many people is important (GoK, 2011).

2.8 Conceptual Framework

The conceptual framework in Figure 2 shows the relationship between variables. The arrows in the framework represent the feedback loops that show the relationships among the variables. Honey production is determined by several factors; weather conditions and anthropogenic factors. Thus, climate variability in turn, influences the livelihood of the people, which affects livestock production, crop production, soil quality, and nature conservation. Rainfall and temperature variability influence plants growth, water availability, forage availability and pest infestation. The increase in temperature will increase the growth of flora up to an optimum level beyond which the production decreases. In addition, it will provide a favorite environment for pest to infest. Anthropogenic factors, socio economic activities, and legal framework will affect honey production.

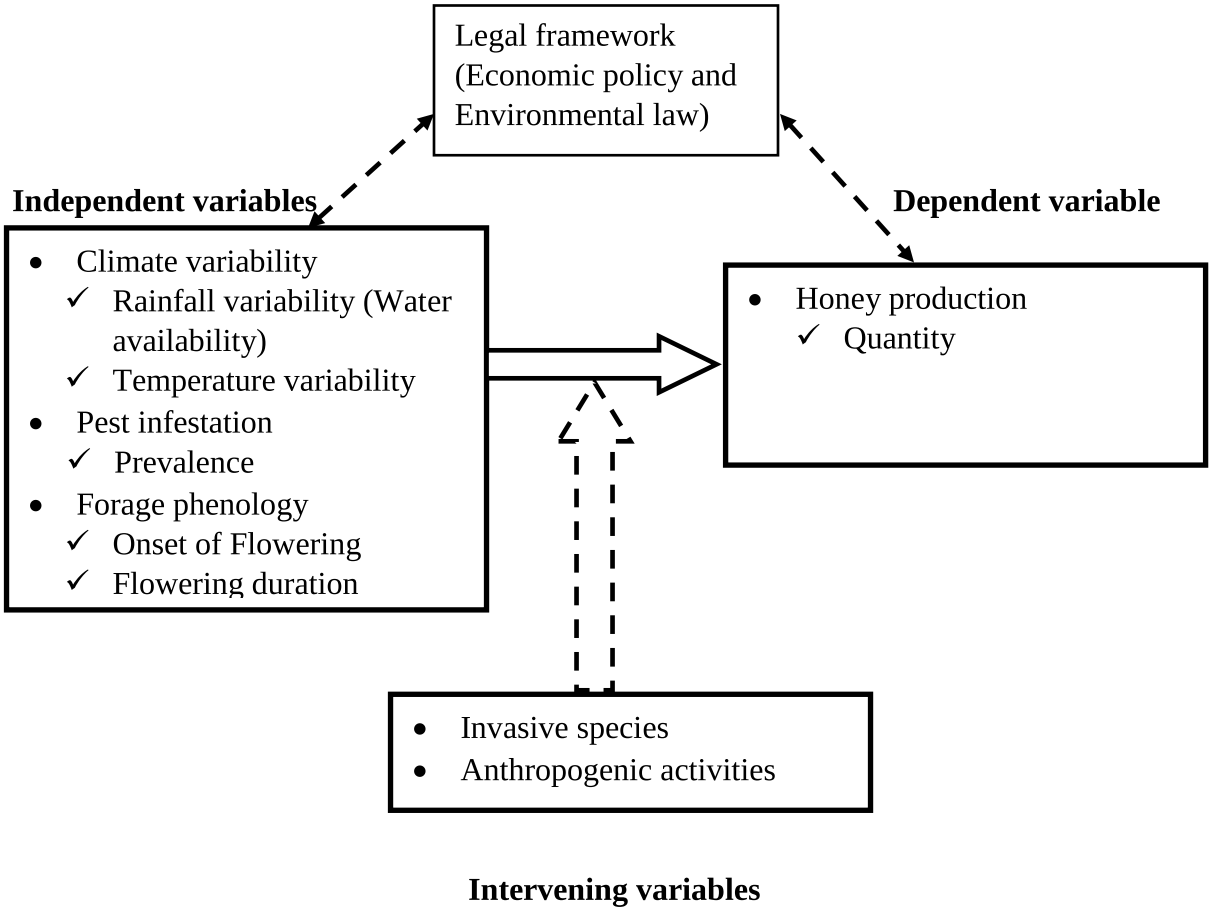

Figure 2: Conceptual framework showing relationship between variables

2.9 Operationalization of variables

Honey production; beekeeping is among major socio-economic activity for the people in Baringo. The variables that were measured include quantity of honey produced, frequency of harvesting in the year and factors that affect honey production

Temperature; Measurement of temperature is based on degree of temperature distribution and interrelationship with other variables.

Rainfall; Characterize the rainfall variability; the amount of rain and frequency of rainfall.

Pest infestation; this involved documenting the types and frequency of pest infestation and the factors influencing their prevalence.

Socio-economic activities; these will include human activities that directly and indirectly affect honey production.

Policies; this include all legal framework including the traditional norms that influence honey production.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the study area, the climatic condition, socio-economic activities of the local residents, vegetation type, topographic characteristics and techniques for data collection and analysis.

3.2 Study Area

3.2.1 Geographical Location and Size

Baringo County is situated in the Rift Valley region. It boarders Turkana and Samburu counties to the North, Laikipia to the East, Nakuru to the South, Uasin Gishu to the South west, and Elgeiyo Marakwet and West Pokot to the west. It is located 36º31′ and 36º30′ E and between latitudes 0º10′ and 1º40′ S (Figure 3). The equator passes across the County at the Southern part (GoK, 2014). Baringo area covers an area of 11,0153sq Km of which 165sq Km is covered by surface water Lake Baringo, Lake Bogoria and Kamnarok . The population estimate was 613,376 in 2012 and is estimated to increase to 677,209 and 723,411 by 2015 and 2017, respectively. The human poverty index is 30.6% compared to the national level of 29% (GoK, 2013, 2014).

3.2.2 Climate and Topography

Baringo County varies in altitude between 3000m above sea level at its highest points and nearly 700m above the sea level at its low points. The mean annual rainfall varies between 1000 mm to 1500 mm in the highlands and 600 mm per annum in the lowlands. Due to their varied altitude, the sub-counties receive different levels of rainfall. The mean annual temperature in the region lies between 25ºC and 30ºC in the southern part and 30ºC and occasionally rises over 35ºC. The hottest months are January to March. The mean, minimum annual temperature ranges from 16ºC to 18ºC but sometimes drops up to 10ºC in the Tugen Hills (GoK, 2013, 2014).

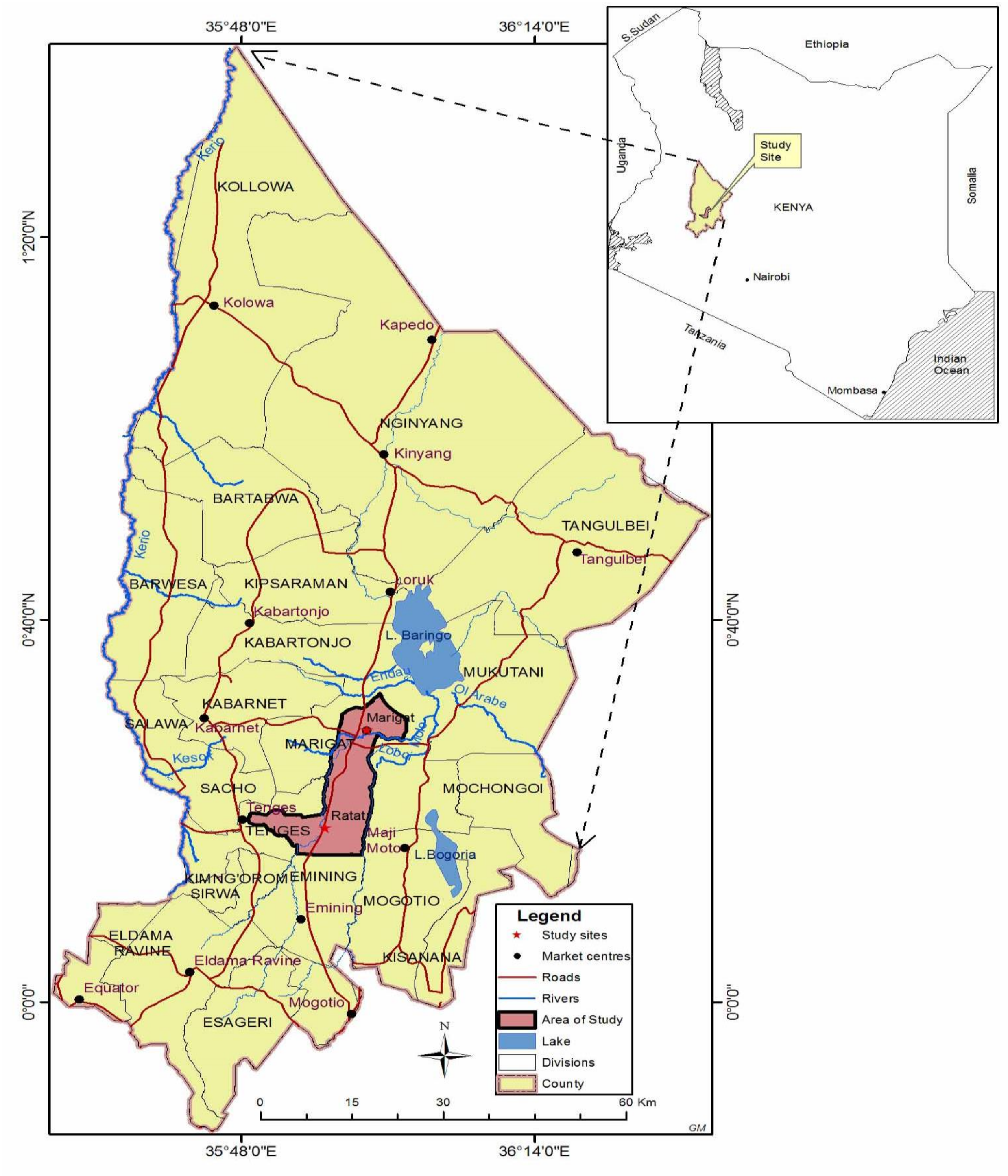

Figure 3: Study area map.

Source is (www.diva-gis.org)

3.2.3 Vegetation Type

Topography differs from one area to another determining the soil type, climate and the type of vegetation in the area. The county has both exotic and indigenous forest that is dominant. The exotic trees are *Grevillea robusta, Cuppressus lusitanica, Eucalyptus saligna and Prosopis juliflora (*dominant in Marigat). Some of the indigenous trees include Podo (*Podocarpus latifolius*), Cedar (*Cedrus libani*), *Osyris lanceolate* and Acacia species. Other vegetation includes coffee at Tugen hills and fruit trees. However, due to the prolific cutting of trees for charcoal burning, there has been a decrease in the vegetation cover density (GoK, 2013, 2014).

3.2.4 Soil type and Water Status

The soils at lowland and highland type vary. The highland consists of well-drained soil that is suitable for agricultural activities while the lowland soil is saline. It is composed of complex alluvial soil, shallow stony, lava, boulders, and sandy soils. This soil is prone to erosion. Baringo County has insufficient available water and cannot meet the need and demand of the population. The sources of water are from the lake, streams, water pans, dams, rivers, boreholes, wells and springs. The County has 5 major rivers: Perkerra, Molo, Kerio, Waseges, Emnos and other seasonal rivers; Amaya, Arabal, Mukutani and Nginyangi (GoK, 2013, 2014).

3.2.5 Socio-economic Characteristics

The main socio-economic activity in Baringo is pastoralism. The communities rely on pastoralism as their major source of livelihood. They keep goats, sheep, cattle and camels, and beekeeping forming their major livestock activities. The communities also grow maize, groundnuts, cotton, vegetables and practice agroforestry. Some members of the communities in the lowland areas undertake charcoal burning as an alternative source of income since the erratic rainfall is not reliable for agriculture. Other socio-economic activities include; ecotourism (Lake Bogoria National game reserve and Lake Baringo) and mining (at Opal near Perkera) (GoK, 2013, 2014).

3.3 Research Design

The study applied a social survey research design. Data collection was through administration of questionnaire and interviews. Purposive random sampling technique was used in selecting the village and the respondents. The key informants were selected based on their experience and association with bee farmers. The sample units entailed the household heads, which was generated based on population statistics. Structured questionnaires were administered to household heads. The respondents were the local residents aged above 20 years who practice bee farming.

3.4 Sample Size

The target population was the small-scale and large-scale beekeepers who have hives in the study area. A cluster sampling approach was used for data collection in Marigat villages (Maoi, Kamung'eyi, Loberer, Endao, Kapkukui, Perkera, Arabal, Koriema and Kimalel). The total population in Marigat is 4393 with 1209 household and 940 (www.opendata.go.ke) in Ratat, Bekibon sub-location with 203 household. Since the exact number of bee farmers is not known, the sample size was determined using the formula by (Naissuma, 2000);

$n= NC^2/(C^2+(N-1)e^2)$

Where

n: is the sample size;

N: is the population size of 1422;

C: is the coefficient of variation (30) and e is the margin of error (3%).

Therefore, the sample size was calculated as follows;

$n=1422\times 0.3^2/(0.3^2+1422\times0.03^2)= 99.5\approx100$ households heads

100 household heads were included in the sample (Table 3). The proportionate distribution of the sample size was calculated as follows;

With total households of 1209 in Marigat, the number of households sampled was calculated as follows;

$$n = \frac{1209 \times 100}{1422} = 85 \text{ households head}$$

In Marigat 85 household heads were interviewed as per the following cluster per sampling unit. Nine villages were sampled in Marigat; Kamung'eyi, Kapkuikui, Koriema, Endao, Maoi, Perkera, Kimalel, Loberer and Arabal.

In Ratat, the total household was 203;

$$n = \frac{203 \times 100}{1422} = 15 \text{ households heads}$$

Table 3: Distribution of the sample frame

Village	**Frequency**
Ratat	15
Kamung'eyi	12
Kapkuikui	11
Koriema	13
Endao	12
Maoi	15
Perkera	2
Kimalel	3
Loberer	11
Arabal	6
TOTAL	100

3.5 Ethical Consideration

Written permission to undertake the study was granted by the NACOSTI (Appendix 4) and the Board of Postgraduate studies in Egerton University and the local area chief. Permission was also obtained from the relevant county authority and local chiefs. Respondents participation was based on their willingness based on informed consent. The information provided was used entirely for academic purposes and personal information of respondents was kept confidential.

3.6 Data Collection

Data was collected from both primary and secondary sources. Primary data were obtained through administering questionnaires (Appendix 1), FGDs and scheduled interviews (Appendix 2). The questionnaires were administered to the household heads by the researcher and four key informants from KALRO Marigat, Marigat Sub-county, Rachemo SACCO and Kamung'eyi selected for a scheduled interview. Two FGDs at Ratat and Kamung'eyi were conducted with the help of the local leaders who identified 5 people to participate in the discussion. Secondary data were obtained from Marigat District water office (Appendix 3-data of rainfall 2012 to 2016), Rachemo SACCO, KALRO Marigat, previous studies and literature review. This was to show the relationship between environmental parameters and honey production in the study area.

3.6.1 Validity and Reliability

A pilot study was conducted in Sandai where 12 questionnaires were administered to respondents to show the reliability of the study instruments. This was pretested prior to the main study. During analysis of the pilot survey questionnaire, it was realized the questions relating to plant phenology and pest infestation were not clear. Therefore, changes were made to take into consideration of the raised issues and make them inclusive.

3.7 Data Analysis

The data was coded and analyzed using SPSS computer software version 20. Rainfall data was tabulated and analysed using Microsoft excel. Excel was used for descriptive statistics to determine the standard error, means, and range. Inferential and descriptive statistics; Chi-square and Correlation analysis were used to determine the relationship between the dependent variable and independent variables, frequency and percentage for qualitative description. This is elaborated in Table 4.

Table 4: Summary of table of Data analysis

Objective	Variables	Data analysis tool
To determine rainfall variability patterns for the period 2012 to 2016	Temperature and Rainfall trends	Measure of central tendency and dispersion, descriptive statistics
To assess the relationship between rainfall variability and forage phenology	Forage phenology of major forage species (length of flowering, time in season)	Correlation analysis and Chi-square
To assess the effects of climate variability on honey yield for the period 2012 to 2016.	Quantity of honey, water availability, colony migration	Measure of central tendency, Correlation analysis
To assess the effects of climate variability on bee pest infestation	Rainfall and temperature variability, Pest infestation	Chi-square

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion of the study in connection to the set objectives. The segment is divided into two sections; demographic characteristics and the findings of the study.

4.2 Characteristics of the Respondents

The demographic characteristics of the respondents interviewed in the study are gender, marital status, age, educational level and occupation. Age, sex, marital status, education level and occupation may influence the level of knowledge in relation to beekeeping.

4.2.1 Gender and marital status of the respondents

Gender of the respondent is an important factor as far as honey production is concerned since different persons regardless of their marital status practice beekeeping. The interest to meet the household needs may prompt majority of the households to engage in beekeeping. Furthermore, the labour distribution within a family is pivotal in beekeeping. The results in figure 4, shows that 95% of the respondents who practice beekeeping were men and 5% were female. A larger proportion (86%) of these respondents were married with a small proportion (8%) being single. This maybe because of the division of labour is more efficient among married couples because they share most of the household responsibilities. This is in line with the tradition of the Tugen community that beekeeping is a domain for men (Gichora, 2003). The women who practice beekeeping are mostly widows, and in most cases, they engage or employ men to make the beehive for them.

A study by Yetim (2015) in Ethiopia revealed that beekeeping is practiced across by all social classes. Other studies by Bekele (2015) in Ethiopia, Gichora *et al.* (2003) and Wambua (2015) in Kenya and Kajobe *et al.* (2016) in Uganda indicated that majority of the beekeepers were men. However, gender is crucial in distribution of labour in most African societies. This is because most of the decisions on household production activities in African societies are made by men (Angelsen and Wunder, 2003; Terry, 2009). Therefore, there is evidence to suggest that men dominance in beekeeping may be because of the societal setup. This portrays how important beekeeping is as a source of livelihood for the pastoral community and it is inclusive.

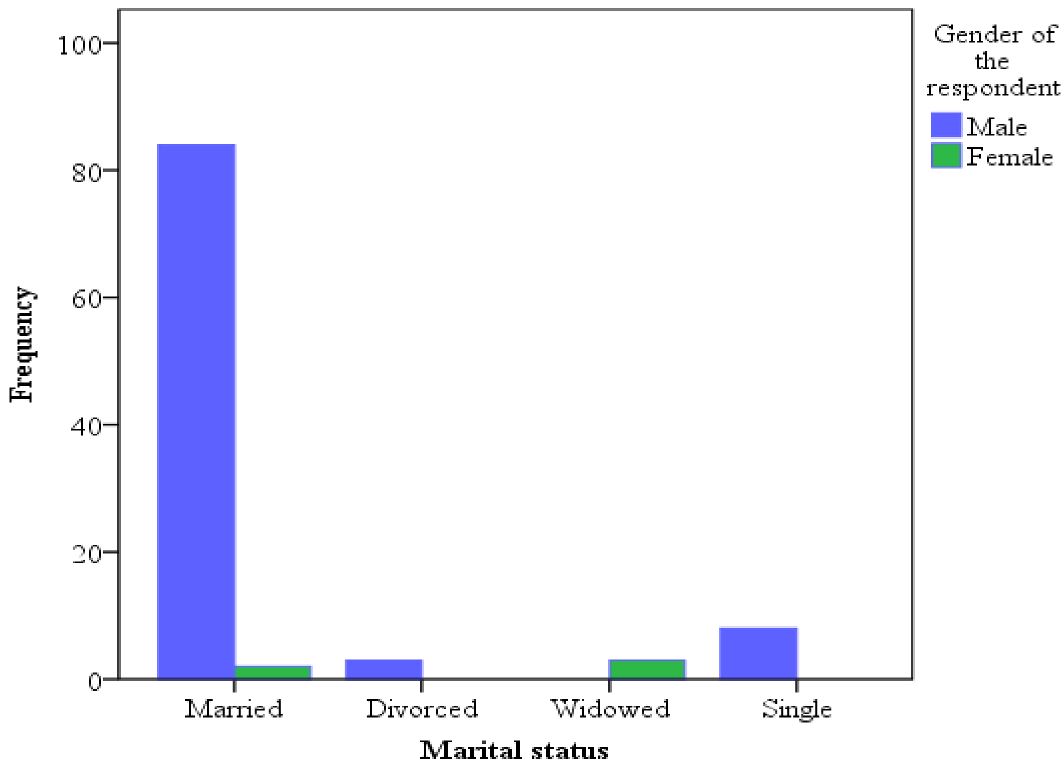

Figure 4: Gender and marital status of the respondents

4.2.2 Age of the Respondents

The age of the respondents is important as it determines their level of understanding of bee management and the change and variation in climate. Out of the sample, 25% of the respondents were above 50 years, 13% between 44-49 years, 10% between 38-43 years, 22% between 32-37 years, 17% between 26-31 years and 13% between 20-25 years (Table 5). It is evident from the results that persons of different age groups ranging from youths to the elderly practice beekeeping. Kinati (2010) and Bekele (2015) in Ethiopia also found that beekeeping is an activity that is practiced by younger age group to the elderly. In another study by Yetim (2015), the author found out in most of the households, the younger age provides labour to their parent at their tender age as they gain experience.

The results in table 5 show the importance of beekeeping as an alternative source of income for households to supplement income from sale of livestock. Pastoralism is the major production system in Baringo County. However, frequent droughts have had a devastating effect on livestock production and hence household members have to look for alternative sources of livelihoods. The evidence of climate change in many counties in ASAL areas, Baringo included, has been observed in terms of an increase in rainfall variability and prolonged drought leading to livestock death. The impacts of low rainfall and prolonged drought include poor crop yields and migration in search for pasture and water that has leads to resource use conflict (GoK., 2017). Arid and semi-arid lands in Kenya have experienced frequent droughts and have become highly vulnerable and drought-prone areas (Nkedianye *et al.*, 2011) and thus drought poses serious challenges to pastoral communities whose livelihoods depend entirely on natural resources (Below *et al.*, 2010). Despite the contribution of pastoralism to the household economies, its capacity to adapt to climatic variability has faced many challenges (Nori *et al.*, 2008) and the risks associated with climate variability may have been accelerated by overgrazing and the decline of woody vegetation hence reducing the forage for bees.

Table 5: Age of the respondents

Age (Years)	**Frequency**
20-25	13
26-31	17
32-37	22
38-43	10
44-49	13
50+	25

4.2.3 Education level of the respondents

The results show that 44% of the respondents have attained primary education, 24% secondary education, 17% tertiary education and 15% had no formal education (Table 6). The findings imply that a larger proportion of the study population have attained primary education and they were relying on indigenous knowledge, understanding and bee production. These findings are in line with Gichora *et al.* (2001) who found out majority (82%) of bee farmers in Baringo had attained primary education. However, as compared to the authors' results, there is an increase in literacy level since the percentage who attained primary education was (44%) was lower as compared to 82%. Education level is an important parameter as it influences adoption of new technology, seeking extension services, proper care of the bee colony and understanding the effects of climate variability on honey production. Furthermore, it was assumed that high level of literacy contributes to the better management of the beehives and understanding of the impacts of climate on apiculture.

Table 6: Educational level of the respondents

Educational level	**Frequency**
No formal education	15
Primary	44
Secondary	24
Tertiary	17

Wasonga (2009) noted that education level is important to pastoral communities in determining different socio-economic activities they engage in. High level of illiteracy is an indication of the farmers unable to seek for formal employment and their reliability on honey production. According to the OECD (1999) report, environmental communication is a two-way social interaction process enabling people to understand key environmental issues such as climate change and people's interdependencies and how to respond to problems associated with the phenomena competently. Information on environmental issues creates a new mind set and perceptions that changes peoples' lifestyles and judgement and efficient use of valuable environmental resources. Environmental communication media plays a critical role in the understanding of the environmental issues which enable people to take actions that lead to mitigation measures to reducing the effectiveness and impacts of adverse changes in the environment (Hansen., 2011).

4.2.4 Occupation of the Respondents

The type of occupation influences the ability of an individual to provide labour, monitor the beehive and understand the variations in honey production. In addition, this was assumed to determine the level of understanding since those who provide tender care to the bees are more knowledgeable than those who rely on casual labourers. Analysis of the survey data indicated that 82% of the respondents were farmers. This makes it easy activity to undertake since it is traditional art inherited from one generation to another (Table 7). The findings also indicated that households' members with other forms of employment rely on beekeeping as an alternative form of livelihood. Kimani (2015) reported that socio-economic activities of Baringo community are founded on their cultural endeavors. Moreover, this also determine the level of income and the capability of the respondent to access to modern beehive and determine the indulgence in apiculture. Beekeeping is an important source of income among the respondents. This was in line with a study by Gichora *et al.* (2001), the author found that the major source of income for the people in Baringo were livestock (49%) and beekeeping (25%).

Table 7: Major occupation of the respondents

Occupation	**Frequency**	**Percentage**
Farmer	82	82
Teacher	4	4
Enterprise	9	9
Other	5	5

4.2.5 Beekeeping activity

The mean experience number of years a person has gained experience in beekeeping was 17 years with a minimum of 3 years and maximum of 57 years (Table 8). There is a strong correlation between the age of the beekeepers and experience that is represented by the strong positive and high significant correlation (r=0.769, p=0.00). The results depict participation of beekeeping activity from young to adults. These results are in agreement with those of Gichora *et al.* (2003) at Baringo who found out that, there is positive correlation (r=0.67, p=0.001) between the age and experience of the respondents.

Majority of the respondents place their hive in the jungle with a maximum of 100 hives and a mean average of 28 hives per person. A small proportion of the respondents place their hive at their homestead (mean average of 1 hive per person) and with some of them preferring to place the beehive at homestead with a mean average of 3 beehives per respondent (Table 8). The results illustrate communities' diversification in their socio-economic activities in order to meet their household needs and thus they have more beehives. It was envisaged that the location of the beehive would influence harvesting of honey by the farmers and ability of the farmers to monitor the effect of climate variability on honey production. Therefore, farmers have to set more beehives in different locations to increase their possibility to catch the swarm of bees.

Majority of the respondents placed their beehives in the jungle since this area has adequate nectar as it is rich in flora (GoK, 2013). The findings indicate the full involvement of all individuals in apiculture as a livelihood. Moreover, majority of the respondents with more beehives were between the age bracket of 25-37. This is possibly because they are energetic and mature and they actively participate in beekeeping. Information from some of the respondents was that, the preference of placing the beehive in the jungle was because of the changing daily temperature and pest infestation. The hive placed high on the tree provides a conducive environment as it is cooler. In addition, placing the beehive away from the homestead and nearby at the roads reduces disturbances since when temperature is moderate, the bees are more aggressive, and they can cause injury to humans and animals. This is in agreement with Wambua (2015) findings, who contend that hives that are placed on the trees are cooler than those placed near the ground.

Table 8: The descriptive statistics showing the mean comparison of age of respondents, experience of beekeeping and number of beehives

	Experience in beekeeping			**No. of beehive on homestead trees**			**No. of Hives in the jungle**			**No. of hives nearby homestead**			**Total number of beehives**
Age of the respondent	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	
20-25	6.15±2.19	5	10	1.07±3.43	0	5	11.61±3.43	0	45	0.00±0.00	0	0	165
26-31	9.82±4.40	3	17	0.00±0.00	0	0	35.82±6.92	0	100	1.06±0.77	0	12	627
32-37	13.14±4.43	5	20	2.09±0.91	0	15	27.18±8.43	0	167	4.63±1.80	0	25	746
38-43	15.10±5.20	6	20	0.60±0.60	0	6	36.20±10.61	0	100	1.50±1.07	0	10	383
44-49	18.46±8.04	3	30	1.08±0.80	0	10	28.62±9.42	0	100	6.46±5.35	0	70	470
50+	32.08±10.69	10	57	1.40±0.72	0	15	29.60±5.85	0	100	4.80±4.04	0	100	895
Total	17.29±1.15			1.15±0.31			28.32±3.13			3.39±1.29			3286

SE=standard error; Min=Minimum; Max=Maximum; N=Number of respondents. **R=0.769**

4.2.5.1 The Type of Beehive

Variation in honey can also be determined with the type of beehive. Farmers with modern beehives monitor their beehive frequently and do harvest more honey. The traditional beehive is constructed with logs and is only capable of providing ambient condition for the bees' survival. The results indicate that 88% of the respondents have traditional log hives and on average 10% had both modern hive and traditional log hives (Table 9). This is an indication of the local society`s inability to adopt the new modern technology. It is also evident that majority of the respondents started beekeeping at a tender age by observing and copying from their neighbours, own interest or by inheritance from their parents (Table 10). The society prefers the locally made log hives because they are cheaper and easily available. In a study conducted by Teferi *et al.* (2011) and Yetim (2015) in Ethiopia, majority of the local people prefer traditional beehive because it is easy to construct and manage, low maintenance cost, it is cheaper and locally available. However, according to Kimitei, and Korir (2012) majority of farmers in Kibwezi in Kenya lacked sufficient funds to buy the modern beehive leading preference of the traditional log hives which is cheaper.

Table 9: Beehive types

Type of beehive	**% of the respondent**
Only traditional beehive	88
Only modern beehive	2
Both modern and traditional beehive	10

n=100

The respondents had varied reason for practicing beekeeping. The results in table 10 indicates that, 63% of respondents practice beekeeping as source of income. The income from sale of honey is mainly for subsistence. According to Gichora *et al.* (2001), farmers sell unrefined honey at a higher price because of the multiple uses of the end product. However, climate variability has had a great impact on honey production. Therefore, the need to put in place urgent measures to cushion risks associated with effects of climate change. The response of many households to climate shocks is that some members do migrate to urban areas to seek for employment in towns (Bohra-Mishra *et al.*, 2014) or use of the natural resources to generate and diversify household income. Extension services provided for bee keeping in the study area is low. This may be due to changes in the policy of the government, where farmers are to go to officers instead of extension staff taking new innovations and information to farmers/livestock or bee keepers.

Table 10: Reasons for Engaging in Beekeeping

Variable	**% of the respondent**
Reason for beekeeping	
Own interest	41
Influenced by the neighbor	25
Inherited from the parents	29
Awareness from agriculture extensions	5
Reasons for honey production	
Income	63
Home consumption	12
To get skills	3
Both income and home consumption	19
Other reasons	3

n=100

4.3 Climate Variability and Respondents Perception on its variation

4.3.1 Temperature and Rainfall Patterns and Trends

This study focused on the monthly rainfall for the period of 2012 to 2016. The year 2012, 2013 and 2016 received a uni-modal rainfall pattern, and 2014 and 2015 received a bimodal rainfall pattern. In the year 2012 the peak rainfall was in July (330.2mm) and August (331.5mm). For the year 2013 and 2014 the peak was in June with 101.2mm and 99.5mm, respectively. This was different for 2015, which had the peak in June and November receiving rainfall amount of 125mm respectively, and for the year 2016, the peak was on July (144.6mm) (Figure 5). This illustrates the variation in monthly rainfall received in the study area. The results conquer with Singh *et al.* (2017) report of peak for rainfall for East Africa is between April and August. The results contrast those of Ute *et al.* (2012) who found out that, it is hard to detect rainfall variability since this will take long. However, the results of this study indicate that the trend in rainfall variability in the study area was evidenced within a short period. In East Africa much rainfall is between April and August. In the year 2014, more rainfall was received between August and December while the year 2016, it rained throughout from January to October continuously.

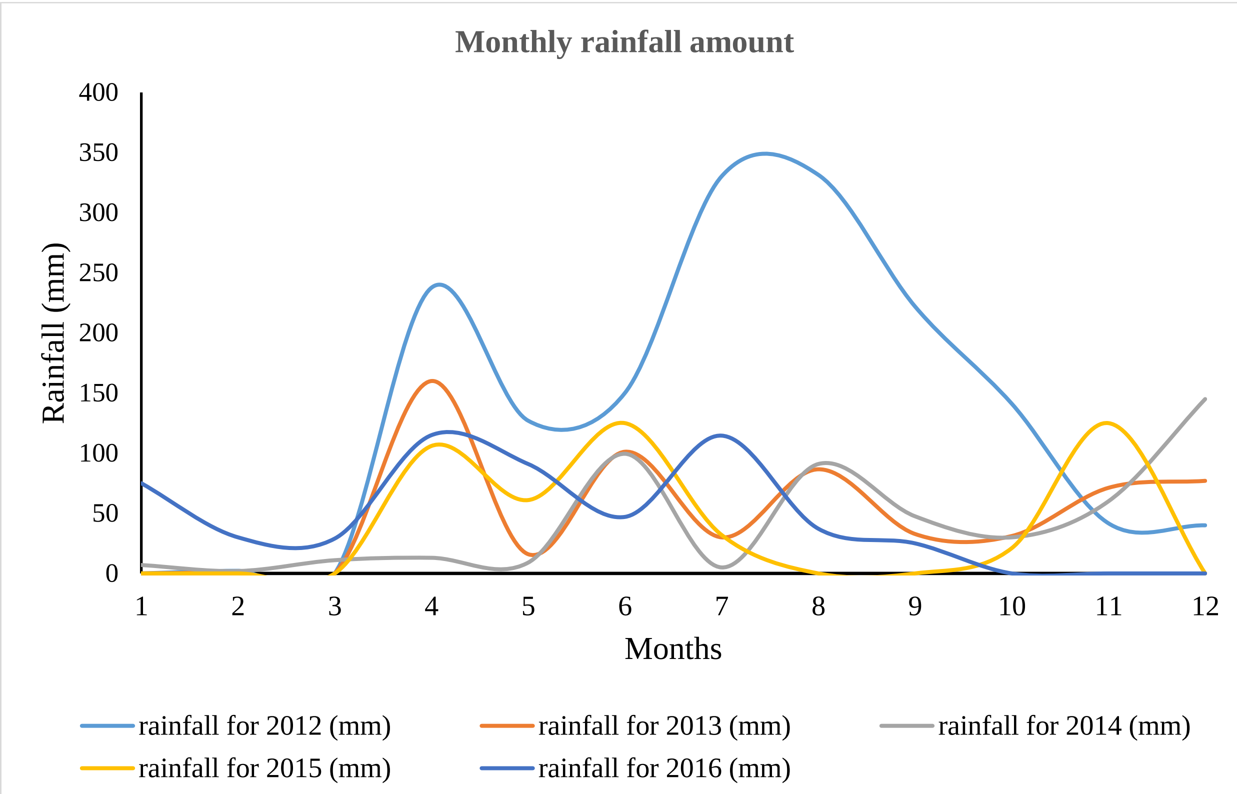

Figure 5: Graph showing monthly rainfall for the period of 2012 to 2016 for Marigat/Ratat

The rainfall amount has decreased drastically from the year 2012. It is clear in figure 6 that rainfall amount was high in the year 2012 (1623.4 mm per year) and low in year 2015 (470mm per year). The annual rainfall for 2013-2015 and 2016 is less half of the annual rainfall for the year 2012. According to Singh *et al.* (2017) study, the author reported that there has been a decrease in rainfall amount in East Africa especially in the ASALs. An increase in temperature is indirectly proportional to rainfall. Temperature increases the evapotranspiration thus reducing ratio of precipitation and evapotranspiration (P/E) affecting the impact of rainfall on soil surface.

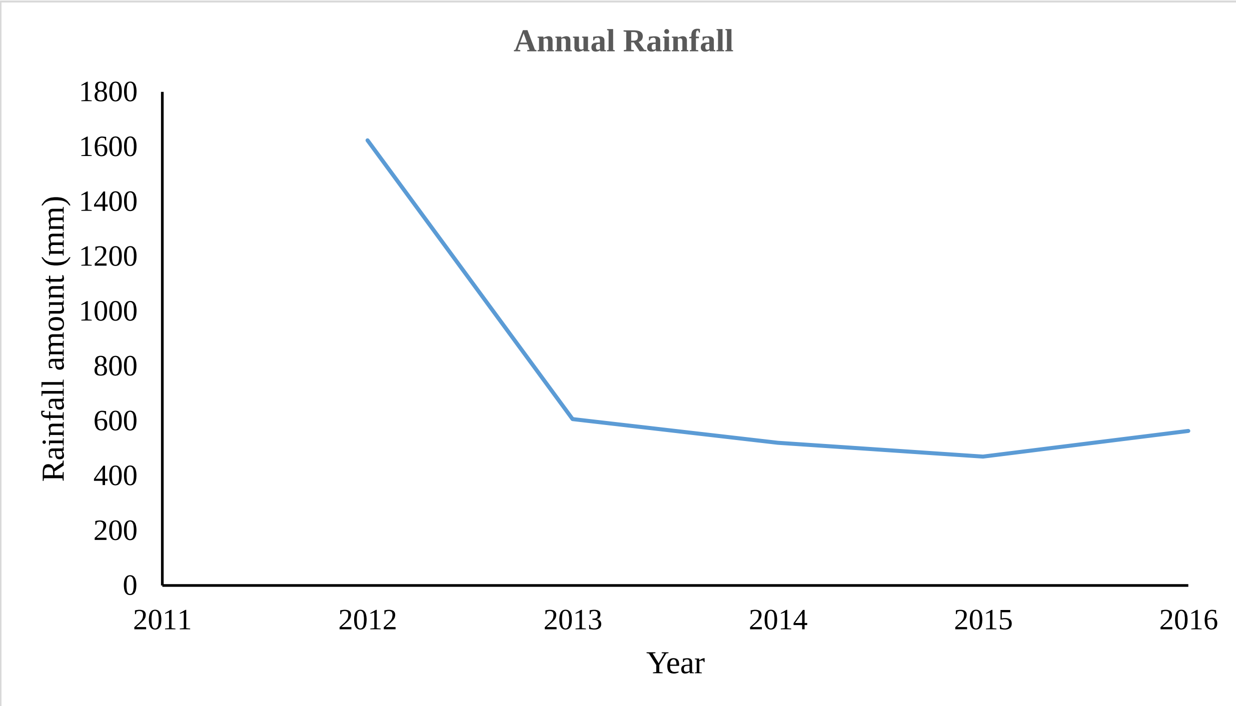

Figure 6: Graph showing the annual trend in rainfall amount for the study area

Source: Marigat District Water Office 2017

From 2012 to 2016, there is the presence of statistically significant decreasing trends in rainfall amount. This depicted from the standard error bar, Figure 7. High rainfall was received in 2012 with a mean average of 135.28±35.56 and the least in the year 2015 with an average of 39.17±14.89. Despite the decrease in rainfall, the maximum rainfall was high in the year 2012 (331.5 mm) and decreased throughout the year (160 mm, 145 mm, 125 mm and 115 mm respectively) with a minimum rainfall of 0 mm for 2012, 2013, 2014 and 2016 and 2 mm for 2014. In the year 2012, this area received rainfall above the average rainfall for ASALs while 2015 received rainfall below the average level. ASALs in Kenya have experienced frequent droughts and have become highly vulnerable and drought poses a serious challenge for pastoral communities whose livelihoods depend entirely on natural resources (Below *et al.*, 2010; Nicholson 2014).

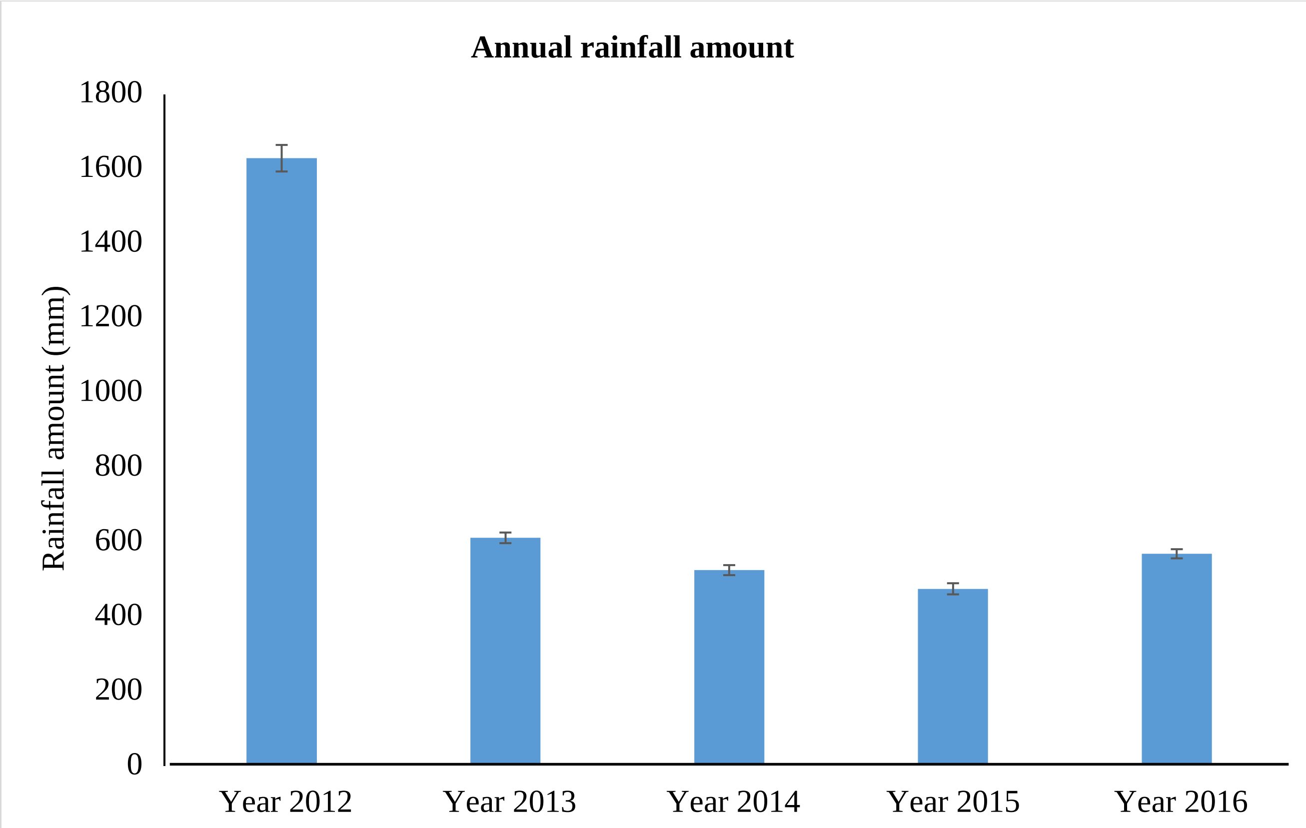

Figure 7: The standard error graph showing the annual rainfall for 2012-2016.

Source: Marigat District Water Office 2017

The exposed soil increases evaporation of the little soil moisture available further accelerating the impacts of climate change (Okoti *et al.*, 2014) on the ASAL environment. The high dependence on rain-fed agriculture (Asseng *et al.*, 2011; Lobell *et al.*, 2011), and forage for bees and livestock production combined with frequent droughts have had adverse effects on both sectors affecting the livelihoods of pastoral communities in Baringo County.

The lowest average temperature was recorded in the year 2012 (16.75 °C) while highest in 2014 (18.58 °C). There is a steady increase in Temperature in 2012 to 2014. The average maximum temperature was high in 2014 (33.8°C) lowest in 2012 (30.5) °C (Figure 8). During the day, the temperatures are high while at night the area experience a cool temperature. The annual average temperature was high in 2014 (26.19°C). It is depicted from figure 8 that, there is slight in in temperature from 2012 to 2014. According to Ozturk *et al.* (2015), climate warming has led to hot condition and an increase in dry conditions in Africa.

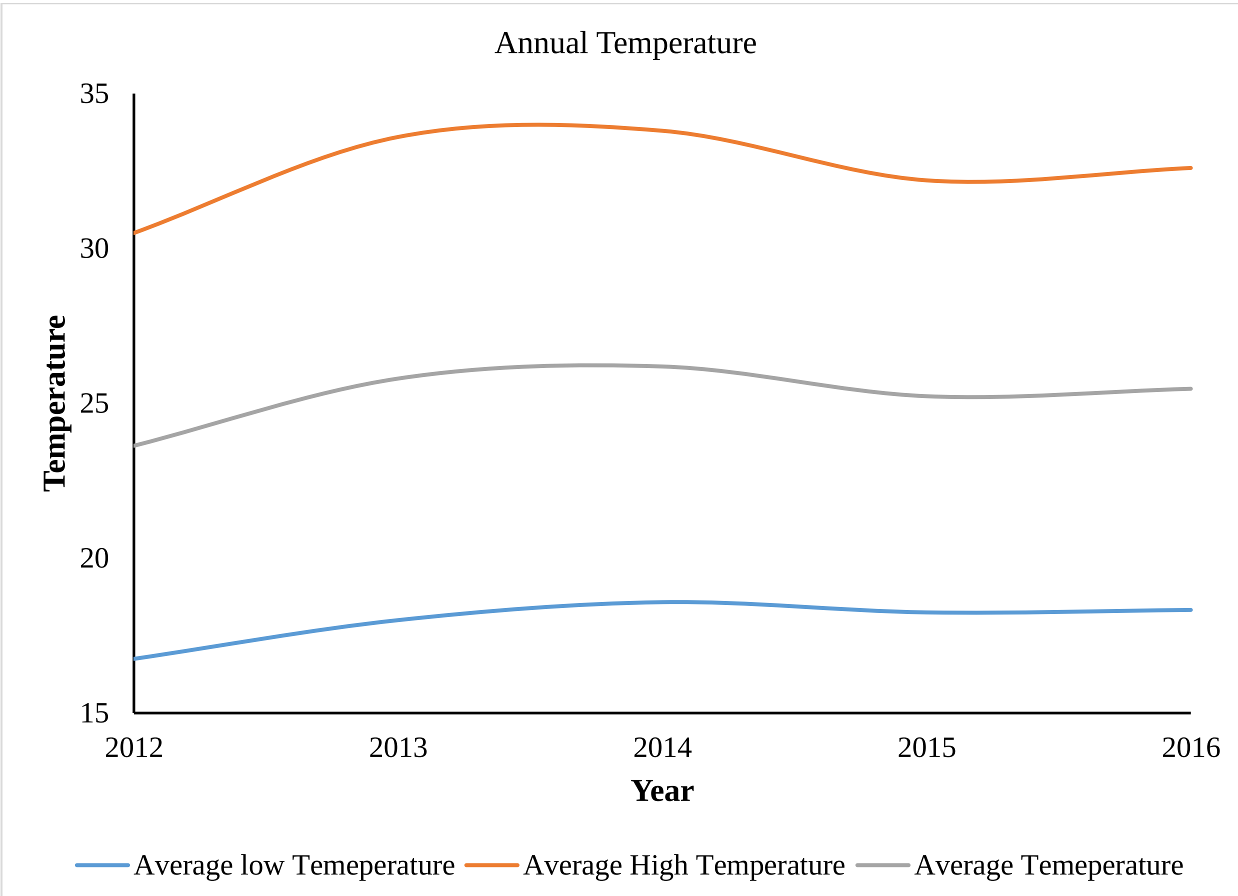

Figure 8: The line graph showing the Annual Temperature in the study area.

4.3.2 Local people perceptions on climate variability

This section presents the respondents understanding and perceptions of climate variability. The findings are based on their indigenous knowledge and how they perceive the variation of climatic parameters. The respondents interviewed demonstrated their level of awareness of climate parameters and the possible effects on their livelihood. The results show that the respondents understood the variation and change in climate such as variation in temperature, rainfall and drought incidences. The local people, the key informants and FGDs participants were asked to state their local perception on climate variability. According to the survey data, it is clear that majority of the respondents (80%) acknowledged that there has been a decrease in rainfall for the past 5 years. On average, 79% of the respondents reported that the duration for rain has changed in the past 5 years (Figure 9). The results were consistent with the Rainfall data that was obtained from Marigat Sub-county water office.

The findings of this study imply that the dependence on pastoralism as a source of livelihood is no longer sustainable due to the high livestock mortality because of frequent droughts. This is in agreement with the study by Ayantunde *et al.* (2011) which indicated that pastoralists have become poor and food insecure due to effects of climate change and that the sustainability of pastoralism as a source of livelihood is in doubt. Climate change is increasing at an alarming rate, and according to Pica-Ciamarra *et al.* (2011) further impacts of climate changes will accelerate environmental degradation. However, an adaptive strategy to cope with the risks associated with climate hazards will be dependent on the socio-economic strength of the affected community (Smit and Wandel, 2006).

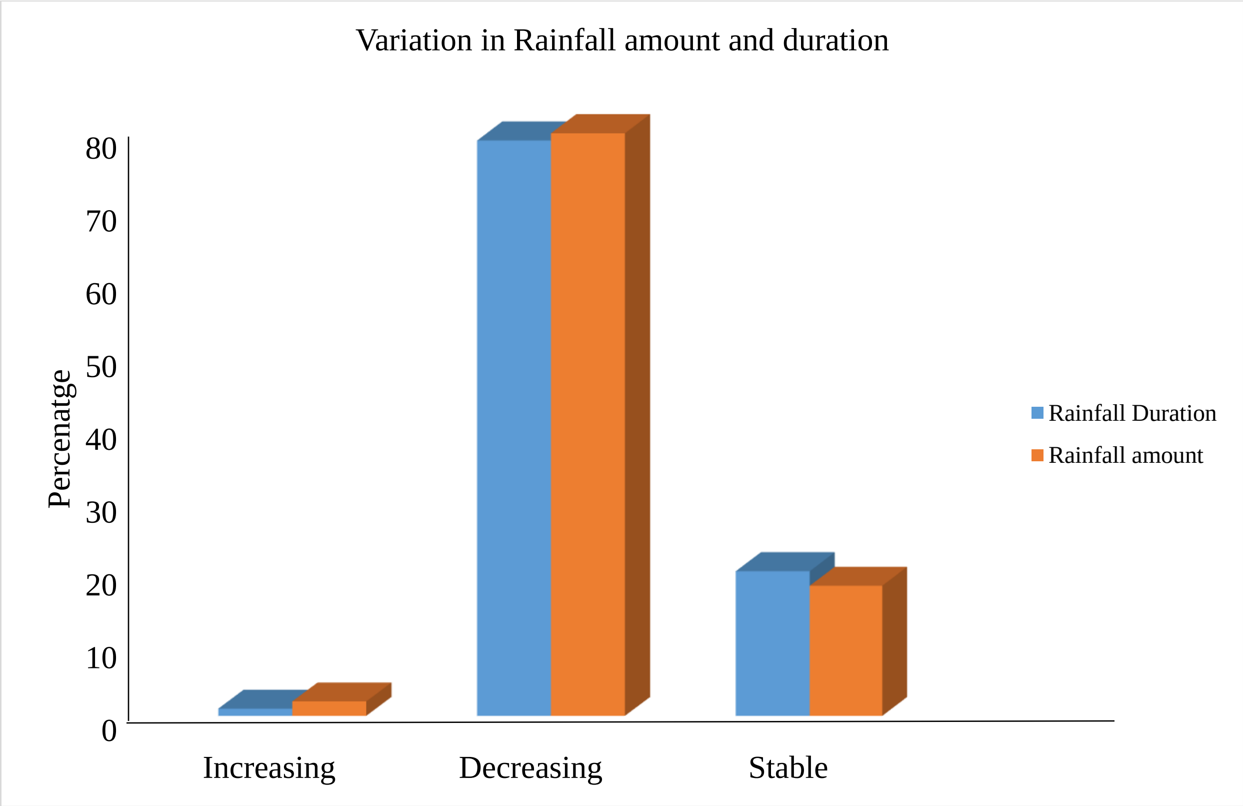

Figure 9: Trends of rainfall amount and duration

The information from key informants, FGDs perception (Text box 1) and respondents perception on rainfall amount (Figure 9) correlate with the Figure 6. The findings from FGDs in text Box1 is in correlates the findings.

> "In the years from 2011 and 2012, this area has been receiving more rainfall but in the year 2013 to date, the amount of rainfall has decreased drastically which has led to many people to change socio-economic activity. The community has experience severe drought, with some of them selling their livestock at throw way price. Temperature has increased and rainfall amount has decreased. In most occasions, we usually receive more rainfall between April and August, with climate variability this has changed. For example for the years 2015, this area received less rainfall."

Text box 1: Climate variability experience from key informant

The results in Figure 10 show that, 90% of the respondents reported an increase in severity of drought for the past years (Figure 9) which is in agreement with Herror *et al.* (2010) findings that Kenya experienced drought with different magnitudes after a period of 3-4 years. In addition, the results indicated that, 92% of the respondents acknowledged the rise in temperature, with only 2% of the respondents reporting decrease in temperature. Globally, increase in temperature varies geographically and spatially. In East Africa, the temperature has increased by an average of 0.21˚C after every ten years (Ongoma and Chen, 2017). Information from the interview with the key informants and FGDs, it was clear that the intensity of temperature has been increasing steadily (Figure 9). The findings of this study are in agreement with Kimani (2015) and Kosonei *et al.* (2017) findings in the same area who reported that there has been a steady increase in temperature in Baringo. According to Kosonei *et al.* (2017) results, the frequency of drought incidences has increased in Marigat and is becoming a yearly hazard.

The results indicate there is an increase in temperature intensity. The respondents reported they do understand the indicators they use to evaluate the change. However, this was difficult among the elderly above 65 years. They are more adhered to the traditional customs that prevent them to access to information on weather and how they can evaluate it and the high level of illiteracy.

According to the information obtained from the key informants, farmers currently are unable to predict climatic change because the incidences of drought has increased.

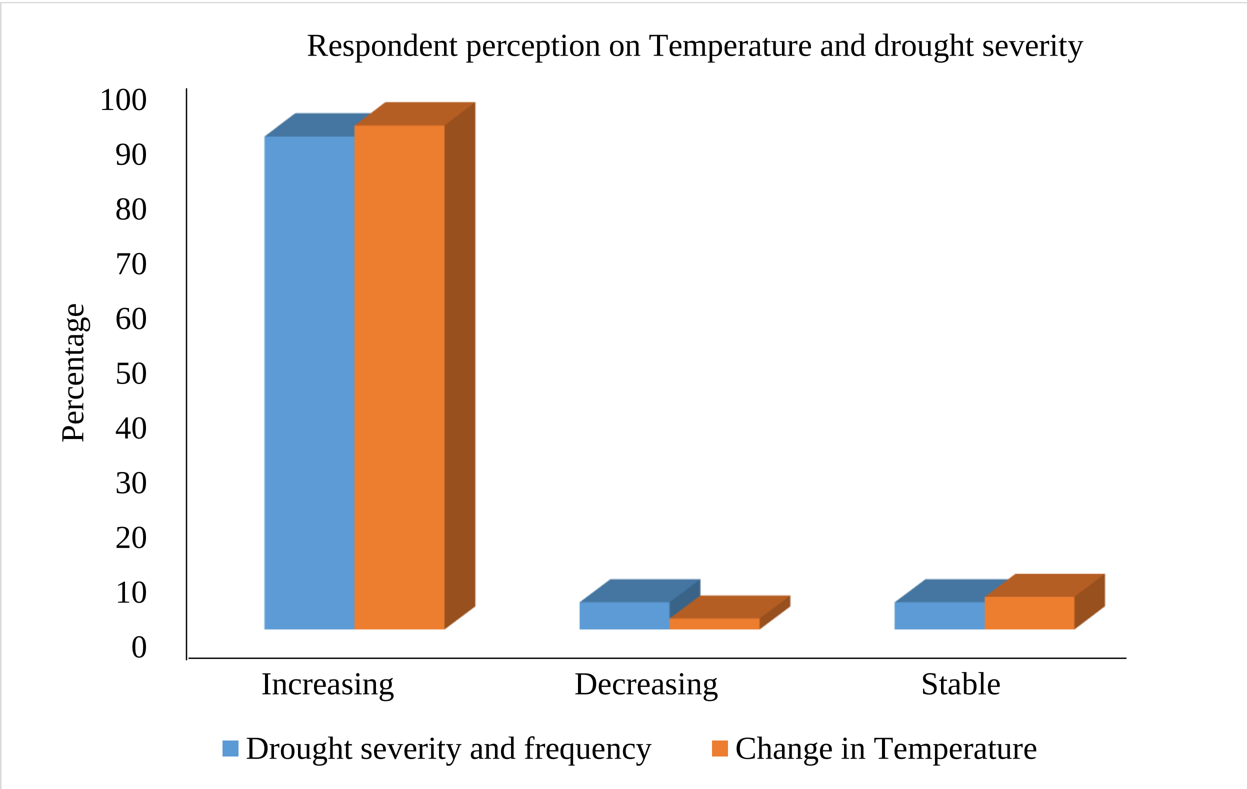

Figure 10: Respondents perception on severity and frequency of drought and temperature

Several indicators were used to evaluate the change in temperature. The indicators were divided into five categories as shown in figure 11. On average, 39% of the respondents mentioned an increase in temperature was depicted by drying of rivers and decrease in rainfall amount, 34% drying of rivers, 15% decrease in rainfall amount, and 3% loss of biodiversity (Figure 11). This is important to farmers and beekeepers because temperature influences the quality of honey and other activities in the ASALs. Temperature affects most of the activities in ASALs. The respondents understanding of factors to evaluate the temperature was based on effects of temperature on their daily socio-economic activities. Drying of rivers is associated with drought.

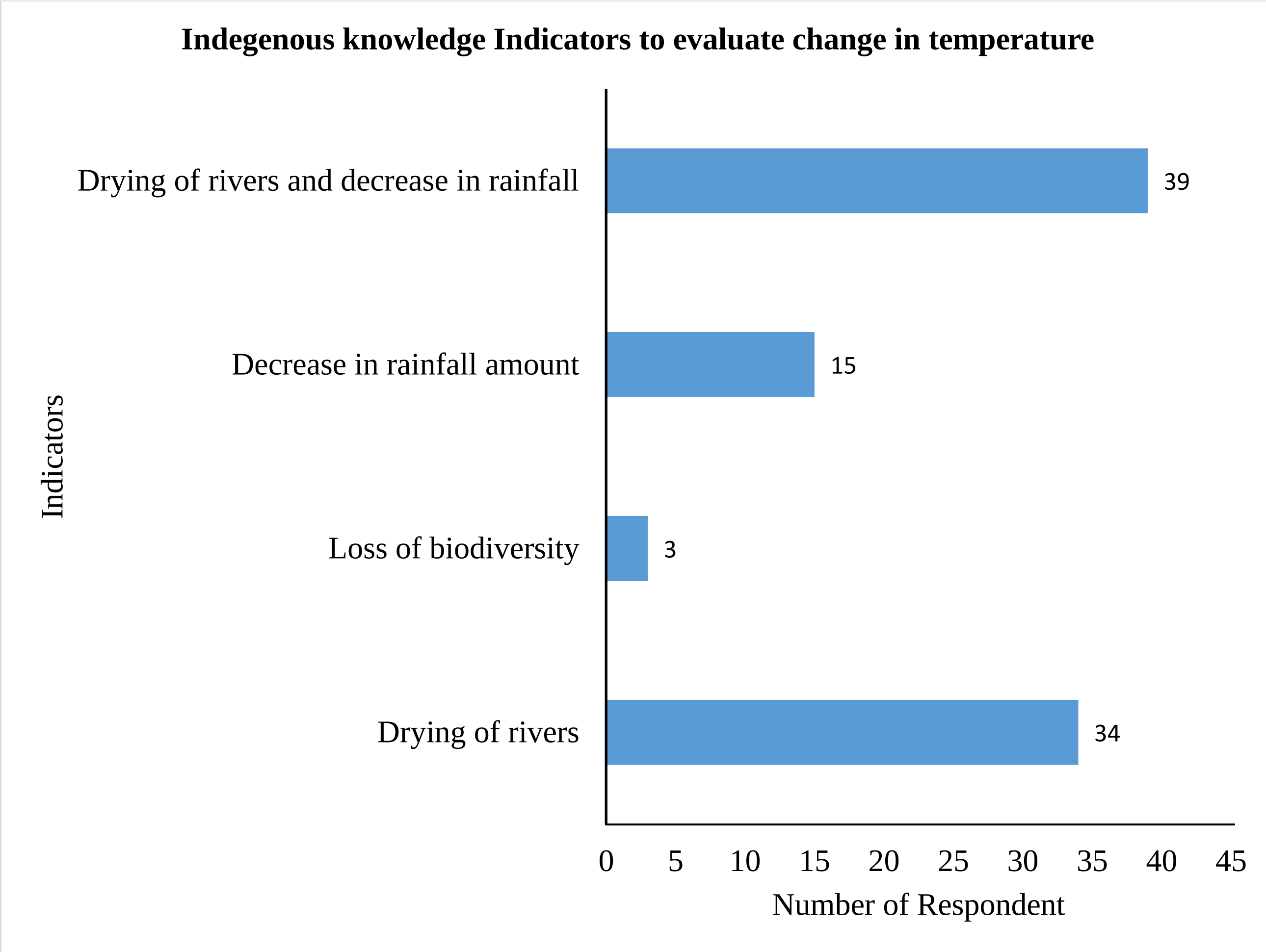

Figure 11: Indicators used to evaluate change in Temperature.

4.4 Relationship between rainfall variability and forage phenology

4.4.1 Plant species preferred by the bees

The respondents identified 19 plant species that the bees prefer (Table 11) which included trees, shrubs, grass and farm crops. Information obtained from the FGDs and the key informant was that immediately it rains the *Acacia tortolis* flowers sprout out immediately hence the bees collect nectar for brood development. However, the respondents acknowledged that the bees prefer collecting nectar from particular plant species. This is because of the adequate nectar, pollen and the energy it contains (Eischen and Graham, 2008). The results imply the ability of the local people to apprehend the different types of plant species that the bees prefer and their flowering period. The findings are in line with Delaplane *et al.* (2010) and Teklay (2011) who reported that local farmers are well informed in relation to the type of forage the bees prefer and their flowering period. Furthermore, results were in accordance with another study by Mattu *et al.* (2012) in Himalaya and Abou-Shaara (2014) in Egypt, who found out that bees have preference on type of forage that they collect nectar and pollen and source of water.

The forage availability varied from one area to another and from one season to another. For instance, the abundance of the *Acacia mellifera and Acacia tortolis* varied from lowland valleys towards the hills. They are more abundant at valleys and less abundant on the hills (This is illustrated in Plate 1). *Acacia brevispa* and *Acacia reficiens* are dominant plant species in Ratat. This was different to Marigat where *Acacia mellifera* is dominant. Plant diversity affects the quality of honey, which differs from one geographical area to another thus influencing the bee population. Gichora *et al.* (2003), Kimitei, and Korir (2012) and Kimani (2015) acknowledged the role of indigenous knowledge on forage preference by bees. However, with changing and variation in weather, there is decline in plant species diversity in ASALs due to frequency of droughts that have negative impacts on bee population and hence low honey production. This was similarly reported by Wasonga *et al.* (2011) that, the abumdance of perrenial plants in Baringo has decreased because of the decrease in rainfall that has led to drought escalation.

Table 11: Ranking of the common preferred bee flora

Rank	Scientific name	Local name	Frequency	Status
1.	*Acacia mellifera*	Ng'orore	78	More abundant
2.	*Acacia tortolis*	Sesiet	73	More abundant
3.	*Croton dichogamus*	Kelelwet	46	More abundant
4.	*Acacia eliator*	Trionde	41	More abundant
5.	*Acacia reficiens*	Parsul	36	Abundant
6.	*Acacia brevispa*	Kornis	31	Abundant
7.	*Euphobia species*	Mutangari	26	Abundant
8.	*Balanites aegyptiaca*	Ng'oswe	25	Abundant
9.	*Acacia senegal*	Chemanga	19	Abundant
10.	*Combretum molle*	Kemel	15	Abundant
11.	*Mimusops kummel*	Lolowe	13	Abundant
12.	*Terminalia brownie*	Bromi/Koloswo	13	Abundant
13.	*Euclea divinorum*	Uswe	8	Medium
14	*Boscia angustifolia*	Likwonde	5	Medium
15.	*Terminalia superba*	Noiwet	4	Medium
16.	*Cissus rotundiflora*	Rorowo	3	Medium
17	*Olinia rocheatiana*	Chepchoboiwo	3	Medium
18	*Grewia similis*	Sitewo	2	Medium
19	*Zea mays*	Maize	2	Seasonal

1  2 

3

Plate 1: The abundance of flora decreasing towards the roadside (1), Euphorbia species most preferred by bees (2), and poisonous plant with a long flowering duration (3).

4.4.2 Flowering of the plants

4.4.2.1 Variation in flowering

Results in Table 12 show that, 99% of the respondents indicated that variation in weather affect flowering and 96% indicated that there is change in flowering pattern in the past 5 years as a result of rainfall variability (Table 12). There is evidence to suggest that variation in weather has had major impacts on flowering of plants. The change in flowering is triggered with variation in weather parameter especially temperature and rainfall. The unpredictable weather coupled with increased sunlight intensity and the physicochemical parameters of soil affects natural resource distribution and plants reproduction. A study by Von Holle *et al.* (2010) revealed that, flowering of plants is triggered by environmental changes of the season which alters the phenophase of plants. Different plants produce flowers at different season depending on the water availability and the physicochemical characteristics of the soil (Riedinger *et al.*, 2014). According to Liseki, and Boniphace (2008) and Delaplane *et al.* (2010), seasonal variability in weather has led plants to produce flowers late or even earlier and this determines specific activity in managing the beehive in relation to variation in flowering, since farmers monitor the change in the season in order to manage the bees and monitor their progress.

Table 12: Respondents' perception on flowering of plants

Variable	Frequency
Variation in weather in relation to flowering	
Agreed	99
Do not Agree	1
Change in flowering in the past years	
Change	96
No change	3
Do not know	1

n=100

4.4.3.2 Seasonal variation in rainfall and plant phenology

The FGDs and key respondents reported that immediately it rains *Acacia tortolis* flowers sprout out immediately and the bees collect nectar from the tree and use it as food for the brood. The respondents reported that the bees do not make honey using the forage from *Acacia tortolis*. Furthermore, there is a trade-off between duration of flowering and temperature, and it was revealed that flowering continue for a long duration when rainfall is distributed throughout the year and hence plenty of forage for bees. This was similar with Von Holle *et al.* (2010) results who reported that, flowers have long duration during the cooler season in Florida. Majority of the respondents who reported the decrease (70%) in the duration of flowers was significant higher ($p=0.00$, $\chi 2=110.16$) (Table 13). This was due to the decrease in rainfall and prolonged drought. Variation in weather alters the vital component of natural systems such as rainfall, temperature and land cover this can facilitate competition among native and non-native species (Jebiwott *et al.*, 2016) with low potential for producing forage for bees limiting honey production.

Table 13: Respondents perception of the relationship of rainfall variability and duration of flowering

Duration of flowers	Frequency	**$\chi 2$**	**P**
Decreasing	70	110.16	0.00
Increasing	13		
Stable	13		
Did not know	4		

n= 100

According to Ngaira (2005), the severity, frequency and magnitude of drought has increased in Kenya from the year 2000. In some circumstances it is usually experienced yearly in dry areas of Kenya and this has a major influence on vegetation cover (Kosonei *et al.*, 2017) and plant phenology (Davies *et al.*, 2013). Because of water stress, plants will limit their physiological process to cope with the changing condition.

It was reported by FGD and Key informant that, immediately the rain season began the grass species sprout and thus an increase in flower that bees prefer. It was revealed that the type of forage the bees collect nectar and pollen from determines the quality and taste of honey. According to the key informant at KARLO Marigat, the quality and taste of honey from Baringo County varies from other honey in Kenya. This was because Baringo has a lot of diversity of plant species that the bee visits. Some of the respondents reported that the honey made from grass species has different sweet taste. In a study by Wasonga *et al.* (2011) in Baringo, it was revealed that the sprouting of grass and their abundance have decreased drastically. Another study in Marigat by Kosonei *et al.* (2017) found out that, there have been a decrease in grass species and abundance of trees species in riparian zones. This was expressed because of decrease in the amount of rainfall and increase in temperature.

The results in table 14 show that, 38.6% of the respondents reported that there is a decrease in the quantity of flowers and the change was much significantly higher ($P<0.00$, $\chi2=30.50$) and only 18.8% of the respondents reporting that the change was very much. This result implies that the erratic rainfall has led to plants to change their physiological process to adjust with the condition. This was in agreement with Primack (1985), Stratton (1989) and Miranda *et al.* (2011) whose results indicated that, decrease in rainfall that has led to bees collect nectar and pollen from other plants whose nectar and pollen does not provide quality honey. In some circumstances especially in Ratat and Kamung'eyi the bees opt in collecting nectar from poisonous plants that have a long flowering duration.

Because of drought, the bees migrate to areas where there is nectar and they come back immediately the season change especially when there is more nectar and pollen. This has reduced the frequency of harvesting honey once or twice a year. For example, *Balanites aegyptiaca* (Ng'oswe) flowers once per year and the flowers have a long duration. Plants have to alter their metabolic activity in order to cope with water stress. According to (Goodwillie and Ness, 2005) change in pollination mode leads to changing number of flowers produced by plant reducing the amount of nectar and pollen available for the bees. Barrett *et al.* (1994) found out that, pollination would influence the number of flowers and the longevity of the flowers display. The respondents affirmed that the duration of flowers has changed because of the erratic rainfall. This implies that the longer the duration of flowering, the higher the nectar and pollen is available for bees hence high honey production. However, some plants have a short life span as coping strategy hence they have short flower duration and affect honey production.

Table 14: Change of the quantity of flowers

Extend of change	**Percentage**	**$\chi 2$**	**P**
Very much	18.8	30.500	0.00
Much	38.6		
Minimal	15.6		
Very minimal	27		

n=100

4.4.3.3 The correlation of rainfall amount and plant phenology

There is positive and significant correlation between rainfall amount and quantity of flowers (r= .423; N=100; P=0.00) (Table 15). The survey results revealed that with decrease in rainfall amount, there is decrease in quantity of flowers. This was in agreement with the study by Elsa *et al.* (2007) who reported that, plant phenology depends more on variation in precipitation in the tropics than variation in temperature. With the erratic cyclone rainfall, bee forage becomes scarce and therefore this influences the activity of the bees.

Table 15: Correlation of change in rainfall amount and change in quantity of flowers

		Change in the quantity of flower
Variation in rainfall amount	Correlation coefficient	.423**
	Sig.(2 tailed)	.000

**Correlation is significant at .001 level (2-tailed)

There is evidence to suggest that, the erratic cyclonic rainfall has led to variation in flowering thus affecting honey production. As the distance from the beehive to nearby forage increases, honey production decreases. The bees will consume more honey for daily activity and hence the available honey will be low. According to (Ricketts *et al.*, 2008), variation in pollination of plants is because of variation of weather thus leading to variation in flowering of plants. Therefore, the author postulated that, this has led to flowering to decrease or increase with distance from the beehive. According to Eischen, and Graham (2008), the bees need more energy to fly for a long distance thus, they will have to fuel their wings by consuming more pollen because it has higher energy content. This decreases the amount of pollen and nectar available for honey production.

Some species are able to alter their phenology in order to respond to change in weather. Therefore, bee forage decrease because of seasonal variation in climate (Kebede and Lemma, 2007). In a study by Tessega (2009), Haftom *et al.* (2013) and Yetim (2015) in Ethiopia, it was revealed that the seasonal variation in flowering affects honey production. According to Bista, and Shivakoti (2001), seasonal variation plant phenology is because of the seasonal fluctuation of climatic conditions and topographic characteristics of the area. Furthermore, the soil characteristics vary in relation to topography, thus plants will blossom seasonally causing variation in the bee production and the well-being of various organisms inherent in such ecosystems (Gao *et al.*, 2014).

It was depicted that, the shortage for forage for bees starts from November through December to March. During the month of January to March, there is critical shortage of forage for bees due to dry conditions that prevalent in ASALs areas. This was attributed to low rainfall that is received during the period between January to March. It is evident that plant species increase their fitness by flowering at different time in an ecosystem (Gordo and Sanz, 2010). The low rainfall amount and temperature affect phylogenetic of plants and plant flowering phenology especially the number of flowers and timing of flowers development (Crimmins *et al.*, 2010). Robbirt *et al.* (2011) reported that, there is a significant relationship between peak for flowering and temperature.

4.5 Effects of temperature and rainfall variability on honey yield

4.5.1 Honey production in Marigat and Ratat.

They results indicated that all (100%) the bee farmers practice migratory beekeeping. Based on their experience in beekeeping, they place the beehive in an ideal position for the bee to inhabit along the migratory bee routes. Bees are some of the organisms that follow a migratory pattern. he and hence famers do place more beehives and they clean the old beehives during the swarming season. This increases the chances of having beehives inhabited by the bees. Some respondents reported that, currently there has been decrease in chances of the bees settling in the beehives as compared to the past years. The possibility of the bees to inhabit a beehive has decreased and sometimes this takes long than usual because of the unfavourable condition.

The results on Table 16 shows that, 85% of the respondents affirmed there is change in the migratory patterns in the past 5 years with only 84% of the respondents agreeing that the change in the migration pattern is because of change in weather. Owing to the variation in weather, the respondents asserted that the bees migrate from lowlands to and from highlands (Tugen hills). They believe that variation in climate and plant phenology has a significant influence on migration of bees. It is evident that the bees migrate to areas with adequate nectar, pollen and water. As drought condition increase, the bees become more vulnerable to this impact.

It was noted from the information from FGDs and key informants that the swarms of bees have reduced in number and when they migrate to highlands, the number of bee colony swarming back to lowland has decreased. There is probability that the bees prefer the highland since there is decrease in the amount of flowers in the lowland. Similar observation were reported by Malisa, and Yanda (2016) in Tanzania that bees prefer areas with high amount of nectar and pollen on flowering plants. According to Yetim (2015), migration of bees is influenced by the availability of pollen and nectar. The results of this study was also in agreement with those of Sharma *et al.* (2013) who reported that bees have a migration pattern and as season changes and farmers objectively set their beehive during the migration period for the bees to occupy them during the migration period.

Table 16: Migration pattern of the bees

Variable	Frequency
Migratory beeping	
Agreed	100
Change in Migration pattern	
There has been a change	85
No change	15
Variation in weather has influenced migration	
Agreed	84
Did not Agree	15

n=100

4.5.2 The relationship between rainfall variability and honey yield

Results on table 17b shows that, majority (60%) of the respondents harvest honey twice a year, 25% harvest once, 14% harvest three times and 1% harvest more than once per year. This can be attributed to the rainfall patterms in the area. This area mostly receive a bimodal rainfall with peak varying yearly. However, the farmers acknowledged that the peak for honey harvesting corelates with rainfall availability. The peak for honey production is on June and from August to September. However, majority of the respondents said they do not keep records of the honey they harvest (95%). In a study by Teklay (2011) in Ethiopia, the author found out that the peak for honey harvesting is related to high flow of pollen for the bees. Another study by Yetim (2015) revealed that, a low proportion of bee farmers harvest more than thrice per year.

Table 17: Trend of honey yield

Variable	Frequency
Annual Honey harvest	
Once	25
Twice	60
Thrice	14
More than 3 times	1
Trend in honey production	
Increasing	19
Decreasing	62
Stable	19
Varies yearly	12

n=100

Rainfall variability has a moderately strong positive and significant effect on honey yield (r=3.69; P<0.00; N=100). As Rainfall amount decrease, there is a decrease in honey production. A larger proportion (62%) of the respondents reported that honey production has decreased (χ^2=72.92; P=0.00) (Table 17). Therefore, there is evidence to suggest that the erratic rainfall aggravates stress on honeybees leading to low honey production. This implies the limited amount of rainfall amount coupled with the demand for water by the plants and the bees to carry out their physiological process and for honey production has led to low honey production.

Table 18: Correlation analysis of the relationship between Rainfall amount and honey yield

		Trend in honey yield
Variation in rainfall amount	Correlation coefficient	.369**
	Sig.(2 tailed)	.000

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

The seasonal rainfall duration has a moderately strong positive and significant effect on honey yield in the past 5 years (r=.460; P<0.00; N=100). This implies that honey production is dependent on the duration of the rainfall. As the rainfall duration increases, honey yield increases and vise versa. In a study conducted by Malisa, and Yanda (2016) in Tanzania, the author found out that decrease in rainfall has led to low honey yield. However, the author also articulated that, honey productiuon is high at moderate rainfall.

Table 19 Correlation of Rainfall duration and trend in honey yield

		Trend in honey yield
Variation in rainfall duration	Correlation coefficient	.460**
	Sig.(2 tailed)	.000

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

Honey bees need water to cool their hive and for honey production (Woyciechowski, 2007; Kovac *et al.*, 2010). However, in Marigat and Ratat, water is deficient and hence during dry season when there is water scarcity, the bees abscond the beehives thus a decrease in honey production. The respondents alleged that the trend of the bees absconding from the beehive has increased. This was as a result of factors associated with weather on the bees. This was similarly reported by Kimitei, and Korir (2012) in Kibwezi where bees abscond their beehive because of insufficient water because bees collect water from the nearby source.

On average, 59% of the respondents reported water is scarce, 26% less available and 18% available. Forty four (44%) of the respondents stated that the rivers are the main source of water for the bees, 26% streams, 12% water pans, both water pans and rivers 12% and only 3% reported they collect water from borehole (Table 20). In Endao village, they were several borehole where the bees collect water. Besides, drought frequency in Marigat has incraesed in the past years (Kosonei *et al.*, 2017). The stream flow, river flow and refilling of the waterpan depend on rainfall which is contary in relation to the receive eratic rainfall receive in this area. The results implies that their is an imbalance between water supply of water and demand of the water in the ecosystem. The exerberated drought cuopled with increased intensity of temperature has led to escalation of this imbalance. Therefore the water is not sufficient to meet the demand.

Table 20: Status and source of water

	Status of water (n=100)		
Source of water	**Scarce**	**Less available**	**Available**
Water pans	6	4	2
Streams	12	15	2
Rivers	29	5	10
Water pans and rivers	1	0	2
Other	8	2	2

4.6 The relationship of Honeybee pest inspection and variation in climate

4.6.1 Inspection of the beehives

In the survey results, 93% of the respondents they inspected their beehive both internal and external (Table 21). However, only 48% of the respondents do visit their beehive frequently. These is purposively to check the status of the hive and to clean the beehive. Also, they regularly check the beehive if the swarm of bees have inhabited. It was reported that 5% of the respondents only do internal inspection before the bee colony inhabit the beehive. However, according to Kebede, and Lemma (2007) and Kinati (2010) indicated that, the majority of the local farmers had limited knowledge about internal inspection of beehives in Ethiopia. These implied that majority of the farmers observe the beehive externally without thorough inspecting internally and this can be attributed to their illiteracy level.

Table 21: Beehive inspection

	Type of inspection (%) (n=100)		
Frequency of inspection	External and internal inspection	Internal inspection	External inspection
Rarely	12	0	0
Frequently	35	3	2
Sometimes	46	2	0

4.6.2 Honeybee pests

Majority of the bee respondents (54%) reported that honey badger as a serious pest causing major loss to beehives. Honey badger was ranked the first followed by Ants (Table 22). Honey badgers are the most destructive of all pest reported because they do climb the tree and drop the whole beehive on the ground, thus destroying their whole beehive. The results are similar with the findings by Maurice (2004) and Muli *et al.* (2015), who reported that honey badger is a threat to beekeeping in Kenya. The incidences of honey badger in Baringo were also reported by Gichora *et al.* (2003) and Berem (2015).

Table 22: Ranking of the major bee pest and their status

Ranks	Major pest	Frequency	Status of the pest			$\chi 2$	P
			Increase (f)	Decrease (f)	Stable (f)		
1st	Honey Badger	54	70	5	20	**114.00**	**.000**
2nd	Ants	38	66	3	18	**94.32**	**.000**
3rd	Wasps	31	18	19	38	**10.16**	**.017**
4th	Lizard	26	13	28	34	**9.36**	**.025**
5th	Rats	17	32	20	15	**9.52**	**.023**
6th	Others	12	25	3	6	**106.16**	**.000**

According to Gichora *et al.* (2003), the incidences of honey badger are common in remote areas. For instance, they were few cases honey badger reported attacking the beehive nearby to the homestead and even along the road. However, Masehela (2017) reported that, the incidences of honey badger are more when a beehive is located in forest habitats where the honey badger inhabits. In Kamung’eyi village, the incidences of honey badger were low since most of the trees in the area are tall and the honey badger cannot climb to the top. However, ants were the major pest that is prevalent in the area. According to Teklu (2016), ants destroy the brood reducing honey production and leading to the bees abscond the beehive because they are nuisance and they feed on both dead and alive bees. Information from the key informant was that majority of the farmers in Kamung’eyi place their beehives indirect contact with the tree, which has led to high infestation by ants. The impacts of ants vary in relation to the type of beehive and type bee species (FAO, 2005). Other pest reported includes; snakes, bee eating birds, tree squirrel, and spider.

Lizards inhabit near the beehive and feed on the bees, and sometimes they find a way into the beehive. Bee-eater birds feed on foraging bees and the rats create their house nearby the beehive that has led to absconding of the bee. However, snakes were new cases as bee pest in Baringo County. They were common in Arabal village as the major bee pest. Tesfay (2014) in a study in Ethiopia and Kajobe *et al.* (2016) in Uganda found out snake as pest but the incidences were minimal in Uganda. Low honey production can therefore be attributed to climate variability and increase in pest infestation as well. This was in agreement with Malisa, and Yanda (2016) findings in Tanzania. Despite the changing season that favour the pest prevalence. Majority of the respondents reported an increase (70%) in the incidences of honey badger ($P=0.00$, $\chi2=114.00$) and ants ($P=0.00$, $\chi2=94.320$) (Table 22). This as a results of the condition favouring the pest prevalence has prolonged over the years. Kosonei *et al.* (2017) reported Marigat sometimes experince drought yearly.

Prevalence of pest has a negative significant effect on honey yield ($r=.-264$; $P<0.001$; $N=100$) (Table 23). This implies that, with an increase in the incidences of pest, the farmers incurs a lot of loss since honey yield will decrease. This pest incidence increase with an increase in drought perid. This can be attributed to the flow of nectar which is high at the beginning of dry period. Therefore, the flow of honey is also high leading to high incidences of pest in dry period as they feed on honey. The resopondent alledged that, sometimes the bees abscond the beehive when they face the threats from the pest. Munyuli *et al.* (2016) had similar results with this study in Democratic Republic of Congo. Furthermore, according to Harrison, and Fewell (2002) study, hive activity are high at high temperature leading to more honey production when temperature are high. According to Mcmenamin *et al.* (2017) study on the impact of hive type on the behaviour and health of honey bee colonies (*Apis mellifera*) in Kenya, majority of the bees abscond their beehive during the hot and dry period. Furthermore, the author found the pest infestation led to the bees absconding their beehive.

Table 23: Correlation analysis of the relationship between prevalence of pest and honey yield

		Honey yield
Pest prevalence	Correlation coefficient	-.264**
	Sig.(2 tailed)	.001

Correlation is significant at level 0.01 (2 tailed)

Variation in climate has led to organism to thrive and the condtion may be favourable for some organism while others they sucumb to the changing environmrntal condtion. Analysis of the survey data indicated that 65% of the respondents reported that the incidences of pest infestaion are high during the dry period and 23% reported during the wet season (Figure 12). Information from the key informats was that there is high incidences for honey badger are more during dry season.

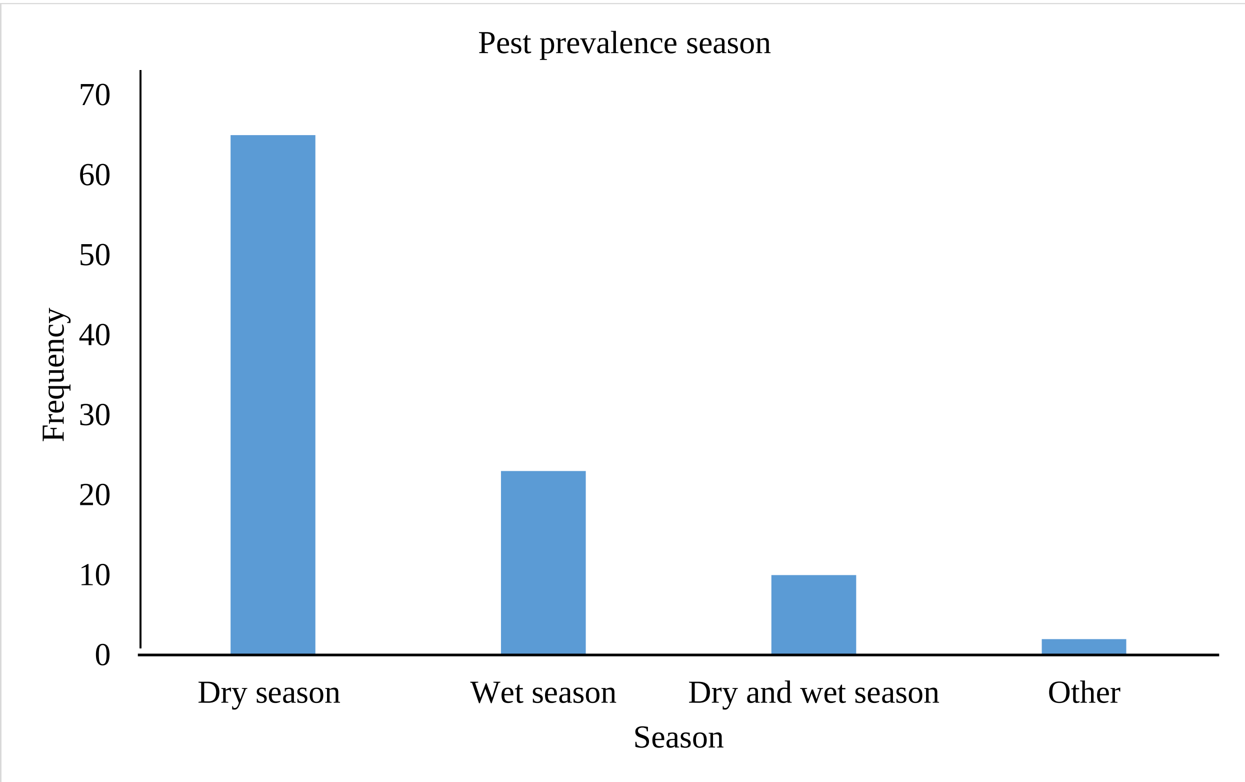

Figure 12: Pest seasonal prevalence

The results imply drought as a factor that has led to high pest infestation. There is a possibility that with the limited available food and escalation of drought incidences, the organism ought to cope with the situation. Therefore, the bees are more vulnerable because during the drought season there is high flow of nectar/pollen and they ought to make more honey which is food for some pest. However, some pest like the bird eating bees, lizards and snakes feed on the bees. This was similar to Chemurot *et al.* (2016) and Munyuli *et al.* (2016) results who reported the prevalence of Varroa mites infestation was high during the dry period than in the wet season in Uganda since this condition was favourable for them to blossom. However, according to Teklu (2016), the author reported high pest infestation during the rainy season in Ethopia because of the flow of honey. It was depicted that, farmers do hang their beehive on a piece of wire to reduce the incidences of honey badger. This is illustrated in plate 2. They also smear grease on the wire to reduce incidences of ants.

1

2

Plate 2: Traditional log hive made with wires (1) and traditional log hive hanged on a tree (2).

CHAPTER FIVE

SUMMARY OF FINDINGS

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study investigated the impacts of climate variability on honey production. This involved assessing beekeepers' farmer perception on variation in rainfall and temperature in relation to honey production. The results indicated there has been a variation in rainfall and temperature that has led to increase in severity and magnitude of drought. The rainfall has decreased and the intensity of temperature has increased steadily.

Women participation in beekeeping was low with men dominating and most of the respondents were farmers. These respondents were knowledgeable about the relationship between climate variability and honey production. Variation in rainfall has had a significant effect on honey production by affecting plant phenology and water availability for bees. Furthermore, increase in frequency of drought has led to high incidences of pest. With regard to honey production, majority of the farmers reported the yield has decreased. They associated with decreasing rainfall amount and duration, increase pest incidences, decrease forage for bees and water scarcity. Therefore, there is evidence to suggest variation in climate has had negative impacts on honey production in Baringo.

5.2 Recommendations

i) There is need to disseminate weather information to the local community and educate them on the need to plan for the changing season.

ii) Rehabilitation of ASALs by planting flora that have long flower duration, alternate seasonally, preferred by bees and are drought resistance.

iii) The local community needs to be enlightened on the need to form self-help group. These will provide them a platform to access more incentives and be able to share more information in relation to honey yield and to put more emphasis on providing food and water to bees during dry season.

iv) There is need for regular inspection of the beehive to enable management of the beehive hence reducing the incidences of pest infestation. Since the incidences of pest infestation are increasing, the beekeepers need to seek for extension services.

5.3 Further research

1. The study has produced a relevant information on climate variability and honey production. The important area research study is on relative abundance of flora preferred by bees and the quantity of pollen and nectar the plant produce.

2. Establish the actual quantity of honey yield over a period.

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APPENDICES

Appendix 1: Questionnaire

My name is Akala Haron, I am a Master's student pursuing master's degree in Environmental Science in the department of Environmental Science of Egerton University. I am interested in studying impacts of climate variability on honey production in Baringo County. The information provided will be used entirely for academic purposes and personal information of respondents will be kept confidential.

SECTION 1: Details

County		Division	
District / Sub-County		Location	
Sub-location		Village	

SECCTION 2: Demography

1.	Name of the respondent						
	Gender of the respondent	Male ☐		☐ Female			
	Location	☐ Marigat		☐ Ratat			
	Marital status	☐Married	☐Divorced	☐ widowed	☐ single		
	Educational level	☐ No formal education	☐Primary	☐Secondary	☐Tertiary		
	Age	☐ 20-25	☐ 26-31	☐32-37	☐38-43	☐ 44-49	☐ 50+
	Occupation	☐ Farmer	☐ Teacher	☐ Enterprise	☐ other		

Section 3: Socio-economic activities

2. How many honey do you have? Traditional hive ☐ Modern hive ☐
3. How did you start beekeeping? ☐Own interest ☐ Influenced by neighbor and relatives ☐ Inherited from the parents ☐ Awareness by agriculture extension ……Other reason (specify)
4. How long have practiced beekeeping? ………….
5. Where do you keep the bees colonies?

Site of the hive	Tick appropriately	Number of hives
Hanging on homestead trees		
In the jungle		

Nearby to the homestead		
Backyard		

Section 4: Climate variability

6. Have you ever noticed the following changes in weather over the last 5 years?

	Trend over the last 5 years(tick the appropriate trend)		
	Increasing	**Decreasing**	**No change**
Amount of rainfall	☐	☐	☐
Duration of rain	☐	☐	☐
Severity and frequency of drought	☐	☐	☐
Temperature	☐	☐	☐

7. If you answer the above question (6), change in temperature, what are the indicators do you use to evaluate climate temperature?Drying of rivers and streams ☐ Loss of biodiversity ☐ Decrease in rainfall amount ☐

Section 5: Effects of climate variability on forage availability and distribution

8. It is known that Baringo County is among major honey producers in Kenya; there are different types of flora that support the activity. Kindly list them and rank them from more abundance to less abundance.

	Species abundance				
Local name of the flora	More abundant	Abundant	Medium	Rare	Very rare
1.	☐	☐	☐	☐	☐
2.	☐	☐	☐	☐	☐
3.	☐	☐	☐	☐	☐
4.	☐	☐	☐	☐	☐
5.	☐	☐	☐	☐	☐
6.	☐	☐	☐	☐	☐

9. Do you think variation in weather has led to the change in flowering and anthesis of flora.

☐ ☐

Yes No

10. If yes, has the flowering of flora changed in the past years? ☐ Yes ☐ No

11. How is the change? ☐ Very much ☐ Much ☐ Minimal Very minimal ☐

12. Which season of the year does shortage in bee forage does happen.

Season	Month of the year	Critical shortage	Less shortage

13. Have ever noticed the impacts of climate variability on flora?

	Trends over the past years		
	Increasing	Decreasing	Stable
Quantity of flowers			
Duration of flowers on the flora			
Quantity of flora preferred			
Invasion of un-preferred flora			
Poisonous plants			

Section 6: Climate variability and Honey production

14. What are the driving forces that influenced you to start honey production?

☐ Income ☐ Home consumption ☐ To get skill ☐ others specify

15. How many times do you harvest honey per year from a single beehive? ☐ Once ☐ Twice

Thrice ☐ More than three times ☐ Sometimes never ☐

16. . When is the peak for honey harvesting in the year?...........

17. Do you practice migratory beekeeping? ☐ Yes ☐ No

18. How long does your colony remain in the hive?0-1yrs ☐ 2-3yrs ☐ 4 years ☐

19. Are there any patterns that the bees follow? ☐ Yes ☐ No

20. Are there any change in the migratory routes? ☐ Yes ☐ No

21.

If yes, do you think change in weather modification has led to change in the migration?	Yes ☐	No ☐
Is there variation in honey yield production in past 5 years?	Yes ☐	No ☐

If yes what is the trend?	decreased ☐	increased ☐	Stable ☐	varies yearly ☐

Is water available for honeybees	Yes ☐	No ☐

22. If yes, tick in the table below

Water	Tick for yes
Scarce	☐
Less available	☐
Available	☐
More available	☐

23. Where do the honeybees get the water? Water pans ☐ Stream ☐ River ☐ Ponds ☐ Other (please specify)

24.

Do you associate insufficient of water to colony migration	Yes ☐	No ☐
If, no how do you provide water for honeybees?		
Does water availability affect production?	Yes ☐	No ☐

25. If it has decreased, kindly use the options to answer the following questions as they have led to low honey production from agreement to disagreement

1 strongly agree 2 Agree 3 Disagree 4 Strongly Disagree

Factors leading to honey production	**1**	**2**	**3**	**4**
Variation in temperature				
Variation in rainfall				
Incidences of pest and predation				
Change in flowering and anthesis.				
Distance from the beehive to nearby flora				
Absconding				
Lack of forage				
Hive shading				
Low availability of quality bee forage				

Section 7: Climate variability and Pest infestation

26. Do you visit your beehive and colonies? ☐ Yes No ☐

27. If yes, which type of inspection do you always do? ☐ External beehive inspection ☐ internal beehive inspection ☐ Both external and internal inspection

28. How often do you inspect the beehive? ☐ Rarely ☐ Frequently ☐ Sometimes

29. Which kind of pests have you noticed infest your beehive? Put them in the rank.

No	Pest	Rank	Increase	Decrease	stable
1	Ants		☐	☐	☐
2	Honey badger		☐	☐	☐
3	Lizard		☐	☐	☐
4	Wasps		☐	☐	☐
5	Rats		☐	☐	☐
6	Others (state)		☐	☐	☐

30. If the pest infestation is increasing, what are factors that lead to increase in pest infestation?

☐ Increase in drought period ☐ Poor hive management ☐ Human activity ☐ Increase in wet season

31. Which season of the year do you experience high pest infestation? ☐ Dry season ☐ Wet season ☐ Others (specify)

Appendix 2: Interview schedule for FGD

1. Based on your on view, does availability of flowers affect migratory behavior of bees
2. Water is essential for honey production. Climate variability has led to reduction in water quantity. Does this affect honey production and migratory behavior of bees?
3. What are predisposing factors based on climate variability for pest infestation?
4. How is the trend in the number of honeybee colonies in the area? Is it increasing or decreasing? Why?
5. Has the swarming trend changed? If yes, what could be the cause?
6. Does honey take long period to be ready?
7. Is trend increasing or decreasing in honey production? Explain the reason
8. Do you associate low honey production is because of climate variability?

9. Has the quantity of honey changed over the past 5 years?
10. Are there new pest that have emerged because of the weather condition suitable for it to thrive?

Key informants

Name

Position

Date

1. Have you noticed variation in temperature and rainfall in the past years?
2. If yes, what are the changes?
3. From your records, has honey production varied based on variation in climatic weather condition?
4. What are the most common pests reported by the farmers that are rampant?
5. Which season of the year when pest infestation is rampant?
6. Major bee forage and their flowering period in the year

Appendix 3: Rainfall data

Amount of Rainfall and Number of rainy daisy for the period of 2011 - 2016for Marigat Sub-county (mm)

	Year and Number of rainy days											
Months	**2011**		**2012**		**2013**		**2014**		**2015**		**2016**	
	Amount	NRD	Amount	NRD	Amount	NRD	Amount	NRD	Amount	NRD	Amount	NRD
January	0	0	0	0	0	0	7	2	0		75	
February	0	0	2.2	2	0.6	1	2	1	0		30	
March	90.6	6	0	0	0	0	11	2	0		29	
April	108.6	7	237.6	18	160	8	13	3	106		115	
May	84.0	4	127	22	16	3	9	3	61		91	
June	365.7	21	150	9	101.2	4	99.5	7	125		47	
July	244	7	330.2	21	30.0	4	5	2	32		114.6	
August	146	12	331.5	32	86.6	6	91	8	0		37.2	
September	146	12	222	12	32.8	13	47.5	5	0		25	
October	108	4	141.2	8	31.1	14	30	6	21		0	
November	233.7	9	41.7	10	71.2	15	60	5	125		0	
December	11.5	2	40	2	77.0	9	145	6	0		0	
Total	**1,538.1**	**84**	**1632.7**	**136**	**608.7**	**77**	**536**		**470**		**563.8**	

Source Marigat District water Office, 2017. (NRD-Number of rainy days)

Interviewing the respondent with the help of the local enumerator at Kamung'eyi

Appendix 4: NACOSTI License

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: 020 400 7000,
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Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref. No. **NACOSTI/P/17/52428/17403**

Date: **30th October,2017**

Akala Haron
Egerton University
P.O. Box 536-20115
EGERTON.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"An assessment of impact of climate variability on honey production. Case study for Ratat and Marigat Areas of Baringo County"*** I am pleased to inform you that you have been authorized to undertake research in **Baringo County** for the period ending **30th October, 2018.**

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

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Baringo County.

The County Director of Education
Baringo County.