UNIVERSITY OF NAIROBI

THE EFFECT OF CLIMATE CHANGE ON MILK PRODUCTION IN SMALLHOLDER FARMS; A CASE OF NANDI COUNTY, KENYA

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DECLARATION

I declare that this thesis is my original work and has not been submitted elsewhere for Examination, award of a degree or publication. Where other people's work or my own work has been used; this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements

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ABSTRACT

Climate variability changes ultimately impact agriculture and food productivity, and security. In Kenya, milk production is predominantly smallholder and dependent on rain-fed agriculture. To ensure that dairy farmers are empowered to prepare effectively, adapt and mitigate the effect of extreme climate changes, this study aimed to investigate the effect of climate change on milk production in smallholder farms; the case of Nandi county, Kenya. Primary data was sourced through structured questionnaires, focus group discussions (FGD), and key informant interviews. Secondary data sources data included observed and climate model outputs (precipitation, maximum and minimum temperature), fodder availability (Normalized Difference Vegetation Index –NDVI and Soil Moisture), and milk production (milk marketed). The study used a concurrent triangulation research design to allow mixed-methods research methodologies. Trend analysis and spatial plots were used to analyse spatiotemporal variability of past and future climate (2021-2050) based on RCP45 and RCP85. The relationship between climate and milk production was based on correlation and multi-regression analysis. Graphical and pie chart analyses were also used to present the results. Past and projected precipitation showed bimodal patterns with high spatial and temporal variability with remarkable differences between baseline and projected precipitation under RCP45 (-19.5% to 11.0%) and RCP85 (-9.5% and 26.3%) scenarios. Past and projected maximum and minimum temperatures showed increasing trends. Monthly NDVI and soil moisture values were higher in April and November, while seasonal values were high/low in JJA/DJF, indicating high/low fodder availability. Milk production showed a positive change from 2007 to 2016, with the highest/lowest values in April/December. Computed percentage change in seasonal milk production showed increases of up to 186% (MAM), 183% (JJA), 202% (SON), and 214% (DJF), whereas annual milk production showed increases of up to 204%. Correlation analysis found low coefficients in precipitation and higher coefficients in minimum temperature at lag 0, 1 and 2. The selected models were based on different climate and fodder availability predictors and showed a positive relationship with milk production. Over 79% of households involved in milk production in Nandi County are male. Although the drought was the leading climate hazard affecting their grazing practices, other factors such as rainfall variability, unpredictability and extreme temperatures also affected grazing practices. The survey results indicated that observed changes in milk production, the amount of water available for the animal, body condition of the animal, heat detected, and growth of calves and heifers were negative in most of the wards in the County. The most important source of animal feed were natural pastures, mainly from own farms (86.9%), crop residue (62.6%), planted fodder such as Nappier grass (39.4%), and communal land (19.2%). The majority of farmers planted fodder in less than 0.5 acres of land for Napier (79.7%), Sorghum (54.3%), Rhodes grass (57.3%), Kikuyu Grass (49.4%), Lucerne (71.9%) and fodder Tree (82.1%) and conserved/preserved crop residue (88.2%), hay (39.9%) and silage (35.4%). Communal lands were overgrazed, and very little fodder was available, with the grass growth not beyond one foot. Methods used to address negative experiences of climate change include the use of conserved hay/silage (44.2%), buying of commercial feeds (40.9%), use of crop residue (74.6%), moving of animals to other farms (8.8%) and selling of animals (17.4%). Other measures adopted by households to help them avert negative climate change included the use of new fodder types/varieties, new planning methods, intercropping of different fodder, and conservation and preservation practices. Smallholder farms had also adopted Climate Smart Agricultural (CSA) technologies such as compost making (18.6%), use of biogas (2.5%), water conservation (56.6%), disease control (95.4%), planting of fodder trees (30.1%), reducing the number of animals (36.6%) and breeding using AI (63.4%). The study findings indicate that dairy productivity is highly sensitive to climate. Moreover, fodder availability which is also vulnerable to changes in climate, significantly influences milk production. Given the high spatial and temporal variability in these environmental factors, it is expected that the projected change will significantly challenge future dairy productivity, especially in Nandi County of Kenya. The study recommends the need to improve on monitoring of weather and climate by increasing observation stations and developing weather and climate products targeting milk production. There is also a need to develop climate-smart fodder varieties/production methods and adopt climate-smart fodder varieties/production methods. Moreover, policy makers need not only to promote the use of climate-smart fodder varieties/production methods but also mainstream climate change information into development planning, budgeting and implementation at national and county levels

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LIST OF ABBREVIATIONS AND ACRONYMS

AMCEN	African Ministerial Conference on the Environment
ASDSP	Agricultural Sector Development Support Programme
CC	Climate Change
CO_2	Carbon dioxide
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRU	Climate Research Unit
CSA	Climate Smart Agriculture
CSAG	Climate Systems Analysis Group
EADD	East Africa Dairy Development Project
ECMWF	European Centre for Medium-Range Weather Forecasts
FAO	Food and Agriculture Organization
FAO	Food and Agriculture Organization
FDG	Focus group discussion
GHG	Greenhouse Gases
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
LAI	Leaf Area Index
Mm	Millimeters
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Vegetation Index
NMHCs	National Meteorological and Hydrological Centers
NOAA	National Oceanic and Atmospheric Administration
^oC	Degree Celsius
RCA4	Rossby Centre regional atmospheric model
RCPs	Representative Concentration Pathways
SD	Sustainable Development
SDG	Sustainable Development Goals
SDP	Smallholder Dairy Project
SMHI	Swedish meteorological and hydrological institute
SSA	Sub Saharan Africa
THI	Temperature Humidity Index

Tmax	Maximum temperatures
Tmin	Minimum temperature
ToC	Tragedy of Commons
UH	Upper Highland
UM	Upper Midland
WCED	World Commission On Environment and Development,
WWF	World Wide Fund For Nature
EROS	Earth Resources Observation and Science
MALF	Ministry of Agriculture, Livestock & Fisheries

DEFINITION OF TERMS

Adaptation refers to a change process through which organisms and species become better suited to fit in their environment.

Climate Change is the permanent shift of weather conditions due to variations in the statistical distribution of weather patterns.

Climate variability is the way aspects of climate (such as temperature and precipitation) differ from an average

Climate-smart Agricultural Practices In this study, climate-smart agricultural practices refer to the use of environmentally friendly production applications to increase dairy productivity

Fodder Availability refers to a characteristic in which any forage grown to be fed to livestock composed of either entire plants, leaves or stalks of the crop is at hand when needed

Formal market refers to an organized market that is in accord with established forms and conventions and operates within boundaries of competitive rules, tax-regulation and is subjected to regulation by the authorities. This study referred to a market in Kenya through which milk is marketed within established channels.

Impact refers to a forceful result or a strong effect. This study refers to a consequence of climate change that is observable on fodder.

Mitigation refers to reducing the force or intensity of something unpleasant. This study referred to the efforts put in place by farmers and organizations to lessen the undesirable outcome of climate change in the study area.

Productivity refers to having the power to produce as indicated by a measure of output per unit of input. In this study, productivity refers to the sustained year-on-year milk yields.

Smallholder refers to a person who owns or rents a small farm for subsistence or commercial purposes. This study refers to a farmer who owns between 0.5 acres and 30 acres and keeps dairy cows and grows crops.

Spatiotemporal refers to a condition in which an item, an event or an occurrence has temporal qualities that belong to space and time. The term was used to assess rainfall patterns, temperature, soil moisture and vegetation cover over the years.

CHAPTER ONE

1 INTRODUCTION

1.1 Background Information

The earth's surface temperature continues to spike, more than in any preceding decade since 1850, with the temperatures exhibiting considerable decadal and inter-annual variability. IPCC sixth assessment report (IPCC, 2021) indicates that emissions of greenhouse gases from human activities are responsible for approximately 1.1°C of warming since 1850-1900 and finds that averaged over the next 20 years, global temperature is expected to reach or exceed 1.5°C of warming with projections indicating that climate change will increase in all regions in the coming decade. For 1.5°C of global warming, there will be increased heat waves, longer warm seasons and shorter cold seasons while at 2°C of global warming, heat extremes would more often reach critical tolerance thresholds for agriculture and health (De Vries, 2018; IPCC, 2021).

Global climate change has resulted in substantial variations in productivity of both irrigated and rain-fed crops and has led to a reduction in cereal production by between 1% and 7% ((Parry et al., 2007) and (Nelson et al., 2010)). The Intergovernmental Panel on Climate change (IPCC, 2014) noted that Africa is at a high risk of experiencing climate change (Serdeczny et al., 2015) as it heavily depends on rainwater for agriculture. At least 22% of the area under cultivation of the world's most important crops will be negatively impacted by climate change by 2050 (Campell et al., 2011). This underscores the contribution of predicting the effect of climatic changes on agriculture, which requires appropriate and dependable data, tools and models (Lobell et al., 2011).

Livestock, which contributes 12.9 % of globally consumed calories, is an essential global contributor to food security, supplying more than 27.9% of the protein consumed daily. It also sources 43% of the global Gross Domestic Product (GDP) from agriculture. It also provides milk, meat and eggs consumed by an estimated 700 million people in developing countries. In pastoral areas, livestock is the source of 100% of income from most households; in others, it supplements other sources (FAO, 2010). Livestock provides socio-economic power since it is an asset and a means of transport, provides manure and acts as work animals for agriculture production (Jutzi, 2009). However, these show decreasing trends among some communities and increasing in others (FAO, 2010). Globally livestock sector occupies 30% of the free terrestrial area, uses natural resources and provides nutrition, income, and employment (Thornton, 2010). In the rural households of developing countries, livestock is a significant contributor to livelihood (Herrero et al., 2009)

Dairy farming and the Dairy industry are crucial segments of livestock farming that actively contribute to the economies of diverse communities in different countries of the world. The demand for dairy products worldwide has increased against a backdrop of a globalizing industry and a resultant intensification of the dairy trade that has grown globally (International Dairy Federation, 2013). Furthermore, according to predictions by the United Nations global population by the middle of the 21st Century will be more than 9 billion. Out of this, 70% will be living in urban areas, which will be more than 50% of people living in urban areas (United Nations, 2008). The estimates for Sub-Sahara Africa are projected to hit 2 billion marks by the year 2050 and 4 billion by the year 2100 (UN Department of Economic and Social Affairs, 2013). Likewise, the projected increase in food demand will reach 70% by 2050 (FAO, 2006). Urbanization is expected to cause ecological impacts beyond the urban borders as land, which is a hundred times the size of the urban areas, will have to meet increased food demand (Grimm et al., 2008). An increase in the wealth of developing countries will change the purchasing power of the ‘middle class’ and practically shift the predominantly grain-based diet of these individuals towards one with higher animal-based protein (Rae & Nayg, 2010). Consequently, the annual per capita milk consumption in developing countries will increase from 55kgs/person/year to 78kgs by 2050 (Steinfeld et al., 2006). The increasing demand for dairy products has led to growing pressure on natural resources, including freshwater and soil (WWF, 2016).

The long-term impact of climate change on dairy productivity due to its undesirable influence on feed and fodder supply may severely alter the existing livestock production systems (FAO, 2004). In East Africa, the undesirable impact of climate change on agricultural productivity, forestry and fisheries will be exacerbated by many factors such as variations in mean temperatures, rainfall patterns, and a rise in sea level (Lobell et al., 2011; Beddington et al., 2012). Studies show that climate projections for the future depend on the GHG pathway chosen, and if human-induced emissions continue at the current trend, more impact is expected (Hayhoe, 2004). Global warming and the associated climate change is, therefore, expected to exacerbate the challenges smallholder dairy farmers in Kenya's face, as it would lead to more crop failure and famine, with many plant and animal species having problems adapting (Muho et al., 2011; Odhiambo et al., 2019). With the dairy subsector dominated by smallholder farmers who remain dependent on rain-fed agriculture, it is expected that adverse climate change-related impacts will be experienced in the dairy subsector (Stefanovic, 2015). Approximately 1.8 million smallholder farmers depend on milk for their livelihood in areas considered dairy zone (Wanyoike et al., 2005), owning 1-5 cows, with average daily production of 8-10 litres per cow (Theron and Mostert, 2008). These dairy farmers are estimated to own 4.3 million dairy cattle that are kept under free grazing, semi-zero-grazing and zero-grazing production systems and produce 3.43 billion litres of milk (Odero-Waitituh, 2017). The other milk is produced by 9.3 million local animals, camels (1 million) and goats (13.9 million) (FAO, 2011).

In Kenya, dairy farming is the single largest sub-sector of agriculture. It contributes 14% of Agricultural (GDP) with an annual growth rate of 4.1% compared to 1.2% of Agriculture (IFAD 2006). Kenya's dairy sector accounts for 6-8% of the country's GDP (USAID/GoK 2009). It is a significant activity in the livestock sector and an essential source of livelihood for approximately 1 million small-scale farmers (IFAD 2006). It is estimated that milk production was 1300 Kgs (Omore et al. 1999) and 4000 Kgs (Peeler and Omore 1997) per cow per year. This depended on the degree of intensification and agro-ecological zones, going up to 4575kg/cow/year in high potential areas (Mugambi et al. 2015). This difference in production was attributed to the availability of high-quality feeds, differences in animal breeds and production system, which was influenced by agro-ecological zones (Muia et al. 2011). The production per individual animal was low compared to the world's best of 9000 litres per year (Technoserve 2008).

Climate change has negatively impacted livestock productivity in addition to adulterated water resources, poor feed quality and being prone to livestock diseases (Rojas-Downing et al., 2017; Escarcha et al., 2018; Rahut et al., 2018). Heat stress in livestock due to rising temperatures leads to an adverse impact on milk production (Bohmanova et al., 2007; Hammami et al., 2013), reproduction (Hansen, 2009), health (Sanker et al., 2013) and mortality rate of animals (Vitali et al., 2009). Air temperature, humidity and wind speed significantly affect milk production and reproduction rate (Houghton, 2001; Herbut et al., 2018). Due to the persistent drought conditions, the lactation period of dairy cattle always shrinks (Abbas et al., 2019). Likewise, milk production quantity and quality decline (Maurya, 2010). The situation would most likely push several smallholder dairy farmers out of business; the net result is that milk demand would greatly outweigh its production.

Rainfall seasonality affects forage availability, livestock production and, ultimately, the livelihoods of these people (Galvin et al., 2003). Therefore, efforts to facilitate adaptation will enhance the resilience of the agricultural sector, ensure food security, and reduce rural poverty. Milk production in Kenya and Uganda is characterized by high milk production during the rainy season and low milk production during the dry season; the changing climate is expected to worsen the conditions. Smallholder milk production is a viable economic enterprise in Kenya. However, major constraints remain inadequate quantity and quality of feeds, poor access to breeding, diseases, poor access to credit facilities and poor access to output markets, i.e. inefficient processing and informal milk markets (Omunyin et al. 2014; Kibiego et al. 2015; Mutavi et al. 2016). With climate change, It is essential to understand how well adapted the Kenyan smallholder dairy farmer is to continue in business and even increase milk production in the advent of climate change. Therefore, the study aimed to assess the effects of climate change on smallholder farms in Nandi County.

1.2 Statement of the Problem

Substantial studies on how climate change affects crop and livestock fodder have been carried out in developed countries. These studies have included investigations on how climate change directly affects milk production during summer and how it indirectly leads to change on both feed and water availability (Peggy*et al*, 1993; Henry*et al*, 2012; Gavin, 2003) Alluded that seasonal characteristics of rainfall affects availability of forage, livestock production and subsequently the livelihoods of smallholder farmers. However, there is limited empirical data on the effect of climate change on dairy production in developing countries. This is despite the fact that, populations in affected countries that include smallholder farmers are the most exposed to climate-related stressors and most vulnerable to critical impacts of global climate variations (Thornton, Steeg, Notenbaet & Herrrero, 2009, WWF-World Wide Fund For Nature, 2006 & Maluwa-Banda, 1998). Nonetheless, some effort have been put in place including introduction of *Brachiaria*, a drought resistant fodder that has been tried in Rwanda, Kenya and Uganda to help smallholder farmers to help them mitigate the effects of climate change ((Maas et al., 2015, Peter, Davis, & Andrew, 2012).

1.3 **Objectives of the Study**

The overall objective of the study was to investigate the impact of fodder on smallholder milk production in Nandi County Kenya, under changing climate. Specific objectives of the study are

i. To determine spatiotemporal pattern of past and future climate in Nandi County of Kenya

ii. To establish the spatiotemporal pattern of fodder availability and milk production in the Nandi county of Kenya

iii. To determine the relationship of fodder availability, milk production and climate in the Nandi county of Kenya

iv. To examine the intervening role of climate adaptation and mitigation strategies on milk production in smallholder farms in the Nandi county of Kenya

1.4 **Research Questions**

The following were the research questions;

i. What are the past and projected spatial and temporal patterns of climate in Nandi

County of Kenya

ii. What has been the trend of fodder availability and milk production in Nandi county of Kenya

iii. What is the relationship of fodder availability, milk production and climate change in Nandi County of Kenya

iv. What are the existing and potential adaptation strategies to climate change in the Nandi county of Kenya

1.5 Hypothesis of study

The study tested the following hypothesis

- Null hypothesis: H01: There is no relationship between climate change and milk production
- Alternate Hypothesis: H01: There is relationship between Climate change and milk production

1.6 Justification and significance of the Study

The 17 goals identified by the United Nations for sustainable development will transform the world. This study responds to Sustainable Development Goal (SDG) number two (SDG2) that is aimed at ending hunger, attainment of food security, improvement of nutrition and promotion of sustainable agriculture. This goal recognizes agriculture as the single biggest global employer with over 500 million smallholder farmers that mostly depending on rain to water their crops. Agriculture provides not less than 80% of food required in developing countries and is the main source of livelihood among the rural households. The study also addressed SDG 11 that aims at building cities that are made up of communities that are inclusive, are safe, resilient and are sustainable (United Nations, 2015). The study recognizes the importance of this goal and aimed at contributing to it by addressing fodder availability as one of the factors that could increase dairy productivity for improved rural livelihood and increase food security for both rural and urban communities. It also addressed the specific goal of increasing value in agriculture spelt in the Kenya's vision 2030 (Government of Kenya, 2007). It is also aligned to the Kenya's climate change act that recognizes, supports and provides grants for technological, scientific and academic research (Government of Kenya, 2016).

Milk production in Kenya that is predominantly smallholder and dependent on rain fed agriculture experiences adverse climate change related impacts (Morton, 2007, Stefanović, 2015). A paper by Kirui, Opere, Ngaina and Nzioka (2015) which forms the basis of this study recommended that dairy farmers be empowered to effectively prepare, adapt and mitigate the effect of extreme climate changes. There is need to investigate the trend of fodder availability and how smallholder dairy farmers are responding to the climate change with an aim of developing suggestions for optimized adaptation strategies.

Understanding the past, trends of fodder availability in Nandi County has provided insight that could enable farmers absorb the shocks because of climate change. The study would also help to identify and promote optimized adaptation strategies that could enhance fodder availability and hence improved milk productivity. Agriculture extension service practitioners could gain insight and knowledge on the current and expected future fodder availability that would enable them develop appropriate and climate-smart agricultural practices that could subsequently support smallholder dairy farmers develop resilience when faced by changes in the climate. Results from this study could also assist programs operating in the country and in the wider East Africa region to plan and adapt to changing climate while increasing milk productivity. The findings have increased knowledge on the effect of climate change on agriculture, which could benefit students, researchers and academicians. Facilitating adaptation through efforts from all stakeholders could enhance the resilience in agricultural productivity, increase food security and result in reduction of rural poverty (Ngigi, *et al*, 2012). To be resilient under changing climatic conditions, smallholder dairy farmers in Kenya should diversify and adopt technologies that enhance fodder availability (Altieri, *et al*, 2015).

Therefore, this study aimed at investigating the impact of fodder availability on smallholder milk productivity, under changing climate in Nandi County, and assessed optimized adaptation strategies.

1.7 Study Area

The study was in Nandi County, that falls within the agro-ecological zones of Upper Highland (UH) to Upper Midland (UM) is one of the major dairy zone in Kenya and is predominately small holder dairy farming that mainly rely on rain fed fodder production. The average farm size in the county has been reducing. It is expected that this land will reduce further because of the fast increase in population that leads to land fragmentation (ASDSP, 2016). The County's population based on 2019 population census was 885,711, comprised of 441,259 males and 444,430 females with an inter-censual growth rate of 3.1 percent, slightly higher than the national rate of 3.0 percent (County Government of Nandi, 2021). To determine the representative sample, both purposive and snowballing sampling techniques were used.

Mean rainfall is between 1,200-2,000 millimetres (mm) per year and bimodal between dry spells between December and March. Rainfall distribution varies according to topography and is influenced by south-westerly winds from Lake Victoria. About 75% of the district is arable and capable of producing diverse crops due to adequate and reliable rainfall. Major staple crops in the area include maize, millet, sorghum, and potatoes while pyrethrum, tea and coffee are main cash crops. Most farmers do practice mixed farming where they keep cross bred of Ayrshires and Friesian under free range grazing and stall feeding production system. The farmers practice intensive and semi intensive dairy farming. Dairy farmers in Nandi grow forage crops such as Nandi *setaria* (*Setariasphacelata*), Rhodes grass (*Chloris gayana*), and Napier grass (*Pennisetum purpureum*). Smallholder farmers market their milk using different milk-marketing channels: either through an informal milk market where milk is sold to middle men or hotels or through formal market where milk is marketed through farmers' organizations' marketing channel. Informal market the ref an example is where about 4000 dairy farmers in Kosirai, a sub-county in Nandi county have joined together to form a farmer organization called Lelchego dairies which

Assist farmers to bulk and market their milk (Lukuyu, 2011).

Figure 1-1: Map Kenya showing Nandi County

1.8 Assumptions of the Study

The following were the assumptions of this study:

i. That the respondents would provide accurate data regarding the patterns of climate in the Nandi County

ii. That the respondents would provide accurate data regarding milk production in the Nandi County

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

This chapter captures relevant literature to the study that includes an overview of dairy productivity in relation to climate change; it gives the theoretical framework and the role of climate change in milk production.

2.2 Overview of Climate Change

Change in climate is represented by significant changes in the indicators of climate that last for extended periods of time (US Environmental Protection Agency, 2016) as evinced through changes in usual weather conditions of a place. For example, this could be a change in the amount of rainfall that is usual for any place annually, or a sustained variation of either monthly or seasonal usual temperature for a place. On a broader perspective it denotes the change of the earth’s climate, which means combined change of all the climates around the world lumped together (NASA, 2014). The change in the earth's climate has been throughout history and usually runs into thousands or even millions of years (Thompson, 2016) US Environmental Protection Agency, 2016, intergovernmental Panel on Climate Change, 2007. There are many natural causes of climate change such as a changing distance between the earth's and the sun , variations in the energy that the sun sends out to the earth,oceanic changes or volcano eruptions (NASA, 2014). However, changes of theclimatein the recent past, andparticularlyglobal warming since the midth of 20th century, cannot be explained purely on natural causes. It is most probable that human activities have been dominantlyled to this warming (US Federal Government, 2014).

2.2.1 Effects of Climate Change

A rapid change in climate is compellingly evidenced through a rising sea level and spikes in global temperature, warmer oceans and ice sheets whose cover area is shrinking. Other evidence including an arctic sea ice that is growing smaller, declining glacia land unusual extreme occurrences such as rainfall that are very intense, acidification of oceanic waters and depleting snow covers (Earth Science Communications Team , 2016). In the year 2015 alone, extreme weather occurrences that are explicably triggered through change in climate included a waves of searing summer heat that struck Europe, flooding in Miami during sunny day, one of worst wildfire seasons in America's Alaska's and extra-ordinarily heavy rainfall that hit China(Thompson, 2016). Analysis results indicate that the extreme drought from May to July 2015in western Canada was most probably due anthropogenic influence of warm spring conditions and naturally forced dry weather (Szeto et al., 2016).

In South and Central America the recurrent hurricanes, horrid flash floods and frequent landslides are weather-war backed battles that are triggered by violent and ever-changing rainfall patterns (Marengo, et al., 2014). The region has notable occurrences including intense rainfall in Venezuela from the year 1999 to 2005, the flooding that his Argentine Pampas from 2000 to 2002, drought in the Brazilian Amazon in 2005; the hailstorms that hit both Bolivia (in 2002) and the Greater Buenos Aires (in 2006): and the devastating hurricane Katrina in 2004. Another evidence is the increased temperature of approximately 1°C experienced in the Mesoamerica and South America and that of 0.5 °C experienced in Brazil (The Energy and Resources Institute, 2016).

According to a UN report cited by Mckie (2014), in Asia, one of the most globally vulnerable areas to global warming, people in hundreds of millions in the low-lying coastal regions especially those living in cities, are exposed to loses of homes due to flooding and famine as well as a rise in sea levels that is sweeping the region. In addition, there are several ways through which changes in the climate are projected to negatively affect the agricultural productivity in South East Asia. Irrigation systems will be negatively affected by changes in rainfall patterns and the subsequent runoff, and which will ultimately results to compromised water quality and clean water supply. Furthermore, an increase in rainfall and temperature could threaten agricultural productivity by exposing crops to stress and reduced yields. According to IFAD, scientific studies have demonstrated that major cereal and tree crops have high sensitivity to changes in temperatures, atmospheric moisture and concentration of carbon dioxide in the magnitudes projected in the Asiatic region (International Fund for Agricultural Development , 2016).

In Africa, the changes in climate through varying temperature affect health, livelihoods, food productivity, water availability, and overall security to the African people. The indicators of this effect are seen through changed weather patterns, reduction in waters supply, impacts on agriculture and food production, human health, shelter, vulnerability of population and national security (Deonarian, 2015). Boko et al. (2007) noted that by 2020, 4 years away from the time of conducting this study, 75 to 250 million African people will be under increased water stress as a result of changes in climate. Within same time some countries will experience reduced yields from rain-fed agriculture by up to 50%. The subsequent reduction in agricultural productivity will lead to severely compromised access to food in many countries, adverse effect on food security and exacerbated malnutrition (AMCEN 2007).

In Southern Africa, freshwater systems will experience increasing changes in the amount of rainfall received as well as rising sea levels. Furthermore groundwater and surface water that include rivers and lakes will shrink while an increase in evaporation will lender soils to be more salty, thus inhibiting growth of crop plants that include fodder. Other Projected estimates indicate that salinization of the groundwater will lead to water shortage that will be experienced by between 50 and 100 million southern Africa people by the mid-century (CSAG, 2016).

While agriculture across the region is overwhelmingly rain fed, in the future a likely reduction in rainfall accompanied by increased incidences of droughts is likely to be experienced in many areas. Lowered crop yields are likely to reduce harvests for staple foods such as irrigated rice (most likely to hit most hard), sorghum wheat and soybean, by an estimated margin of 5 percent and 20 percent, especially due to rising temperatures likely to hit the region (CIRT, 2016; Waithaka et al., 2013). Scientific literature reviewed by World Wide Fund for Nature (WWF) shows that a change in climate in the region is both a conservation challenge but a socioeconomic issue that demands a global scale action (World Wide Fund For Nature , 2006). Effects of change in climate are already being felt in Kenya with resultant devastating effect on country's productivity in agriculture. Prediction of seasonal rainfall remains high uncertain and erratic in both space and time while soils are losing nutrients. In some areas smallholder farms are struggling to produce enough food to feed their communities (Ndunda, 2015, Namale, 2015).

2.2.2 Sustainable Development Goal and Climate Change

A UN report that showed the world population was 7.2 billion by 2013 projected it to increase at a rate of 1 billion over 12 years tohit 9.6 billion people by 2050(Department of Economic and Social Affairs, 2013). Thisgrowth is expected to be higherin developing countries, where more than 50% will be in Africa. Projections shows that by 2050 , 5.6 billion people will be living in cities and that 95% will be in developing countries (United Nations, 2014). According to Ahlburg(1996) rapid population growth probably reduces per capita income growth and subsequent well-being of the citizens, and an increase in poverty. In addition, in the densely populated and poor nations the subsequent increased pressure on limited land accompanied by a highgrowth ofpopulation leads tomasses becoming landless,which is a factor to poverty. McNicoll, (2000) argues that the link between population growth and poverty by focusing on population-related environmental changes that predicate on poverty especially based on the tragedy of commons theory.Furthermore, as population increases, food productivity must increase. To feed this bludgeoning, urbanizing richer population, food productivity must increase by at least 70 percent, whileproduction ofcereals across the globe shouldannually to rise to more than 3 billion tonnes from the current 2.1 billion. In addition, annual meat shall need to rise by by over 200 million tonnes to reach the expected consumption level of 470 million tonnes (FAO, 2013).

A global effort to counteract the undesirable effects of global changes includes the United Nations millinium Development Goals and their successors, Sustainable Development Goals (SDGs), which precisely are a set of intergovermental goals to be achieved globally. They are aimed at guiding orgarnizations and nations on how they should align their strategies to contribute toward transforming the world towards the 2030's agenda for Sustainaable Development (United Nations 2014). This study has thus contributed to the global efforts under sustainable development goals.

2.3 Smallholder milk Production

Smallholder farmer also referred as small scale farmer can be defined based on the endowment of production factors such as land size, source of labour and access to market(FAO, 2017). In Kenya it is estimated that there are 1.8 million smallholder farmer who depend on milk for their livelihood in areas that are considered dairy zone(Wanyoike*et al.*, 2005) owning 1-5 cows,with average daily production of 8-10 litres per cow (Theron & Mostert, 2008). This dairy farmers in Kenya are estimated to own 4.3 million dairy cattle that are kept under free grazing, semi- zero grazing and zero grazing production systems and produce 3.43 billion litres of milk (Odero-Waitituh, 2017). The other milk is produced by 9.3 million local animals, camels (1 million) and goats (13.9 million) (FAO, 2011).

2.3.1 Dairy cattle Production

Keeping of dairy cattle in Kenya was introduced at the beginning of the twentieth century by European settlers who brought exotic high milk-producing cattle breeds from Europe, however indigenous people were only allowed to keep dairy cattle after 1955 when the Swynnerton Plan of 1954 allowed them to take on commercial agriculture (Connelly, 1998). At independence the dairy herd was 400000(Muriuki, 2009) however through subsidized government services on animal health, artificial inseminations, livestock production and the entrance of other actors in the dairy industry after introduction of Structural Adjustment Programmes (GOK., 1986)has contributed to the increase in dairy cattle population, with breeds mainly composed of Friesian, Ayrshire, Guernsey and Jersey animals and their crosses. These cattle are mainly found in the Kenya highlands (high-potential areas) that spread from central Kenya, Rift Valley, western part of the country and the coastal strip because of the favourable agroclimate (Muriuki, 2009),

2.3.2 Milk Production system

Milk in Kenya is mainly produced from exotic dairy breeds, their crosses, and indigenous cattle that are kept by medium and smallholder dairy farmers with less than 5 acres of land keeping less than 6 dairy cows(Wambugu et al., 2011)that produce about 56 percent of the total milk; this comprises approximately 80 percent of the marketed milk in the country (Muriuki, 2009),

2.3.3 Milk Consumption and Demand

Milk consumption is based on absolute per capita milk accessibility(KAVES, 2015),in Kenya demand for milk and milk products has been increasing with annual per capita milk consumption been estimated at 145 litres, (Kaitibie S, 2010)and is among the highest in the developing world according to an SDP report(SDP, 2004),

2.3.4 Dairy Value Chain

Raw milk is very perishable and need to get to the consumer or cooling facility within the shortest time possible, as a result of the perishability nature of milk the dairy value chain is relatively short and involves the producer, the Traders (formal and informal) and consumer. According to Omore (2004), "Informal "involves traders operating outside the law including taxation or small scale trader with licences (Omore A., 2004). In developing countries informal milk markets estimated to handle over 80% of milk is supplied by smallholder producers and account for over 80% of milk supplies to consumers and its supply-chain-related actors include small-scale (Omore., 2004), the rest of the raw milk (about 20%) is handled in a "formal" set up by the large scale processor or traders who are registered with the Kenya dairy board, The main market intermediaries include cooperatives, milk bulking/cooling centres and transporters (KAVES, 2015).

2.3.5 Dairy cattle Feeding

Smallholder dairy farms in Kenya have three production system, the zero grazing system where fodder is grown cut and brought to animals free grazing system where animals are grazed

(Mbugua, 1999) while in the semi zero grazing both grazing and cut and carry system is practiced. Under free grazing system, cattle are grazed on public land and private land, in the semi zero-grazing where cattle are grazed and supplemented with extra gathered feeds, and in pure zero-grazing, where cattle are fed in total confinement (Lukuyu, 2011)

2.4 Effect of Climate Change on Fodder

Climatic conditions are determinant of the types of crops (including fodder) that grow in specific geographical areas. In addition, weather elements and particularly light, rainfall and temperatures directly effects physiological processes that occur in plants such as plant growth and development, photosynthesis and leaves expansion, Changes in crop production systems due to climatic change have an indirect influence to dairy production, since dairy production relies on plants for fodder whose growth is dependent on water and temperature. Even though drinking water seems an obvious need by the livestock, it is a minor fraction of the total water consumed in the livestock sub-sector (Peden, 2007). In Sub Saharan Africa major water used in livestock rearing goes into production of either fodder or pasture. This water that is referred to as the green water is relatively in higher demand compared to water for drinking (Steinfeld, et al., 2006). The green water is associated with transpiration during photosynthesis to make carbohydrates. Plants assimilate carbon by one of the photosynthesis pathways; C_3, C_4 or CAM. The C_3, C_4 and CAM plants respond differently to increase in temperature and therefore the rise in temperature because of climate change affects plants water use efficiency. Extreme temperatures are synonymous with climate change (Amthor & Loomis, 1996). Lobell et al., 2011) observed that maize yields dropped across Africa by up to 1.7% for an increase in each degree above 30^0C. Maize is an important livestock feed along with other cereals such as wheat, barley, oats and sorghum which are used extensively as high value feed (Pond & Pond, 2000). A drop therefore in cereal yields occasioned by climate changes negates availability of livestock feeds.

Weather also controls the spread of fungal diseases, insect pests and weeds which affect growth. Furthermore, greenhouse gas-induced global warming alters temporal and spatial patterns of rainfall, temperature, humidity, radiation and wind, which all contribute to plant growth. Increase in air and land surface temperatures could lead to increase in evapo-transpiration which could alter soil moisture condition of most agricultural lands (Ogola et al., 1997). This study measured the trends in rainfall, temperature and soil moisture in the study area.

Freshwater resources and the integrated management of these resources have been cited as critical environmental and developmental issues over the coming decades, and which incidentally affects dairy sector. According to UNESCO (UNESCO, 2002) out of the entire water on earth, only 2.5% of fresh water, which is the only amount that supports life. Almost all of it is locked up in ice and in the ground. Only a little more than 1.2% of all freshwater is surface water, which serves most of lives needs (United States Geological Survey, 2015, The Global Education Project, 2016). In addition over-pumping is depleting water tables much faster than nature could replenish it in the food producing zones of northern and central China. Similar effect is being felt in other parts of Asia such as northwest India and parts of Pakistan. In North American United States is experiencing depleting water tables as well as countries in North Africa, areas of Middle East, and also in the water scarce Arabian Peninsula(The Global Education Project, 2016).

Change in climate can affect water is in several fronts. Rise in temperatures results in evaporation that sometimes leads to droughts as well as high rate of melting of glacial ice, an important source of freshwater worldwide (GRACE Communications Foundation Communications Foundation, 2016). It could also lead to flooding (Mcintyre, 2012), reduction of quantity and quality drinking water, depleted irrigation supplies and power-supply disruptions (Union of Concerned Scientists, 2011). Semi-arid and arid areas are more vulnerable to outcomes and impacts of change in climate on fresh water bodies, especially because annual rainfall and river water availability is limited to just over a few months (Know Your Climate Change, 2016).

Change in climate can also have a big impact on structure, functions and performance of soils. Subsequently, these changes will affect productivity per crop area cover when changes in soil, variation in air temperature and erratic rainfall negatively affect crops maturity process and compromises potential harvest (Soil-net.com, 2016). Potential changes in soil-forming linked directly changes in climate include the supply of organic matter from biomass, ranges of soil temperature and soils' hydrology. More rapid change processes under varying external climatic conditions touch on soils chemical and mineralogical alterations due to loss of salts and nutrient cations. These processes are exacerbated by increased leaching, and salinization triggered by net upward water movement due an increase in evapo-transpiration, decreased rainfall and/or due to supply of irrigation water. Certain fragile soils could experience much worse change due to the nature of dominant soil-forming processes, making them vulnerable to increased, decreased or more strongly seasonal rainfall (Brinkman & Sombroek, 2005).

A paper by Adams et al. (1998) that reviewed the extant literature on human adaptations in response to changes in climate, on possible impacts to agriculture systems regionally and possible changes to patterns of food productivity and pricing showed climate is the primary determinant of agricultural productivity. A study by Kalra et al., (2007) shows that a simple empirical techniques that could evaluate the impact of future climatic changes by historically analyzing the response of crops to the inter-seasonal climatic changes. Within this context, interactions exist between temperature variations, concentration of the carbon dioxide, solar radiation and rainfall, and the effect of this interaction on growth and crops' yield.

In their study Schlenker and Lobell (2010) demonstrated that a panel analysis that combine historical crop production and weather data, provides robust model among several key African crops that could predict response of crop yields to change in climate. The study specific projected mean estimates of aggregate changes in production in Sub Saharan Africa (SSA) by mid-century, under a preferred model to be maize, − 22, sorghum − 17, millet − 17, groundnut − 18, and cassava − 8%. In all the projections there is a high probability (at 95%) that damages will exceed 7%, and a low probability (at 5%) that they will exceed 27% except for cassava. The model further predicts that countries with the highest average yields will have largest yield losses. This suggested that the well-fertilized and modern seed varieties are more highly susceptible to heat related losses.

2.5 **Effect of Climate Change on Dairy Productivity**

Dairy is an important part of the agriculture industry. Increasing dairy productivity will contribute by meeting the expected demand for animal products.According to FAO (2016) producing, processing and consuming milk and dairy products sustainably is a benefit to people and the planet, and could help achieve SDGs. However, Climate change has complex impacts on domestic animal production systems that include animal's feed supply (Bajagai, 2011, Kalra, et al., 2007, Thornton, et al.,, 2009).

Thornton *et al.* (2009) observes that in the context of broader development trends empirical knowledge on interactions of climate and increasing climate changes and other drivers of change in livestock systems is scanty. Within the tropics and subtropics, changes in livestock systems are rapid in many areas while the spatial heterogeneity in terms of household response to this change may be very wide. In East Africa smallholder dairy farmers face several challenges such as uneven milk production mainly because they rely on rain fed forage production all the same milk production grew steadily in East Africa in the 1980s and 1990s. According to Ngigi, (2004) the annual of milk productivity in the 1990s was 4.1% in Kenya while in Uganda, it was 2.6% and which was mainly led by a high domestic consumption among other reasons. .In Kenya it is estimated that there are 1.8 million smallholder farmer who depend on milk for their livelihood in areas that are considered dairy zone (Wanyoike *et al.*, 2005)with average daily production of 8-10 litres per cow (Theron & Mostert, 2008) This growth has since increased mainly driven by recent high rates of par capita income growth and expanding urbanization, even though exact figures may not be easy to verify (Place *et al.*, 2009). This current study aims at establishing how the varying climate is affecting milk productivity in Kenya, with a particular focus of Nandi County

Kenya`s Policy document, Agriculture Sector Development Strategy 2010-2020 (Republic of Kenya, 2010) showed that despite the heavy investment in research, extension and other donor supported dairy development initiatives, productivity still remains low and positively correlated to seasonal patterns. The resultant higher temperatures and changes in rainfall patterns, has enhanced the emergence and spread of vector –borne diseases (Thornton & Herrero, 2008) which worsens milk productivity in the county (Wambugu & Opiyo, 2011). This notwithstanding farmers experience frequent droughts, excessive rains in the wet season and subsequent crop failures associated to changes in climate. This results in reduced livestock productivity which increases smallholder’s vulnerability to food insecurity and poverty (Zagst, 2011). It is in this context that this study aims at investigating how climate change and variability influences availability of fodder and therefore influence milk production in Nandi County, Kenya.

Although agricultural production is affected by climate change, evidence shows that current agricultural practices are a factor to the continued change in climate. Globally livestock contribute directly or indirectly 18% of global GHG, which is equivalent to 7.1 billion tons of emission of methane, nitrous oxide and carbon dioxide gases (FAO, 2004). Livestock GHG emission is a human-activity that throughout the commodity value chain emits 65% of nitrous oxide, 37% of Methane and 9% carbon dioxide. There are possible mitigation options to reduce emission through restoration of organic carbon, manure management and sequestration of carbon through agro forestry, proper animal diet, nutrient management and use of biogas. Methane gas is mainly emitted during the enteric fermentation process of animals' natural digestion and through management of manure while carbon dioxide results from fodder production activities which require opening of new land, use of fertilizer use of fossil fuel and other factors of fodder production (Sejian *et al*, 2015). This current study sought to establish the extent to which farmers are aware and are able to put in place measures that mitigate climate change.

2.6 Adaptation and Mitigation Strategies

Practices that sustainably increase agricultural productivity and resilience and enhance national food security while in mitigation reducing or removing GHS emissions are referred to as Climate Smart Agriculture (CSA) (Chaudhury *et al.*, 2012). According to FAO (2010) CSA are vulnerability reduction approaches that aim at helping the mainly subsistence and rural small scale farmers to adapt to changes in climate through diversification or intensification of their livelihood strategies. It involves adopting new agro-ecological and socio-economic agricultural production systems that achieve higher productivity and lower output variability within the context of climate-change risks. CSA practices are concerned with management of soils and nutrients, harvesting of water, conservation and pest and disease control practices and/ or resilient ecosystems (CGIAR, 2015). Other CSA practices include increasing soil organic matter, practicing mixed-species forestry or agro-forestry to improve the soil quality and reduction of impacts of droughts and/or floods. It is concerned with efficient water management, a critical and a far reaching adaptation and livelihood goal to a resource that is threatened by climate change (Hobbs *et al.*, 2008). Water resource management include adopting better irrigation practices, adoption of better water harvesting technology, and inclusion of terrace or contour farming systems to contribute to improved water-use efficiency and conservation Milder *et al.* (2010). Incorporating shifts in hydrologic regimes and water availability in response to changes in climate and incorporating this shifts in design and management of water resources and systems is a concern under CSA that enhances adaptation (Falloon & Betts, 2010).

CSA principles are applicable in adopting integrated nutrient management principles. This can achieved by use of green manures or planting nitrogen-fixing crops, or mixing livestock manures with soils. It can also be done through reduction of the amount of nitrogen lost through water runoff or emissions of nitrous oxide gas. These management principles will improve soil quality and decrease farmers' dependence on external inputs and thus costs management. Furthermore, organic-farming practices and the use of non-synthetic inputs are factors that that help soils to retain carbon by 15% to 28% and nitrogen by 8% to 15%, thus significantly reducing the costs of fertilizer inputs (Milder *et al*., 2010).

Agroforestry is another CSA practice that contributes to attainment of climate-smart objectives, in which live fences are planted alongside crops and trees. Agroforestry practice and tree crops are contributors to resilience of communities since they provide diversification of crop, income and nutrient by providing timber, fruits, fuel, medicines and nuts as well as nitrogen-fixation services. Some of these economically useful trees and shrubs are sources of fodder, do contribute to reduction of soil erosion and are able to maintain higher levels of biomass through extended growth periods and root systems than annually tilled crops, are able to store more carbon and could be a habitat for some habitat. (Milder *et al*., 2010). In analysing the impact of how climate change affects agricultural productivity, the fast paced changes in the use of land and depleting land cover cannot be excluded and should be strongly linked to the socioeconomic aspects. Nonetheless, adaptation strategies that include adoption of improved agronomic management options (for example, altering the date of sowing and scheduling water and nutrients) are approaches that can sustain agricultural productivity under climate change. (Kalra, *et al*., 2007).

CSA aims at sustainable intensification of agriculture production systems in order to increase and enhance productivity thus contributing to achievement of national food security and to the attainment of development goals. As a strategy, it aims at safeguarding the SDGs and reducing the vulnerability of rural communities socio-economically, especially in developing countries. Furthermore, it aims at increasing the resilience of agriculture production systems and rural livelihoods and at reduction of agriculture's GHG emissions through increased production efficiency and in mitigation, increase carbon sequestration. Investing in CSA aims at smartly meeting growing global demand for food within changing climate (Hobbs *et al*., 2008). However, since there are no blueprints for CSA, regard to specific contexts of countries and communities is essential in informing and shaping how it is implemented (CGIAR, 2015, FAO, 2016).This study sought to establish whether small holder farmers have adopted CSA practices such as increasing organic matter in fodder cropping, incorporating livestock manures into the soil by planting nitrogen-fixing crops, and whether there are efforts of improving soil quality through mixed-species forestry or agro-forestry.

2.7 **Theoretical Framework**

This study was guided by the theory of Tragedy of Commons (ToC), the theory of greenhouse effect and the theory of sustainable development that are discussed in the section below.

2.7.1 Theory of Tragedy of Commons (ToC)

This study was guided on the tragedy of common theory by Garret Hardin (1968). This theory is premised on a limited economic resource in which every individual member competitively tries to reap the greatest benefit. Demand for the resource ultimately overwhelms the supply, a point at which whoever consumes an additional unit is in direct harm to others who can no longer enjoy the benefits. The theory posits that, the limited resource of interest is generally easily available accessible to all individuals. The tragedy of the commons strikes when individuals driven by self-interest neglect the well-being of other society members and thus results in destruction of all (Investopedia, 2016, Ponce, 2015).

The Hardin's classic piece of "The Tragedy of the Commons," regards commons as a shared natural resource. "Shared" denotes a lack of entitlement or lack of absolute claim to any part of the resource by any individual, but rather, leeway to use any portion of the resource for his/her own benefit. The tragedy occurs when, in the absence of any control or regulation, each individual tends to take personal advantage and exploit the commons without a limit, and which results to depletion and eventual ruin of the commons.

The root of the tragedy is the unrestricted self-interest exhibited by some individuals, misinformed by an underlying reasoning that when commons is eventually used up, the person that effected the greatest use will stand to benefit the most. This perspective is basically an astronomical focus on benefit/cost ratio, and while benefits could accrue solely to the user, costs are shared among all others sharing the commons. Commons are un-owned resources that are commonly-held. They are a "pool" of resources that are "free," and are not allocated by markets. In the operational perspective of the theory individuals are rational actors basis of short-termism and self-interested in which they seek to maximize their own gains. These actors go to great lengths to exploit commons by for example having more babies, adding their cattle for pastures and polluting the air, motivated by a notion that that the costs to them individually are less when compared to the benefits. Escalation of this perception lenders individual to believe and behave a manner that ensures that the commons are quickly filled, are degraded, and ruined together with the erstwhile exploiters (Western Washington University, 2010).

People will consent to change habits that threaten the common good if they understand the dire consequences as postulated by ToC. Hardin posited a finite biophysical world meaning the more people increase, the lesser a share each person's gets, a reality that technology cannot alter. In practical terms, the theory means that biophysical limits should dictate humanity and must stabilize population. Humanity must make hard choices on which "goods" should be sought. Change of climate that is as a result of GHG emitted through anthropogenic activities is an example of ToC where great nations emit higher amount of greenhouse gas to the atmosphere without caring about the other nations, increased greenhouse gases has contributed to climate change which has a global effect (Engel & Saleska, 2005). In the context of this study therefore understanding the risk reducing fodder has on milk productivity and the longer term effect on food security could ‘jolt’ the stakeholders in general and specifically small dairy farmers in the area and beyond to act in order to mitigate the undesirable effects.

2.7.2 Theory of Green House Gas Effect (GHG)

This study was also based on the Green House Gas Effect Theory, as postulated by Svante Arrhenius (1896). The theory was founded on the fact that amount and concentration of Carbon Dioxide (CO_2) gas is linked to the temperature of earth planet. This was first advanced by Joseph Fourier, a French scientist, who realized that certain atmospheric gases capably shrouded the earth like a bell jar. The gases though transparent to sunlight, do absorb infrared rays, a phenomenon that results in the earth's atmosphere getting heated from both above by sunlight as it shines through and from below by the infrared rays that the earth emits when cooling during the night. The Green House Gas Effect theory posits that should amount of CO_2 levels be reduced by half, then the temperature of the earth's surface would fall by between 4^0C and 5^0C. On the flipside this argument postulates that doubling abundance of CO_2 would lead to a rise of between 5^0C -6^0C (Sample, 2005). According to this theory, the climate system is at equilibrium through warming of the earth's troposphere and the cooling of stratosphere (Ramanathan, 1988).Without this natural greenhouse effect, temperature on earth surface would be much lower, to about -33°Cwhile the average temperature on the planet would be low -18 °C instead of the bearable and usual 15 °C. A warmer climate is a critical contributor to existence of water on earth and in the atmosphere, in all its three phases, snow or ice, liquid and gaseous. This also supports the cycling of water between land, the ocean and the atmosphere and thus contributing to sustenance of life. This cycling of water is responsible for replenishing of fresh water needed and available to life on earth that includes fodder (Government of Canada, 2015). The water cycle is also an important factor of weather patterns on earth's and the earth's general climate system.

In the context of theory, active gases that include Nitrous Oxide (N_2O), CO2, Ammonia, (NH_3), and chlorofluorocarbon such as Trichlorofluoromethane (CFC-11) and Dichlorodifluoromethane (CFC-12) among others that result from human activities have continued to increase and has now reached critical stage. These gases absorb infrared radiation that is emitted by warmer surface and is then emitted to space through radiation to the cool atmospheric temperature. This results to trapping of thermal energy on net within the atmosphere, which is thus referred to as the greenhouse effect and the consequential global warming. Anthropogenic activities that build up these gases in the atmosphere links humankind activities to an increase of overall warming of earth's surface commonly called "global warming(Scripps Institution of Oceanography, 2015). Documented effects of global warming and observations from real life include spikes in droughts and floods, depleting ice and snow, extreme weather occurrences and arise in the sea level (British Geological Survey, 2016, West, 2016).

In this study, the greenhouse effect is associated with climate change, which is the context within which this research is conducted. The greenhouse gas alters the trends of temperatures and rainfall in the study area. This subsequently affects the fodder that is grown in the area. The study sought to establish whether temperature, which is a major factor and indicator of greenhouse effect and a precursor to climatic change is taking place in the study area.

2.7.3 Theory of Sustainable development (SD)

Theory of Sustainable development Theory was advanced by Gro Harlem Brundt land Commission (1987) in which the needs for present generation are met without compromising the ability of future generations to meet their own needs (World Commission On Environment and

Development, 1987). At the core of this theory is the capacity of the earth and its natural systems to bear the challenges that humanity face, at all times. The precepts of this theory posits sustainable development to be never in a fixed state of harmony, but always changing in a process where there sources are exploited, investments are directed, technological developments are orientated, and change at institutions are taking place in a manner that is consistent and aligned to both the future and present needs. The process is neither easy nor straightforward and puts a demand on humanity to make painful choices (Brundtland & Mansour, 1987).

The scope of the current study has sustainable development captured under sustainable agriculture. A growing global population demands sustainable increase in agriculture productivity as a matter of urgency in order to ensure food security. This should encapsulate improved global food supply chain, decreased food losses and waste, and ensuring that all people facing starvation and malnutrition are able to access adequate nutritious food (Sustainable Development Organization, 2016). It is within the context of sustainable agriculture that this study sought to establish whether fodder productivity in the study area and by extension in the region is sustainable.

2.8 **Conceptual Framework**

Understanding how climate change could influence fodder/pasture availability and indirectly dairy productivity would enhance the capacity of agriculture production systems to increase food security. Enhancing existing and potential adaptation measures while identifying practices with potential for mitigation, could enhance dairy productivity. For instance, developing new fodder and pasture seeds and improving the fodder/pasture conservation could be beneficial to smallholder dairy farmers who are under resource constraints. Knowledge on the baseline, present and expected fodder availability trend could help organizations and policy makers when planning for future dairy programs. Understanding how farmers are currently adapting to climate change could help to build on the existing local knowledge when developing and disseminating new technologies. All the identified influencing factors were in-built in the study. To control for internal validity a relatively bigger sample size of 384 respondents was randomly selected from study sites.

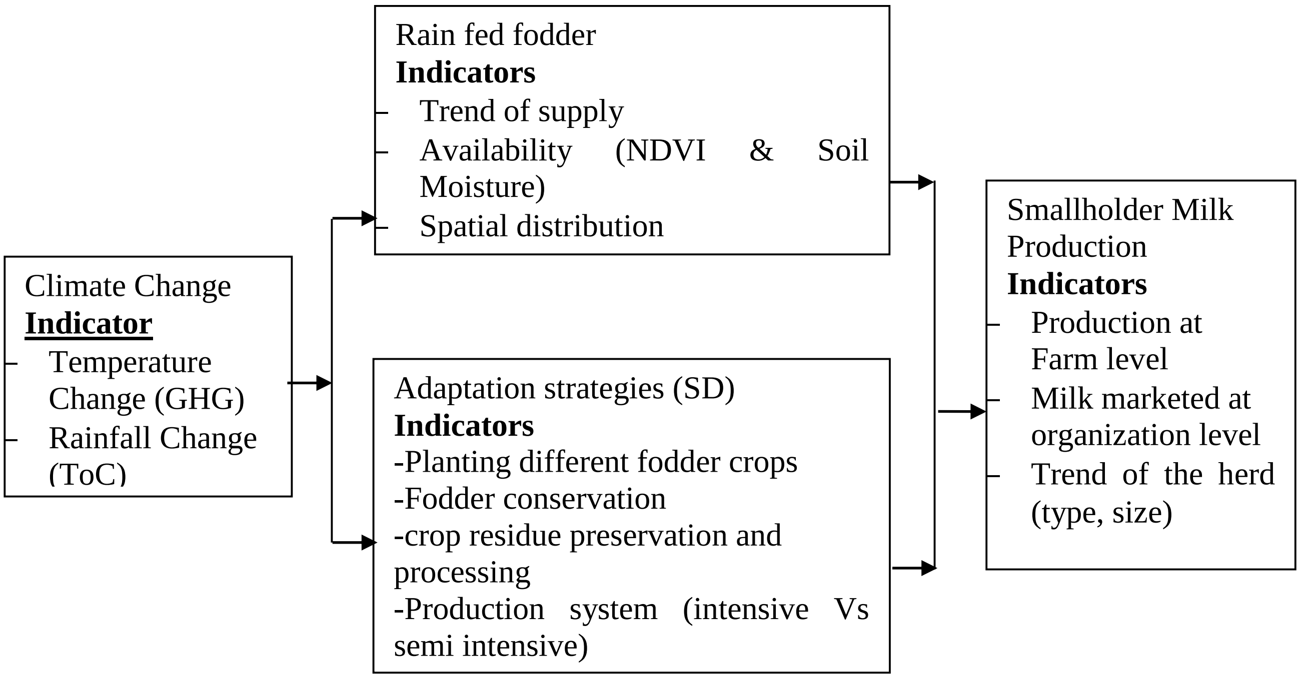

Figure 2-1: Conceptual framework of the stud

1 Table 2-1 Tables Showing the Research Gaps

Researcher (s)	Topic Area	Findings	The Gap	Focus of the current Study
Szeto, *et al.* (2016)	Analysis of the extreme drought in western Canada from May to July 2015	The drought was probably due anthropogenic influence of warm spring conditions and naturally forced dry weather	The study was done in Canada, thus presenting a contextual gap	Prolonged dry weather, effect on milk productivity and mitigation measures in place
Marengo, *et al* (2014)	Climate Change in Central and South America: Recent Trends, Future Projections, and Impacts on Regional Agriculture	Recurrent hurricanes, horrid flash floods and frequent landslides are weather-war backed battles that are triggered by violent and ever-changing rainfall patterns	The study was done in Central and South Africa and did not focus on how changing rainfall patterns are affecting milk productivity (a contextual gap)	The current study focused on how changing rainfall pattern are affecting milk productivity in Nandi County of Kenya
Namale, Douglas (2015)	Effects of Climate Change and Global Warming in Kenya	Effects of change in climate are already being felt in Kenya with resultant devastating effect on country's productivity in agriculture. The rain seasons are unpredictable and erratic while soils are losing nutrients. In some areas smallholder farms are struggling to produce enough food to feed their communities	The study did not focus on effect of climate change on milk productivity in Kenya (a conceptual gap)	The effect of climate change on milk productivity as an aspect of agriculture

Lobell, B D; Schlenker, W; Costa-Roberts, J (2011)	Climate Trends and Global Crop Production Since 1980	Maize yields dropped across Africa by up to 1.7% for an increase in each degree above 30^0C.	The study did not at how the drop in fodder (that might include maize) affects drop in milk productivity	The study looked at how changes in fodder productivity affects milk productivity in Nandi County
Ogola, *et al*. (1997)	Effects of Climate Change on Agriculture	Increase in air and land surface temperatures could lead to increase in evapo-transpiration which could alter soil moisture condition of most agricultural lands	The study did not link the production of fodder with milk production	This study looked at how changes in fodder production due to climate changes leads to changes in milk productivity
Schlenker and Lobell (2010)	Robust Negative Impacts of Climate Change on African Agriculture. *IOP Environmental Research Letters,, 1*.	Demonstrated that a panel analysis that combine historical crop production and weather data, provides robust model among several key African crops that could predict response of crop yields to change in climate	The study focused on crops but did not show how the change in climate affects fodder productivity and subsequently milk productivity. The study was also broad and touched on several countries thus presenting a conceptual gap.	This study focused on effect of climate change on fodder productivity and how these affects milk production in Kenya
Kalra, *et al*. (2007).	Impacts of Climate Change on Agriculture.	Climate change has complex impacts on domestic animal production systems that include animal's feed supply	The study did not focus on specific case of Kenya	This study focused on Kenya with specific focus on fodder productivity
Zagst, L. (2011).	Socioeconomic Survey: EADD-MICCA Kenya Pilot	The study showed reduced livestock productivity increases smallholders' vulnerability to food insecurity and poverty	The study did not focus on the how change in fodder productivity affects milk production	this study investigated how climate change and variability influences availability of fodder and therefore influence milk

	Project report. Rome: FAO.			production in Nandi County, Kenya
Sejian *et al* (2015).	Global Warming: Role of Livestock. Research Gate Publications, pp. 142-185.	Livestock GHG emission is a human-activity that throughout the commodity value chain emits 65% of nitrous oxide, 37% of Methane and 9% carbon dioxide which are contributors to climate change	The study did not look at the adaptation and mitigation measures practised locally	This current study sought to establish the extent to which farmers are aware and are able to put in place measures that mitigate climate change
Milder *et al*., 2010	Trends and Future Potential of Payment For Ecosystem services To Alleviate Rural Poverty In Developing Countries. Ecology and Society 15, 321-340.	Some economically useful trees and shrubs are sources of fodder, but also contribute to reduction of soil erosion and are able to maintain higher levels of biomass through extended growth periods and root systems and are able to store more carbon thus mitigate the effects of climate	The study did not focus on local practices and extent of use of similar mitigation and adaptation strategies by smallholder milk farmers in Kenya	This study sought to find out the extent to which useful trees and shrubs as sources of fodder are used to adaptation and mitigation to climate change.

2

2.9 Research Gaps

Literature review has shown that many areas in East African region are likely to experience reduced rainfall, increased incidences of droughts and rising temperatures. This study aimed at determining the state of climate change in Nandi County by focusing on the trend of three main variables of CC; temperature, rainfall and soil moisture, looking at the baseline (1971 to 2000) and then projecting to between 2021 and 2050. In addition this study sought to establish the changes in fodder productivity 2001 and 2017, and the soil moisture between the period 1982 and 2017. The study further sort to understand the trend of milk production between the period 2010 and 2016, using marketed milk as a proxy. It also sought to examine how fodder affects milk productivity in Nandi County, Kenya by determining milk production estimates from County for the period between 2008 and 2017.

CHAPTER THREE

3 DATA AND METHODOLOGY

3.1 Introduction

This chapter has the description of data, sources and methodological approach that was adopted in the study. It also discusses the ethical considerations in the study.

3.2 Data

The study used appropriate research instruments to obtain information on the effects of fodder on smallholder milk productivity in Nandi County under changing climate. The sources of data for the proposed study were both primary and secondary aimed at providing information on climate, fodder availability, milk production and existing adaptation and mitigation strategies. This included use of observed and climate model outputs, structured questionnaires, focus group discussion, and key informant interviews.

3.2.1 Climate Data

The study used both observed and climate model data which comprised rainfall, maximum and minimum temperature.

3.2.1.1 Observed climate data

Observed climate data which included rainfall, minimum and maximum temperature were sourced from Kenya Meteorological department for stations located in Nandi County which included Nandi hills Tea estate and Kobujoi Forest station which were mainly rainfall stations. Due to limited availability of observational stations, the study utilized both satellite derived and assimilated climate variables. This included Climate Research Unit (CRU) precipitation datasets as detailed in Harris et al. (2020).

3.2.1.2 Model based climate data

Climate model data which includes rainfall, maximum and minimum temperatures data were based on eight (8) CORDEX models as shown in Table 3-1 downscaled by Rossby Centre Regional Atmospheric Model, (RCA4) run by Swedish meteorological and hydrological institute (SMHI). The RCA4 model is forced by lateral and surface boundary conditions from the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim Re-Analysis (ERA-Interim). The baseline period considered for the study was 1971 to 2000 while the future period (projection) considered for the study was 2021 to 2050. The future projections use Representative Concentration Pathways (RCPs) scenario 4.5wm^2 and 8.5wm^2.

Table 3-1*: List of CMIP5 GCMs used in the study*

Institute name	**GCM name**	**Calendar**
CCCma (Canada)	CanESM2	365 days
CNRM-CERFACS (France)	CNRM-CM5	standard
MOHC (UK)	HadGEM2-ES	360 days
NCC (Norway)	NorESMI-M	365 days
ICHEC (Europe)	Ec-EARTH	Standard
MIROC (Japan)	MIROC5	365 days
NOAA GFDL (USA)	GFDL-ESM2M	365 days
MPI-M (Germany)	MPI-ESM-LR	standard

3.2.2 Fodder availability data

The Normalized Difference Vegetation Index (NDVI) and Soil moisture were utilized as proxy for fodder availability.

3.2.2.1 Normalized Difference Vegetation Index

The U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center distributes satellite-derived vegetation products generated from the Collection 6 Moderate Resolution Imaging Spectroradiometer (MODIS) instrument flown aboard the Aqua satellite. These products, known as Earth Resources Observation and Science (EROS)--Moderate Resolution Imaging Spectroradiometer (e-MODIS) respond to operational land monitoring applications requiring near-real time Normalized Difference Vegetation Index (NDVI) data for comparison against historical records. Real-time and historical NDVI products are composited in 10-day (dekadal) intervals on a Geographic-mapping grid. This study utilized the eMODIS 10-day maximum-value composite NDVI images at 250m spatial resolution to monitor vegetation conditions over Nandi County. NDVI, a measure of the density of chlorophyll contained in vegetative cover, is defined as (NIR - RED) / (NIR + RED), where NIR is the near-infrared reflectance and RED is the visible-red reflectance. These vegetation products are generated from MODIS L1B Aqua surface reflectance, corrected for molecular scattering, ozone absorption, and aerosols using MODIS Science Team algorithms. The NDVI data used in the study spans the period between 2001 and 2017

3.2.2.2 Soil moisture

The soil moisture distribution products are derived from the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS) Noah Land Surface Model L4. The source data are provided by NASA through the GES DISC site in netCDF format. The netCDF file contains a series of land surface parameters simulated from the Noah model within FLDAS. This simulation is forced by a combination of the Modern Era Retrospective-analysis for Research and Applications Version 2 (MERRA-2) and Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) data. The simulation is initialized on January 1st 1982 using soil moisture and other state fields from a FLDAS/Noah model climatology for that day of the year. The data are

0.10-degree resolution while the temporal resolution is monthly. The soil moisture utilized in this study was based on two soil layer depths: 0-10 cm and 10-40 cm and spans the period between 1982 and 2017.

3.2.3 Milk production data

Data on milk production was sourced from dairy farmers' organization. Milk marketed was used as proxy for milk produced. The actual milk marketed data was sourced from the farmer organization for the period between 2007 and 2016.

3.2.4 Adaptation and mitigation strategies data

Information on existing adaptation and mitigation strategies to climate change was collected based on questionnaires, focus group discussion and key informant interviews.

3.2.4.1 Questionnaires

The study used questionnaire as the tool for data collection. The use of the questionnaire in this study reduced biases which are as a result of the personal characteristics of interviews. The respondents had adequate time to fill the questionnaires. A structured questionnaire was used because it was easily coded and analysed quantitatively using statistical methods. The researcher distributed the questionnaires and then collected them later. The administering of the questionnaires was done by the researcher personally because of the high return rates. The questionnaire contained closed and open ended items and was divided into various parts that gathered general and demographic information (Appendix 2). The qualitative data collected was used to supplement the information obtained in the qualitative data.

3.2.4.2 Focus Group Discussion

Focus Group Discussions (FGD) was used to gather qualitative data from the respondents in the area of study. The sessions were guided by open ended questions that gave qualitative data. FGD brought together respondents with similar experiences to discuss the impact of fodder on smallholder milk production under changing climate in Nandi County. A leader was chosen from each group to conduct the discussion by introducing the topic and who helped the members to participate in a highly interactive and healthy discussion. This provided a deeper insight on their views on the topic at hand. It also gave room for a wide range of opinions and many ideas and whereby participants expressed their concerns without fear.

3.2.4.3 Key Informant interviews

Interviews were applied in this study to gather data from the key informants. A structured interview guide was used to collect primary data from the officials. Since interview helped to arrive to a deeper insight of the information collected, the responses were used to add to the quantitative data collected. This therefore led to higher quality ideas on the answers the project was seeking to get thus making analysis easier.

3.2.4.4 Reliability of the Instrument of the Study

The reliability of a research instrument is determined by the extent to which it produces like results even when performed repeatedly (Orodho, 2012). This therefore means that there will be stability and consistency thus making it reliable. To assess reliability of the instruments, a pilot study was conducted in which the reliability coefficient of the questionnaire was determined using Cronbach's coefficient alpha, and in which a threshold of 0.70 was acceptable. The pilot study was done in Nakuru, a county in Rift Valley and a dairy production area in Kenya with similar socioeconomic conditions to Nandi County.

3.3 **Research Methodology**

The study used concurrent triangulation research design which allowed Mixed-Methods Research

Methodologies. This design allowed for both qualitative and quantitative data to be collected concurrently in one phase which was then analysed separately (Center for Innovation in Research and Teaching, 2016). The researcher collected both survey data and data from scientific models at the same time in order confirm, cross-validate or corroborate findings. The design enabled the researcher to overcome the weakness of using just one method by incorporating the strengths of another method.

3.3.1 Spatiotemporal analysis of climate, fodder availability and milk production

3.3.1.1 Assessment of the skill of Climate models

The ability of the climate model to match the long-term historical climate observations was determined through both graphical and statistical approaches. Graphical analysis involved comparison of climatology based on precipitation, and maximum and minimum temperature. Correlation and Mean Absolute Error (MAE) analysis was used to compare observed and climate model data. Correlation measures the degree of association between two variables. The higher the correlation, the more one variable explains the variability in the other variable (Wilks, 1995). Positive correlation implies that when one quantity increases, the other one increases and vice-versa. If it's negative, it implies that when one quantity increases, the other decreases and vice-versa. The significance of the strength of the correlation is tested using the student t-test. Product moment correlation coefficient was computed between the climate variables temperature and rainfall) and NDVI as proxy for vegetation cover using Equation 2.

$$r_{xy} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad (1)$$

In Equation 1, r_{xy} is the correlation coefficient, n is the sample size, xi and yi are the variables being correlated and $(\bar{x}), (\bar{y})$ are the mean values of variables of satellite and gauge based data respectively. The student t-test with n-2 degrees of freedom was used to assess the significance of the correlation at the 95% confidence level. The t-test is given by the equation

$$t_{n-2} = r\sqrt{\frac{n-2}{1-r^2}} \qquad (2)$$

Where r is the Pearson correlation coefficient while n is the sample size

3.3.1.2 Temporal analysis of climate and fodder availability

This activity involved determination of temporal variability of past and future climate over Nandi County. The presence of a monotonic increasing or decreasing trend was tested with the nonparametric Mann-Kendall test while the slope of a linear trend was estimated with the nonparametric Sen's method (Gilbert 1987). Furthermore, the true slope of the existing trend (as change per year) was estimated using the Sen's nonparametric method.

Mann-Kendall test is a test that evaluates whether y values tend to increase or decrease over time through what is essentially a nonparametric form of monotonic trend regression analysis. To perform a Mann-Kendall test, compute the difference between the later-measured value and all earlier-measured values, (y_j-y_i), where j>i, and assign the integer value of 1, 0, or –1 to positive differences, no differences, and negative differences, respectively (Kendall, 1975). The test statistic, S, is then computed as the sum of the integers:

$$\mathrm{s} = \sum_{i-1}^{n-1} \sum_{j=i+1}^{n} sign(y_j - y_i) \qquad (3)$$

Where $sign(y_j - y_i)$, is equal to +1, 0, or -1 as indicated above. When S is a large positive number, later-measured values tend to be larger than earlier values and an upward trend is indicated. When S is a large negative number, later values tend to be smaller than earlier values and a downward trend is indicated. When the absolute value of S is small, no trend is indicated (Kendall, 1975). The test statistic τ can be computed as:

$$\tau = \frac{S}{n(n-1)/2} \qquad (4)$$

which has a range of –1 to +1 and is analogous to the correlation coefficient in regression analysis. The null hypothesis of no trend is rejected when S and τ are significantly different from zero. If a significant trend is found, the rate of change can be calculated using the Sen slope estimator (Helsel and Hirsch 1992) given as

$$\beta_1 = median\left(\frac{y_j - y_i}{x_j - x_i}\right) \qquad (5)$$

for all i < j and i = 1, 2, …, n-1 and j = 2, 3,…, n; in other words, computing the slope for all pairs of data that were used to compute S. The median of those slopes is the Sen Slope estimator

The tested significance levels α are 0.001, 0.01, 0.05 and 0.1. A two-tailed test is used for four different significance levels α: 0.1, 0.05, 0.01 and 0.001. The significance level 0.001 means that there is a 0.1% probability that the values $x_i$are from a random distribution and with that probability we make a mistake when rejecting H_0 of no trend. Thus the significance level 0.001 means that the existence of a monotonic trend is very probable. Respectively the significance level 0.1 means that there is a 10% probability that we make a mistake when rejecting H_0.

For the four tested significance levels the symbols used include *** if trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance, * if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance and ++ if the significance level is greater than 0.1. The true slope of an existing trend (as change per year) was estimated using the Sen's nonparametric method. The Sen slope was then expressed as percent of the mean quantity per unit time (Salmi et al., 2002; Slack et al., 2003). That is:

$$\% \, trend = \frac{[Sen\ Slope\ Estimator\ Q]}{mean\ f(year)} \qquad (6)$$

3.3.1.3 Temporal analysis of milk production

Temporal analysis of milk production was based on both graphical and statistical approaches as detailed in section 3.3.1.2. Based on review of several studies such as Omore (2004), Muriuki (2009) and Wambugu (2011), it was shown that only 55% of milk produced (MP) in Kenya is marketed (sold) either formally or informally. The remaining 45% is consumed at home and others fed to calves. Further, these studies indicate that total milk marketed formally in Kenya accounts for 20% of the total milk produced. Therefore, equation 7 (Author, 2022) was used to compute the average milk supplied per HH to farmer organization (AMSHH),

$$AMSHH = \frac{\mathrm{TMO}}{\mathrm{NAS}} \qquad (7)$$

Where TMO is the Total Milk procured by the farmer organization and NAS is the average number of active milk suppliers.

Consequently, the total milk produced per household (TMHH) was computed using equation 8 (Author, 2022)

$$\mathrm{TMHH} = \left(\frac{\mathrm{AMSHH}}{0.2}\right) \qquad (8)$$

Where AMSHH is the average milk supplied per HH to farmer organization

3.3.1.4 Spatial analysis of climate, fodder availability and milk production

To determine spatial variability of climate and fodder availability, maps were used. Plotting of maps was based on geospatial information systems tools. The analysis included plotting of both seasonal and annual maps.

3.3.2 Relationship between milk production, fodder availability and climate

In order to determine the combined effect of fodder availability and climate on milk production, Multiple Linear Regression (MLR) analysis methodology was employed. Multiple linear regression analysis is performed in order to understand how well a set of variables is able to predict a particular outcome i.e. to determine which variable in a set of variables is the best predictor of an outcome. MLR is based on a least squares where the model is fit such that the sum-of-squares of differences of observed and predicted values is minimized. The model expresses the value of a predictand variable as a linear function of one or more predictor variables and an error term.

$$Y_{\mathrm{i}} = \mathrm{B}_o + B_1(x_{i,1}) + B_2(x_{i,2}) + \dots\dots\dots\dots.. + B_{\mathrm{n}}(x_{i,n}) + \epsilon_i \qquad (9)$$

In equation 9, B_0 regression constant, B_n is coefficient on the nth predictor, $x_{i,n}$ value of the nth predictor, n is the total number of predictors, Y_1 predictand and ϵ_i is the error term.

In this study, milk production datasets were considered as dependent variables. Fodder availability and climate data were considered as independent variable. Worth noting, all variables were re-gridded to $0.25^o \times 0.25^o$ resolution for comparison purposes. Variable collinearity was detected using Variable Inflation Factors (VIFs) which measure the impact of collinearity on the standard errors of the estimate. Collinear variables offer the same information about the predictand. The square root of VIF shows how much the standard error is inflated by the other variables in the model. Collinearity was addressed by re-specifying the model i.e. dropping one or more collinear variables.

Stepwise variable selection was adopted where both the backward and forward strategies are combined until no changes occur. Model selection was based on the Akaike information criterion (AIC) which measures the relative quality of a statistical model, for a given set of data. It deals with the trade-off between the goodness of fit of the model and the complexity of the model. Durbin-Watson test-statistic was used to assess model independence i.e. the hypothesis of uncorrelated errors. It is based on differences between consecutive residuals. It is constrained to lie between 0 and 4 and values around 2 indicate independence. Small/large test statistics indicate positive/negative autocorrelation. Model‘s residual normality was checked visually using histograms. For normality histograms should be symmetrical (bell-shaped). Wilk-Shapiro test was used to check whether the residuals come from a normal distribution. Small/large p-values signal strong evidence against/for normality. The goodness of fit of the models was assessed using the coefficient of determination, R^2. It is a statistical measure of how well the regression line approximates the real data points. An R^2 of 1 indicates that the regression line perfectly fits the data.

A Chi-Square (χ^2) test was computed to assess the relationship between the different variables. The calculation of the Chi-Square statistic is quite straight-forward and intuitive:

$$x^2 = \sum \frac{(f_o - f_e)^2}{f_e} \qquad (10)$$

where f_o = the observed frequency and f_e = the expected frequency if NO relationship existed between the variables.

3.3.3 Examination of existing and potential adaptation and mitigation strategies to climate change

Since data was not gathered from the entire population, the study involved sampling. Purposive

Sampling was used to target experts in the Ministry of Agriculture Livestock & Fisheries (MALF), the dairy cooperatives, Kenya Dairy Board (KDB) and the Kenya Agriculture Research Institute (KARI), experts who have in-depth knowledge on vegetation, soils, cultivation of fodder and both the adaptation measures and mitigation strategies used in the Nandi County. Purposive sampling is a non-probability sampling technique and thus it based on the researcher's judgment.

Snowball sampling was used because it is faster in collecting sensitive information and is convenient for studying hard-to-reach populations. Subjective sampling was employed to select areas with evidence of climate change and vegetation cover changes. Subjective sampling was used because it is a flexible sampling scheme, permits use of experience and decision making ability of researcher and saves time by selecting typical and useful cases only (Alaska Geobotany Centre, 2015).

The study also used a systematic random sampling technique to identified local house hold heads with the help of a local chief. Household that were included in research work were those who engage in dairy production and grow fodder. Using systematic random sampling is advantageous because the sample was easier to identify (Krueger & Casey, 2000).

The mathematical formula of determining a sample size from a given population by Krejcie & Morgan (1970) was used as follows.

$$\boldsymbol{s = X^2NP(1-P) \div d^2(N-1) + X^2P(1-P)} \qquad (\mathbf{11})$$

Where $\boldsymbol{s}$ is the required sample size, $\boldsymbol{X^2}$ is the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841), N is the population size (300000), P is the population proportion (assumed to be .50 since this would provide the maximum sample size) and d is the degree of accuracy expressed as a proportion (.05). Therefore, the required sample size was given as 3.841 x 300000 x 0.5 (1-0.5) ÷ 0.05 x 0.05 (300000 -1) + 3.841 x 0.5 (1-0.5) which resulted to a sample size of 384.

Therefore, a target population was defined which comprised 384 individuals drawn from farmers and government employees and experts within the Nandi County. After collection, data was organized and prepared for analysis by way of coding and keying it into the Statistical Package for Social Sciences (SPSS) version 20.0 software. Field survey questionnaire and Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL), a project planning tool was used in Focus Group Discussion (FGD). For the FGD using CRiSTAL tool, the focus was placed on how climate had changed over the past 30 years and how it had affected their farming practices especially on dairy production and for specific on fodder. A total of 15 respondents from Kabiyet, Lesssos, Kosirai, Kapsabet and Kaptumo Sub Counties participated. The assessment based on CRiSTAL tool was meant to enrich the FGD and get a clear view on the changes that had taken place over time. Worth noting, participants were selected to include representatives of farmer cooperative, Ministry of Agriculture and ordinary dairy farmers.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents results and discussion based on the study objectives which are determination of spatiotemporal pattern climate, fodder availability and milk production and their relationship and finally examining the existing and potential adaptation and mitigation strategies to climate change in the Nandi county of Kenya.

4.2 Spatiotemporal variability of past and future climate over Nandi County

Analysis of spatiotemporal variability of past and future climate over Nandi County involved assessing the performance of CORDEX RCA4 model in simulating climate and analysis of spatiotemporal variability of past and future climate over Nandi County.

4.2.1 Performance of CORDEX RCA4 model in simulating climate over Nandi County

Performance of CORDEX RCA4 model in simulating climate over Nandi County was based on determination of the skill of the model and error analysis based on observed and model outputs.

4.2.1.1 Determination of the skill of CORDEX RCA4 model in simulating climatology

The Figure 4-1 to Figure 4-3 presents climatology analysis for precipitation, maximum and minimum temperature based on CORDEX RCA4 models and observed data over Nandi County.

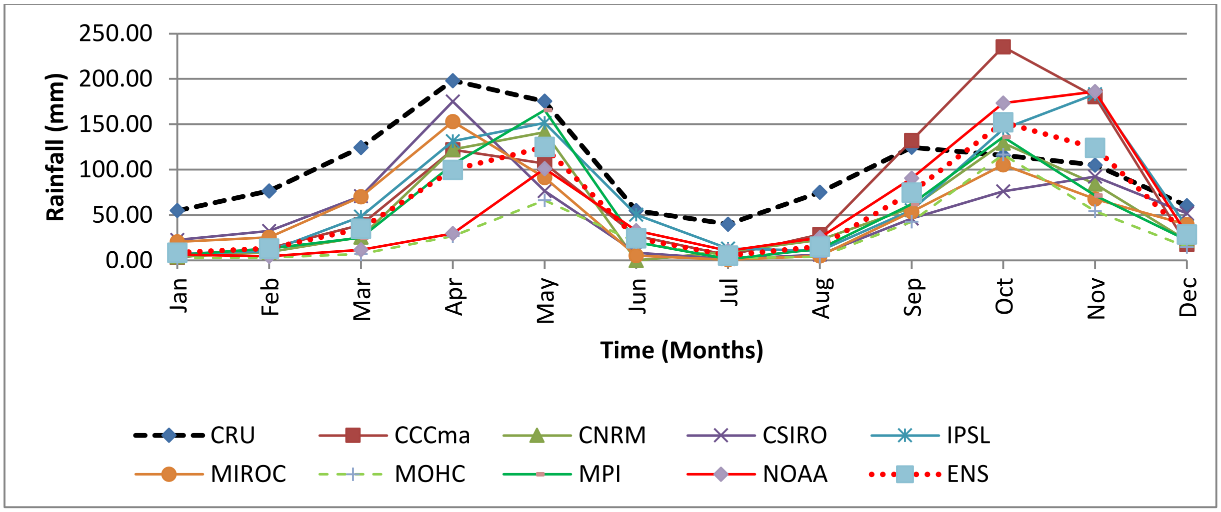

Figure 4-1: Precipitation climatology over Nandi County

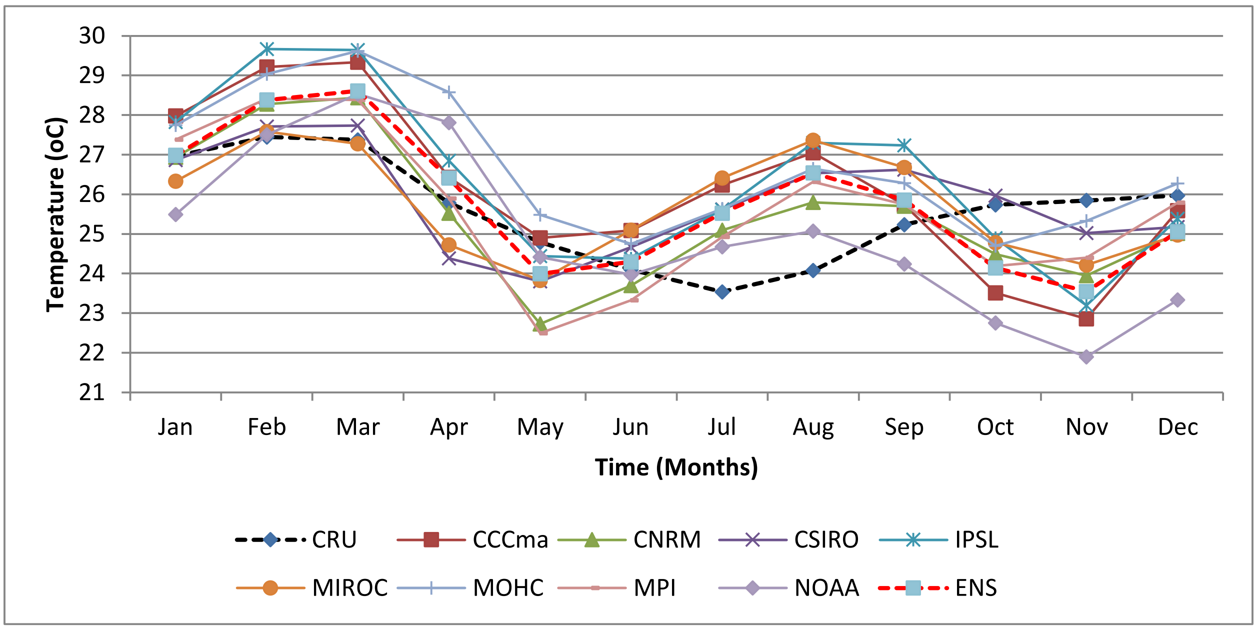

Figure 4-2: Maximum temperature climatology over Nandi County

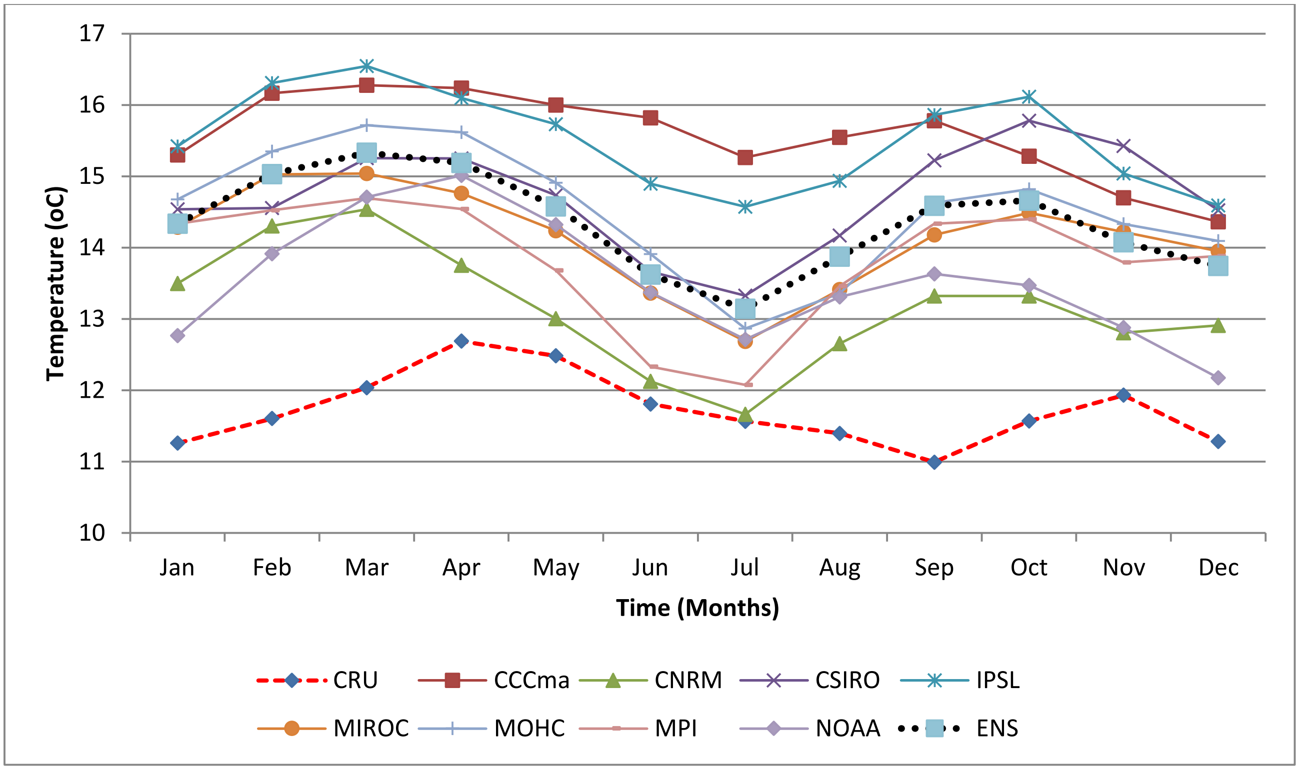

Figure 4-3: Minimum temperature climatology over Nandi County

The Figure 4-1 showed that Nandi County largely experienced bimodal rainfall distribution with peaks in April during the MAM season and October during the SOND season. Further, it is noted that the climatology of observed and RCA4 results are comparable with differences between MAM and OND season attributed to the location of ITCZ in the vicinity of the equator during season. This is affirmed by numerous studies that have associated the bimodal rainfall regime over equatorial Africa to the passage the ITCZ, that sweeps the greater East Africa region twice annually (Omondi et al. 2012; Gitau et al., 2015; Omondi et al., 2015 and Wakachala et al., 2015). The study show that CORDEX RCA4 models underestimated observed rainfall during MAM season and overestimated rainfall during OND season. According to Panitz et al. (2014), regional climate models (RCMs) driven by GCMs inherits biases through the lateral boundary conditions that are added to those of the RCM limiting the ability of downscaling to improve the simulation skills of large-scale forcing while other cases may involve substantial difference of RCM climate change signal to that of the driving GCM (Dosio and Panitz, 2016). Omondi et al. (2015) noted that such dissimilarities may arise from different schemes employed in the individual models that are not able to capture the local circulation systems especially in the western parts of the country.

The study show that CORDEX RCA4 models underestimated observed rainfall during MAM season and overestimated rainfall during OND season. According to(Panitz, Dosio, Büchner, Luthi, & Keuler, 2014), regional climate models (RCMs) driven by GCMs inherits biases through the lateral boundary conditions that are added to those of the RCM limiting the ability of downscaling to improve the simulation skills of large-scale forcing while other cases may involve substantial difference of RCM climate change signal to that of the driving GCM (Dosio & Panitz, 2016).(Omondi et al., 2015) also noted that such dissimilarities may arise from different schemes employed in the individual models that are not able to capture the local circulation systems especially in the western parts of the country

The Figure 4-2 showed that maximum temperatures peaked in February and September October. Noticeably, an ensemble of all the RCA4 models was comparable to the observed maximum temperature. During MAM and OND, the region receives the highest temperatures compared to JJA which receives the lowest temperatures. Similarly, Figure 4-3 showed that minimum temperatures peaked in February and September. However, all the CORDEX RCA4 models were noted to overestimate the observed minimum temperature. The spatial distributions of maximum and minimum temperature are attributed to the apparent seasonal movement and position of the sun (Meehl, et al., 2007; Omondi et al. , 2015).

4.2.1.2 Comparison of observed and CORDEX model outputs over Nandi County

The Table 4-1 presents error analysis between observed (CRU) and CORDEX RCA4 ensemble model output over Nandi County.

Table 4-1: Error analysis between observed (CRU) and Model output

Model	Rainfall		TMAX		TMIN	
	Correlation	MAE	Correlation	MAE	Correlation	MAE
CCCma	0.12	94.17	0.41	1.82	0.31	3.79
CNRM	0.21	89.79	0.51	1.39	0.22	1.51
CSIRO	0.15	91.58	0.43	1.35	0.24	2.93
ICHEC	0.21	83.48	0.48	1.25	0.18	2.56
IPSL	0.20	90.91	0.45	1.98	0.32	1.37
MIROC	0.17	86.68	0.16	1.80	0.21	3.76
MOHC	0.10	90.03	0.58	1.64	0.38	2.35
MPI	0.20	102.90	0.54	1.55	0.18	2.76
NOAA	-0.10	100.84	0.27	1.81	0.29	2.76
ENS	0.18	100.84	0.52	1.81	0.40	2.76

In Table 4-1, correlation analysis indicates that CNRM and ICHEC models had the highest correlation while MOHC and NOAA had the lowest correlation with observed rainfall. Similarly, the models with highest correlation coefficient showed the lowest MAE i.e. 89.79 and 83.4 and thus the best performing models whereas the ensemble of all models had a MAE of 100.84. The low correlation coefficient values for rainfall could be attributed to its high spatiotemporal variability. The highest correlation coefficient for maximum temperature was noted in MOHC with a value of 0.58 whereas the lowest correlation coefficient in MIROC with a value of 0.16. Further, MOHC model had the lowest MAE. For minimum temperatures, an Ensemble of all the models showed the highest correlation compared to individual models whereas models with highest correlation coefficients showed lower MAE values. Ideally, ensemble of all models is expected to perform better than individual models. However, for the case of Nandi County, the study noted that individual models performed better than ensemble of the RCA4 driven CORDEX models in simulating precipitation and maximum temperature while the ensemble of all the models performed well in simulating minimum temperature.

4.2.2 Temporal variability of past climate over Nandi County

Temporal variability of past climate over Nandi County was based on graphical and statistical analysis.

4.2.2.1 Graphical trend analysis of past climate

The Figure 4-4 to Figure 4-6 presents graphical analysis of the trend of past climate over region within Nandi County

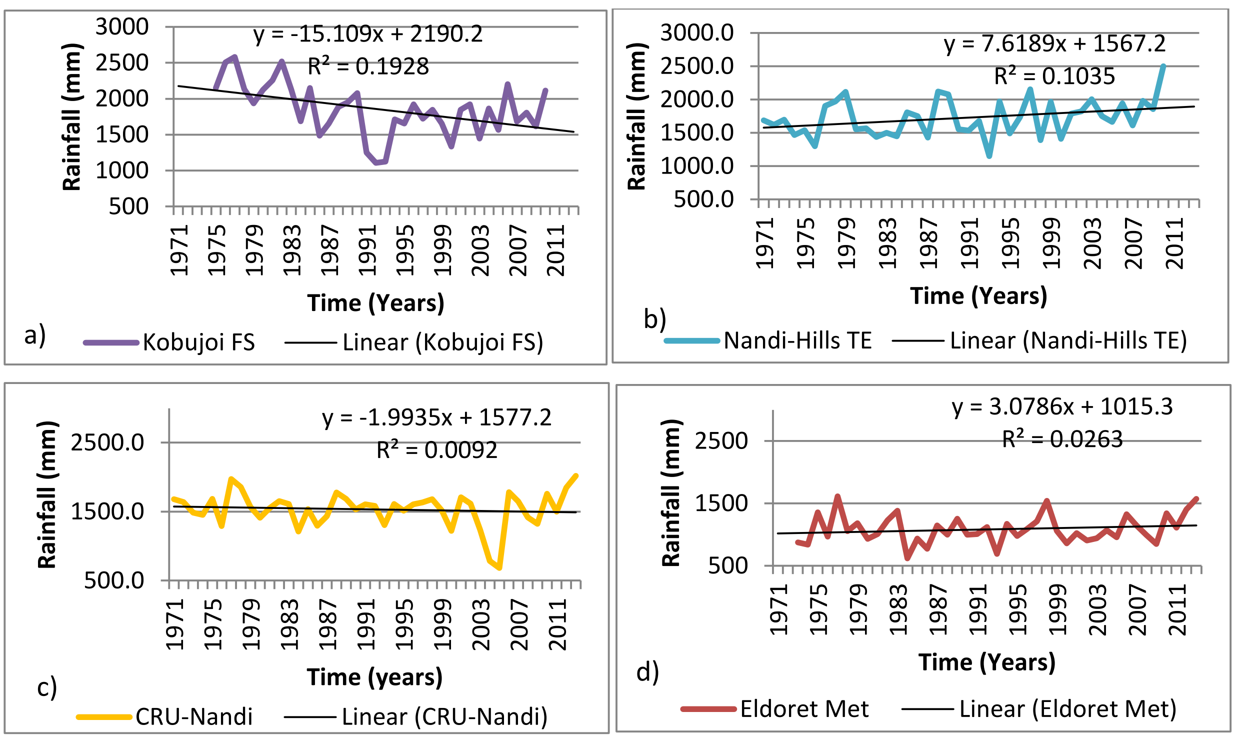

Figure 4-4: Graphical analysis of the trend of observed rainfall based on a) Kobujoi FS b) Nandi

Hills TE, c) CRU and d) Eldoret stations

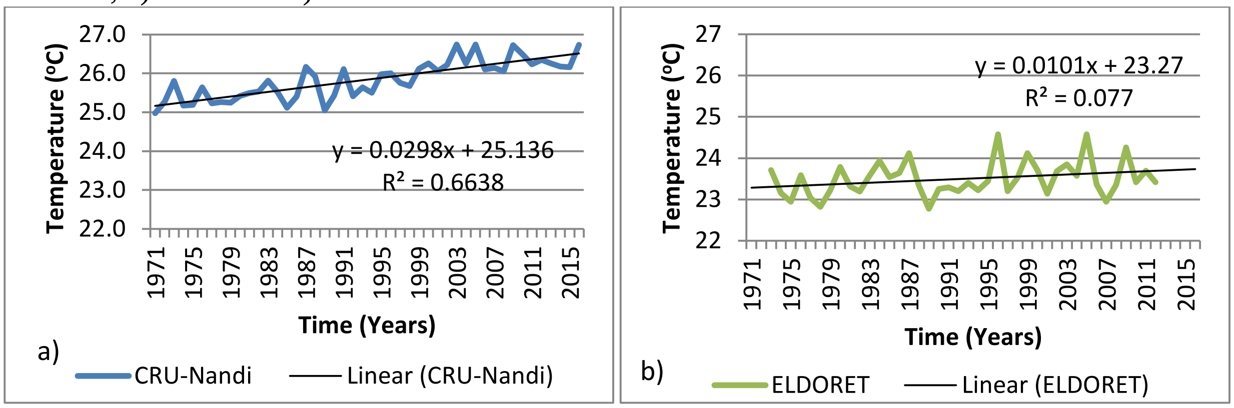

Figure 4-5: Graphical analysis of the trend of observed maximum temperature based on a) CRU-Nandi and b) Eldoret Stations.

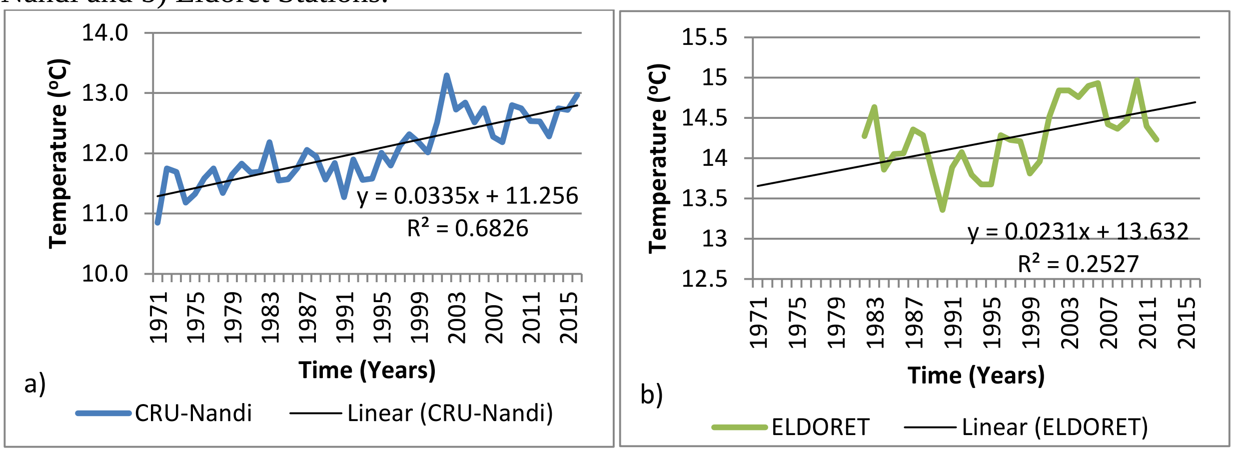

Figure 4-6: Graphical analysis of the trend of observed minimum temperature over Nandi County

The Figure 4-4 (a) showed that rainfall over Kobujoi station has been decreasing between 1971 and 2012. However, the coefficient of determination indicated that only 19.28% of data could be fitted along the line of best fit. Over Nandi hills tea estate (Figure 4-4 (b), the graph showed that rainfall had been increasing between 1971 and 2012. However, the coefficient of determination indicated that only 10.35% of data could be fitted along the line of best fit. An aerial average based on CRU (Figure 4-4 (c) indicated that rainfall had been decreasing over Nandi County. Compared to the nearest synoptic station located in Eldoret (Figure 4-4 (d)) showed that rainfall had been increasing with only 2.6% of the data fitted along the line of best fit. The varied results prove that rainfall remains highly variable even at small spatial and temporal scale. This necessitates the need to have more rainfall observation stations within the county. Moreover, it was noted that none of the stations within Nandi County were being observed at synoptic times..

The Figure 4-5 (a) and Figure 4-6 (a) shows that maximum and minimum temperatures over Nandi based on CRU dataset for the period 1971-2015 had been increasing with R^2 indicating that 66.38% and 68.26% of data could be fitted in the line of best fit respectively. Similarly patterns of increasing maximum (Figure 4-5 b) and minimum (Figure 4-6 b) temperatures were observed in Eldoret. However, the R^2 indicated that only 7.7% and 25.3% for maximum and minimum temperatures could be fitted in the line of best fit. In general, both maximum and minimum temperatures have shown increasing trend within Nandi County and consistent with studies by (Ongoma et al., 2013; Wakachala et al., 2015).

4.2.2.2 Statistical trend analysis of past climate

The Table 4-2 to Table 4-4 presents statistical analysis of the trend of past climate over Nandi County.

The Table 4.2 show that the trend of annual rainfall for the period 1971 to 2000 were all increasing (positive) for all RCA4 models except CNRM (-0.3), CSIRO (-1.5) and NOAA (-0.4). An ensemble of RCA4 models indicates an increasing trend of 1.0 while observations from CRU, Nandi hills and Kobujoi stations showing decreasing trend except Eldoret station. However, these trend were noted to be significant at α level greater than 0.1. The magnitude of the slope (Q) varied between -3.5 and 4.0 for the RCA4 models and higher up to -49.6 for observed data. The study also showed that the annual percentage change ranged between -15.9% and 25.2% with an ensemble value of 6.7% and less than 1.5% for observed data.

Analysis of DJF rainfall season (Table 4.2) show an increasing trend in RCA4 models except

CNRM (-1.4), MIROC (-2.1), MPI (-1.9) and NOAA (-0.4) while the ensemble of these models showed that the trend was neither increasing nor decreasing. Although observations from CRU (-0.2), Nandi Hills (-1.4) and Kobujoi (-1.5) showed decreasing trend, an increasing trend was recorded for the Eldoret station. The trends for DJF were noted to be significant at α level equal or greater than 0.1 except the MIROC model whose significance level was 0.05. The magnitudes of the slope (Q) for the RCA4 models ranged between -3.6 and 1.1. Computed DJF percentage change ranged between -81.7% and 98.8%.

Analyses of JJA rainfall season (Table 4.2) show decreasing trends in all datasets except CNRM (0.3), IPSL (1.1), MIROC (0.7) and Eldoret (0.1). An ensemble of all the models shows a negative trend of -1.4. However, all the trends were significant at $\alpha \geq 0.1$. Moreover, the magnitude of the slope of the trend line ranged between -9.4 (Kobujoi) and 0.8 (IPSL) while the computed percentage change ranged between -67.8% and 31.0%.

Analyses of MAM rainfall season (Table 4.2) show that the trend based on all datasets were either increasing or decreasing with an ensemble value of 0.5 which implied increasing trend. However, the trend were all significant at $\alpha \geq 0.1$ except MIROC which was significant at $\alpha = 0.05$. Besides, the magnitude of the slope of the trend ranged between -8.4 and 2.7 whereas computed percentage change ranged between -33.5% and 38.8%. Analysis of SON rainfall season (Table 4.2) show decreasing trends based on all datasets except CNRM (-0.4), CSIRO (-0.6), ICHEC (-0.4) and Kobujoi (-1.0) while the ensemble of all the models yielded a positive change of 1.6. However, these trends were all significant at $\alpha \geq 0.1$ except IPSL which was significant at 0.05 whereas computed annual percentage change ranged between -33.5% and 38.8% whereas computed percentage change ranged between -29.3% and 43.6%.

In overall, trend statistics based on past rainfall is highly variable since different models indicate either increasing or decreasing rainfall. An ensemble of all the models show increasing trend for annual, MAM and SON rainfall seasons whereas JJA season was noted to decrease at significant $\alpha \geq 0.1$. Moreover, the study found that the annual ensemble percentage change of rainfall ranged between -12% and 10%. Moreover, the study noted that as much as the amounts of seasonal rainfall have been increasing, the rate of increase during the SON season is higher compared to the MAM season.

Analysis past annual maximum temperature (Table 4-3) show that the trend of all RCA4 models and CRU are increasing except MOHC model. The significance of the trend varied between α = 0.01 (CRU) and α> 0.1. However, an ensemble of all the RCA4 models show that the positive trend is significance at α =0.01. Although the magnitudes of the trend were all close to zero, the annual percentage changes were noted to be positive except for MOHC with an ensemble of RCA4 models having a value of 1.4%.

Analyses of DJF seasonal maximum temperatures (Table 4-3) show positive trend for all datasets except CCCma (-0.6) and MOHC (-0.7). The trend was significant at $\alpha \geq 0.1$ for all datasets except the ensemble of RCA4 models and CRU whose trend were significant at α =0.05. Although the magnitude of the slopes of the trend line were all close to zero, the annual percentage change was noted to be all positive and ranged between 1.5% and 3.5% except CCCma (-0.6%) and MOHC (-0.6%).

Analyses of JJA seasonal maximum temperatures (Table 4-3) show positive trend in all datasets except MIROC (-0.9) and MPI (-0.6). The trend was significant at $\alpha \geq 0.1$ for all datasets except

CCCma (α =0.01), NOAA (α =0.01) and CRU (α =0.001). The significance level for the ensemble of RCA4 models was at α =0.01. The magnitude for the slope of the trend were all close to zero with the annual percentage change being positive and ranged between 1.1% and 3.8% except for MIROC (-1.1%) and MPI (-1.7%).

Analyses of MAM seasonal maximum temperatures (Table 4-3) show positive trend for all datasets except CNRM (-0.5), MIROC (-0.2) and MOHC (-1.7). The trend was significant at $\alpha \geq 0.1$ for all datasets. The magnitude for the slope of the trend line were all close to zero with the annual percentage change being positive and ranged between 1.0% and 3.0% except for CNRM (-0.7%), MIROC (-0.6%) and MOHC (-2.3%).

Analyses of SON seasonal maximum temperatures (Table 4-3) show positive trend for all datasets except CCCma (-0.4), IPSL (-0.4) and MIROC (-0.7). The trend was significant at $\alpha \geq 0.1$ for all datasets except CRU whose trend was significant at α = 0.01. The magnitude for the slope of the trend line were all close to zero with the annual percentage change being positive and ranged between 0.2% and 4.0% except for CCCma (-0.5%), IPSL (-0.3%) and MIROC (-1.0%).

Analyses of past annual, DJF, JJA, MAM and SON minimum temperatures (Table 4-4) show that the trend of all RCA4 models and CRU are increasing (positive). The significance of these trend varied between α = 0.001 (CRU) and $\alpha \geq 0.1$ with all ensembles indicating that the trends were significant at $\alpha \leq 0.01$. The magnitudes of the trend lines were all close to zero, the percentage changes being noted to be positive and ranged 2.87%-5.51% for annual, 0.67%-4.96% for DJF, 1.41-8.83% for JJA, 1.98-6.20% for MAM and 1.62%-7.51% for SON.

Table 4-2: Trend statistics of past rainfall (1971-2000) over Nandi County

Period	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA	CRU	Nandi Hills	Kobujoi	Eldoret
ANN	Z	1.1	-0.3	-1.5	1.0	0.2	0.9	1.6	0.2	0.4	-0.4	-0.8	-0.6	-2.0	0.3
	α	++	++	++	++	++	++	++	++	++	++	++	++	*	++
	Q	4.0	-0.5	-3.5	1.5	0.5	3.3	5.4	0.2	2.1	-1.1	-2.6	-3.5	-31.3	2.9
	%	13.3	-2.3	-15.9	6.7	2.0	11.7	25.2	1.4	9.8	-6.3	-5.0	-6.6	-49.6	7.5
DJF	Z	1.9	-1.4	0.0	0.0	0.1	0.4	-2.1	1.5	-1.9	-0.4	-0.2	-1.4	-1.5	0.2
	α	+	++	++	++	++	++	*	++	+	++	++	++	++	++
	Q	1.1	-0.6	-0.1	0.0	0.0	0.3	-2.3	0.5	-0.9	-0.4	-0.6	-2.0	-3.6	0.3
	%	98.8	-55.0	-3.4	0.4	4.1	18.0	-81.7	66.4	-66.4	-18.5	-9.3	-19.6	-32.2	9.4
JJA	Z	-0.9	0.3	-1.8	-1.4	-0.6	1.1	0.7	-0.7	0.0	-1.0	-1.7	-0.6	-1.9	0.1
	α	++	++	+	++	++	++	++	++	++	++	+	++	+	++
	Q	-0.4	0.2	-0.4	-0.2	-0.2	0.8	0.1	-0.2	0.0	-0.3	-2.8	-1.4	-9.4	0.5
	%	-17.8	12.4	-67.8	-12.6	-13.5	31.0	30.1	-23.3	1.7	-25.6	-17.5	-8.4	-54.7	3.5
MAM	Z	-0.5	-0.1	-0.7	0.5	1.1	-0.5	2.0	0.6	0.9	-0.8	-0.2	0.4	-1.8	-0.3
	α	++	++	++	++	++	++	*	++	++	++	++	++	+	++
	Q	-1.4	-0.1	-1.9	0.7	1.5	-0.9	4.1	0.4	2.7	-1.1	-0.7	0.8	-8.4	-1.1
	%	-15.9	-1.4	-18.0	8.1	15.0	-8.6	38.8	13.0	27.7	-29.4	-3.8	4.7	-33.5	-9.0
SON	Z	1.6	-0.4	-0.6	1.6	-0.4	2.1	1.6	0.0	0.3	0.4	0.7	0.9	-1.0	1.8
	α	++	++	++	++	++	*	++	++	++	++	++	++	++	+
	Q	5.2	-1.0	-1.4	1.3	-1.9	4.8	2.6	0.1	0.5	1.0	1.6	2.3	-6.0	3.0
	%	28.7	-11.3	-19.6	10.8	-13.8	37.7	35.0	1.6	5.6	9.1	13.9	17.8	-29.3	43.6

Table 4-3: Trend statistics of past maximum temperature (1971-2000) over Nandi County

Period	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA	CRU
ANN	Z	1.0	0.6	1.6	3.0	2.4	1.9	0.0	-0.7	1.3	2.6	3.6
	α	++	++	++	**	*	+	++	++	++	*	***
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	1.2	0.6	2.4	1.4	2.9	1.5	0.0	-0.7	1.3	2.8	3.0
DJF	Z	-0.6	1.3	0.8	2.2	1.7	0.9	2.5	-0.7	2.4	1.5	2.3
	α	++	++	++	*	+	++	*	++	*	++	*
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	-0.6	1.8	1.7	1.5	2.6	1.2	3.5	-0.6	2.6	2.9	3.1
JJA	Z	2.0	0.9	1.0	3.0	1.6	1.2	-0.9	1.0	-0.6	2.8	3.5
	α	*	++	++	**	++	++	++	++	++	**	***
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	3.6	1.1	1.3	1.9	2.4	2.2	-1.1	1.2	-1.4	2.9	3.8
MAM	Z	0.6	-0.5	1.0	1.0	1.2	1.0	-0.2	-1.7	0.2	1.9	1.5
	α	++	++	++	++	++	++	++	+	++	+	++
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	2.2	-0.7	3.0	1.0	2.0	2.3	-0.6	-2.3	0.7	3.0	2.1
SON	Z	-0.4	1.1	0.7	1.6	1.7	-0.4	-0.7	0.1	0.9	1.0	2.9
	α	++	++	++	++	+	++	++	++	++	++	**
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	-0.5	2.7	2.0	1.1	4.0	-0.3	-1.0	0.2	1.9	2.1	2.6

Table 4-4: Trend statistics of past minimum temperature (1971-2000) over Nandi County

Period	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA	CRU
ANN	Z	1.03	2.68	1.96	3.85	3.53	2.46	1.39	1.61	1.89	2.85	3.18
	α	++	**	*	***	***	*	++	++	+	**	**
	Q	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02
	%	4.08	4.14	3.53	3.81	5.51	4.12	3.11	2.87	3.31	4.80	5.23
DJF	Z	0.18	1.71	0.32	3.03	0.89	2.07	0.71	2.11	2.53	1.78	1.14
	α	++	+	++	**	++	*	++	*	*	+	++
	Q	0.00	0.02	0.01	0.01	0.01	0.03	0.01	0.02	0.02	0.02	0.01
	%	0.67	3.40	1.22	2.98	1.58	4.96	1.39	3.93	4.93	3.89	2.47
JJA	Z	1.64	2.25	2.39	3.43	2.25	2.07	1.25	0.75	0.93	2.60	2.93
	α	++	*	*	***	*	*	++	++	++	**	**
	Q	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.01	0.01	0.03	0.04
	%	4.17	5.57	6.63	5.25	8.83	5.12	3.99	1.41	3.09	7.65	9.35
MAM	Z	1.43	1.11	0.89	3.28	3.75	1.61	2.03	1.32	1.25	2.39	2.21
	α	++	++	++	**	***	++	*	++	++	*	*
	Q	0.02	0.01	0.01	0.02	0.02	0.02	0.03	0.01	0.01	0.02	0.03
	%	4.60	2.45	1.98	3.39	5.12	3.38	5.21	2.58	2.93	4.75	6.20
SON	Z	1.39	1.82	1.64	3.96	3.00	2.36	0.93	1.25	2.18	2.64	3.16
	α	++	+	++	***	**	*	++	++	*	**	**
	Q	0.02	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.02	0.03	0.03
	%	3.42	3.06	2.89	3.71	6.97	4.51	1.61	2.52	3.50	5.67	7.51

4.2.3 Spatial variability of past climate over Nandi County

Spatial variability of past climate over Nandi County is presented below for precipitation (Figure 4-7 to Figure 4-11). The study noted that spatial maps based on individual RCA4 models were comparable for both maximum and minimum temperatures. Therefore, an ensemble of all RCA4 models and CRU are presented for maximum temperature (Figure 4-12 and Figure 4-13) and minimum temperature (Figure 4-14 and Figure 4-15).

Analyses of past DJF (Figure 4-7), MAM (Figure 4-8), JJA (Figure 4-9), SON (Figure 4-10) and annual rainfall patterns based on RCA4 models and CRU data indicated high spatial variability in rainfall in Nandi County. For DJF (Figure 4-7), the study noted that rainfall values varied from 0 to 100mm. The RCA4 model which included CNRM, MIROC, MOHC and MPI were noted to have much dry conditions compared to CRU, CCCma, IPSL and NOAA. Analysis of past MAM (Figure 4-8) showed that seasonal values ranged between 0 and 300mm with CRU, CCCma, CNRM, CSIRO, IPSL, MIROC and MPI showing wet conditions compared to MOHC and NOAA models. For JJA season (Figure 4-9), rainfall values also varied between 0 and 300mm. However, all RCA4 models showed dry conditions compared to CRU. For SON season (Figure 4-10), rainfall values varied between 50mm and 500mm. The study noted that the RCA4 models indicated wetter conditions over the study area compared to CRU. For annual rainfall (Figure 4-11), values ranged between 250mm and 300mm. However, MOHC model was observed to be extremely dry compared to other RCA4 models.

The Figure 4-12 show that maximum temperatures based on CRU were higher in the SW compared to the NE parts of Nandi County with values ranging between 22^{o}C and 28^{o}C. Spatial analysis based on RCA4 models ensemble (Figure 4-13) show similar pattern of maximum temperatures with low values of 26^{o}C and high of 36^{o}C. This meant that the RCA4 model ensemble values were slightly higher than those observed from CRU dataset. Similarly, a comparison of Figure 4-14 and Figure 4-15 show that minimum temperatures were higher in RCA4 based output compared to CRU. The minimum temperatures were up to a maximum of 28ºC.

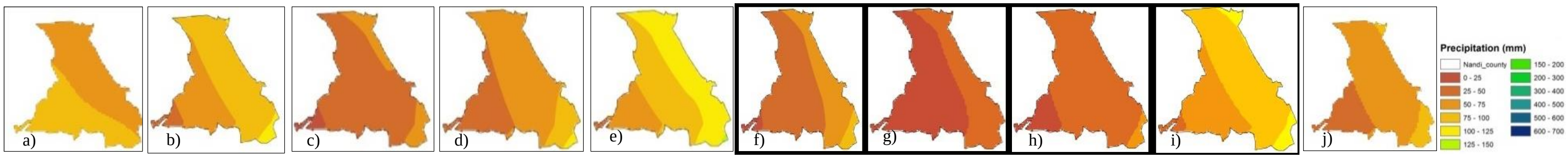

Figure 4-7: Spatial variability of past DJF rainfall based on a) CRU and RCA4 downscaled b) CCCma c) CNRM d) CSIRO e) IPSL f) MIROC g) MOHC h) MPI i) NOAA and j) ENS models over Nandi County

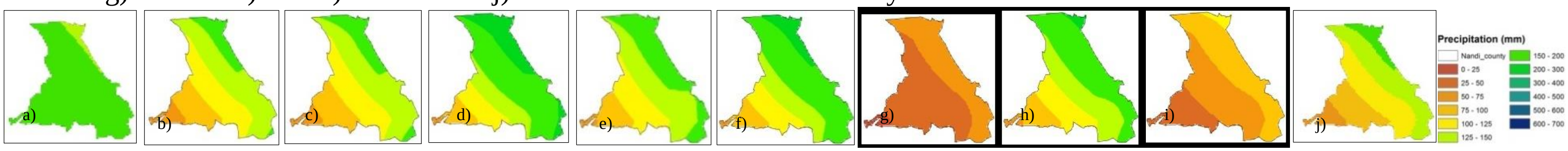

Figure 4-8: Spatial variability of past MAM rainfall based on a) CRU and RCA4 downscaled b) CCCma c) CNRM d) CSIRO e) IPSL f) MIROC g) MOHC h) MPI i) NOAA and j) ENS models over Nandi County

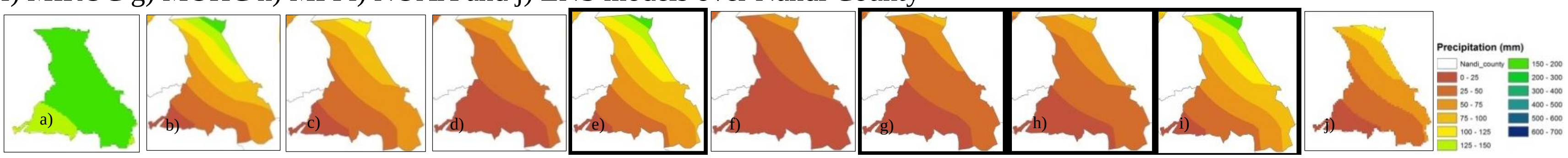

Figure 4-9: Spatial variability of past JJA rainfall based on a) CRU and RCA4 downscaled b) CCCma c) CNRM d) CSIRO e) IPSL f) MIROC g) MOHC h) MPI and i) NOAA models over Nandi County

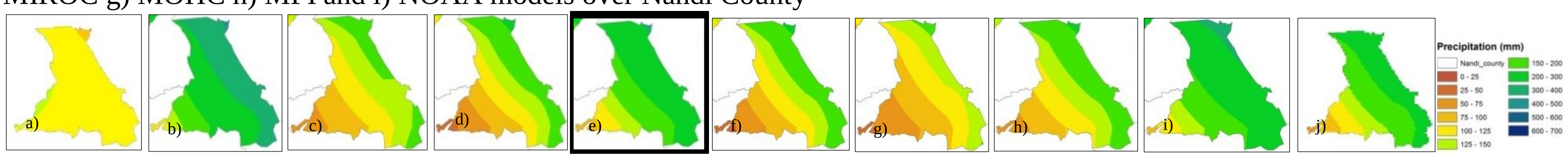

Figure 4-10: Spatial variability of past SON rainfall based on a) CRU and RCA4 downscaled b) CCCma c) CNRM d) CSIRO e) IPSL f) MIROC g) MOHC h) MPI and i) NOAA models over Nandi County

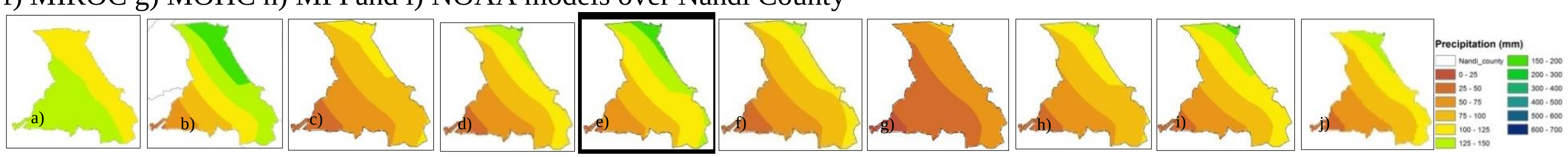

Figure 4-11: Spatial variability of past ANN rainfall based on a) CRU and RCA4 downscaled b) CCCma c) CNRM d) CSIRO e) IPSL f) MIROC g) MOHC h) MPI and i) NOAA models over Nandi County

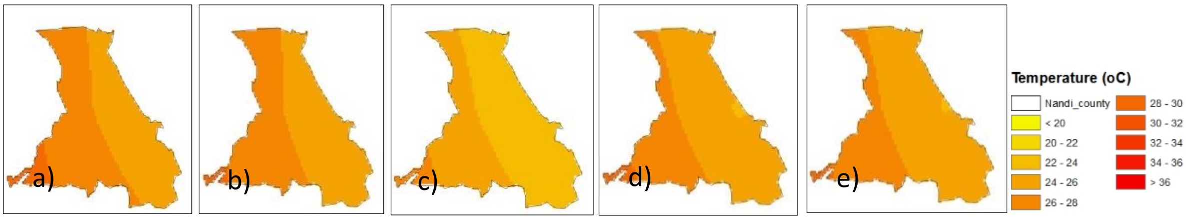

Figure 4-12: Spatial variability of pasta) DJF b) MAM c) JJA d) SON and e) ANN maximum temperature based on CRU over Nandi County

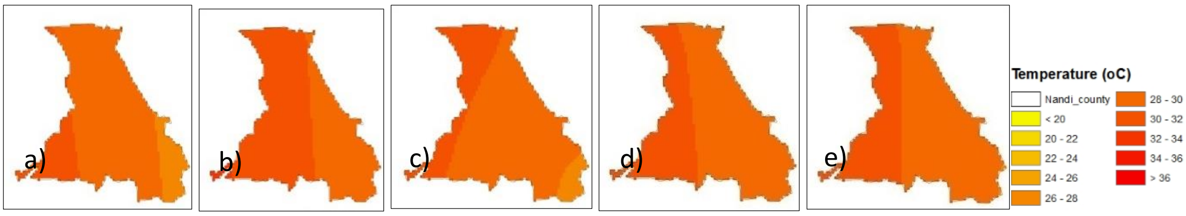

Figure 4-13: Spatial variability of pasta) DJF b) MAM c) JJA d) SON and e) ANN maximum temperature based on RCA4 ensemble over Nandi County

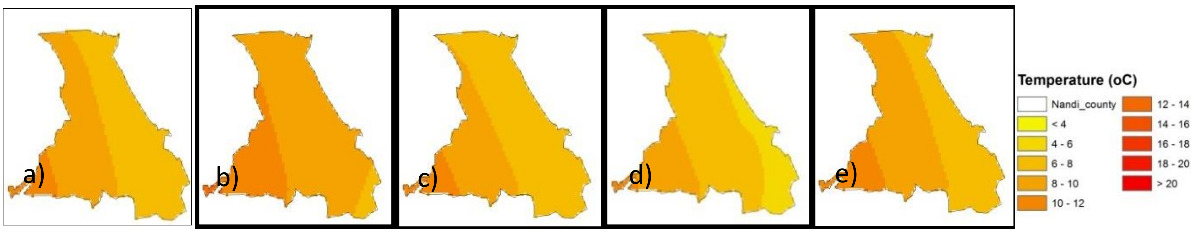

Figure 4-14: Spatial variability of pasta) DJF b) MAM c) JJA d) SON and e) ANN minimum temperature based on CRU over Nandi County

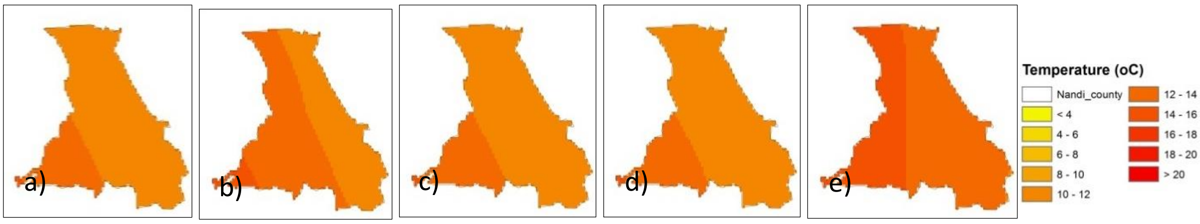

Figure 4-15: Spatial variability of pasta) DJF b) MAM c) JJA d) SON and e) ANN minimum temperature based on RCA4 ensemble over Nandi County

4.2.4 Temporal variability of future climate over Nandi County

Temporal variability of future climate over Nandi County was based on graphical and statistical analysis.

4.2.4.1 Graphical trend analysis of future climate

The Figure 4-16 to Figure 4-18 presents graphical analysis of the trend of future climate over Nandi County

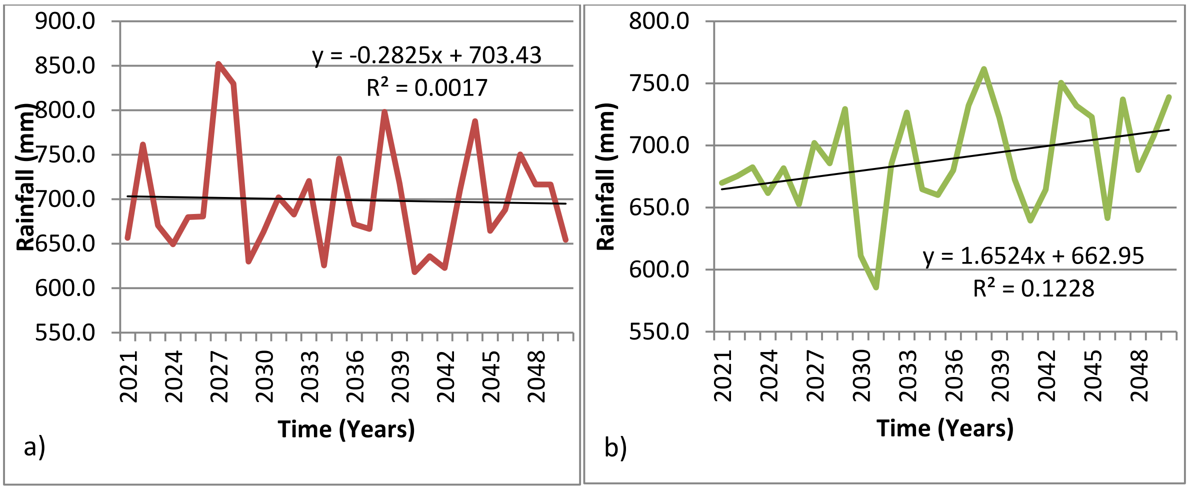

Figure 4-16: Graphical analysis of the trend of future rainfall under a) RCP45 and b) RCP85 over Nandi County

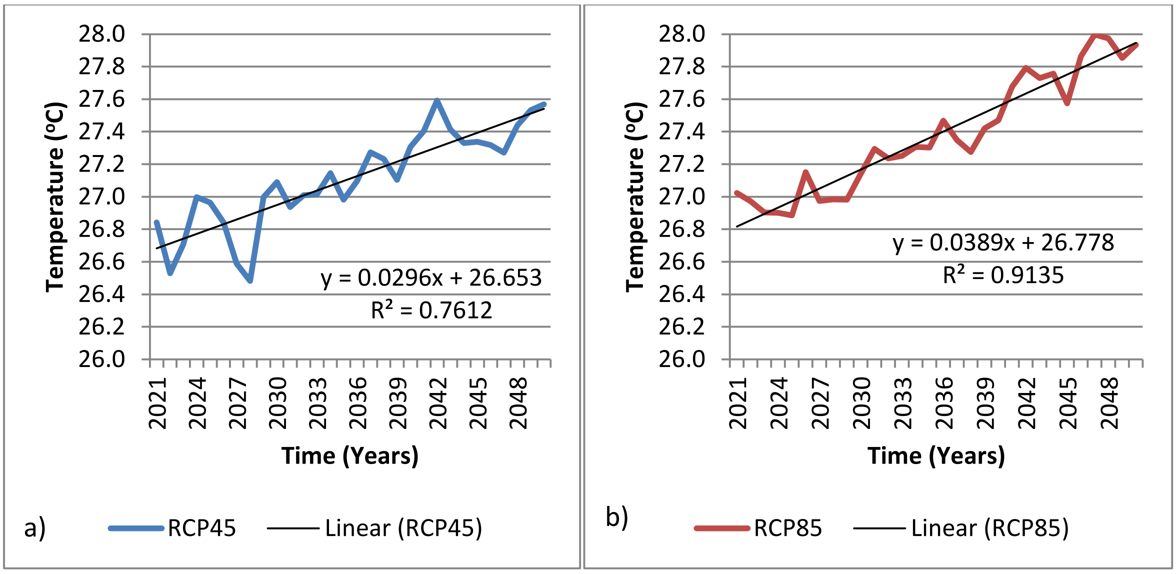

Figure 4-17: Graphical analysis of the trend of future maximum temperature under a) RCP45 and b) RCP85 over Nandi County

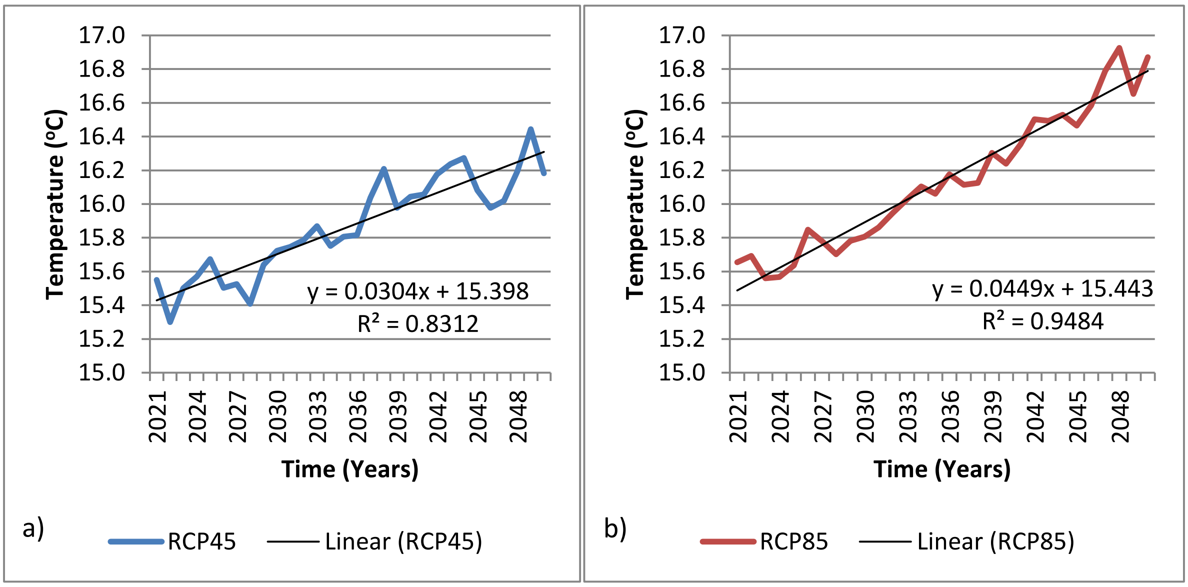

Figure 4-18: Graphical analysis of the trend of minimum temperature under a) RCP45 and b) RCP85 over Nandi County

Graphical analysis of the trend of projected rainfall under RCP45 for the period 2021-2050 (Figure 4-16a) show slight decrease in rainfall whereas projected rainfall trend under RCP85 for the period 2021-2050 (Figure 4-16b) show a steady increase in rainfall. Further analyses based on R^2 show that < 1% for RCP45 and < 12% for RCP85 of all the data could be fitted into the line of best fit. Graphical analysis of the trend of projected maximum temperature under both RCP45 (Figure 4-17a) and RCP85 (Figure 4-17b) for the period 2021-2050 show a steady increase in temperatures. Analyses based on R^2 show that up to 76% and 91.4% of datasets under RCP45 and RCP85 respectively could be fitted along the line of best fit making these trends very significant. Similarly, analyses of trend of projected minimum temperatures under both RCP45 (Figure 4-18a) and RCP85 (Figure 4-18b) for the period 2021-2050 show a steady increase in temperatures. Analyses based on R^2 show that up to 83.1% and 94.8% of datasets under RCP45 and RCP85 respectively could be fitted along the line of best fit making these trends very significant

4.2.4.2 Statistical trend analysis of future climate over Nandi County

Statistical analyses of future climate over Nandi County are presented below for precipitation based on RCP 45 (Table 4-5) and RCP85 (Table 4-6). Statistical analysis of the trend of projected rainfall for JJA season based on RCP45 (Table 4-5)

Table 4-5: Trend statistics of projected rainfall based on RCP45 (2021-2050) over Nandi County

	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	-0.7	2.7	1.2	0.1	0.0	-1.1	0.8	0.4	-0.5	-1.3
	α	++	**	++	++	++	++	++	++	++	++
	Q	-3.1	7.0	4.5	0.3	-1.0	-4.9	4.4	0.7	-1.7	-4.2
	%	-10.7	28.6	20.2	1.5	-3.4	-15.6	19.9	5.6	-6.9	-22.2
	Δ%	-24.0	30.9	36.1	-5.3	-5.4	-27.3	-5.3	4.2	-16.7	-15.9
DJF	Z	0.2	0.9	1.1	0.5	-0.2	-0.8	0.7	-0.6	1.0	1.0
	α	++	++	++	++	++	++	++	++	++	++
	Q	0.1	0.5	1.8	0.2	-0.3	-0.7	0.8	-0.2	0.8	0.9
	%	5.0	36.5	41.2	11.4	-17.6	-27.9	25.0	-22.6	48.4	28.8
	Δ%	-93.8	91.5	44.6	11.0	-21.7	-45.9	106.7	-89.0	114.8	47.3
JJA	Z	1.4	-0.1	0.4	-2.7	-1.3	-1.6	0.1	-0.5	-2.0	-1.3
	α	++	++	++	**	++	++	++	++	*	++
	Q	0.8	-0.1	0.1	-0.4	-0.9	-0.7	0.0	-0.2	-1.0	-0.5
	%	43.7	-5.3	14.4	-32.1	-63.5	-27.5	5.9	-27.5	-84.4	-45.0
	Δ%	61.5	-17.7	82.2	-19.5	-50.0	-58.5	-24.2	-4.2	-86.1	-19.4
MAM	Z	-2.4	1.5	0.0	-0.3	0.6	-0.1	0.7	-0.1	0.1	-2.3
	α	*	++	++	++	++	++	++	++	++	*
	Q	-6.0	2.7	-0.3	-0.1	1.5	-0.1	1.4	-0.3	0.2	-3.0
	%	-68.8	26.4	-2.6	-1.6	17.9	-1.0	15.7	-8.6	1.7	-98.1
	Δ%	-52.9	27.8	15.4	-9.7	2.9	7.7	-23.1	-21.6	-26.0	-68.7
SON	Z	0.5	2.0	1.8	0.1	-0.4	-1.1	0.7	1.6	-1.3	-0.8
	α	++	*	+	++	++	++	++	++	++	++
	Q	1.1	4.2	2.6	0.1	-1.1	-2.4	1.7	1.8	-2.6	-2.1
	%	6.5	38.7	31.9	0.7	-6.7	-15.6	19.4	29.3	-23.7	-17.7
	Δ%	-22.2	50.0	51.5	-10.1	7.1	-53.3	-15.6	27.7	-29.3	-26.8

Table 4-6: Trend statistics of projected rainfall based on RCP85 (2021-2050) over Nandi County

Period	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	-0.5	0.4	1.5	1.8	-0.8	0.8	1.1	-1.6	0.3	1.4
	α	++	++	++	+	++	++	++	++	++	++
	Q	-1.6	0.6	4.1	1.5	-2.5	2.5	3.9	-3.6	0.7	5.5
	%	-5.6	2.5	17.7	6.7	-8.6	8.3	17.3	-29.3	3.2	29.4
	Δ%	-18.9	4.8	33.6	0.0	-10.6	-3.4	-7.9	-30.7	-6.6	35.7
DJF	Z	1.2	-1.3	1.6	1.8	0.5	-0.6	-0.8	-0.4	1.6	1.7
	α	++	++	++	+	++	++	++	++	++	+
	Q	0.6	-0.6	2.4	0.6	0.2	-0.5	-0.7	-0.3	0.6	2.0
	%	45.3	-50.1	54.7	26.7	13.6	-19.2	-24.8	-28.1	47.8	72.5
	Δ%	-53.5	4.9	58.1	26.3	9.5	-37.2	56.9	-94.5	114.2	91.0
JJA	Z	-0.6	1.1	-0.1	0.3	0.4	-0.8	-0.3	0.2	-0.5	-0.5
	α	++	++	++	++	++	++	++	++	++	++
	Q	-0.3	0.9	0.0	0.0	0.3	-0.7	-0.1	0.1	-0.2	-0.1
	%	-16.0	37.7	-3.5	2.4	16.5	-26.6	-10.4	7.2	-14.2	-12.1
	Δ%	1.8	25.3	64.3	15.0	30.0	-57.6	-40.5	30.5	-15.9	13.5
MAM	Z	1.0	0.0	0.7	-0.3	-3.2	-0.7	0.4	-0.1	1.8	0.7
	α	++	++	++	++	**	++	++	++	+	++
	Q	2.0	-0.2	1.0	-0.1	-7.4	-1.1	1.2	-0.1	3.9	1.0
	%	23.2	-2.3	9.5	-1.4	-75.1	-9.0	12.3	-1.7	40.1	35.9
	Δ%	39.1	-0.9	27.5	-9.5	-90.1	-0.4	-26.5	-14.7	12.4	65.3
SON	Z	-1.6	0.7	-0.5	1.5	1.9	3.2	1.0	-2.0	-1.0	1.6
	α	++	++	++	++	+	**	++	*	++	++
	Q	-2.9	1.3	-1.0	1.1	4.0	6.5	2.2	-3.6	-1.9	3.4
	%	-17.9	12.9	-13.1	9.4	24.5	52.1	22.9	-54.7	-19.0	28.4
	Δ%	-46.6	24.2	6.5	-1.5	38.3	14.4	-12.1	-56.3	-24.6	19.3

Statistical analysis of the trend of annual projected rainfall based on RCP45 (Table 4-5) show a positive change for all RCA4 models except CCCma, IPSL, MPI, and NOAA. However, these changes were significant at $\alpha > 0.1$ for all RCA4 models except for CNRM which was significant at $\alpha = 0.01$. The magnitude of the slope of the trend line ranged between -4.9 and 7.0 whereas computed annual percentage ranged between -22.2% and 28.6%. A comparison between baseline and projected rainfall indicate a negative change in all the RCA4 models except CNRM, CSIRO and MOHC. An ensemble of the RCA4 models (ENS) indicated a positive change of 0.1 that was significant at $\alpha > 0.1$ and a magnitude of 0.3 for the slope of the trend line. Besides, ENS indicated an annual percentage change of 1.5% while computed change between baseline and projected annual rainfall showed a negative change of -5.3%.

Statistical analysis of the trend of annual projected rainfall based on RCP85 (Table 4-6) show a positive change for all RCA4 models except CCCma, ICHEC and MOHC. However, these changes were significant at $\alpha > 0.1$ for all RCA4 model. The magnitude of the slope of the trend line ranged between -3.6 and 5.5 whereas computed annual percentage ranged between -29.3% and 29.4%. A comparison between baseline and projected rainfall indicate a negative change in all the RCA4 models except CNRM, CSIRO and NOAA. An ensemble of the RCA4 models (ENS) indicated a positive change of 1.8 that was significant at $\alpha = 0.1$ and a magnitude of 6.7 for the slope of the trend line. Besides, ENS indicated an annual percentage change of 1.5% while computed change between baseline and projected annual rainfall did not show any change.

Statistical analysis of the trend of projected rainfall for DJF season based on RCP45 (Table 4-5) show a positive change for all RCA4 models except ICHEC and IPSL. These changes were significant at $\alpha > 0.1$ while the magnitude of the slope of the trend line ranged between -0.7 and 1.8 whereas computed annual percentage ranged between -27.9% and 48.4%. An ensemble of the RCA4 models (ENS) indicated a positive change of 0.5 and significant at $\alpha > 0.1$.Moreover, annual percentage change for ENS was 11.4% while computed change between baseline and projected annual rainfall based on RCP45 showed a positive change of 11%.

Statistical analysis of the trend of projected rainfall for DJF season based on RCP85 (Table 4-6) show a positive change for all RCA4 models except CNRM, MIROC, IPSL and MOHC. These changes were significant at $\alpha \geq 0.1$ while the magnitude of the slope of the trend line ranged between -0.7 and 2.4 whereas computed annual percentage ranged between -50.1% and 72.5%. A comparison between baseline and projected rainfall indicate a positive change in all the

RCA4 models except CCCma, IPSL and MOHC. An ensemble of the RCA4 models (ENS) indicated a positive change of 1.8 and significant at α = 0.1.Moreover, annual percentage change for ENS was 26.7% while computed change between baseline and projected annual rainfall based on RCP45 showed a positive change of 26.3%.

Statistical analysis of the trend of projected rainfall for JJA season based on RCP45 (Table 4-5) show a negative change for all RCA4 models except CCCma, CSIRO and MIROC. These changes were significant at α> 0.1 except MPI (α> 0.05) while the magnitude of the slope of the trend line ranged between -1.0 and 0.8. Computed annual percentage change ranged between -84.4% and 43.7% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -86.1% and 82.2%. An ensemble of the RCA4 models (ENS) indicated a negative change of 2.7 and significant at α> 0.01.Moreover, annual percentage change for ENS was -32.1% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -19.5%.

Statistical analysis of the trend of projected rainfall for JJA season based on RCP85 (Table 4-6) show a negative change for all RCA4 models except CNRM, ICHEC and MOHC. These changes were significant at α> 0.1 while the magnitude of the slope of the trend line ranged between -0.7 and 0.9. Computed annual percentage change ranged between -26.6% and 37.7% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -57.6% and 64.3%. An ensemble of the RCA4 models (ENS) indicated a positive change of 0.3 and significant at α> 0.1. However, the magnitude of change in the line of best fit was neither increasing nor decreasing. Moreover, annual percentage change for ENS was 2.4% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -15.0%.

Statistical analysis of the trend of projected rainfall for MAM season based on RCP45 (Table

4-5) show a positive change for all RCA4 models except CCCma, IPSL, MOHC and NOAA. These changes were significant at α> 0.1 except CCCma and NOAA which were significant at α> 0.05. The magnitude of the slope of the trend line ranged between -6.0 and 2.7. Computed annual percentage change ranged between -98.1% and 26.4% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -68.7% and 27.8%. An ensemble of the RCA4 models (ENS) indicated a negative change of 0.3 and significant at α> 0.1.Moreover, annual percentage change for ENS was -1.6% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -9.7%.

Statistical analysis of the trend of projected rainfall for MAM season based on RCP85 (Table 4-6) show a positive change for all RCA4 models except ICHEC, IPSL and MOHC. These changes were significant at α ≥ 0.1 except ICHEC which was significant at α> 0.01. The magnitude of the slope of the trend line ranged between -7.4 and 3.9. Computed annual percentage change ranged between -75.1% and 40.1% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -90.1% and 65.3%. An ensemble of the RCA4 models (ENS) indicated a negative change of -0.3 and significant at α> 0.1 and a magnitude of -0.1 for the line of best fit. Moreover, annual percentage change for ENS was -1.4% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -9.5%.

Statistical analysis of the trend of projected rainfall for SON season based on RCP45 (Table 4-5) show a positive change for all RCA4 models except ICHEC, IPSL, MPI and NOAA. These changes were significant at α ≥ 0.1 except CNRM which were significant at α> 0.05. The magnitude of the slope of the trend line ranged between -2.6 and 2.4. Computed annual percentage change ranged between -23.7% and 38.7% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -53.3% and 51.5%. An ensemble of the RCA4 models (ENS) indicated a positive change of 0.1 and significant at $\alpha > 0.1$.Moreover, annual percentage change for ENS was 0.7% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -10.1%.

Statistical analysis of the trend of projected rainfall for SON season based on RCP85 (Table 4-6) show a positive change for all RCA4 models except CCCma, CSIRO, MOHC and MPI. These changes were significant at $\alpha \geq 0.1$ except IPSL ($\alpha = 0.01$) and MOHC ($\alpha > 0.05$). The magnitude of the slope of the trend line ranged between -3.6 and 6.5. Computed annual percentage change ranged between -54.7% and 52.1% whereas the difference between the baseline and projected rainfall for all RCA4 models ranged between -56.3% and 38.3%. An ensemble of the RCA4 models (ENS) indicated a positive change of 1.5 and significant at $\alpha > 0.1$ while the magnitude of the slope of the trend line was found to be 1.1. Moreover, annual percentage change for ENS was 9.4% while computed change between baseline and projected annual rainfall based on RCP45 showed a negative change of -1.5%.

4.2.4.3 Statistical analysis of the trend of projected maximum temperature over Nandi County

Statistical analyses of future climate over Nandi County are presented below for maximum temperature based on RCP 45 (Table 4-7) and RCP85 (Table 4-8).

Table 4-7: Trend statistics of projected maximum temperature based on RCP45 (2021-2050) over Nandi County

	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	2.78	0.71	2.89	5.67	2.43	3.07	1.53	3.60	2.89	2.28
	α	**	++	**	***	*	**	++	***	**	*
	Q	0.03	0.01	0.03	0.03	0.03	0.04	0.02	0.04	0.03	0.03
	%	3.12	0.59	3.79	3.04	3.10	4.27	2.31	3.71	3.77	2.80
	Δ%	1.93	-0.03	1.43	1.67	0.16	2.75	2.34	4.41	2.47	-0.04
DJF	Z	2.32	0.61	0.04	4.39	2.43	3.10	0.71	2.11	2.03	0.57
	α	*	++	++	***	*	**	++	*	*	++
	Q	0.02	0.01	0.00	0.03	0.04	0.04	0.01	0.03	0.03	0.01
	%	2.45	0.99	0.19	2.77	4.16	4.36	1.06	2.61	2.83	0.96
	Δ%	3.07	-0.78	-1.50	1.31	1.60	3.18	-2.44	3.22	0.22	-1.93
JJA	Z	2.14	1.43	3.60	5.53	1.75	3.00	1.64	3.46	2.03	2.07
	α	*	++	***	***	+	**	++	***	*	*
	Q	0.03	0.02	0.05	0.04	0.03	0.04	0.03	0.04	0.05	0.03
	%	3.69	2.16	4.96	4.12	3.30	4.23	3.08	4.18	5.68	3.58
	Δ%	0.07	1.02	3.70	2.22	0.94	2.04	4.20	2.99	7.05	0.72
MAM	Z	1.96	0.00	2.84	3.75	0.89	0.68	0.25	2.43	1.50	2.25
	α	*	++	**	***	++	++	++	*	++	*
	Q	0.04	0.00	0.04	0.03	0.01	0.02	0.01	0.04	0.03	0.05
	%	4.55	0.04	4.54	2.99	1.06	1.74	0.60	3.92	2.85	4.71
	Δ%	2.38	0.74	1.50	1.99	-0.90	-0.54	1.23	6.21	2.15	1.69
SON	Z	0.71	0.00	1.71	3.68	0.79	2.43	1.25	2.28	2.64	1.78
	α	++	++	+	***	++	*	++	*	**	+
	Q	0.01	0.00	0.04	0.03	0.02	0.04	0.04	0.02	0.04	0.03
	%	1.55	0.07	4.14	3.31	2.83	4.35	5.01	2.36	4.34	4.05
	Δ%	2.05	-2.64	2.17	2.18	-1.13	4.70	5.98	2.15	2.46	1.95

Table 4-8: Trend statistics of projected maximum temperature based on RCP85 (2021-2050) over Nandi County

	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	4.10	3.75	3.71	6.32	4.82	5.07	1.68	5.28	2.64	1.75
	α	***	***	***	***	***	***	+	***	**	+
	Q	0.05	0.04	0.03	0.04	0.05	0.05	0.02	0.06	0.04	0.02
	%	5.39	3.97	3.69	4.28	6.38	5.44	2.02	6.24	3.90	2.25
	Δ%	4.20	3.35	1.33	2.91	3.44	3.92	2.06	6.94	2.59	-0.59
DJF	Z	4.03	3.46	1.14	5.39	3.00	4.28	2.28	4.71	2.64	0.50
	α	***	***	++	***	**	***	*	***	**	++
	Q	0.05	0.04	0.02	0.03	0.03	0.05	0.03	0.07	0.03	0.01
	%	4.79	3.86	2.25	3.60	3.46	4.91	3.21	6.71	2.81	0.60
	Δ%	5.40	2.10	0.56	2.14	0.90	3.73	-0.29	7.32	0.20	-2.29
JJA	Z	3.43	3.50	4.82	6.39	4.39	4.28	1.43	3.60	1.86	2.46
	α	***	***	***	***	***	***	++	***	+	*
	Q	0.06	0.04	0.07	0.05	0.06	0.07	0.03	0.05	0.03	0.03
	%	6.22	4.43	7.21	5.77	7.28	7.42	2.90	5.73	3.93	3.54
	Δ%	2.59	3.29	5.95	3.86	4.92	5.23	4.02	4.54	5.30	0.68
MAM	Z	0.93	2.28	1.00	4.89	3.96	3.32	0.11	3.32	0.79	0.68
	α	++	*	++	***	***	***	++	***	++	++
	Q	0.02	0.05	0.01	0.04	0.11	0.08	0.00	0.05	0.02	0.01
	%	2.40	5.19	1.48	4.16	12.59	7.98	0.16	4.64	1.87	1.36
	Δ%	0.23	5.89	-1.56	3.15	10.63	5.70	0.79	6.93	1.16	-1.67
SON	Z	4.25	1.39	2.60	4.53	1.03	1.07	0.93	4.07	2.11	1.00
	α	***	++	**	***	++	++	++	***	*	++
	Q	0.07	0.02	0.05	0.04	0.01	0.01	0.01	0.07	0.05	0.02
	%	8.58	2.40	5.09	4.17	1.90	1.58	1.62	8.13	5.52	1.81
	Δ%	9.09	-0.31	3.12	3.03	-2.07	1.92	2.60	7.92	3.65	-0.29

Statistical analysis of the trend of projected annual maximum temperature based on RCP45 (Table 4-7) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all RCA4 models except CNRM and MIROC which were significant $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.01 and 0.04. Computed annual percentage changes were all positive and ranged between 0.59% and 4.27% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -0.04% and 4.41%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.67 and significant at α = 0.001.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.03 and 0.7% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 showed a positive change of 1.67%.

Statistical analysis of the trend of projected annual maximum temperature based on RCP85 (Table 4-8) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.01$ for all RCA4 models except MIROC and NOAA whose significance levelα = 0.1. The magnitudes of the slope of the trend line were all positive and ranged between 0.02 and 0.06. Computed annual percentage changes were all positive and ranged between 2.02% and 6.38% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -0.59% and 6.94%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.32 and significant at α = 0.001.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.04 and 4.28% respectively while computed change between baseline and projected annual maximum temperature based on RCP85 showed a positive change of 2.91%.

Statistical analysis of the trend of projected maximum temperature for DJF season based on RCP45 (Table 4-7) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all RCA4 models except CNRM, CSIRO, MIROC and NOAA which were significant at $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.01 and 0.04. Computed annual percentage changes were all positive and ranged between 0.99% and 4.36% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -1.93% and 3.22%. An ensemble of the RCA4 models (ENS) indicated a positive change of 4.39 and significant at α = 0.001.Moreover, magnitude of the slope of the trend line and the annual percentage change for

ENS was 0.03 and 2.77% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 showed a positive change of 1.31%.

Statistical analysis of the trend of projected maximum temperature for DJF season based on RCP85 (Table 4-8) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all RCA4 models except CSIRO and NOAA which were significant at $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.01 and 0.07. Computed annual percentage changes were all positive and ranged between 0.60% and 6.71% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -2.29% and 7.32%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.39 and significant at $\alpha = 0.001$.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.03 and 3.60% respectively while computed change between baseline and projected annual maximum temperature based on RCP85 showed a positive change of 2.14%.

Statistical analysis of the trend of projected maximum temperature for JJA season based on RCP45 (Table 4-7) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CCCma, CNRM, CSIRO, ICHEC, MIROC and NOAA which were significant at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.00 and 0.04. Computed annual percentage changes were all positive and ranged between 0.04% and 4.71% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -0.90% and 6.21%. An ensemble of the RCA4 models (ENS) indicated a positive change of 3.75 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.03 and 2.99% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 had a positive change of 3.68%.

Statistical analysis of the trend of projected maximum temperature for JJA season based on

RCP85 (Table 4-8) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except MIROC and MPI which were significant at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.03 and 0.07. Computed annual percentage changes were all positive and ranged between 3.93% and 7.42% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between 0.68% and 5.30%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.39 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.05 and 5.77% respectively while computed change between baseline and projected annual maximum temperature based on RCP85 showed a positive change of 3.86%.

Statistical analysis of the trend of projected maximum temperature for MAM season based on RCP45 (Table 4-7) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CNRM, ICHEC, IPSL, MIROC and MPI which were significant at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.00 and 0.05. Computed annual percentage changes were all positive and ranged between 0.04% and 4.71% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -0.90% and 6.21%. An ensemble of the RCA4 models (ENS) indicated a positive change of 3.75 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.03 and 2.99% respectively while computed change between baseline and projected MAM maximum temperature based on RCP45 showed a positive change of 1.99%.

Statistical analysis of the trend of projected maximum temperature for MAM season based on RCP85 (Table 4-8) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CCCma, CSIRO, MIROC, MPI and NOAA which were significant at $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.01 and 0.11. Computed annual percentage changes were all positive and ranged between 0.16% and 12.59% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -1.67% and 10.63%. An ensemble of the RCA4 models (ENS) indicated a positive change of 4.89 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.04 and 4.16% respectively while computed change between baseline and projected MAM maximum temperature on RCP85 showed a positive change of 3.15%.

Statistical analysis of the trend of projected maximum temperature for SON season based on RCP45 (Table 4-7) show a positive change for all RCA4 models. These changes were significant at $\alpha \geq 0.1$ for all the RCA4 models except IPSL, MOHC and MPI which were significance at $\alpha \leq 0.05$. The magnitudes of the slope of the trend line were all positive and ranged between 0.00 and 0.04. Computed annual percentage changes were all positive and ranged between 0.07% and 5.01% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -2.64% and 5.98%. An ensemble of the RCA4 models (ENS) indicated a positive change of 3.68 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.03 and 3.31% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 showed a positive change of 2.18%.

Statistical analysis of the trend of projected maximum temperature for SON season based on RCP85 (Table 4-8) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CNRM, ICHEC, IPSL, MIROC and NOAA which were significance at $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.01 and 0.07. Computed annual percentage changes were all positive and ranged between 1.58% and 8.13% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -2.07% and 9.09%. An ensemble of the RCA4 models (ENS) indicated a positive change of 4.53 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.04 and 4.17% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 showed a positive change of 3.03%.

4.2.4.4 Statistical analysis of the trend of projected minimum temperature over Nandi County

Statistical analyses of future climate over Nandi County are presented below for minimum temperature based on RCP 45 (Table 4:9) and RCP85 (Table 4:10).

Table 4-9: Trend statistics of projected minimum temperature based on RCP45 (2021-2050)

	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	2.8	3.1	3.8	5.9	3.2	4.0	1.8	4.9	3.4	3.3
	α	**	**	***	***	**	***	+	***	***	**
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	%	4.6	4.6	7.3	5.9	5.2	5.8	4.0	8.5	7.4	4.7
	Δ%	0.6	0.5	3.8	2.1	-0.3	1.7	0.9	5.7	4.1	-0.1
DJF	Z	2.2	1.4	2.4	5.2	3.3	2.4	1.1	3.9	3.0	0.9
	α	*	++	*	***	**	*	++	***	**	++
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	3.7	3.0	6.0	5.5	7.8	4.9	4.0	7.9	7.2	1.7
	Δ%	3.0	-0.4	4.8	2.6	6.3	-0.1	2.6	3.9	2.2	-2.2
JJA	Z	2.6	2.1	3.3	5.1	0.6	2.5	1.6	4.8	2.2	3.0
	α	**	*	**	***	++	*	++	***	*	**
	Q	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	%	6.9	5.7	9.7	7.3	2.3	4.7	8.1	13.0	8.2	8.0
	Δ%	2.7	0.1	3.1	2.1	-6.6	-0.5	4.1	11.6	5.1	0.4
MAM	Z	2.2	1.6	3.7	4.7	1.8	3.3	0.9	3.2	2.1	3.6
	α	*	++	***	***	+	**	++	**	*	***
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	4.5	2.5	8.0	5.2	3.4	6.5	3.4	6.8	4.3	5.5
	Δ%	-0.1	0.0	6.0	1.8	-1.7	3.2	-1.8	4.2	1.3	0.8
SON	Z	1.5	4.6	3.0	5.4	1.9	3.9	2.1	4.5	3.7	2.0
	α	++	***	**	***	+	***	*	***	***	*
	Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	%	2.3	4.4	5.9	5.4	4.4	5.0	6.4	5.9	7.3	3.7
	Δ%	-1.1	1.3	3.0	1.7	-2.5	0.5	4.8	3.3	3.8	-2.0

Table 4-10: Trend statistics of projected minimum temperature based on RCP85 (2021-2050) over Nandi County

Period	Stats	CCCma	CNRM	CSIRO	ENS	ICHEC	IPSL	MIROC	MOHC	MPI	NOAA
ANN	Z	4.7	4.6	5.2	7.0	5.6	6.4	2.8	5.1	3.3	3.6
	α	***	***	***	***	***	***	**	***	***	***
	Q	0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0
	%	9.0	7.1	9.7	8.3	10.9	9.7	6.3	10.0	7.5	5.2
	Δ%	5.0	3.0	6.2	4.5	5.4	5.6	3.1	7.1	4.2	0.4
DJF	Z	4.4	3.1	4.0	6.2	4.0	4.9	2.4	4.9	3.8	1.6
	α	***	**	***	***	***	***	*	***	***	++
	Q	0.1	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0
	%	11.2	6.0	10.4	7.6	6.0	9.1	5.4	10.9	8.4	2.1
	Δ%	10.5	2.6	9.2	4.7	4.4	4.2	4.0	6.9	3.4	-1.8
JJA	Z	3.1	3.9	4.4	6.5	4.8	4.9	2.5	3.8	2.4	4.0
	α	**	***	***	***	***	***	*	***	*	***
	Q	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1
	%	8.7	9.5	11.8	10.8	17.7	11.8	9.5	10.7	8.5	9.3
	Δ%	4.5	4.0	5.1	5.5	8.9	6.7	5.5	9.3	5.4	1.7
MAM	Z	3.2	3.8	4.4	6.2	4.6	5.2	2.0	4.6	1.7	1.8
	α	**	***	***	***	***	***	*	***	+	+
	Q	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0
	%	6.8	7.6	8.6	7.5	14.1	13.0	3.9	9.9	4.0	3.6
	Δ%	2.2	5.2	6.6	4.1	8.9	9.6	-1.3	7.3	1.0	-1.2
SON	Z	4.3	3.4	3.8	6.3	3.7	4.2	1.7	4.9	3.1	3.6
	α	***	***	***	***	***	***	+	***	**	***
	Q	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	%	7.9	5.0	8.6	7.6	7.4	6.6	4.1	10.8	8.3	5.7
	Δ%	4.5	1.9	5.7	3.9	0.4	2.1	2.5	8.3	4.8	0.0

Statistical analysis of the trend of projected annual minimum temperature based on RCP45 (Table 4-9) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.01$ for all RCA4 models except MIROC which was significant $\alpha = 0.1$. The magnitude of the slope of the trend line was positive in MOHC while the other models neither increasing nor decreasing trend. Computed annual percentage changes were all positive and ranged between 4.0% and 8.5% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -0.1% and 5.7%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.9 and significant at $\alpha = 0.001$.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 5.9% respectively while computed change between baseline and projected annual minimum temperature based on RCP45 showed a positive change of 2.1%.

Statistical analysis of the trend of projected annual minimum temperature based on RCP85 (Table 4-10) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.01$ for all RCA4 models. The magnitudes of the slope of the trend line were either slightly increasing or showed no significant change. Computed annual percentage changes were all positive and ranged between 5.2% and 10.9% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between 0.4% and 7.1%. An ensemble of the RCA4 models (ENS) indicated a positive change of 7.0 and significant at $\alpha = 0.001$.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 8.3% respectively while computed change between baseline and projected annual minimum temperature based on RCP85 showed a positive change of 4.5%.

Statistical analysis of the trend of projected minimum temperature for DJF season based on RCP45 (Table 4-9) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all RCA4 models except CNRM, MIROC and NOAA which were significant at $\alpha > 0.1$. The magnitudes of the slope of the trend line were neither positive nor negative. Computed annual percentage changes were all positive and ranged between 3.0% and 7.9% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -2.2% and 6.3%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.2 and significant at $\alpha = 0.001$.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 5.5% respectively while computed change between baseline and projected annual minimum temperature based on RCP45 showed a positive change of 2.6%.

Statistical analysis of the trend of projected minimum temperature for DJF season based on RCP85 (Table 4-10) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all RCA4 models except NOAA which were significant at $\alpha > 0.1$. The magnitudes of the slope of the trend line were all positive and ranged between 0.00 and 0.01. Computed annual percentage changes were all positive and ranged between 2.1% and 11.2% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -1.8% and 10.5%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.2 and significant at $\alpha = 0.001$.Moreover, magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 7.6% respectively while computed change between baseline and projected annual minimum temperature based on RCP85 showed a positive change of 4.7%.

Statistical analysis of the trend of projected minimum temperature for JJA season based on RCP45 (Table 4-9) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except ICHEC and MIROC which were significance at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were neither positive nor negative except CSIRO and MOHC which had a value of 0.1. Computed annual percentage changes were all positive and ranged between 2.3% and 13.0% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -6.6% and 11.6%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.1 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 7.3% respectively while computed change between baseline and projected annual minimum temperature based on RCP45 showed a positive change of 2.1%.

Statistical analysis of the trend of projected minimum temperature for JJA season based on RCP85 (Table 4-10) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except ICHEC and MIROC which were significant at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were neither positive nor negative except CSIRO and MOHC which had a value of 0.1. Computed annual percentage changes were all positive and ranged between 8.7% and 17.7% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between 1.7% and 9.3%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.5 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.01 and 10.8% respectively while computed change between baseline and projected annual minimum temperature based on RCP85 showed a positive change of 5.1%.

Statistical analysis of the trend of projected minimum temperature for MAM season based on RCP45 (Table 4-9) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CNRM, ICHEC and MIROC which were significant at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were all neither positive nor negative. Computed annual percentage changes were all positive and ranged between 2.5% and 6.8% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -1.8% and 6.0%. An ensemble of the RCA4 models (ENS) indicated a positive change of 4.7 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 5.2%

respectively while computed change between baseline and projected MAM minimum temperature based on RCP45 showed a positive change of 1.8%.

Statistical analysis of the trend of projected minimum temperature for MAM season based on RCP85 (Table 4-10) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except MPI and NOAA which were significant at $\alpha = 0.1$. The magnitudes of the slope of the trend line were all neither positive nor negative except CSIRO, ICHEC, IPSL, and MOHC which had a value of 0.1. Computed annual percentage changes were all positive and ranged between 3.6% and 14.1% whereas the difference between the baseline and projected minimum temperature for all RCA4 models ranged between -1.3% and 9.6%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.2 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 7.5% respectively while computed change between baseline and projected MAM minimum temperature on RCP85 showed a positive change of 4.1%.

Statistical analysis of the trend of projected maximum temperature for SON season based on RCP45 (Table 4-9) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.05$ for all the RCA4 models except CCCma and ICHEC which were significance at $\alpha \leq 0.05$. The magnitudes of the slope of the trend line were all neither positive nor negative. Computed annual percentage changes were all positive and ranged between 2.3% and 7.3% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between -2.0% and 4.8%. An ensemble of the RCA4 models (ENS) indicated a positive change of 5.4 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 5.4% respectively while computed change between baseline and projected annual maximum temperature based on

RCP45 showed a positive change of 1.7%.

Statistical analysis of the trend of projected maximum temperature for SON season based on RCP85 (Table 4-10) show a positive change for all RCA4 models. These changes were significant at $\alpha \leq 0.01$ for all the RCA4 models except CCCma and ICHEC which were significance at $\alpha \geq 0.1$. The magnitudes of the slope of the trend line were all neither positive nor negative except CCCma, CSIRO and MOHC which had a value of 0.1. Computed annual percentage changes were all positive and ranged between 4.1% and 10.8% whereas the difference between the baseline and projected maximum temperature for all RCA4 models ranged between 0% and 10.8%. An ensemble of the RCA4 models (ENS) indicated a positive change of 6.3 and significant at $\alpha = 0.001$. Moreover, the magnitude of the slope of the trend line and the annual percentage change for ENS was 0.00 and 7.6% respectively while computed change between baseline and projected annual maximum temperature based on RCP45 showed a positive change of 3.9%.

4.2.5 Spatial variability of future climate over Nandi County

4.2.5.1 Spatial analysis of projected rainfall over Nandi County

Spatial variability of projected rainfall over Nandi County is presented in Figure 4-19 to Figure 4-28).

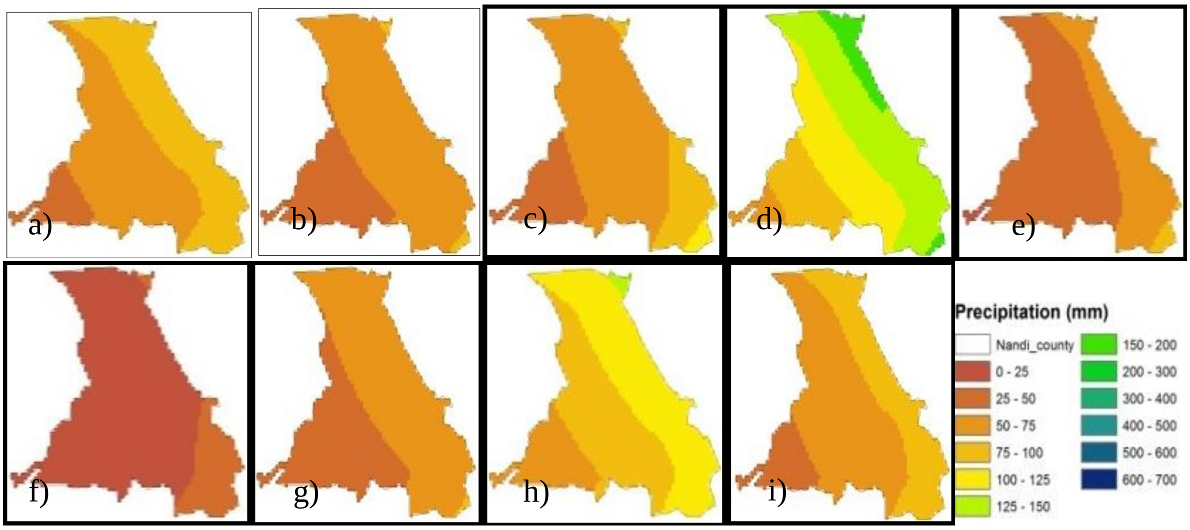

Figure 4-19: Spatial variability of projected (RCP 45) DJF rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

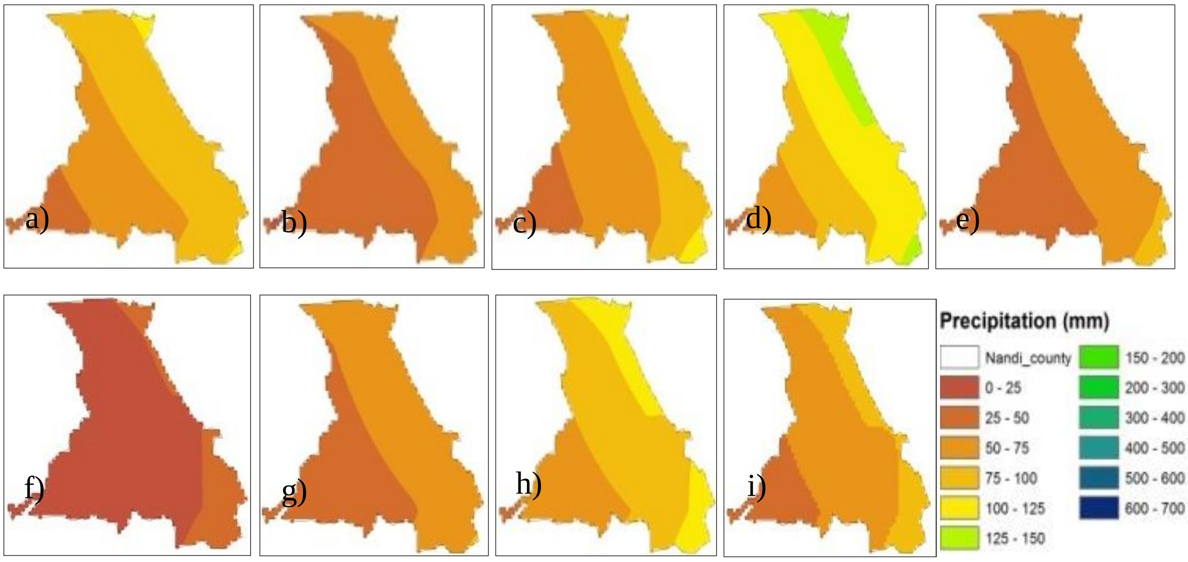

Figure 4-20: Spatial variability of projected (RCP 85) DJF rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

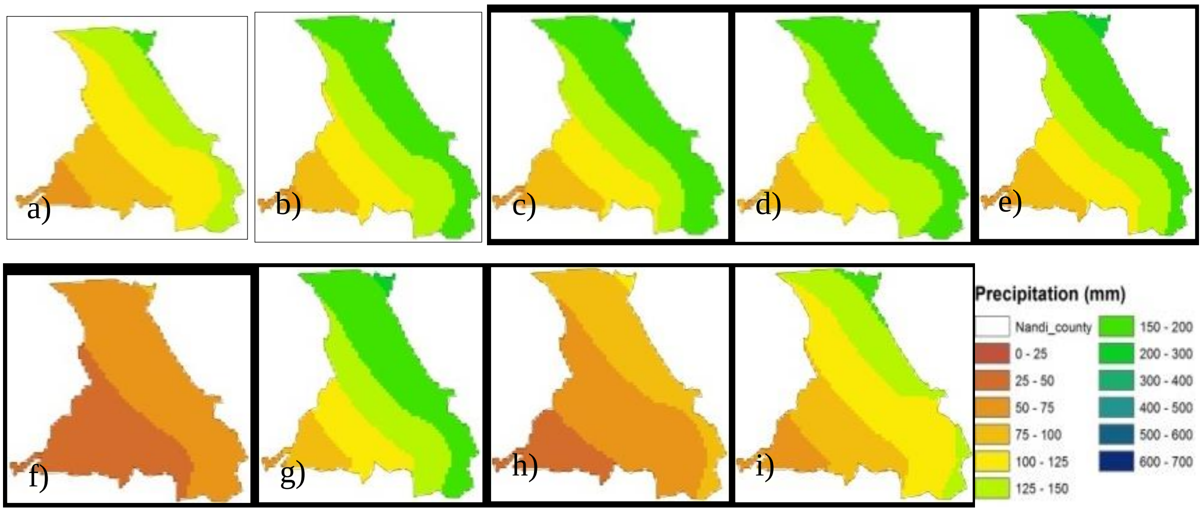

Figure 4-21: Spatial variability of projected (RCP 45) MAM rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

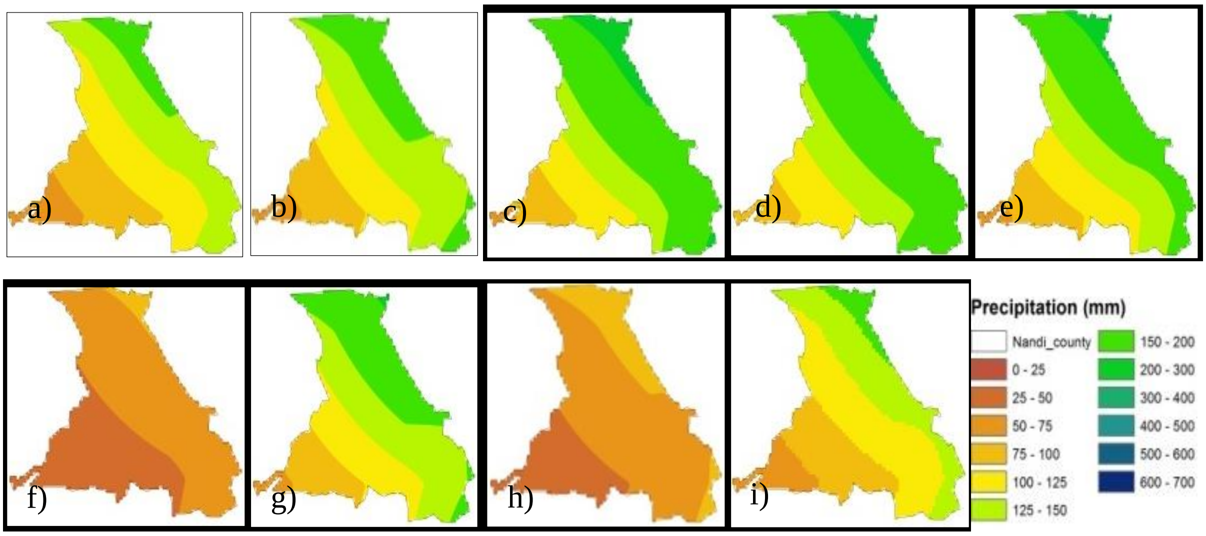

Figure 4-22: Spatial variability of projected (RCP 85) MAM rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

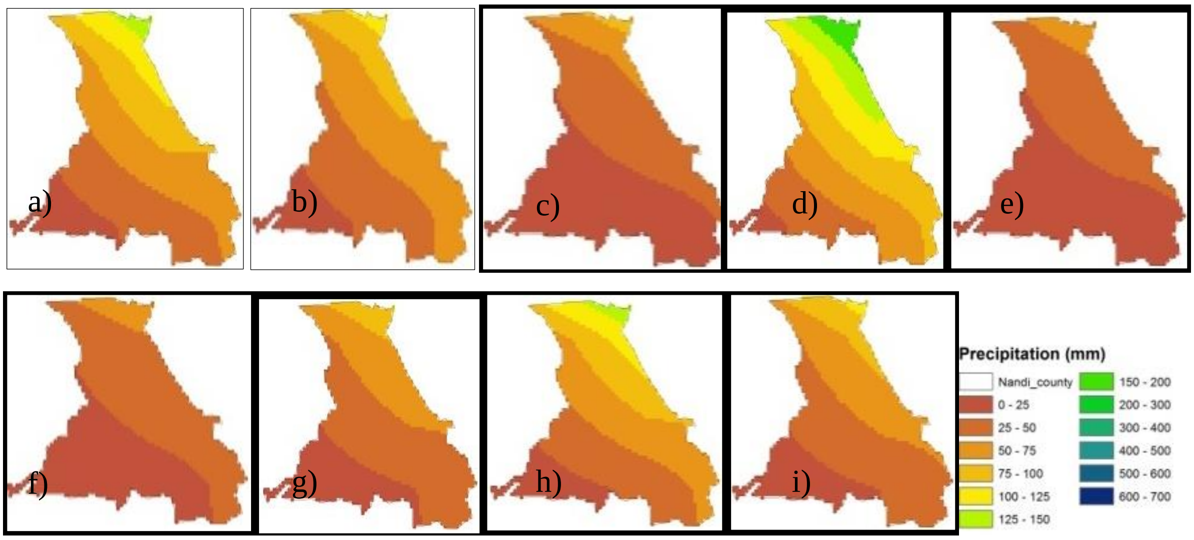

Figure 4-23: Spatial variability of projected (RCP 45) JJA rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

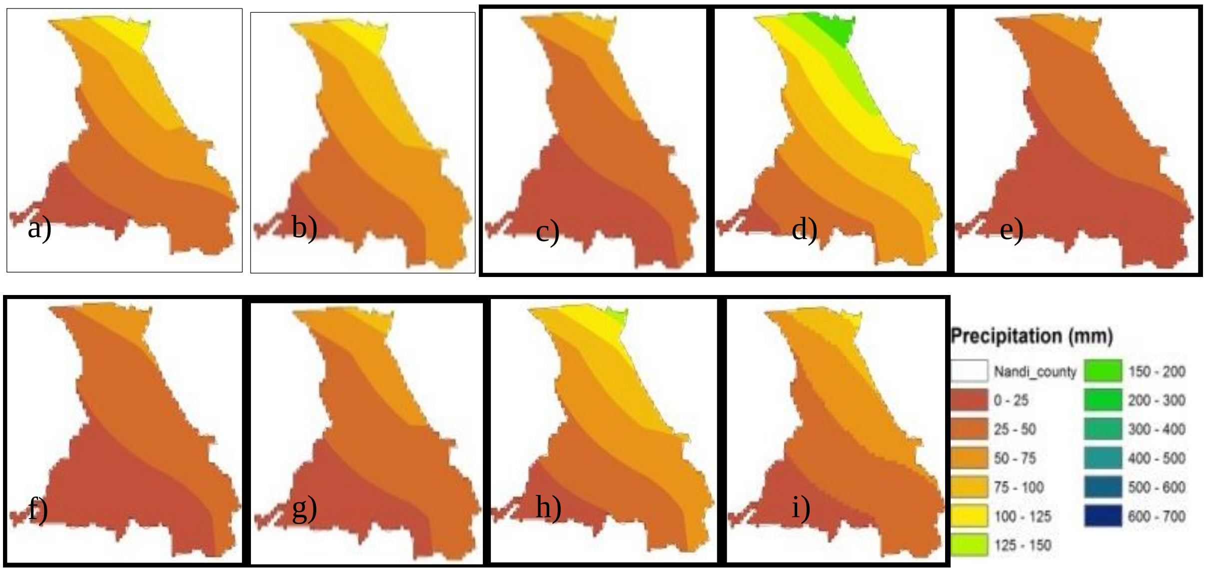

Figure 4-24: Spatial variability of projected (RCP 85) JJA rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

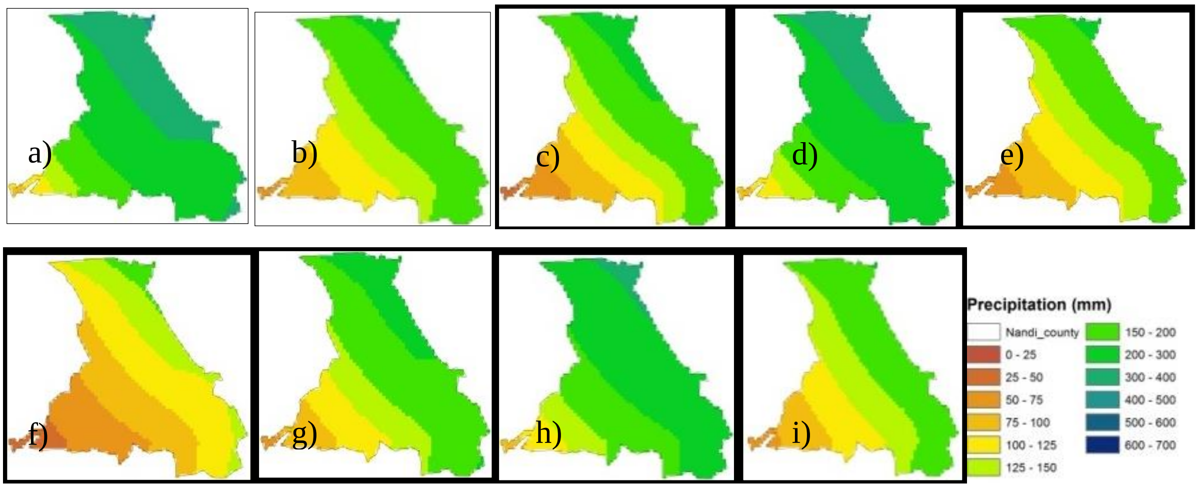

Figure 4-25: Spatial variability of projected (RCP 45) SON rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

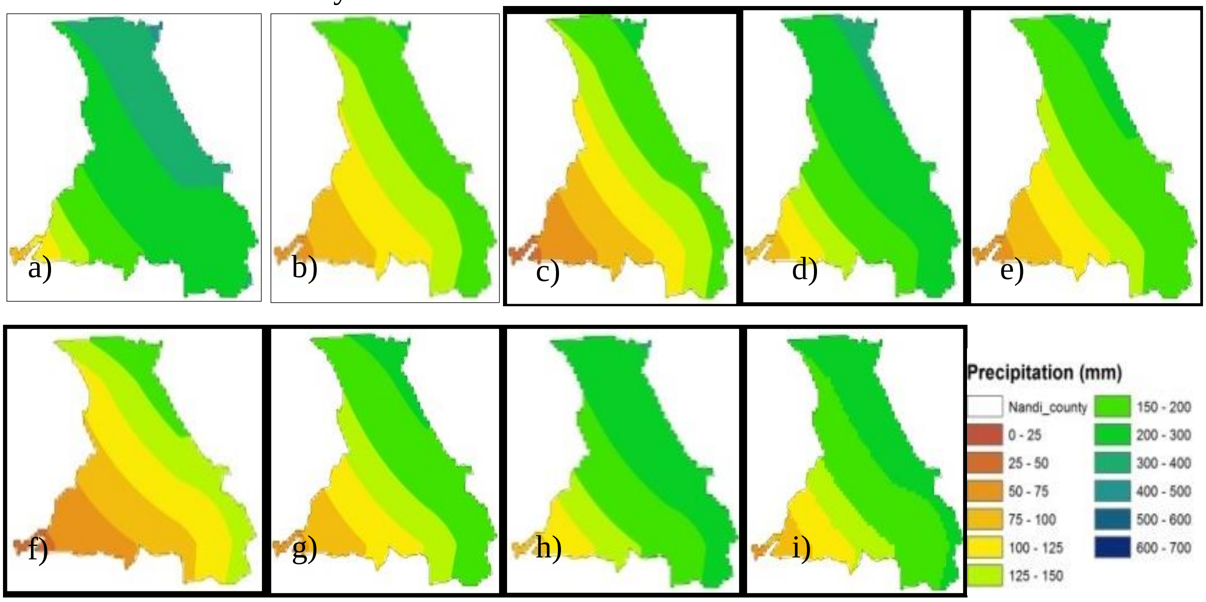

Figure 4-26: Spatial variability of projected (RCP 85) SON rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

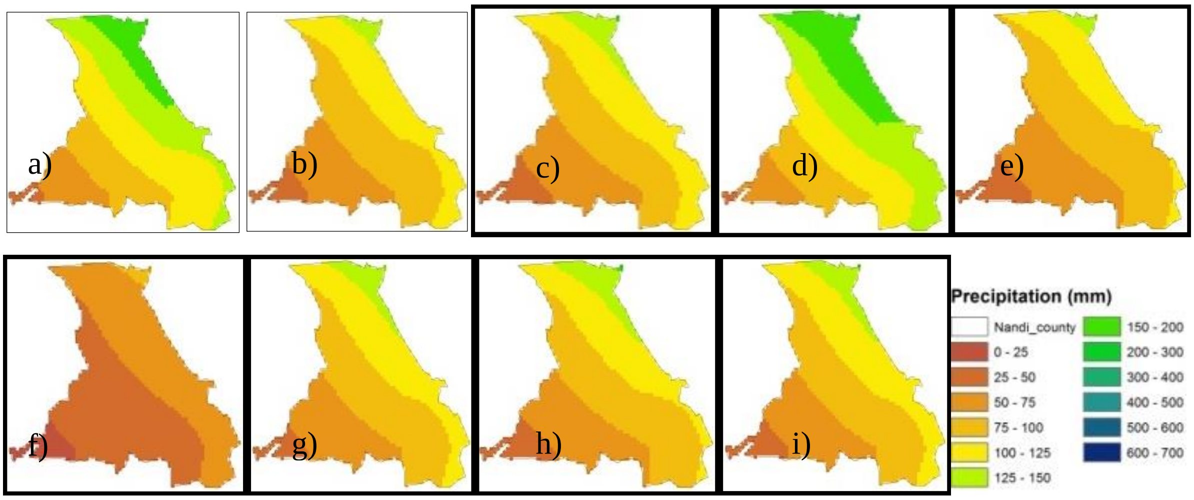

Figure 4-27: Spatial variability of projected (RCP 45) ANN rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

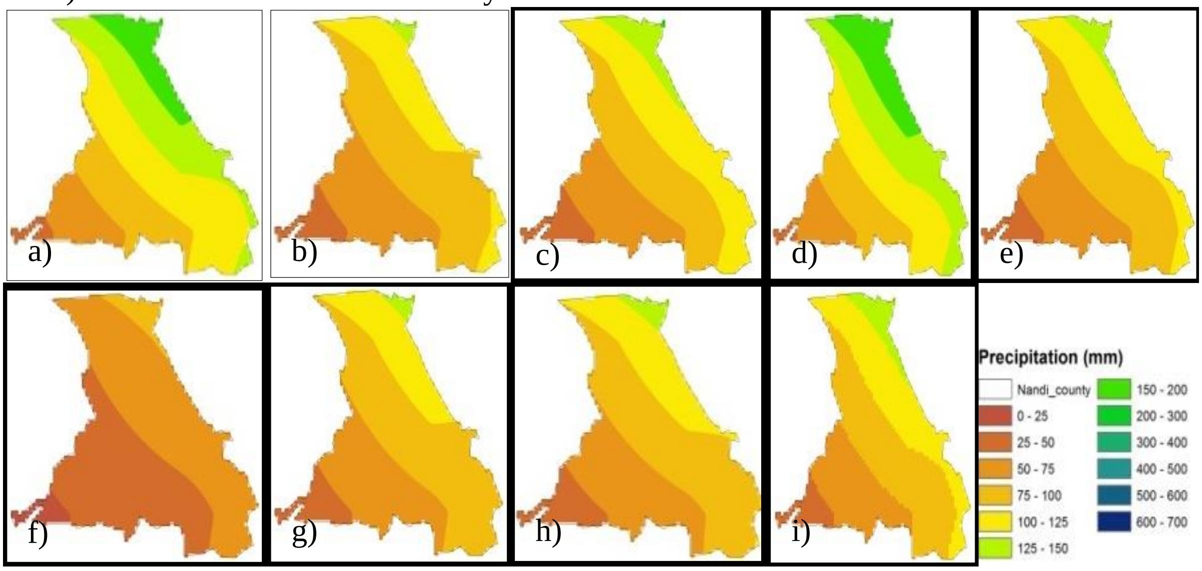

Figure 4-28: Spatial variability of projected (RCP 85) ANN rainfall based on RCA4 downscaled a) CCCma b) CNRM c) CSIRO d) IPSL e) MIROC f) MOHC g) MPI h) NOAA and i) ENS models over Nandi County

The Figure 4-19 show that during the DJF season under RCP45, SW of Nandi County receives lower rainfall and increases towards NE in all RCA4 models except MOHC. The IPSL model showed the highest rainfall of up to 300mm in NE while the lowest rainfall was shown by MIROC and MOHC of up to 25mm. Besides, an ensemble of all the RCA4 models (ENS) indicates a SW to NE increases in rainfall with amounts ranging from 0 to 100mm for the DJF season. Similarly, under RCP 85, the DJF seasonal rainfall show increases in rainfall from SW towards NE with the IPSL model indicating wetter conditions of up to 150mm while MOHC show drier conditions of between 0 and 25mm.

The Figure 4-21 show that during the MAM season under RCP45, SW of Nandi County receives lower rainfall and increases towards NE in all RCA4 models with most models indicating highest rainfall of up to 300mm except MOHC and NOAA which a maximum of up to 100mm. Besides, an ensemble of all the RCA4 models (ENS) indicates a SW to NE increases in rainfall with amounts ranging from 0 to 300mm for the MAM season. Similarly, under RCP 85 (Figure 4-22), the MAM seasonal rainfall show increases in rainfall from SW towards NE with wetter conditions of up to 300mm and drier conditions of between 0 and 25mm.

The Figure 4-23 show that during the JJA season under RCP45, SW of Nandi County receives lower rainfall and increases towards NE in all RCA4 models with most models indicating highest rainfall of up to 100mm except CCCma and IPSL which had a maximum of up to 200mm. Besides, an ensemble of all the RCA4 models (ENS) indicates a SW to NE increases in rainfall with amounts ranging from 0 to 100mm for the JJA season. Similarly, under RCP85 (Figure 4-24), the JJA seasonal rainfall show increases in rainfall from SW towards NE with wetter conditions of up to 100mm in most models except IPSL and drier conditions of between 0 and 25mm.

The Figure 4-25 show that during the SON season under RCP45, SW of Nandi County receives lower rainfall and increases towards NE in all RCA4 models with most models indicating highest rainfall of up to 400mm. Besides, an ensemble of all the RCA4 models (ENS) indicates a SW to NE increases in rainfall with amounts ranging from 50 to 200mm for the SON season. Similarly, under RCP85 (Figure 4-26), the JJA seasonal rainfall show increases in rainfall from SW towards NE with wetter conditions of up to 400mm and drier conditions of between 25 and 50mm.

The Figure 4-27 show that during the ANN season under RCP45, SW of Nandi County receives lower rainfall and increases towards NE in all RCA4 models with most models indicating highest rainfall of up to 200mm. Besides, an ensemble of all the RCA4 models (ENS) indicates a SW to NE increases in rainfall with amounts ranging from 0 to 200mm for the ANN season. Similarly, under RCP85 (Figure 4-28), the ANN seasonal rainfall show increases in rainfall from SW towards NE with wetter conditions of up to 200mm and drier conditions of between 0 and 25mm.

4.2.5.2 Spatial analysis of projected maximum temperature over Nandi County

Spatial variability of projected maximum temperature over Nandi County is presented in Figure 4-29 and Figure 4-30.

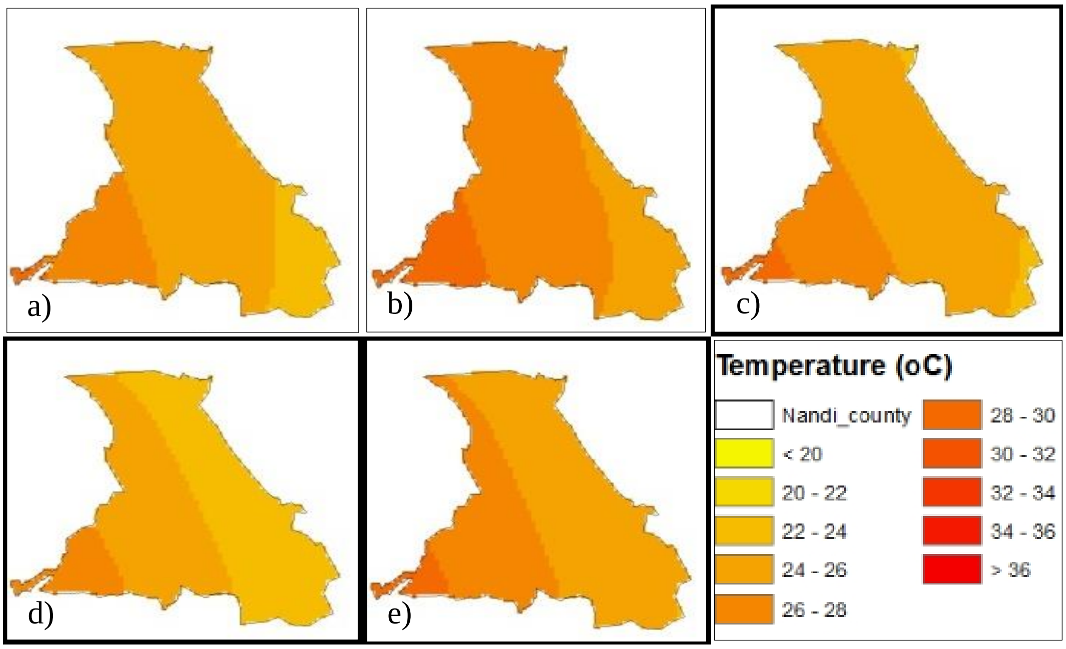

Figure 4-29: Spatial analysis of projected maximum temperature (RCA4 models Ensemble) based on RCP45 for a) DJF b) MAM c) JJA d) SON and e) ANN over Nandi County

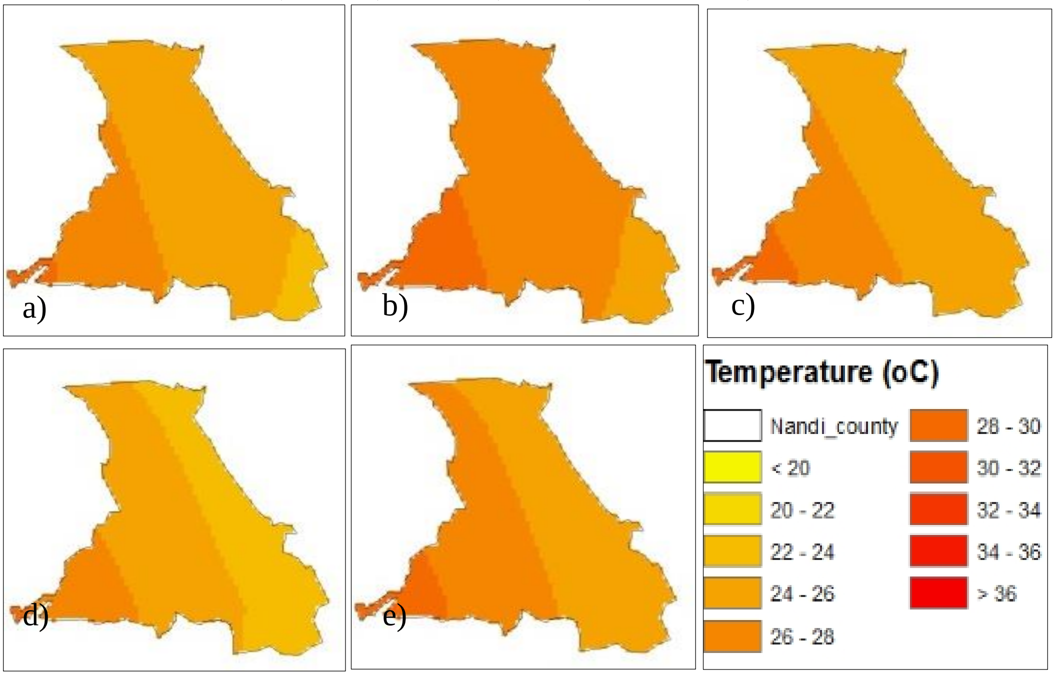

Figure 4-30: Map showing distribution of projected maximum temperature (RCA4 models Ensemble) based on RCP85 for a) DJF b) MAM c) JJA d) SON and e) ANN over Nandi County

The Figure 4-29 (a) shows that projected maximum temperatures during DJF season decreases eastwards with maximum values of between 28 and 30 and minimum values of between 20 and 22. Similarly, MAM (Figure 29 b), JJA (Figure 29 c), SON (Figure 29 d) and ANN (Figure 4-29 e) showed that temperatures were decreasing from west to east. The MAM seasons were noted to have the highest maximum temperature. Under RCP85, the Figure 4-30 shows that projected maximum temperatures during DJF, MAM, JJA, and SON seasons decreases eastwards whereas the MAM seasons indicated the highest maximum temperature compared to other seasons. Generally, projected maximum temperatures were noted to be higher under RCP45 compared to RCP85 for both annual and seasonal temperatures.

4.2.5.3 Spatial analysis of projected minimum temperature over Nandi County

Spatial variability of projected maximum temperature in Nandi Countyis presented in Figure 4-31 and Figure 4-32.

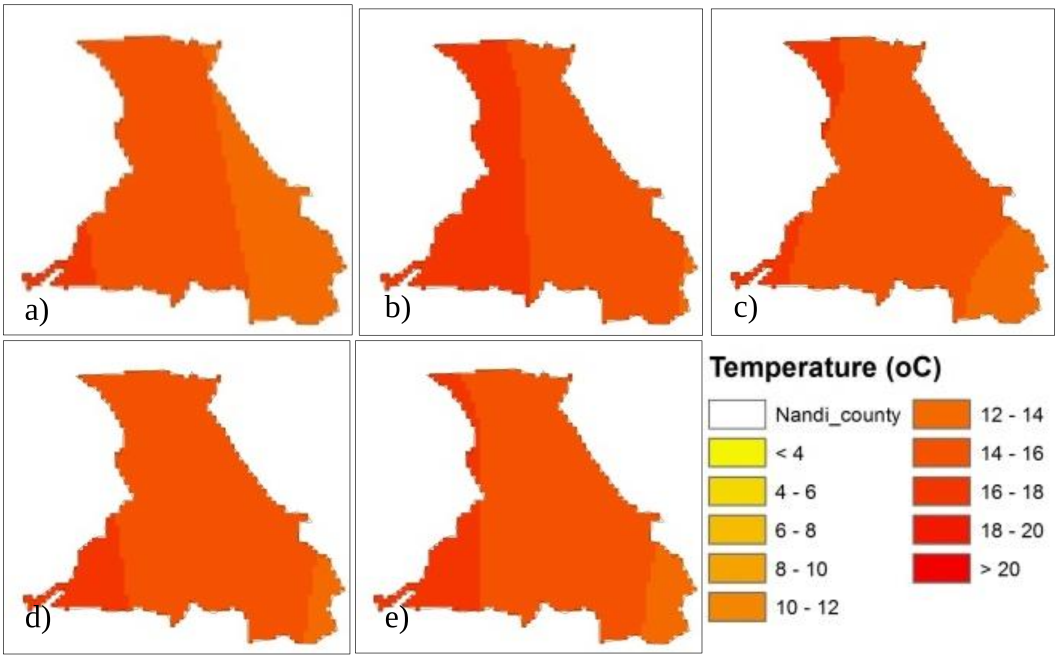

Figure 4-31: Map showing distribution of projected minimum temperature (RCA4 models Ensemble) based on RCP45 for a) DJF b) MAM c) JJA d) SON and e) ANN over Nandi County

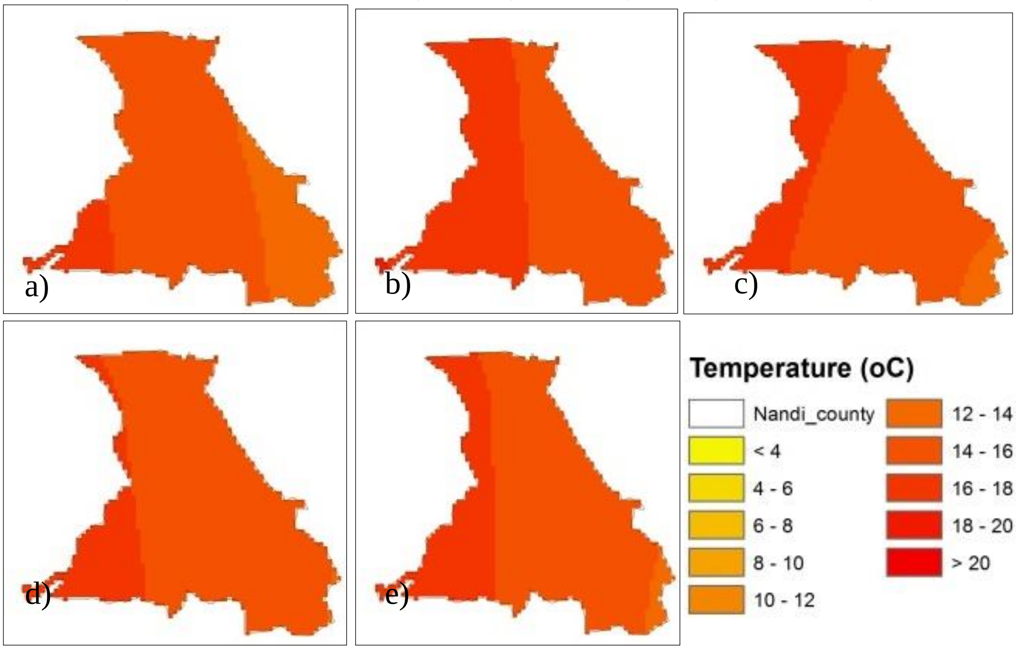

Figure 4-32: Map showing distribution of projected minimum temperature (RCA4 models Ensemble) based on RCP85 for a) DJF b) MAM c) JJA d) SON and e) ANN over Nandi County

As shown in Figure 4-31, projected minimum temperatures during DJF, MAM, JJA, SON and ANN showed that temperatures were decreasing from west to east and ranged between 12^oC and 20^oC. The MAM season was noted to have the highest minimum temperature compared to other seasons. Similarly, under RCP85, the Figure 4-32 shows that projected minimum temperatures during DJF, MAM, JJA, and SON seasons decreases eastwards whereas the MAM seasons indicated the highest minimum temperature compared to other seasons. Generally, projected minimum temperatures were noted to be higher under RCP45 compared to RCP85 for both annual and seasonal temperatures.

4.3 **Spatiotemporal variability of fodder availability in the Nandi County of Kenya**

Determination of spatiotemporal variability of fodder availability over Nandi County involved analysis of spatiotemporal variability of NDVI and soil moisture content over Nandi County.

Temporal variability of NDVI and moisture content over Nandi county of Kenya

Temporal patterns of NDVI and moisture content was based on graphical and statistical analysis.

4.3.1.1 Analysis of the trend of NDVI .

4.4 The Spatiotemporal variability of fodder availability in the Nandi County of Kenya

Determination of spatiotemporal variability of fodder availability over Nandi County involved analysis of spatiotemporal variability of NDVI and soil moisture content over Nandi County.

4.4.1 Temporal variability of NDVI and moisture content over Nandi county of Kenya

Temporal patterns of NDVI and moisture content was based on graphical and statistical analysis.

4-33and Figure 4-34 presents graphical analysis of climatology and annual NDVI

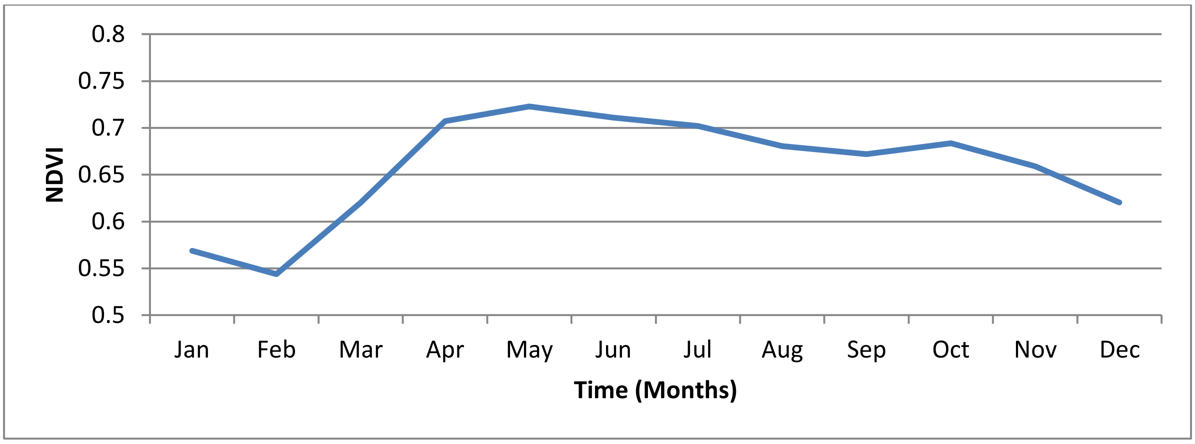

Figure 4-33: Climatology of NDVI over Nandi County

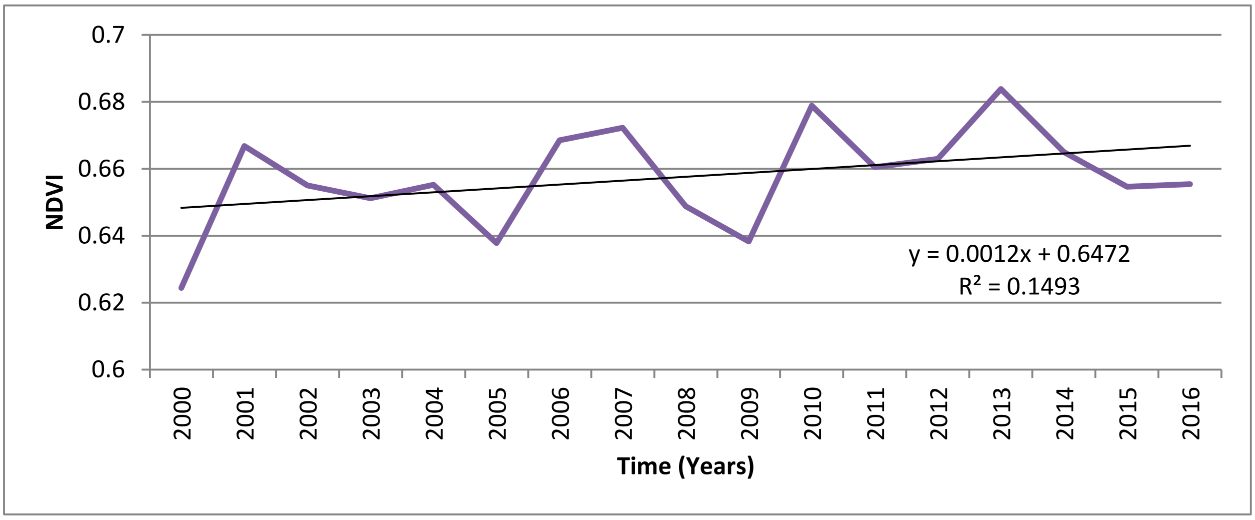

Figure 4-34: Analysis of annual NDVI over Nandi county

Table 4-11: Trend statistics of NDVI over Nandi County (2000 to 2016)

Variable	n	Test Z	Significance level (α)	Sen Slope (Q)	Mean	%Δ
DJF	16	0.59	++	0.0023	0.62	6.00
MAM	17	0.12	++	0.0007	0.62	1.96
JJA	17	0.62	++	0.0009	0.71	2.13
SON	17	1.03	++	0.0017	0.68	4.16
ANN	17	1.28	++	0.0010	0.66	2.53

As shown in Figure 4-33, the lowest NDVI value of 0.54 is noted in February and peaks in May where the NDVI value reaches 0.74. The study notes that between April and November, NDVI values were always greater than 0.65, an indication of presence of vegetation cover and thus fodder for livestock. The DJF season is noted to be the period whereby vegetation cover is expected to decrease and hence inadequate feed for the livestock. Graphical analysis of trend (Figure 4-34) show gradual increase in annual NDVI values between 2000 and 2016 and thus an indicator that vegetation cover over the county has been increasing. However, the coefficient of determination indicates that only 14.9% of data could be fitted along the line of best. Further analysis of trend (Table 11) indicated that NDVI changes were all positive during DJF, MAM, JJA, SON and ANN period. However, these changes were noted to be significant at $\alpha > 0.1$. The slope of the line of best fit ranged between 0.0007 and 0.0023 while the mean NDVI values for DJF, MAM, JJA, SON and ANN were found to be 0.62, 0.62, 0.71, 0.68 and 0.66 respectively. Moreover, the percentage change for NDVI values during DJF, MAM, JJA, SON and ANN were found to be 6.0%, 1.96%, 2.13%, 4.16% and 2.53% respectively.

Seasonal and annual mean values of above 0.6 imply presence of good and favourable vegetation conditions throughout the year to support dairy production however this could not be realised as majority (75.9%) of smallholder farmers in Nandi allocated less than 2 acres of land to dairy farming that relied on unimproved natural pasture for feed resource (Lukuyu et al., 2011) making it more vulnerable to changes in climate. The observed seasonal trend of vegetation is affirmed by studies such as Amadi et al. (2018) on sensitivity of vegetation to climate variability and its implications for malaria risk in Baringo which indicated that the annual NDVI decreased between January and March, and steadily increased between April and June whereas a decrease was observed between September and October that was followed by an increase between November and December.

4.4.1.1 Analysis of the trend of moisture content

Analysis of climatology and LTM soil moisture content over Nandi County is presented in Figure 4-35 and Figure 4-36 respectively. Statistical analyses of the trend of moisture content over Nandi County are presented below are presented in Table 4:11 and Table 4:12.

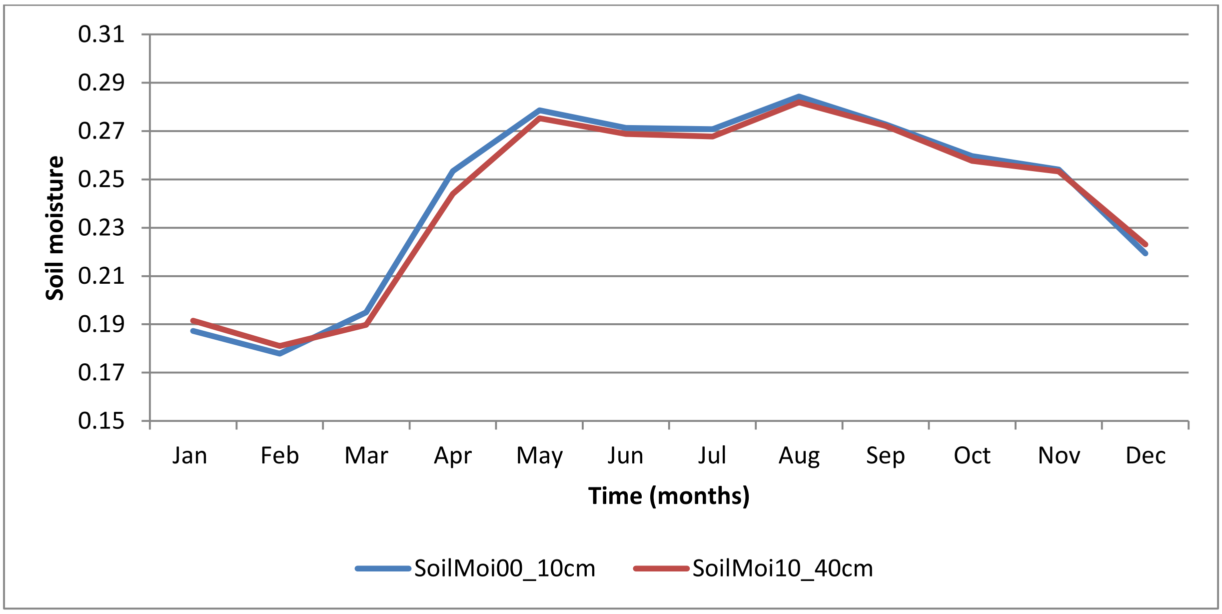

Figure 4-35: Climatology of soil moisture content over Nandi County

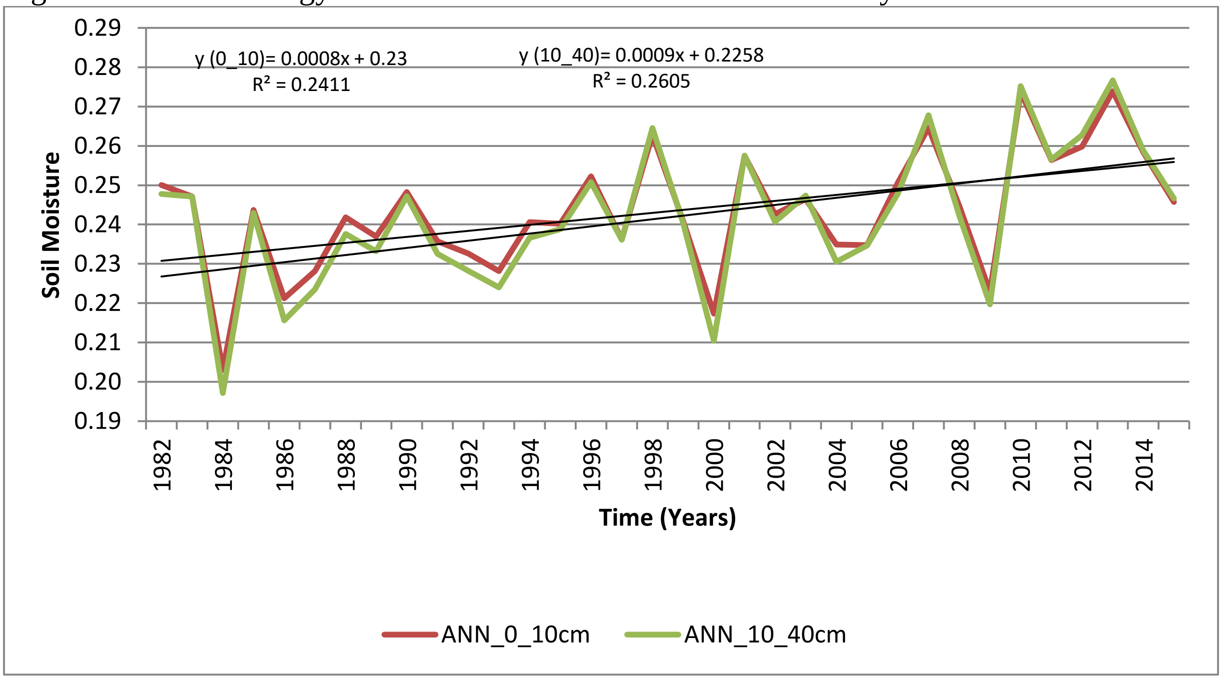

Figure 4-36: Analysis of annual LTM soil moisture content over Nandi county

Table 4-12: Trend statistics of soil moisture over Nandi County (1983-2016)

Variable	n	Test Z	Significance level (α)	Sen's slope (Q)	Mean	%Δ
ANN_0_10cm	34	2.55	*	0.0008	0.243	10.7
ANN_10_40cm	34	2.82	**	0.0009	0.242	12.7
DJF_0_10cm	34	1.99	*	0.0010	0.192	17.1
DJF_10_40cm	34	2.61	**	0.0014	0.195	23.7
JJA_0_10cm	34	1.81	+	0.0006	0.276	7.2
JJA_10_40cm	34	1.96	+	0.0007	0.273	8.1
MAM_0_10cm	34	1.69	+	0.0006	0.242	8.3
MAM_10_40cm	34	2.22	*	0.0007	0.235	10.2
SON_0_10cm	34	2.88	**	0.0011	0.262	14.7
SON_10_40cm	34	2.79	**	0.0013	0.261	16.5

As shown in Figure 4-35, the annual patterns of soil moisture content at both 0-10cm and 10-40cm are lowest in January-February-March with values of less than 0.20.The soil moisture content is noted to be above 0.25 between April and November and thus an indication of moisture available to support plant growth. Graphical analysis of trend as shown in Figure 4-36 displays gradual increase in LTM soil moisture content between 1982 and 2016 and thus an indicator sustained conditions necessary for plant growth. However, the coefficient of determination for both soil moisture content at 0-10cm and 10-40cm indicated that only 24.1% and 26.1% of data could be fitted along the line of best. Further analysis of trend (Table 12) indicated that LTM soil moisture content changes were all positive during DJF, MAM, JJA, SON and ANN period and ranged between 1.69 and 2.88 for 0-10cm level and between 1.96 and 2.82 for 10-40cm level. It was noted that these changes were significant at $\alpha \leq 0.05$ for all levels except MAM (0-10cm), JJA (10-40cm) and JJA (0-10cm). The slope of the line of best fit were all less than 0.001 while the mean NDVI values for DJF, MAM, JJA, SON and ANN were found to range between 0.192 and 0.276 at 0-10cm level and between 0.195 and 0.273 at 10-40cm level. Moreover, the percentage change for soil moisture content during DJF, MAM, JJA, SON and ANN ranged between 7.2% and 17.1% at 0-10cm level and between 8.1% and 23.7% at 10-40 level. In addition, the positive soil moisture content affirmed presence of suitable conditions to sustain fodder production. Makoni et al. (2014) linked seasonality to fodder and feed access as evidenced by lack of consistent milk supply that led to underutilization of bulking and cooling capacity in the dry season while making milk bulking and chilling capacity is insufficient during the wet season

4.4.2 Spatial variability of NDVI and moisture content over the Nandi county of Kenya

4.4.2.1 Spatial variability of NDVI over the Nandi county of Kenya

Spatial variability of fodder availability is presented for annual and seasonal NDVI in Figure 4-37.

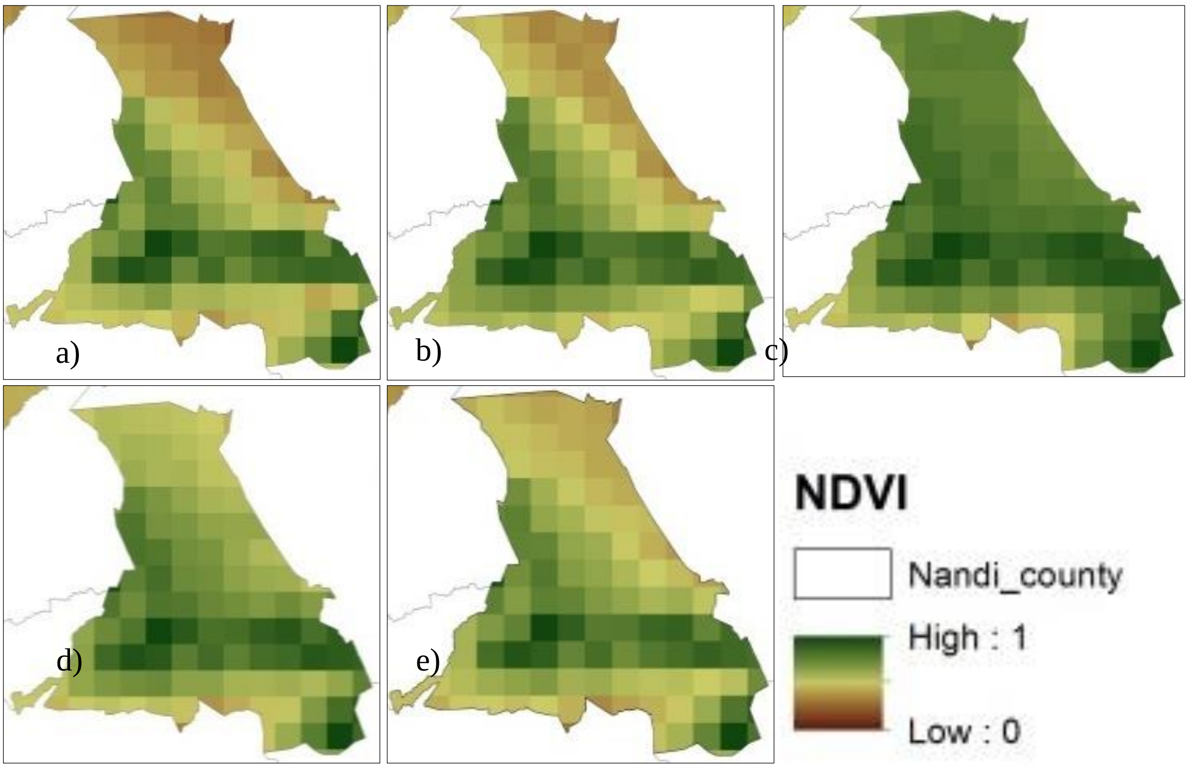

Figure 4-37: Spatial variability of a) DJF b) MAM c) JJA d) SON and e) ANN NDVI over Nandi County

As shown in Figure 4-37 seasonal progression of NDVI indicate that vegetation cover is lowest during the DJF season followed by MAM especially over North eastern parts of Nandi County. However, during the JJA, NDVI values were very high. Notably, NDVI values over the Central parts of Nandi county remained fairly high throughout the year.

4.4.2.2 Spatial variability of soil moisture content over the Nandi county of Kenya

Spatial variability of fodder availability is presented below for annual and seasonal soil moisture (Figure 4-38 and Figure 4-39).

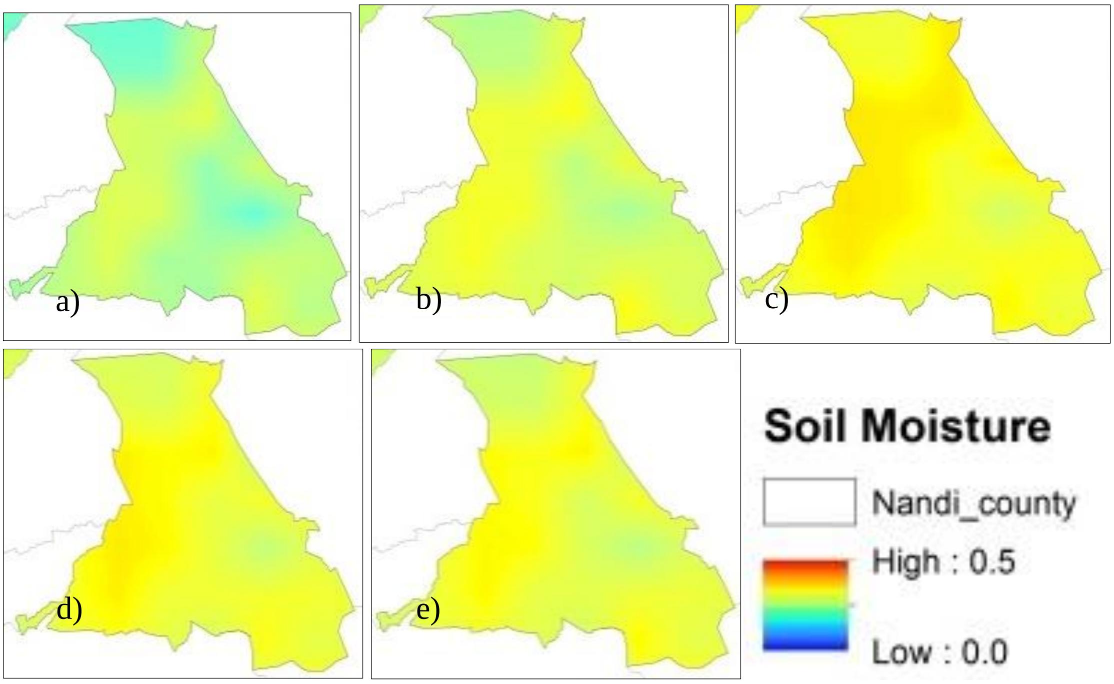

Figure 4-38: Spatial variability of a) DJF b) MAM c) JJA d) SON and e) ANN soil moisture content (0-10cm) over Nandi County

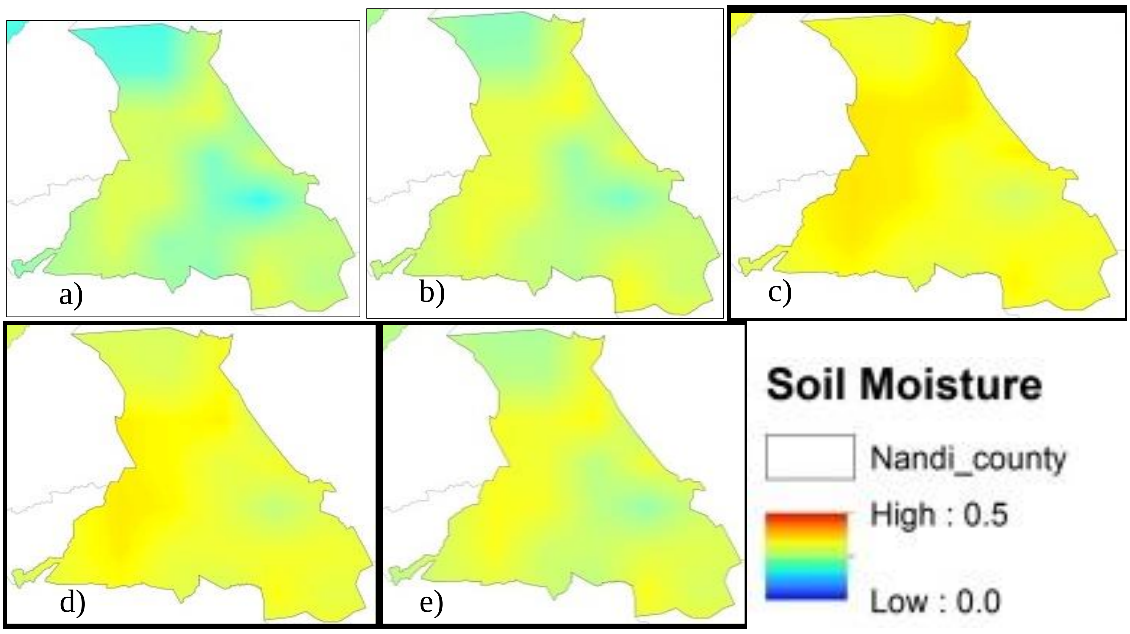

Figure 4-39: Spatial variability of a) DJF b) MAM c) JJA d) SON and e) ANN soil moisture content (10-40cm) over Nandi County

As shown in Figure 4-38, soil moisture at 0-10cm level was noted to be high during the JJA season while DJF season showed lower values of soil moisture content. Similarly, soil moisture content (Figure 4-39) was noted to be very during DJF season and very high JJA.

4.5 **Milk production in Nandi County of Kenya**

4.5.1 Characteristic of Dairy production in Nandi County

4.5.1.1 Land Ownership

During the data collection, respondents were asked to indicate their total land size household and the land size allocated for dairy farming and the results are presented in Table 4.25, Table 4.26, Table 4.27, Figure 4-51, Figure 4-40 and Figure 4-42

Table 4-13: Total Land Size of Households

Sub County	Ward	< 1 acres		1 to 3 acres		3 to 5 acres		5 to 10 acres		10 to 20 acres		> 20 acres		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	2	4.5	18	40.9	10	22.7	9	20.5	5	11.4	0	0.0	44
	Kobujoi	2	12.5	4	25.0	2	12.5	5	31.3	2	12.5	1	6.3	16
	Koyo-Ndurio	5	8.2	22	36.1	20	32.8	12	19.7	2	3.3	0	0.0	61
	Total	9	7.4	44	36.4	32	26.4	26	21.5	9	7.4	1	0.8	121
Chesumei	Kosirai	2	8.3	9	37.5	7	29.2	4	16.7	2	8.3	0	0.0	24
	Ngechek	8	18.2	17	38.6	7	15.9	9	20.5	3	6.8	0	0.0	44
	Total	10	14.7	26	38.2	14	20.6	13	19.1	5	7.4	0	0.0	68
Emgwen	Kilibwoni	5	8.5	16	27.1	12	20.3	14	23.7	12	20.3	0	0.0	59
Mosop	Kabisaga	0	0.0	0	0.0	2	10.5	4	21.1	12	63.2	1	5.3	19
	Kabiyet	0	0.0	1	7.1	3	21.4	1	7.1	5	35.7	4	28.6	14
	Total	0	0.0	1	3.0	5	15.2	5	15.2	17	51.5	5	15.2	33
Nandi Hills	Chepkunyuk	0	0.0	4	12.1	12	36.4	13	39.4	4	12.1	0	0.0	33
	Lessos	5	7.7	10	15.4	16	24.6	22	33.8	10	15.4	2	3.1	65
	Total	5	5.1	14	14.3	28	28.6	35	35.7	14	14.3	2	2.0	98

Table 4-14: Total Land Size Allocated to dairy farming

Sub County	Ward	< 0.25 acres		0.25 to 0.5 acres		0.5 to 2 acres		2 to 10 acres		> 10 acres		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	4	9.1	13	29.5	18	40.9	9	20.5	0	0.0	44
	Kobujoi	1	6.3	3	18.8	6	37.5	5	31.3	1	6.3	16
	Koyo-Ndurio	4	8.3	14	29.2	22	45.8	8	16.7	0	0.0	48
	Total	9	8.3	30	27.8	46	42.6	22	20.4	1	0.9	108
Chesumei	Kosirai	2	8.7	6	26.1	12	52.2	3	13.0	0	0.0	23
	Ngechek	4	9.1	10	22.7	16	36.4	14	31.8	0	0.0	44
	Total	6	9.0	16	23.9	28	41.8	17	25.4	0	0.0	67
Emgwen	Kilibwoni	6	10.5	16	28.1	23	40.4	12	21.1	0	0.0	57
Mosop	Kabisaga	0	0.0	0	0.0	6	46.2	7	53.8	0	0.0	13
	Kabiyet	0	0.0	1	11.1	8	88.9	0	0.0	0	0.0	9
	Total	0	0.0	1	4.5	14	63.6	7	31.8	0	0.0	22
Nandi Hills	Chepkunyuk	3	9.4	10	31.3	14	43.8	5	15.6	0	0.0	32
	Lessos	8	12.5	22	34.4	14	21.9	20	31.3	0	0.0	64
	Total	11	11.5	32	33.3	28	29.2	25	26.0	0	0.0	96

Table 4-15: Land tenure system

Sub County	Ward	Secured with title deed		Secured but family land		Rented		Squatter		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	19	45.2	23	54.8	0	0.0	0	0.0	42
	Kobujoi	7	43.8	9	56.3	0	0.0	0	0.0	16
	Koyo-Ndurio	41	70.7	17	29.3	0	0.0	0	0.0	58
	Total	67	57.8	49	42.2	0	0.0	0	0.0	116
Chesumei	Kosirai	9	37.5	15	62.5	0	0.0	0	0.0	24
	Ngechek	12	27.3	32	72.7	0	0.0	0	0.0	44
	Total	21	30.9	47	69.1	0	0.0	0	0.0	68
Emgwen	Kilibwoni	34	63.0	19	35.2	0	0.0	1	1.9	54
Mosop	Kabisaga	14	77.8	4	22.2	0	0.0	0	0.0	18
	Kabiyet	10	76.9	3	23.1	0	0.0	0	0.0	13
	Total	24	77.4	7	22.6	0	0.0	0	0.0	31
Nandi Hills	Chepkunyuk	18	54.5	15	45.5	0	0.0	0	0.0	33
	Lessos	45	71.4	17	27.0	0	0.0	1	1.6	63
	Total	63	65.6	32	33.3	0	0.0	1	1.0	96

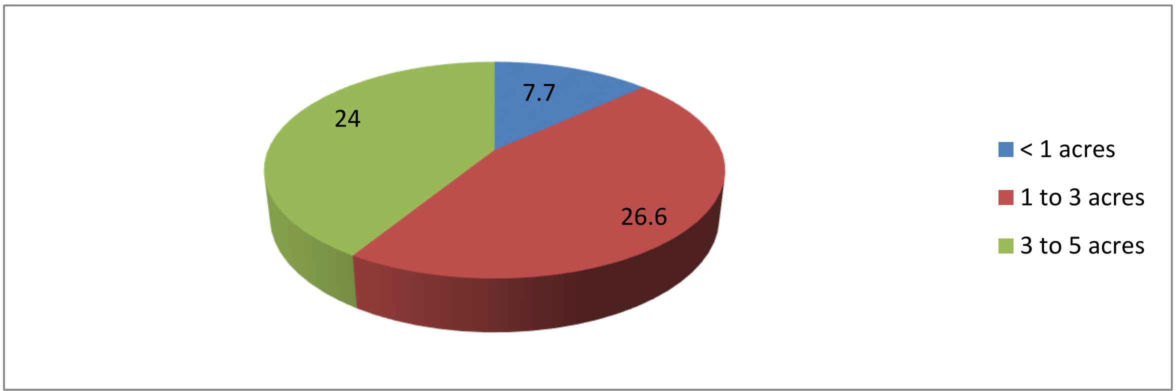

Figure 4-40: Total Land Size of Households in Nandi County

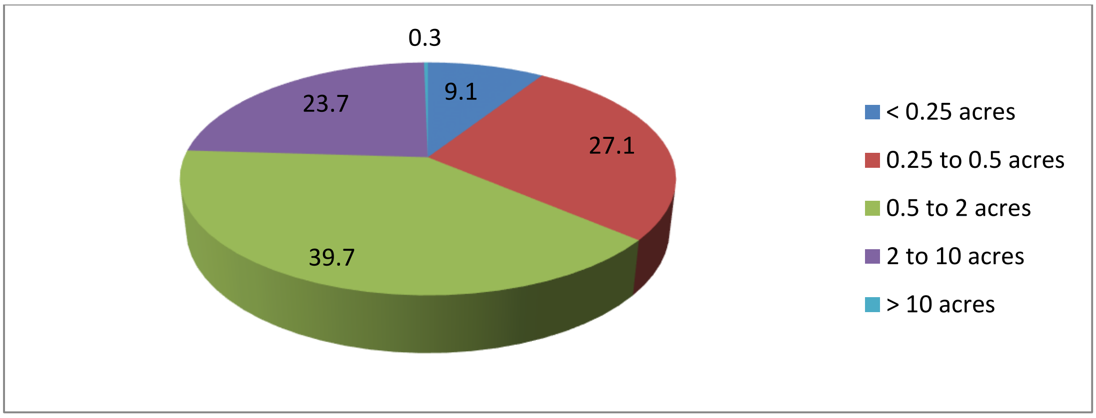

Figure 4-41: Total Land Size Allocated to dairy farming

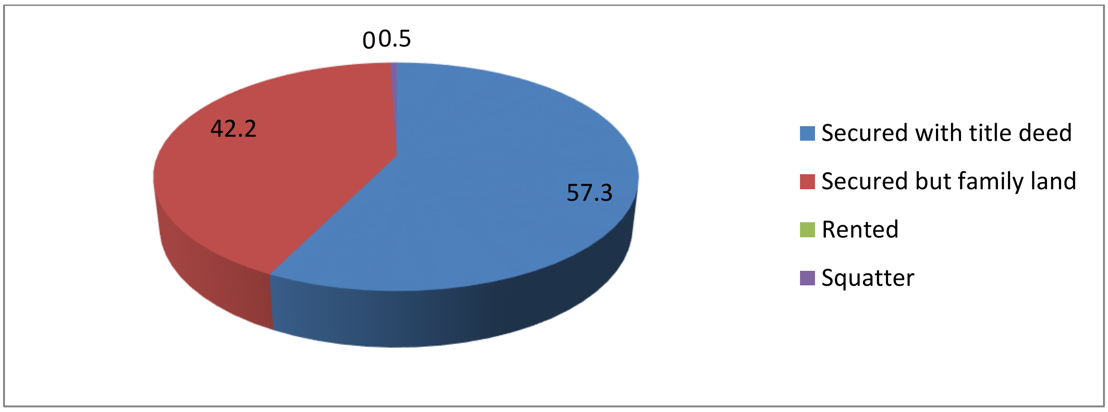

Figure 4-42: Land tenure system

As shown in Table 4-13, it is noted that in Aldai sub County, majority of households in Kaptumo (40.9%) and Koyo Ndurio (36.1%) owned 1 to 3 acres of land whereas majority in Kobujoi (31.3%) ward of Aldai subcounty and Chepkunyuk and Lessos ward of Nandi hills owned between 5 and 10 acres. Similarly, majority of households in Emgwen (27.1%) and Chesumei sub County in Kosirai (37.5%) and Ngechek (38.6%) owned between 1 and 3 acres of land. In Mosop Sub County, majority of households in Kabisaga (63.2%) and Kabiyet (35.7%) owned between 10 and 20 acres of land.Generally, majority of household owned between 1 and 20 acres of land. The Table 4-14 notes that majority of these households in all sub counties allocated between 0.5 to 2 acres of land for dairy farming except households in Lessos who allocated between 0.25 and 0.5 acres of land for dairy farming. The percentage of households allocating less than 1 acre of land for milk production could be attributed zero grazing farming systems and population densities. The differences would arise from the fact that though the size of land could be the same, how the land is utilized for dairy farming results to the observed difference. Moreover, the Table 4-15 show that majority of household had their land secured with title deed or practised farming on land secured with title deed but belonging to the family. Less than 1% of the household had rented land or were squatters. The findings agree with Makoni et al. (2014) which showed that in Eldoret and Nyahururu areas of rift-valley, dairy production was less intensive with large tracts of land available resulting in farms of 20–2,000 hectares. With majority of farmers owning improved breed dairy cows meant that they were heavy feeders with potential of producing more milk but sensitive to feed availability seasonality

4.5.1.2 Dairy animals Ownership

Analysis of characteristic of dairy production in Nandi County based on livestock population, dairy cows, lactating cows and milk sales data from the Ministry of Livestock are presented in Table 4-16. During the data collection, respondents were also asked to indicate their total number of dairy animals inclusive of mature and young cows and their breed type. The results presented in Table 4.17 to Table 4.19 and Figure 4-43 to Figure 4-44

Table 4-16: Trend statistics of dairy production in Nandi County

Variable (2008-2017)	Sample Size (n)	Test Z	Significance level (α)	Sen's slope (Q)	Mean	%Δ
Livestock Population	10	3.9	***	4729.7	295160.9	16.0
No. of Dairy cows	10	3.9	***	2838.0	177096.6	16.0
No. lactating cows	10	3.9	***	1277.3	79693.4	16.0
Milk sales (KES)	10	3.9	***	1623173.7	101292991.9	16.0

Table 4-17: Total dairy cows owned

Sub County	Ward	1 to 3 cows		4 to 6 cows		7 to 9 cows		> 10 cows		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	67	76.1	18	20.5	2	2.3	1	1.1	88
	Kobujoi	22	68.8	6	18.8	0	0.0	4	12.5	32
	Koyo-Ndurio	69	58.0	43	36.1	7	5.9	0	0.0	119
	Total	158	66.1	67	28.0	9	3.8	5	2.1	239
Chesumei	Kosirai	29	61.7	11	23.4	6	12.8	1	2.1	47
	Ngechek	58	68.2	22	25.9	2	2.4	3	3.5	85
	Total	87	65.9	33	25.0	8	6.1	4	3.0	132
Emgwen	Kilibwoni	76	65.5	27	23.3	5	4.3	8	6.9	116
Mosop	Kabisaga	5	13.9	16	44.4	11	30.6	4	11.1	36
	Kabiyet	8	28.6	4	14.3	10	35.7	6	21.4	28
	Total	13	20.3	20	31.3	21	32.8	10	15.6	64
Nandi Hills	Chepkunyuk	42	62.7	22	32.8	1	1.5	2	3.0	67
	Lessos	85	65.9	26	20.2	13	10.1	5	3.9	129
	Total	127	64.8	48	24.5	14	7.1	7	3.6	196
Total		461	61.7	195	26.1	57	7.6	34	4.6	747

Table 4-18: Mature dairy cows owned

Sub County	Ward	1 to 3 cows		4 to 6 cows		7 to 9 cows		> 10 cows		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	29	65.9	13	29.5	1	2.3	1	2.3	44
	Kobujoi	10	62.5	4	25.0	0	0.0	2	12.5	16
	Koyo-Ndurio	24	39.3	30	49.2	7	11.5	0	0.0	61
	Total	63	52.1	47	38.8	8	6.6	3	2.5	121
Chesumei	Kosirai	15	62.5	4	16.7	4	16.7	1	4.2	24
	Ngechek	29	65.9	13	29.5	0	0.0	2	4.5	44
	Total	44	64.7	17	25.0	4	5.9	3	4.4	68
Emgwen	Kilibwoni	37	62.7	13	22.0	5	8.5	4	6.8	59
Mosop	Kabisaga	0	0.0	9	50.0	5	27.8	4	22.2	18
	Kabiyet	3	21.4	2	14.3	4	28.6	5	35.7	14
	Total	3	9.4	11	34.4	9	28.1	9	28.1	32
Nandi Hills	Chepkunyuk	16	47.1	17	50.0	0	0.0	1	2.9	34
	Lessos	38	58.5	16	24.6	7	10.8	4	6.2	65
	Total	54	54.5	33	33.3	7	7.1	5	5.1	99
Total		201	53.0	121	31.9	33	8.7	24	6.3	379

Table 4-19: Number of young dairy cows owned per ward

Sub County	Ward	1 to 3 cows		4 to 6 cows		7 to 9 cows		> 10 cows		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	38	86.4	5	11.4	1	2.3	0	0.0	44
	Kobujoi	12	75.0	2	12.5	0	0.0	2	12.5	16
	Koyo-Ndurio	45	77.6	13	22.4	0	0.0	0	0.0	58
	Total	95	80.5	20	16.9	1	0.8	2	1.7	118
Chesumei	Kosirai	14	60.9	7	30.4	2	8.7	0	0.0	23
	Ngechek	29	70.7	9	22.0	2	4.9	1	2.4	41
	Total	43	67.2	16	25.0	4	6.3	1	1.6	64
Emgwen	Kilibwoni	39	68.4	14	24.6	0	0.0	4	7.0	57
Mosop	Kabisaga	5	27.8	7	38.9	6	33.3	0	0.0	18
	Kabiyet	5	35.7	2	14.3	6	42.9	1	7.1	14
	Total	10	31.3	9	28.1	12	37.5	1	3.1	32
Nandi Hills	Chepkunyuk	26	78.8	5	15.2	1	3.0	1	3.0	33
	Lessos	47	73.4	10	15.6	6	9.4	1	1.6	64
	Total	73	75.3	15	15.5	7	7.2	2	2.1	97
Total		260	70.7	74	20.1	24	6.5	10	2.7	368

Table 4-20: Number of dairy breeds per ward

Sub County	Ward	Local		Improved		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	0	0.0	44	100.0	44
	Kobujoi	3	18.8	13	81.3	16
	Koyo-Ndurio	0	0.0	58	100.0	58
	Total	3	2.5	115	97.5	118
Chesumei	Kosirai	0	0.0	23	100.0	23
	Ngechek	0	0.0	41	100.0	41
	Total	0	0.0	64	100.0	64
Emgwen	Kilibwoni	0	0.0	57	100.0	57
Mosop	Kabisaga	0	0.0	18	100.0	18
	Kabiyet	0	0.0	14	100.0	14
	Total	0	0.0	32	100.0	32
Nandi Hills	Chepkunyuk	2	6.1	31	93.9	33
	Lessos	0	0.0	64	100.0	64
	Total	2	2.1	95	97.9	97

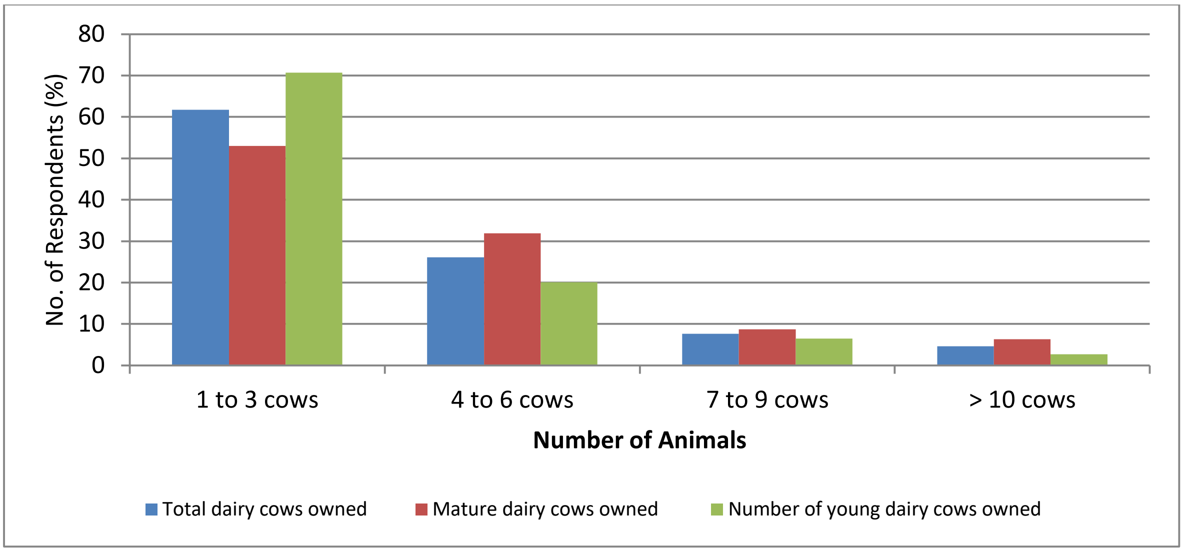

Figure 4-43: Ownership of dairy animals in Nandi County

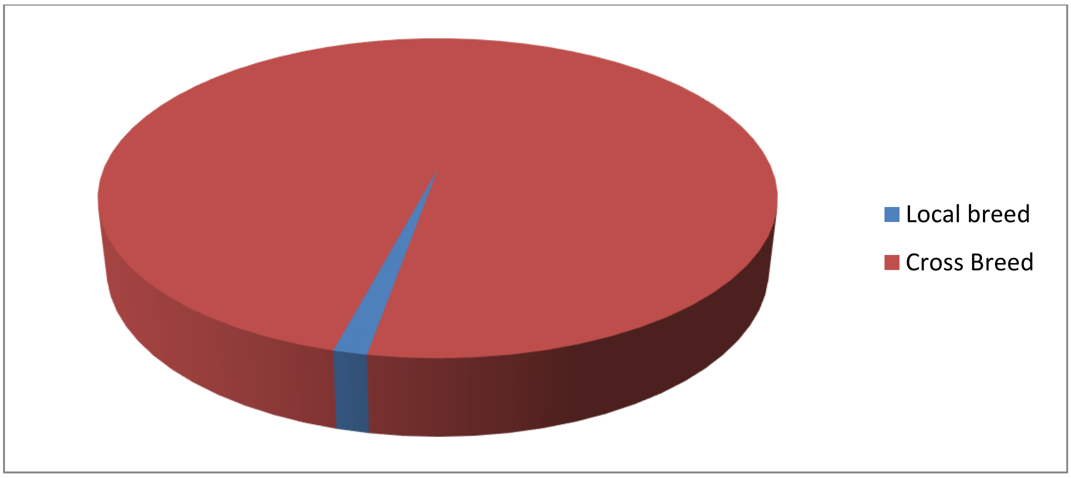

Figure 4-44: Number of dairy breeds in Nandi County

The Table 4-16 shows that the trend of dairy production based on livestock population, dairy cows, lactating cows and milk sales were all positive with a magnitude of 3.9 with significance level (α) of 0.001 and thus an increasing trend. The Sen's estimator for the true slope of linear trend for livestock population, dairy herd, lactating herd and sales were found to be 4729.7, 2838.0, 1277.3 and 1623173.7 respectively with corresponding mean values of 295160.9 (livestock population), 177096.6 (dairy cows), 79693.4 (Lactating cows) and 101292991.9 (milk sales). Notably, the trend of dairy production showed increased of up to 16%.

The Table 4-17 show that most of the households in all sub counties owned between 1 and 3 cows except in Mosop Sub County where majority in Kabisaga (44.4%) and Kabiyet (35.7%) owned between 4 to 6 cows and between 7 to 9 cows respectively. The Table 4-18 show that the number of mature dairy animals in all sub counties was found to be between 1 to 3 cows except in Koyo Ndurio (49.2%) in Aldai, Kabisaga (50.0%) in Mosop and Chepkunyuk (50.0%) in Nandi Hills with 4 to 6 cows. Similarly, the Table 4-19 show that the numbers of young cows in all subcounties were mainly between 1 and 3 cows except in Kabisaga (38.9%) which showed that majority of households had between 1 and 3 young cows. In Overall, Figure 4-43 shows that up to 61.7% of respondents in Nandi County owned 1 to 3 cows, of which 53% of these cows being mature while 70.7% being young dairy cows Further, the FGD indicated that most households had an average of 2 lactating cows throughout the year. Table 4-20 and Figure 4-44 show that majority of farmers of up to 98.6% in all sub counties in Nandi County owned dairy cows which were improved breeds that include crosses of local and pure breeds. The local breeds owned by few farmers were mainly the Zebu. The FGD identified that these improved breeds of dairy cows were mainly crosses of Friesian, Guernsey and Ayrshire.

4.5.2 Temporal pattern of milk production in Nandi County of Kenya

Determination of spatiotemporal variability of milk productivity over Nandi County involved analysis of milk production farmers' cooperative society.

4.5.2.1 Graphical trend analysis of milk production

The Figure 4-45 and Figure 4-50 presents graphical analysis of milk production based on actual procured milk by the farmer Organization, Number of Active milk suppliers and milk supplied per household to farmer organisations.

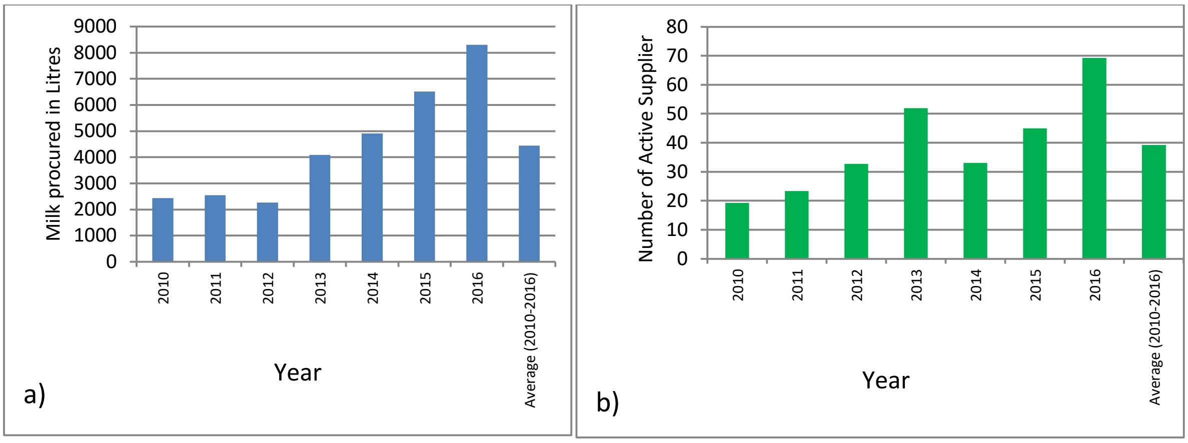

Figure 4-45: Mean daily a) milk procured by farmer organisations and b) number of active milk suppliers to the farmer organisation in Nandi County

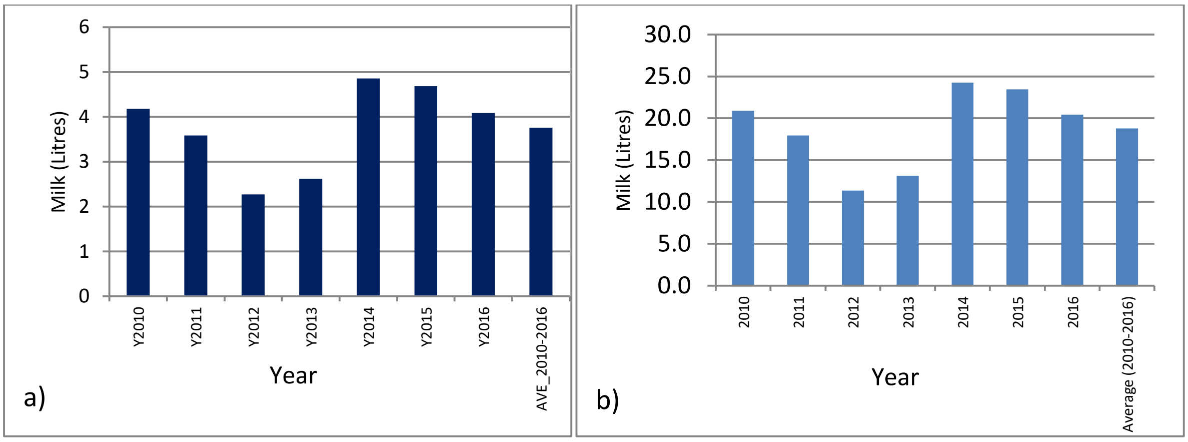

Figure 4-46:Mean daily milk a) supplied per household to the farmer organisation and b) production per household in Nandi County

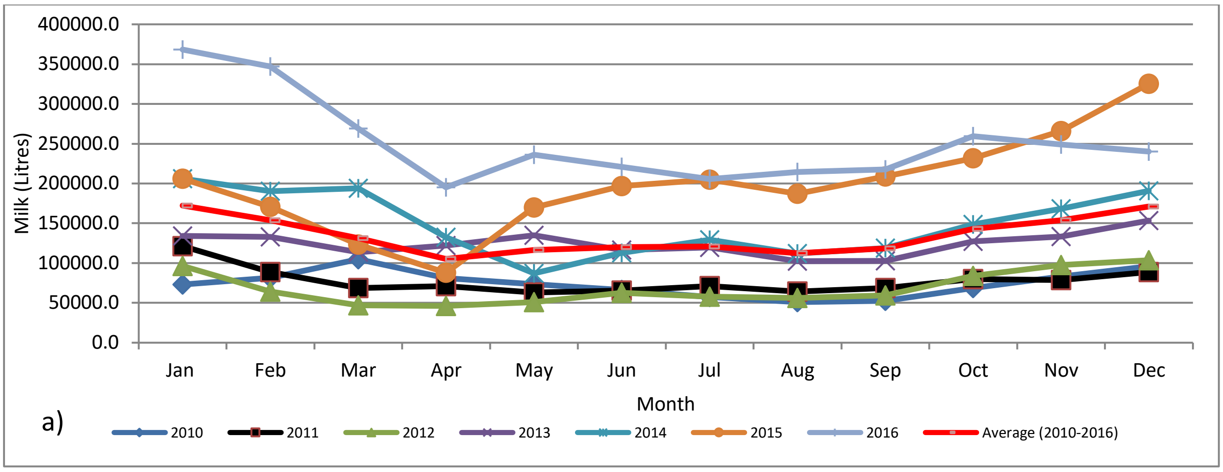

Figure 4-47: Monthly average milk procured by farmer organizations in Nandi County

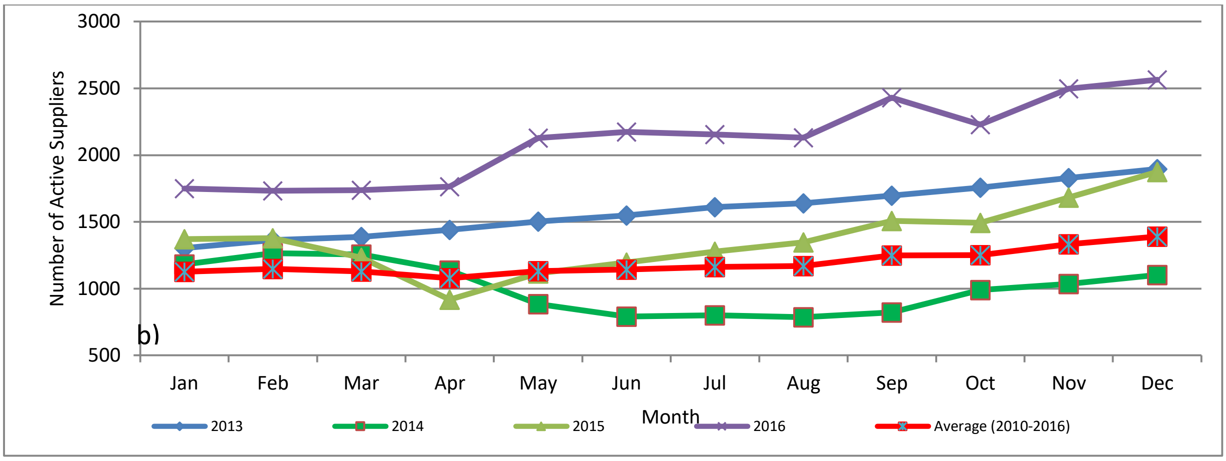

Figure 4-48: Monthly average number of active milk Suppliers to farmer organisation in Nandi County

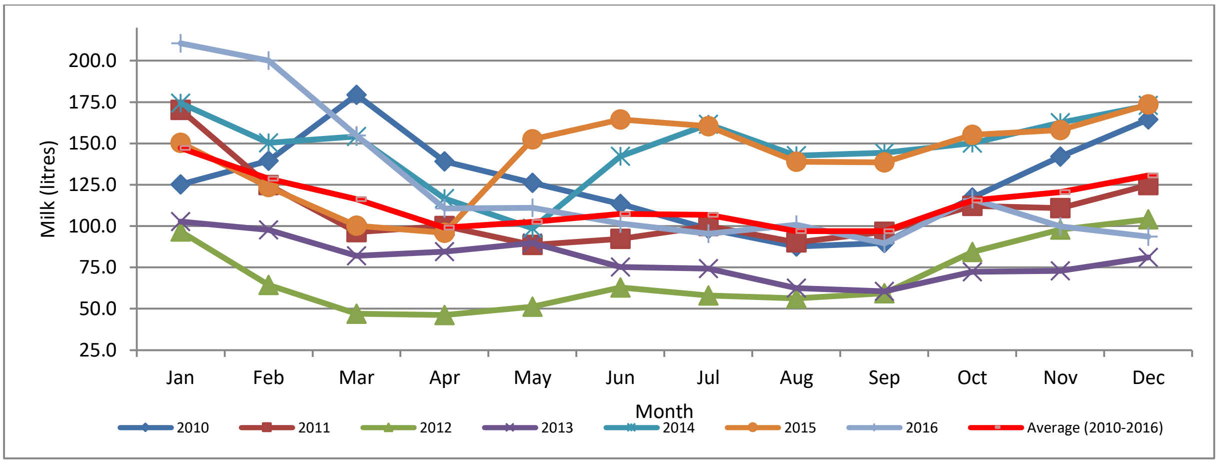

Figure 4-49: Monthly average milk procured per household by farmer organisation in Nandi County

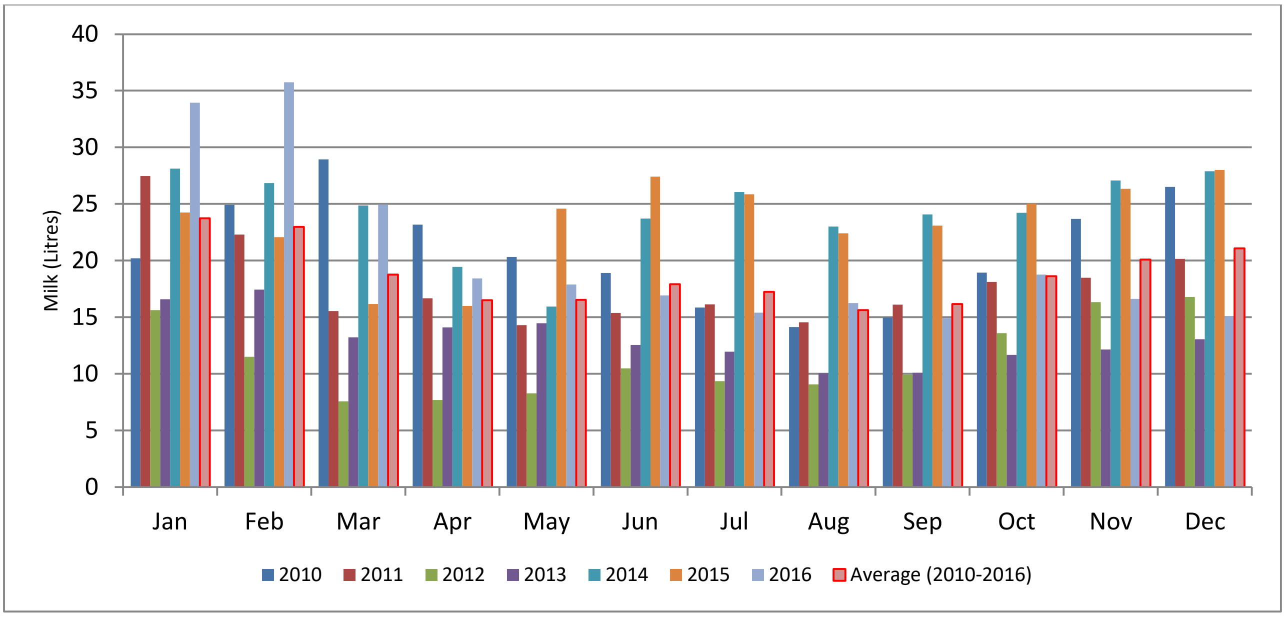

Figure 4-50: Daily average milk production per household in Nandi County

As shown in Figure 4-45 (a), the trend of average (2010-2016) daily milk procured by farmer organization increased from 2010 to 2016 with the minimum of 2261.2 litres per day recorded in 2012 and a maximum of 8305.5 litres per day in 2016. The average (2010-2016) daily milk procured by farmer organization was 4439.5 litres. The observed increase in the amount of average daily milk procured could be attributed to the number of active milk suppliers which was noted in Figure 4-45 (b) to undergo a lot of fluctuations with average daily active milk suppliers minimum of 19 households in 2010 and maximum of 69 households in 2016. The average (2010-2016) daily active milk suppliers were 39 households per day. Figure 4-46 (a) shows that computed average (2010-2016) daily milk per household supplied to farmer organisation was noted to fluctuate between 2.3 litres per household in 2012 and 4.9 litres per household in 2014 and thus giving average daily milk supplied per household to farmer organisation between 2010 and 2016 to be 3.8 litres per household. Computed milk production per household (Figure 4-46 b) was based on the assumption that milk supplied to farmer organisation i.e. formally marketed only accounted for 20% of total milk produced per household and thus found to vary between 11.4litres per household in 2012 and 24.3 litres per household in 2014 and thus giving average daily milk produced per household in the county between 2010 and 2016 to be 18.8 litres per household.

The yearly statistics shown in Figure 4-47indicate that the highest monthly average milk procured by farmer organisations in 2010 was in March (104780.8 litres), in 2011 was in January (121106.5 litres), in 2012 was in December (103616.0 litres), in 2013 was in December (153547.0 litres), in 2014 was in January (205933.0 litres), in 2015 was in January (205933.0 litres) and in 2016 was in January (368340.7 litres). It is also noted in Figure 4-47 that yearly records indicated that the lowest monthly average milk procured to farmer organisations in 2010 was in August (51151.0 litres), in 2011 was in May (63047.6 litres), in 2012 was in April (46017 litres), in 2013 was in August (102697.3 litres), in 2014 was in May (87303.5 litres), in 2015 was in April (88069.0 litres) and in 2016 was in April (195198.0 litres). In overall, the Figure 4-47 show that the monthly average milk procured by farmer organizations in Nandi County was highest in January (172122.3 litres) and December (171180.7 litres) and recorded to be lowest in April (105178.7 litres).

Yearly statistics indicate that in 2010, 2011 and 2012, the monthly average number of active suppliers was 584 HH, 711 HH and 996 HH respectively (Figure 4-48). Computed statistics showed that the highest monthly average number of active milk suppliers in 2013 was in December (1896 HH), in 2014 was in February (1265 HH), in 2015 was in December (1874 HH) and in 2016 was in December (2565 HH). Moreover, Figure 4-48 shows that the lowest monthly average number of active milk suppliers in 2013 was in January (1303 HH), in 2014 was in June (792 HH), in 2015 was in April (918 HH) and in 2016 was in February (1734 HH). Generally, the monthly average number of active milk suppliers was noted to be high in 2015 and 2016. In overall, the Figure 4-48 shows that the monthly average number of active milk suppliers was highest in December (1390 HH) and lowest in April (1079 HH).

The Figure 4-49 shows that the monthly average milk production per HH in 2010, 2011, 2012, 2013, 104, 2015 and 2016 was highest in March (179.4 litres), January (170.3 litres), December (104.0 litres), January (102.8 litres), January (174.4 litres), December (173.6 litres), January (210.5 litres) and January (147.2 litres) respectively. Notably, Figure 4-49 show that the lowest monthly average milk production per HH in 2010 was in August (87.6 litres), in 2011 was in August (90.3 litres), in 2012 was in April (46.2 litres), in 2013 was in September (60.6 litres), in 2014 was in May (98.8 litres), in 2015 was in April (95.9 litres) and in 2016 was in September (89.5 litres). In overall, Figure 4-49 shows that monthly average milk production per household was lowest during the period August-September (97.0 litres) and highest in January 147.2 litres).

Similarly, the Figure 4-50 presents computed daily average milk production per household in Nandi County in 2010, 2011, 2012, 2013, 104, 2015 and 2016. It is noted that the daily milk production per household in 2010 was highest/lowest in March (28.9litres)/August (14.1 litres), in 2011 was highest/lowest in January (27.5litres)/May (14.3 litres), in 2012 was highest/lowest in December (16.8 litres)/March (7.6 litres), in 2013 was highest/lowest in February (17.4 litres)/August (10.1 litres), in 2014 was highest/lowest in January (28.1 litres)/May (15.9 litres),in 2015 was highest/lowest in December (28.0 litres)/April (16.0 litres) and in 2016 was highest/lowest in February (35.7 litres)/December (15.1 litres). The Figure 4-50 shows that the daily average milk production per household between 2010 and 2016 was highest/lowest in January (23.7 litres)/August (15.6 litres).

The FGD linked the observed variation in milk procured by farmer organization and the number of active milk suppliers to feed seasonality and climate that led to reduced milk production and thus increased demand for milk which meant that there was competition for the available milk from farmer organizations and other alternative markets such as informal traders. The study further noted that informal traders were highly competitive as they collected milk from the households and offered better prices which were paid on daily basis and thus reducing the amount of milk formally marketed. Further, the FGD noted that sale of milk through informal market was common during the dry season due feed shortage and hence to supplement the available feed resource, farmers purchased feeds for the cows. Moreover, household milk demand which included milk for calves and home consumption was noted to reduce not only the amount of milk procured by farmer organizations but also the number of active milk suppliers.

Corné et al. (2016) acknowledged that seasonality of milk production and competition in milk procurement with informal sales, which members engaged in to diversify milk income streams to household were biggest challenges for the cooperatives. Kruse (2012) and ACET (2015) found that informal sales were made possible due to ready alternative markets available to farmers as milk traders, local markets and neighbours provided direct cash with prices being up to 70% higher under informal agreement with traders. Kruse (2012) noted that establishment of processor-owned bulking points closer to the farm also provided an incentive for farmers to sell their milk rather than to cooperatives.

4.5.2.2 Statistical trend analysis of milk production

Statistical analyses of the trend (daily and seasonal) of milk production over Nandi County are presented below are presented in Table 4:21 and Table 4-22

Table 4-21: Trend statistics of milk production over Nandi County (2007 to 2016)

Variable	n	Test Z	Significance level (α)	Sen Slope (Q)	Mean	%Δ
MAM	10	3.04	**	50190.02	269257.5	186.40
JJA	10	3.76	***	51078.07	278787.8	183.20
SON	10	3.58	***	67952.45	336234.6	202.10
DJF	10	3.76	***	82792.70	386095.5	214.44
ANN	10	3.58	***	260135.10	1270375	204.77

Table 4-22: Daily average milk production

Variable	n	Test Z	Sign. level (α)	Sen Slope (Q)	Daily average	%Δ
Total Milk procured by farmer organization	84	8.6	***	75.8	4439.6	143.5
Number of Active Suppliers	84	9.2	***	0.57	39.2	123.0
Milk procured per HH by farmer organisation	84	1.8	+	0.01	3.8	22.8
Milk produced per HH		1.79	+	0.05	18.8	22.8

Analysis of trend of seasonal and annual milk production over Nandi County (Table 4-21) showed positive values, an indication of increasing milk production throughout the year with a magnitude ranging from 3.04 (MAM) to 3.76 (JJA and DJF). The trends of milk production were all significant α level ≤ 0.05. The Sen's estimators for the true slope of linear trend were positive for MAM (50190.02), JJA (51078.07), SON (67952.45), DJF (82792.70) and ANN (260135.10). The corresponding mean values were found to be MAM (269257.5), JJA (278787.8), SON (336234.6), DJF (386095.5) and ANN (1270375). Worth noting, the trend of milk production showed increased of up to 186%, 183%, 202%, 214% and 204% during MAM, JJA, SON, DJF and ANN respectively.

Analysis of trend of daily average milk production over Nandi County (Table 4-22) showed positive change and thus an indicator of increasing milk production with a magnitude 8.6, 9.2 and 1.8 for Milk procured by farmer organization, Number of Active Suppliers and Milk production per HH respectively. The Sen's estimators for the true slope of linear trend were positive for Milk procured by farmer organization (75.8), Number of Active Suppliers (0.57) and Milk production per HH (0.01). The corresponding mean values were found to be Milk procured by farmer organization (4439.6), Number of Active Suppliers (39.2) and Milk production per HH (3.8). The study found that the trend of Milk procured by farmer organization, Number of Active Suppliers and Milk production per HHwas increasing at 143.5%, 123.0% and 22.8% respectively.

4.6 Relationship between milk production, fodder availability and climate

4.6.1 Correlation analysis

The Table 4-23 shows correlation analysis between monthly milk production and indicators of climate (precipitation, maximum and minimum temperature) and fodder availability (Soil moisture content and NDVI).

Table 4-23: Correlation analysis between monthly milk production and lagged climate and fodder (2007-2016)

Milk production / Variable	Correlation coefficient (r)		
	Lag 0	Lag 1	Lag 2
Precipitation	0.036	0.003	0.027
Maximum temperature	0.165	0.214	0.220
Minimum temperature	0.224	0.232	0.273
Soil moisture content 0-10cm	0.151	0.024	-0.055
Soil moisture content 10-40cm	0.177	0.065	-0.012
NDVI	-0.063	-0.121	-0.082

The Table 4-23 indicates that at lag 0 and lag 1, there is a positive correlation between milk production and indicators of climate and fodder availability except NDVI. However, at lag 2, the correlation coefficients were all positive for climate indicators and negative for fodder availability indicators. It is noted that the highest correlation coefficient were found based on minimum temperature at lag 0, 1 and 2 whereas, precipitation showed the lowest correlation coefficient for lag 0, 1 and 2.

4.6.2 Multiregression analysis

The Table 4-24 shows models developed through multivariate regression analysis based on climate (precipitation, maximum and minimum temperature) and fodder availability (Soil moisture content and NDVI) as indicators of milk production whereas Figure 4-51 and Figure 4-52 shows histograms of standardized residuals on models selected based AIC values

Table 4-24: Multivariate Regression Analysis (2007-2016)

Model Selected	Predictors	Auto – correlation	Durbin Watson	Wilk Shapiro	VIFs	AIC
5	PRE + TMX + TMN + NDVI	0.89	0.17	0.92	1.067	-6.65
6	PRE + TMX + TMN + soilm1	0.87	0.22	0.92	1.154	-15.88
13	PRE + TMX + TMN + soilm1 + soilm2	0.84	0.26	0.93	1.180	-16.43
23	PRE + TMX + TMN + soilm2	0.86	0.23	0.93	1.170	-17.43
1	PRE + TMX + TMN + soilm1 + NDVI	0.83	0.28	0.93	1.198	-18.21
21	TMX + TMN + soilm1 + soilm2	0.85	0.25	0.93	1.179	-18.33
24	PRE + TMX + TMN + SOILM1 + soilm2 + NDVI	0.81	0.31	0.94	1.226	-18.89
29	TMX + TMN + soilm1 + NDVI	0.83	0.27	0.93	1.198	-20.18
30	TMN + soilm1 + soilm2 + NDVI	0.82	0.30	0.94	1.224	-22.75

Alternative hypothesis: true autocorrelation is greater than 0

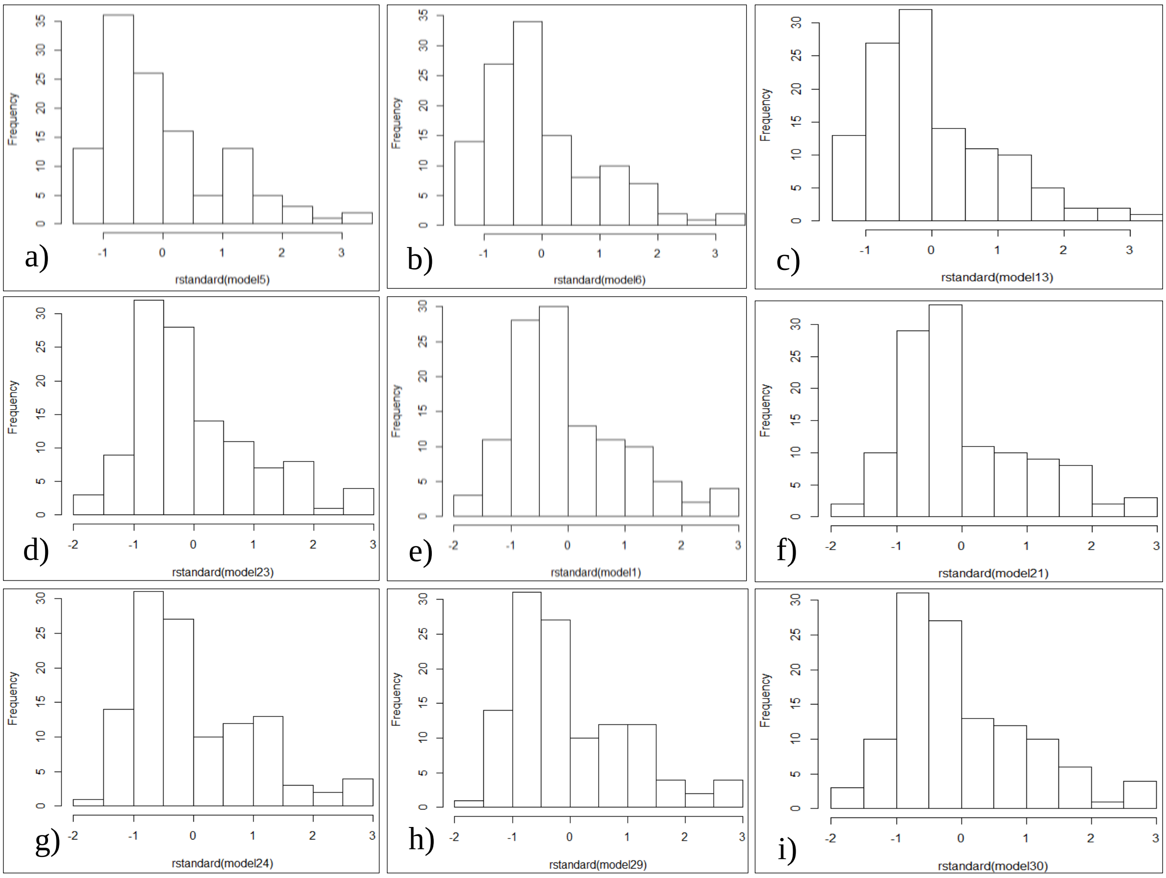

Figure 4-51: Histograms of standardized residuals model a) 5, b) 6, c) 13, d) 23, e) 1, f) 21, g) 24, h) 29 and i) based low AIC values

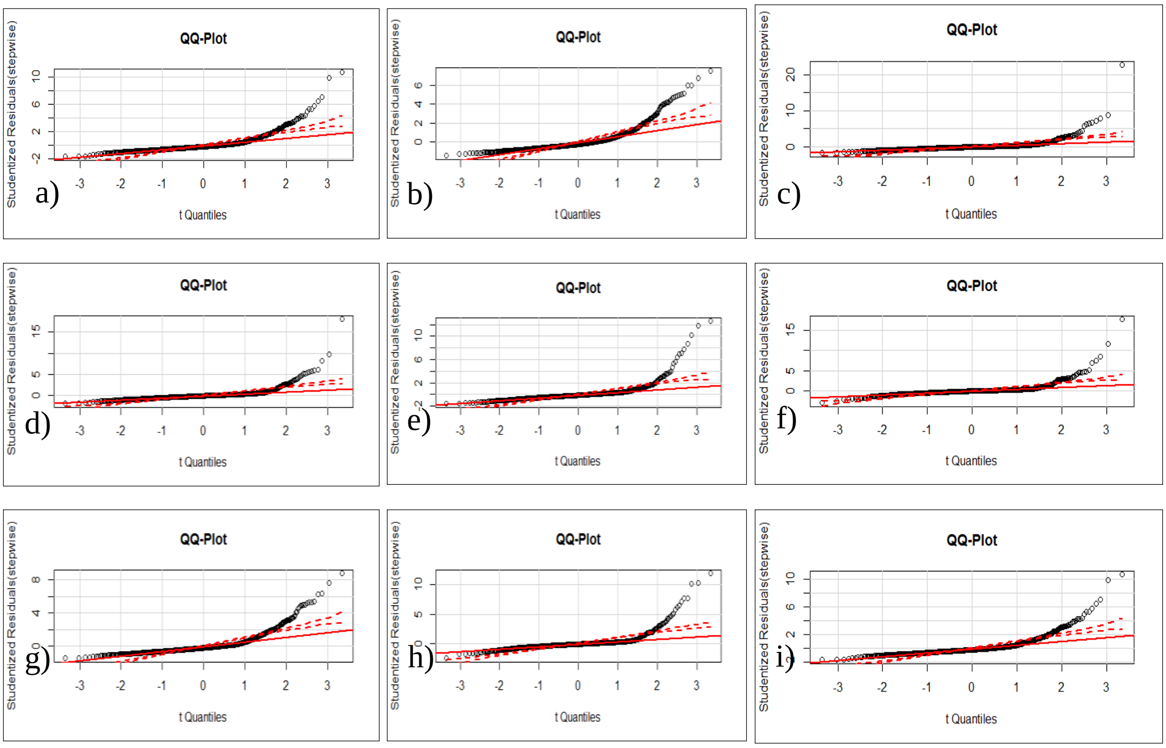

Figure 4-52: Normality Test Based on QQ Plots on model a) 5, b) 6, c) 13, d) 23, e) 1, f) 21, g) 24, h) 29 and i) based low AIC values

In Table 4-23, autocorrelation analysis showed that all selected models based on different predictors had positive relationship with milk production. Durbin Watson test (D-W) indicated that these variables were independent as the values were distributed around 2 for different models. A comparison of selected models with at least four predictors indicated that the model with the lowest AICs value of -6.65 composed of precipitation, maximum temperature, minimum temperature and NDVI whereas the selected model with the highest AICs value composed of minimum temperature, soil moisture content (0-10cm), soil moisture content (10-40cm) and NDVI. Furthermore, the VIFs of the predictor variables ranged between 1.067 and 1.226 for the selected models, an indication that the standard errors for the coefficient of the predictor variable were approximately 1.1 times as large as it would be if that predictor variable were uncorrelated with the other predictor variables.

Histograms of model residual were symmetrical in shape for the selected models and thus an indication of normality in the model residuals (Figure 4-51). The results based on histograms were affirmed by the QQ plots for the selected stations which followed a straight line (Figure 4-52). Wilk-Shapiro test showed strong evidence against normality an indication that did not come from a normal distribution.

4.7 Examination of existing and potential adaptation and mitigation strategies to climate change in the Nandi county of Kenya

Information on existing and potential adaptation and mitigation strategies to climate change was collected based on questionnaires, focus group discussion and key informant interviews.

4.7.1 Questionnaire Response rate

Questionnaires were administered to dairy farmers in five (5) sub counties of Nandi County. The study targeted a population of 30,000 respondents as computed in chapter three (3), section 3.3.3 of the study which resulted to a sample size of 384. Of the 384 questionnaires distributed, only 382 questionnaires were found to be fit for analysis as two questionnaires were partially filled. This gave a response rate of 99.5%. This was possible because of the fact that the research assistants administered the questionnaires and hence eliminated the risk of non-return as it was possible to recover the questionnaires once they were completed.

4.7.2 Household Information

Household information collected included distribution of farmers by gender and household characteristics (gender, age, occupation, number of people and animals, relationship and type of household, level of education, wealth status and land). The results are presented in the subsequent sections.

4.7.2.1 Distribution of Farmers by Gender

During the data collection, farmers were asked to state their gender and the results presented in Table 4.25and Figure 4.53.

Table 4-25: Gender of Respondent

Sub County	Ward	Male		Female		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	24	55.8	19	44.2	43
	Kobujoi	5	31.3	11	68.8	16
	Koyo Ndurio	37	59.7	25	40.3	62
	Total	66	54.5	55	45.5	121
Chesumei	Kosirai	4	17.4	19	82.6	23
	Ngechek	30	68.2	14	31.8	44
	Total	34	50.7	33	49.3	67
Emgwen	Kilibwoni	42	72.4	16	27.6	58
Mosop	Kabisaga	13	68.4	6	31.6	19
	Kabiyet	8	57.1	6	42.9	14
	Total	21	63.6	12	36.4	33
Nandi Hills	Chepkunyuk	27	79.4	7	20.6	34
	Lessos	36	55.4	29	44.6	65
	Total	63	63.6	36	36.4	99

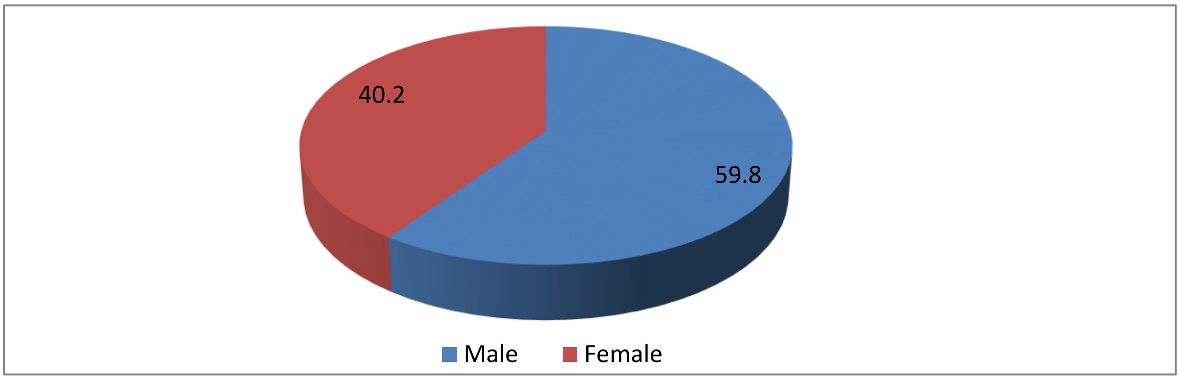

Figure 4-53: Gender of respondent over Nandi County

The response rate based on gender (Table 4-24) indicated that there were 54.5% male compared to 45.5% female in Aldai, 50.7% male compared to 49.3% female in Chesumei, 68.4% male compared to 31.6% female in Emgwen, 63.6% male compared to 36.4% female in Mosop and 63.6% male compared to 36.4% female in Nandi Hills. In overall, the response rate of dairy farmers by gender in Nandi County (Figure 4-53) indicated that 59.8% were male compared to 40.2% who were female.

4.7.2.2 Household Characteristics

4.7.2.2.1 Type of Household and their Relationship to Household Head

The type of household and their relationship to household head is presented in Table 4.26, Table 4-27 and Figure 4.54.

Table 4-26: Type of Household in Nandi County

Sub County	Ward	Male Headed		Female Headed		Child Headed		Others		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	34	79.1	9	20.9	0	0.0	0	0.0	43
	Kobujoi	13	81.3	3	18.8	0	0.0	0	0.0	16
	Koyo-Ndurio	35	63.6	18	32.7	2	3.6	0	0.0	55
	Total	82	71.9	30	26.3	2	1.8	0	0.0	114
Chesumei	Kosirai	19	82.6	4	17.4	0	0.0	0	0.0	23
	Ngechek	39	90.7	4	9.3	0	0.0	0	0.0	43
	Total	58	87.9	8	12.1	0	0.0	0	0.0	66
Emgwen	Kilibwoni	49	83.1	9	15.3	1	1.7	0	0.0	59
Mosop	Kabisaga	18	94.7	1	5.3	0	0.0	0	0.0	19
	Kabiyet	9	64.3	5	35.7	0	0.0	0	0.0	14
	Total	27	81.8	6	18.2	0	0.0	0	0.0	33
Nandi Hills	Chepkunyuk	28	82.4	6	17.6	0	0.0	0	0.0	34
	Lessos	50	76.9	14	21.5	0	0.0	1	1.5	65
	Total	78	78.8	20	20.2	0	0.0	1	1.0	99

Table 4-27: Relationship of respondent to Household Head

Sub County	Ward	Household Head		Spouse		Child		Grandchild		Son/Daughter in Law		Others		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	37	86.0	2	4.7	4	9.3	0	0.0	0	0.0	0	0.0	43
	Kobujoi	6	37.5	2	12.5	8	50.0	0	0.0	0	0.0	0	0.0	16
	Koyo-Ndurio	47	79.7	7	11.9	1	1.7	1	1.7	3	5.1	0	0.0	59
	Total	90	76.3	11	9.3	13	11.0	1	0.8	3	2.5	0	0.0	118
Chesumei	Kosirai	7	29.2	17	70.8	0	0.0	0	0.0	0	0.0	0	0.0	24
	Ngechek	29	65.9	7	15.9	6	13.6	0	0.0	2	4.5	0	0.0	44
	Total	36	52.9	24	35.3	6	8.8	0	0.0	2	2.9	0	0.0	68
Emgwen	Kilibwoni	47	79.7	10	16.9	2	3.4	0	0.0	0	0.0	0	0.0	59
Mosop	Kabisaga	0	0.0	19	100	0	0.0	0	0.0	0	0.0	0	0.0	19
	Kabiyet	0	0.0	14	100	0	0.0	0	0.0	0	0.0	0	0.0	14
	Total	0	0.0	33	100	0	0.0	0	0.0	0	0.0	0	0.0	33
Nandi Hills	Chepkunyuk	27	77.1	7	20.0	1	2.9	0	0.0	0	0.0	0	0.0	35
	Lessos	41	65.1	15	23.8	2	3.2	1	1.6	1	1.6	3	4.8	63
	Total	68	69.4	22	22.4	3	3.1	1	1.0	1	1.0	3	3.1	98
Total (overall)		241	64.1	100	26.6	24	6.4	2	0.5	6	1.6	3	0.8	376

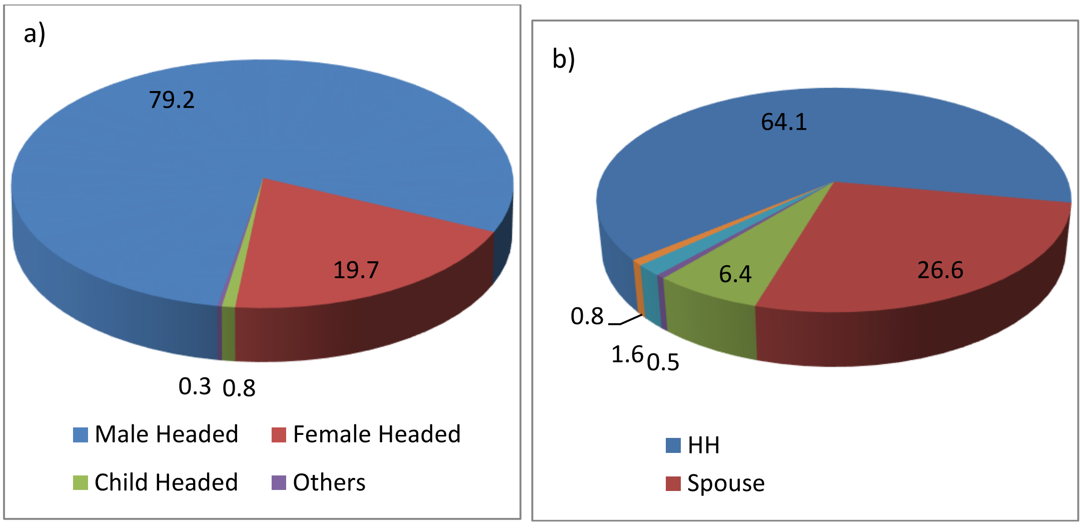

Figure 4-54: Analysis of a) Type of household and b) relationship of respondent to Household Head in Nandi County

The Table 4-26 show that majority of household in Nandi County are male headed as indicated by 71.9% in Aldai,87.9% in Chesumei, 83.1% in Emgwen, 81.8% in Mosop and78.8% in Nandi Hills. Most of the respondents were the household heads as indicated by 76.3% in Aldai, 52.9% in Chesumei, 79.7% in Emgwen and 69.4% in Nandi except Mosop (100%) sub County where all the respondents were spouses to the household head (Table 4-27).In overall, 79.2% of household are male headed and 19.7% are female headed with less than 1% being headed by children and other members of the family (Figure 4-54 a) whereas 64.1% of the respondents were the household heads while 26.6% are spouses to the household heads while less than 10% were either children, grandchildren sons/daughters in laws and other members of the family (Figure 4-54 b). This finding agrees with Wambugu et al. (2011), who found that males are more involved in smallholder dairy farming than their female counter parts with only a small percentage of young people aged being interested in dairy farming. In addition, Gallina (2016) noted that dairy production being a family operation required that all family members led by the HH head contribute to the day to day dairy production.

4.7.2.2.2 Number of people in the Household

During the data collection, respondents were asked to indicate number of people in their Households and results presented in Table 4.28and Figure 4.55.The Table 4-28 shows that in

Aldai, Chesumei and Emgwen and Sub Counties, majority of households composed of 4 to 6 people as observed in Kaptumo (53.7%), Kobujoi (46.7%), Koyo Ndurio (50.0%), Kosirai (58.3%), Ngechek (59.1%) and Kilbwoni (64.9%) wards. However, in Mosop Sub County, majority of households were composed of more than 6 people as observed in Kabisaga (47.4%) and Kaniyet (50.0%) wards. On the contrary, the study found out that Chepkunyuk ward of Nandi Hills had between 4 and 6 people whereas Lessos ward reported household to be majorly composed of between 1 and 2 people. The study showed that more than 51.8% of households in Nandi County comprises between 4 and 6 people while household with greater than 6 people comprised of 26.6%. The study notes that household with many people are more effective in their use of economic resources. Moreover, household with many multiple members implies that available of labor to work in the farms.

Table 4-28: Number of people in the Household per sub county

Sub County	Ward	1 to 3 people		4 to 6 people		> 6 people		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	6	14.6	22	53.7	13	31.7	41
	Kobujoi	4	26.7	7	46.7	4	26.7	15
	Koyo-Ndurio	13	22.4	29	50.0	16	27.6	58
	Total	23	20.2	58	50.9	33	28.9	114
Chesumei	Kosirai	7	29.2	14	58.3	3	12.5	24
	Ngechek	6	13.6	26	59.1	12	27.3	44
	Total	13	19.1	40	58.8	15	22.1	68
Emgwen	Kilibwoni	6	10.5	37	64.9	14	24.6	57
Mosop	Kabisaga	2	10.5	8	42.1	9	47.4	19
	Kabiyet	0	0.0	7	50.0	7	50.0	14
	Total	2	6.1	15	45.5	16	48.5	33
Nandi Hills	Chepkunyuk	8	25.0	21	65.6	3	9.4	32
	Lessos	26	45.6	16	28.1	15	26.3	57
	Total	34	38.2	37	41.6	18	20.2	89
Total		78	21.6	187	51.8	96	26.6	361

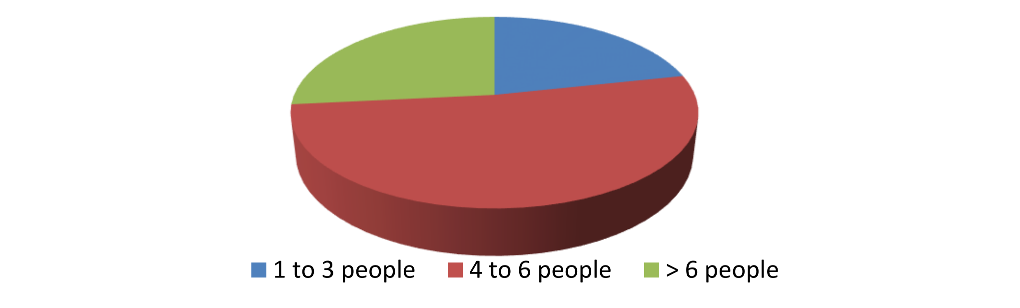

Figure 4-55: Number of people in the Household in Nandi County

4.7.2.2.3 Age distribution and Education Level

During the data collection, farmers were asked to indicate their age and level of education and results presented in Table 4.29, Table 4-30, Figure 4-56 and Figure 4-57.

Table 4-29: Age distribution of Household Head

Sub County	Ward	16 to 30		31 to 45		46 to 60		Above 60		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	5	11.4	14	31.8	16	36.4	9	20.5	44
	Kobujoi	1	6.3	2	12.5	10	62.5	3	18.8	16
	Koyo-Ndurio	6	9.7	22	35.5	25	40.3	9	14.5	62
	Total	12	9.8	38	31.1	51	41.8	21	17.2	122
Chesumei	Kosirai	2	8.3	4	16.7	13	54.2	5	20.8	24
	Ngechek	6	13.6	28	63.6	6	13.6	4	9.1	44
	Total	8	11.8	32	47.1	19	27.9	9	13.2	68
Emgwen	Kilibwoni	3	5.2	19	32.8	24	41.4	12	20.7	58
Mosop	Kabisaga	0	0.0	9	47.4	10	52.6	0	0.0	19
	Kabiyet	0	0.0	7	50.0	3	21.4	4	28.6	14
	Total	0	0.0	16	48.5	13	39.4	4	12.1	33
Nandi Hills	Chepkunyuk	1	2.9	9	25.7	17	48.6	8	22.9	35
	Lessos	5	7.9	29	46.0	19	30.2	10	15.9	63
	Total	6	6.1	38	38.8	36	36.7	18	18.4	98

Table 4-30: Level of Education of the household head

sub county	Ward	Informal		Primary		Secondary		College		Tertiary		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	0	0.0	7	15.9	22	50.0	10	22.7	5	11.4	44
	Kobujoi	0	0.0	3	18.8	4	25.0	8	50.0	1	6.3	16
	Koyo-Ndurio	4	6.5	18	29.0	22	35.5	12	19.4	6	9.7	62
	Total	4	3.3	28	23.0	48	39.3	30	24.6	12	9.8	122
Chesumei	Kosirai	1	4.2	8	33.3	10	41.7	1	4.2	4	16.7	24
	Ngechek	0	0.0	10	22.7	19	43.2	9	20.5	6	13.6	44
	Total	1	1.5	18	26.5	29	42.6	10	14.7	10	14.7	68
Emgwen	Kilibwoni	3	5.1	20	33.9	14	23.7	10	16.9	12	20.3	59
Mosop	Kabisaga	0	0.0	5	26.3	0	0.0	3	15.8	11	57.9	19
	Kabiyet	2	14.3	3	21.4	2	14.3	3	21.4	4	28.6	14
	Total	2	6.1	8	24.2	2	6.1	6	18.2	15	45.5	33
Nandi Hills	Chepkunyuk	3	8.6	9	25.7	16	45.7	4	11.4	3	8.6	35
	Lessos	1	1.6	26	40.6	23	35.9	10	15.6	4	6.3	64
	Total	4	4.0	35	35.4	39	39.4	14	14.1	7	7.1	99

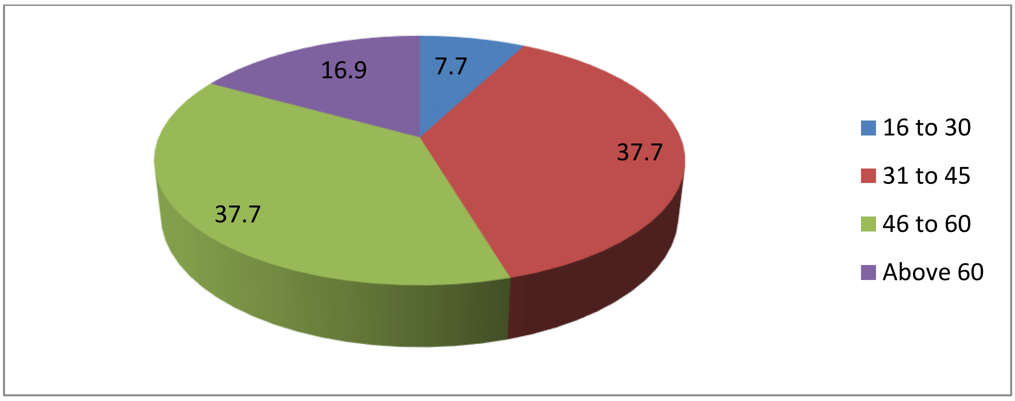

Figure 4-56: Age distribution of Household Head

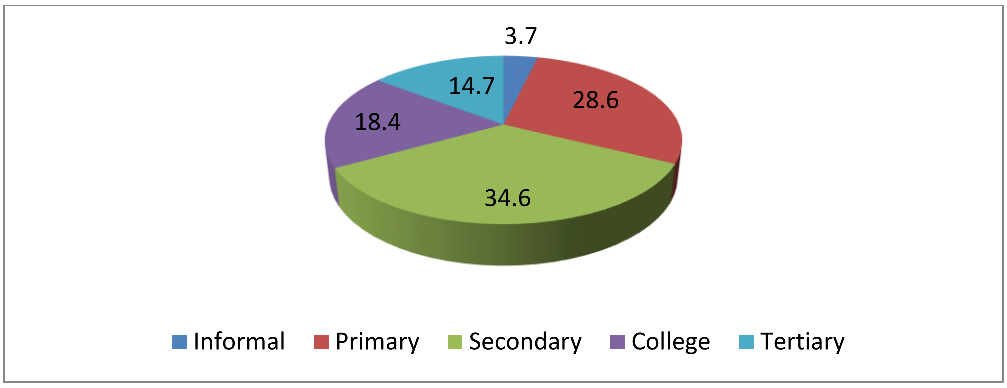

Figure 4-57: Level of Education of Household Head

The Table 4-29 shows that in Aldai and Emgwen sub counties, most household heads are between the ages of 46 and 60 years while in Chsumei, Nandi Hills and Mosop sub counties, majority of household headare betweenthe age of 31 and 45 years. In overall, the age of the household head (Figure 4-56) were equally distributed between the ages 31 to 45 years and 46 to 60 years accounted for 75.4%. This may be attributed to migration and movement of younger generation towards areas closest to urban centres e.g. Kapsabet town due to rapid urbanization due to devolution.The age differences are assumed to contribute to the experience in dairy farming. Although an older population may be less productive, it is assumed that this group is more settled and experienced. However, age may also be a limiting factor when it comes to innovation as younger people are considered innovative. According to government of Kenya (GOK, 2012), the average age of a farmer is 60 years. Studies show that there is decline of youth interest in agriculture. Although agricultural sector provide great opportunity, youth involvement in agriculture is declining in Africa; Kenya included (Mibey, 2015) as youth perceived agriculture as a low status profession practiced by old, illiterate and poor rural people since majority of African farmers were aged 55-70 years (Njeru et al., 2015). Moreover, Muhoma (2014) noted that young people have limited access to credit facilities that hinder their ability to invest in smallholder dairy farming. However, this group of young people can still be involved in dairy farming through value addition and milk value chain and ultimately expected to engage in milk production once they realize the potential provided by the sector.

As shown in Table 4.30, most of the household head had attained primary education and above in all sub counties of Nandi County. Majority of household heads in Aldai (39.3%), Chesumei (42.6%) and Nandi Hills (39.4%) sub counties had attained secondary education while majority of household heads in Emgwen had attained primary education. The study found that most respondents in Mosop Sub County had attained tertiary education. In overall, 34.6% of the respondents in Nandi County had attained secondary education whereas more than 33% had post-secondary education (Figure 4-57). It is assumed that farmers with formal education tend to be innovative and well suited to implement best farming practices whereas farmers with informal educationmay not be capable to understand and implement best practices in the absence of extension officers or experts such as mixing of concentrates and administration of medicine. The studies noted that farmers with formal education were more likely to adopt new technologies and are also more innovative. Karanja (2003) noted that limited education levels are likely to negatively affect the adoption of new and improved milk production practices by farmers which may led to low milk production. In addition, a farmer with education is able to increase their environmental awareness and ability to obtain and process information as education boosts the farmers' ability to identify beneficial coping alternatives (Mbwesa, 2004).

4.7.2.2.4 Occupation of the Household Head

During the data collection, respondents were asked to indicate their main occupation and income of the household and the results presented in Table 4.31, Table 4.32, Figure 4-58 and Figure 4-59.

Table 4-31: The main occupation of the Household head per ward

Sub county	Ward	Farmer		Business		Formal Employment		Others		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	43	97.7	0	0.0	1	2.3	0	0.0	44
	Kobujoi	12	75.0	0	0.0	4	25.0	0	0.0	16
	Koyo-Ndurio	59	95.2	2	3.2	1	1.6	0	0.0	62
	Total	114	93.4	2	1.6	6	4.9	0	0.0	122
Chesumei	Kosirai	18	75.0	1	4.2	5	20.8	0	0.0	24
	Ngechek	32	72.7	6	13.6	5	11.4	1	2.3	44
	Total	50	73.5	7	10.3	10	14.7	1	1.5	68
Emgwen	Kilibwoni	44	74.6	5	8.5	9	15.3	1	1.7	59
Mosop	Kabisaga	12	63.2	2	10.5	5	26.3	0	0.0	19
	Kabiyet	13	92.9	0	0.0	1	7.1	0	0.0	14
	Total	25	75.8	2	6.1	6	18.2	0	0.0	33
Nandi Hills	Chepkunyuk	27	77.1	3	8.6	4	11.4	1	2.9	35
	Lessos	46	70.8	8	12.3	9	13.8	2	3.1	65
	Total	73	73.0	11	11.0	13	13.0	3	3.0	100
Total		306	80.1	27	7.1	44	11.5	5	1.3	382

Table 4-32: The main source of Income for the Household per Ward

Sub county	Ward	Farming		Business		Formal Employment		Others		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	44	100	0	0	0	0	0	0	44
	Kobujoi	14	87.5	2	12.5	0	0	0	0	16
	Koyo-Ndurio	58	95.1	1	1.6	2	3.3	0	0	61
	Total	116	95.9	3	2.5	2	1.7	0	0	121
Chesumei	Kosirai	20	87	3	13	0	0	0	0	23
	Ngechek	34	77.3	4	9.1	5	11.4	1	2.3	44
	Total	54	80.6	7	10.4	5	7.5	1	1.5	67
Emgwen	Kilibwoni	48	81.4	7	11.9	2	3.4	2	3.4	59
Mosop	Kabisaga	17	89.5	2	10.5	0	0	0	0	19
	Kabiyet	13	92.9	0	0	0	0	1	7.1	14
	Total	30	90.9	2	6.1	0	0	1	3	33
Nandi Hills	Chepkunyuk	27	77.1	5	14.3	3	8.6	0	0	35
	Lessos	50	76.9	10	15.4	4	6.2	1	1.5	65
	Total	77	77	15	15	7	7	1	1	100
Total		325	85.5	34	8.9	16	4.2	5	1.3	380

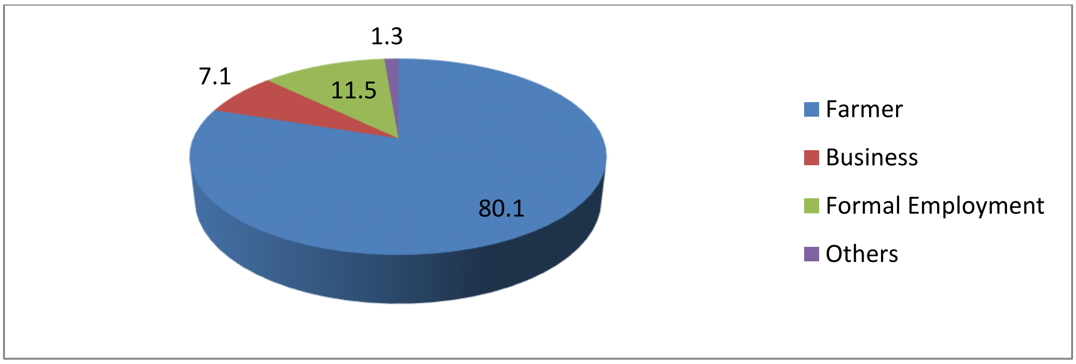

Figure 4-58: The main occupation of the Household head in Nandi County

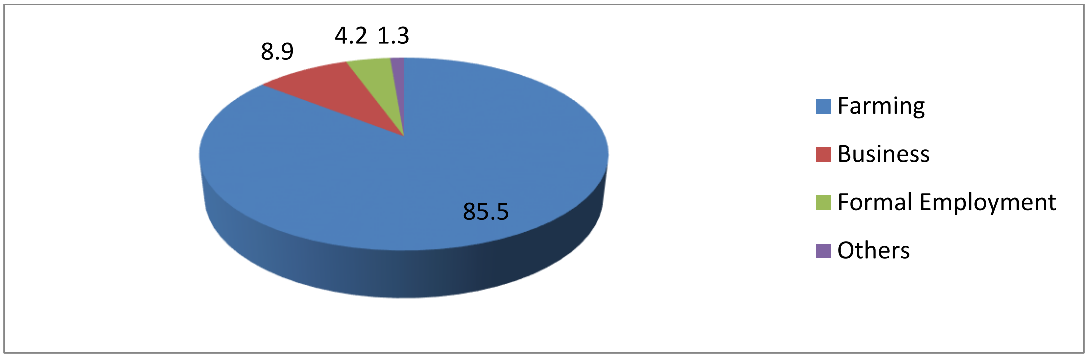

Figure 4-59: The main source of Income for the Household in Nandi County.

The Table 4-31 show that majority of respondents in all the wards in the sub counties are farmers with observation indicating 93.4%, 73.5%, 74.6%,75.8% and 73.0% in Aldai, Chesumei, Emgwen, Mosop and Nandi Hills respectively. Overall results showed that 80.1% of respondents are farmers whereas less than 20% of the respondents regarded farming as secondary and were mainly engage in business, formal employment and other activities (Figure 4-58). Moreover, the Table 4-32 indicated that majority of these respondents' main source of income was farming in Aldai (95.9%), Chesumei (80.6%), Emgwen (81.4%), Mosop (90.9%) and Nandi Hills (77%). In Overall, over 80% of respondents are mainly dependent on farming as a source of income in Nandi County (Figure 4-59).

4.7.2.2.5 Household wealth status

During the data collection, respondents were asked to state the items owned in their household and the results presented in Table 4.33 and Figure 4-60.

The Table 4-33 show that in Aldai sub County all the respondents owned a mobile phone while more than 97.4% owned a radio/TV while 75.9%, 83.6 and 96.6% of the respondents did not have solar panel/electricity, vehicle and tractor respectively. In Chesumei sub County, 94.1%, 95.6% and 48.5% of the respondents owned radio/TV, Cell phone and Solar panel/Electricity respectively while 95.6% and 94.1% of the respondents did not own a vehicle and tractor respectively. In Emgwen sub County, 98.3%, 100% and 77.6% of the respondents owned radio/TV, Cell phone and Solar panel/Electricity respectively while 56.9% and 81.0% of the respondents did not own a vehicle and tractor respectively. In Mosop sub County; all respondents were found to owned Radio/TV and Cell phone with 90.9%, 57.6% and 45.5% of the respondents indicating that they had solar panel/Electricity, vehicle and a tractor. In Nandi Hills sub County, 88.4%, 89.5% and 63.2% of the respondents owned radio/TV, Cell phone and Solar panel/Electricity respectively while 88.4% and 94.7% of the respondents did not own a vehicle and tractor respectively. In General, the study found out that in Nandi County, 94.9%, 96.5% and 53.0% of the respondents owned radio/TV, Cell phone and Solar panel/Electricity respectively while 79.2% and 89.5% of the respondents did not own a vehicle and tractor respectively (Figure 4-60)

Table 4-33: Household ownership

Sub County	Ward	Radio and TV				Cellphone				Solar Panel/ Electricity				Vehicle				Tractor			
		Yes		No		Yes		No		Yes		No		Yes		No		Yes		No	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	42	100	0	0.0	42	100	0	0.0	17	40.5	25	59.5	4	9.5	38	90.5	0	0.0	42	100
	Kobujoi	16	100	0	0.0	16	100	0	0.0	6	37.5	10	62.5	7	43.8	9	56.3	3	18.8	13	81.3
	Koyo-Ndurio	55	94.8	3	5.2	58	100	0	0.0	5	8.6	53	91.4	8	13.8	50	86.2	1	1.7	57	98.3
	Total	113	97.4	3	2.6	116	100	0	0.0	28	24.1	88	75.9	19	16.4	97	83.6	4	3.4	112	96.6
Chesumei	Kosirai	23	95.8	1	4.2	24	100	0	0.0	15	62.5	9	37.5	2	8.3	22	91.7	2	8.3	22	91.7
	Ngechek	41	93.2	3	6.8	41	93.2	3	6.8	18	40.9	26	59.1	1	2.3	43	97.7	2	4.5	42	95.5
	Total	64	94.1	4	5.9	65	95.6	3	4.4	33	48.5	35	51.5	3	4.4	65	95.6	4	5.9	64	94.1
Emgwen	Kilibwoni	57	98.3	1	1.7	58	100	0	0.0	45	77.6	13	22.4	25	43.1	33	56.9	11	19.0	47	81.0
Mosop	Kabisaga	19	100	0	0.0	19	100	0	0.0	18	94.7	1	5.3	11	57.9	8	42.1	8	42.1	11	57.9
	Kabiyet	14	100	0	0.0	14	100	0	0.0	12	85.7	2	14.3	8	57.1	6	42.9	7	50.0	7	50.0
	Total	33	100	0	0.0	33	100	0	0.0	30	90.9	3	9.1	19	57.6	14	42.4	15	45.5	18	54.5
Nandi Hills	Chepkunyuk	28	87.5	4	12.5	29	90.6	3	9.4	16	50.0	16	50.0	2	6.3	30	93.8	0	0.0	32	100
	Lessos	56	88.9	7	11.1	56	88.9	7	11.1	44	69.8	19	30.2	9	14.3	54	85.7	5	7.9	58	92.1
	Total	84	88.4	11	11.6	85	89.5	10	10.5	60	63.2	35	36.8	11	11.6	84	88.4	5	5.3	90	94.7
Total		351	94.9	19	5.1	357	96.5	13	3.5	196	53.0	174	47.0	77.0	20.8	293	79.2	39	10.5	331	89.5

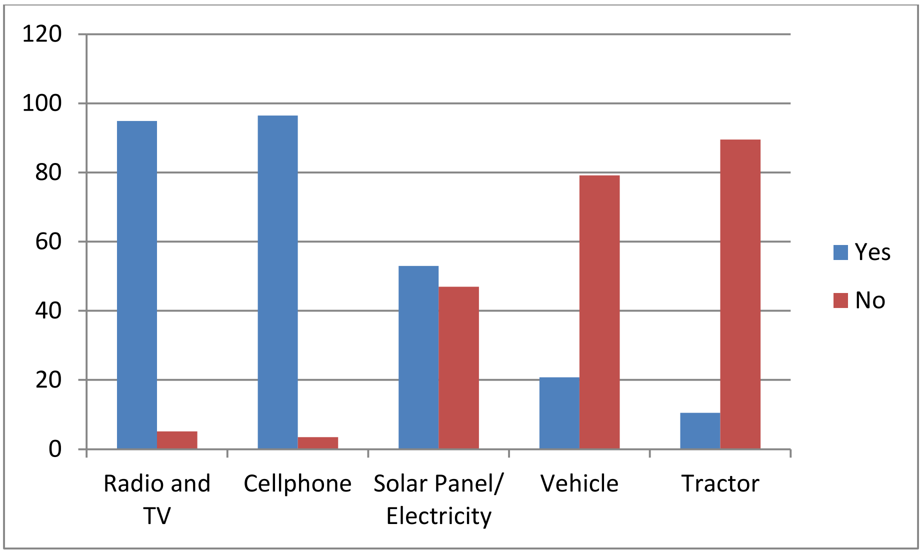

Figure 4-60: Household ownership in Nandi County

4.7.2.2.6 Relationship between characteristics and type of households.

The Table 4-34 shows computed χ^2 values to be greater that the critical chi square values between the type of HH with age group ($\chi^2 = 47.61$), level of education ($\chi^2 = 25.18$), Occupation ($\chi^2 = 11.34$), source of Income ($\chi^2 = 39.47$), HH ownership (Cell phone) ($\chi^2 = 13.63$), HH ownership (Solar Panel) ($\chi^2 = 21.72$), HH ownership (Vehicle) ($\chi^2 = 14.85$), and HH ownership. (Tractor) ($\chi^2 = 14.17$) and hence an indication of a statistically significant association

Table 4-34: Chi-Square test (Association with type of HH at α = 0.05)

Variable	Chi Square	P Value	Critical Value
Age group	47.61	0.000	21.03
Level of education	25.18	0.048	25.00
Occupation	11.34	0.250	16.92
Source of Income	39.47	0.000	21.03
HH ownership (Radio & TV)	12.06	0.060	12.59
HH ownership (Cell phone)	13.63	0.030	12.59
HH ownership (Solar Panel)	21.72	0.001	12.59
HH ownership (Vehicle)	14.85	0.020	12.59
HH ownership (Tractor)	14.17	0.030	12.59

(Source: Research Data, 2021)

4.7.3 Climate Change and Dairy Productivity

The study collected data on climate information related to climate change hazards, grazing systems practiced by households and the sensitivity of grazing systems to hazards.

4.7.3.1 Climate change Hazards

During field data collection, respondents were asked to identify climate change hazards affecting their milk production, the results are presented in Table 4.35 to Table 4.37 and Figure

4-61 to 4-63.

The Table 4-35 shows that 82.3% of the respondents indicated that the main climate hazards in all sub counties was drought followed by rainfall unpredictability (41%) and rainfall variability (25.1%). Extreme temperatures were accounted for by 7.4% of the respondents and less than 2% accounting for flooding as one of the main hazards. In overall, 82.3% of the respondents indicated that drought was the main climate hazard (Figure 4-61). Majority of the respondents noted that the effects of climate change on fodder crops (Table 4-36) was moderate in Aldai (92.2%), Chesumei (61.5%), and Emgwen (78.0%), Mosop (93.9%) while in Nandi Hills, the effects were very severe as accounted for by 67.3% of the respondents. In overall, 68.5% of the respondents showed that climate change had moderate effects while 28.3% showed that climate effects were severe in Nandi County (Figure 4-62). This means drought is regarded as a major climate hazard in the area and confirms a report by FAO & GDP (2019) indicating that the world is already experiencing more frequent floods, storms and droughts, forest fires which are not only damaging the environment, but they are disrupting people's livelihoods.

The Table 4-37 shows that in Aldai, Chesumei and Nandi Hills Sub Counties, up to 91.2%, 41.05% and 69.1% of these respondents respectively noted that the frequency of occurrence of climate change hazards was after every four years. In Emgwen Sub County, up to 58.6% of these respondents noted that the frequency of occurrence of climate change hazards was after every two years while in Mosop Sub County, up to 75.8% of these respondents noted that the frequency of occurrence of climate change hazards was after every three years. An overall statistics for Nandi County show that 57.6% of respondents acknowledged that extreme climate events recurred after every four years (Figure 4-63).

The FGD noted that up to 1978, people in Nandi County had to be moved to higher levels around April during the long rains season (MAM). On the contrary, the current trends show that rainfall patterns have changed, become unreliable and unpredictable with corresponding drying of rivers. Moreover, their observations indicate that mist no longer form in the morning with regular incidents of frost and hail that destroy crops especially tea. Other observations made by the FGD included decrease of birds such as crown birds and destruction of forest. The FGD noted that unreliable rainfall affected availability of fodder for dairy animals with overdependence on paddocked grass which means little feed available for the animals hence reduced milk production. Moreover, too much rainfall received leads to a lot of moisture content in the feeds and thus reducing the amount of feeds available for the animals which may lead to diarrhoea and low milk production. These FGD noted that they noted significant changes climate after the 1997/1998 El Niño where the county received extremely high rainfall and in 2013, 2016 and 2017 limited rainfall which led to drought. The changes showed that drought and floods frequency had become regular and approximated to occur between 3 to 5 years.

During wet weather spells, there was slow milk delivery to the market due to impassable slippery wet surface of the poor road network. This finding agrees with Muia et al. (2011), who note that most of the dairy produce during the wet season does not reach the market due to poor road infrastructure and distance to the markets. Other noted negative impacts of increase in precipitation include increase in water borne diseases, deaths of the animals due to increase in the possibility of floods. According to Muriuki (2003), cattle diseases such as Foot and Mouth, East Coast Fever etc., have been of concern since they have an immediate and direct reduction of the dairy productivity in the long run. These findings are also in agreement with the results of a study by Ngeno et al. (2013), who found that changes in temperature influence the quantity and quality of forages and that grazing period in hot dry conditions, may reduce the quality and consistency of the feeds and feeding which may impact on the welfare and productivity of the animal. The wet seasons resulted into possibilities of occurrence of floods, surplus fodder, good feeding habits and healthy state of the animals. Ngeno et al. (2013), notes that with frequent flooding, dairy farming may be restricted to a smaller area. High precipitation resulted in gain of weight of the livestock, adequate quantities of water leading to increase in the production and sale of milk. However, according to Muia et al. (2011), the large quantities of produced milk during the wet season has been known to be associated with the high-post harvest losses, due to inability by the smallholder dairy farmers‟ capacity to afford and install the expensive milk cooling equipment for the preservation of the highly perishable milk produce.

The Table 4-38 shows that computed χ^2 values are less than the critical chi square values between the type of HH with main climate hazards experienced ($\chi^2 = 4.50$), effects of climate change on fodder/crops (($\chi^2 = 4.18$) and frequency of climate change hazard occurrence ($\chi^2 = 5.05$) and hence an indication that there is no statistically significant association which implied that climate change had the same effect to different households.

Table 4-35: Main climate hazards experienced

Sub County	Ward	Drought		Flooding		Rainfall variability		Rainfall unpredictability		Extreme temperatures		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	41	95.3	1	2.3	14	32.6	6	14.0	0	0.0	43
	Kobujoi	15	93.8	0	0.0	13	81.3	9	56.3	2	12.5	16
	Koyo-Ndurio	59	98.3	1	1.7	3	5.0	0	0.0	1	1.7	60
	Total	115	96.6	2	1.7	30	25.2	15	12.6	3	2.5	119
Chesumei	Kosirai	22	91.7	1	4.2	2	8.3	8	33.3	1	4.2	24
	Ngechek	23	52.3	0	0.0	20	45.5	9	20.5	1	2.3	44
	Total	45	66.2	1	1.5	22	32.4	17	25.0	2	2.9	68
Emgwen	Kilibwoni	59	100	2	3.4	3	5.1	31	52.5	0	0.0	59
Mosop	Kabisaga	19	100	0	0.0	0	0.0	14	73.7	0	0.0	19
	Kabiyet	14	100	0	0.0	0	0.0	14	100	0	0.0	14
	Total	33	100	0	0.0	0	0.0	28	84.8	0	0.0	33
Nandi Hills	Chepkunyuk	34	100	0	0.0	1	2.9	26	76.5	2	5.9	34
	Lessos	25	38.5	0	0.0	39	60.0	38	58.5	21	32.3	65
	Total	59	59.6	0	0.0	40	40.4	64	64.6	23	23.2	99
Total		311	82.3	5	1.3	95	25.1	155	41.0	28	7.4	378

Table 4-36: Effects of climate change on fodder/crops

Sub County	Ward	No effect		Very little effect		Moderate effect		Very severe effect		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	0	0.0	2	4.7	36	83.7	5	11.6	43
	Kobujoi	0	0.0	0	0.0	14	87.5	2	12.5	16
	Koyo-Ndurio	0	0.0	0	0.0	57	100	0	0.0	57
	Total	0	0.0	2	1.7	107	92.2	7	6.0	116
Chesumei	Kosirai	0	0.0	1	4.3	8	34.8	14	60.9	23
	Ngechek	0	0.0	5	11.9	32	76.2	5	11.9	42
	Total	0	0.0	6	9.2	40	61.5	19	29.2	65
Emgwen	Kilibwoni	0	0.0	1	1.7	46	78.0	12	20.3	59
Mosop	Kabisaga	0	0.0	1	5.3	18	94.7	0	0.0	19
	Kabiyet	0	0.0	0	0.0	13	92.9	1	7.1	14
	Total	0	0.0	1	3.0	31	93.9	1	3.0	33
Nandi Hills	Chepkunyuk	0	0.0	0	0.0	2	5.9	32	94.1	34
	Lessos	1	1.6	1	1.6	28	43.8	34	53.1	64
	Total	1	1.0	1	1.0	30	30.6	66	67.3	98
Total		1	0.3	11	3.0	254	68.5	105	28.3	371

Table 4-37: Frequency of climate change hazard occurrence

Sub County	Ward	Every year		Every two years		Every Three years		Every four years		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	14	33.3	5	11.9	3	7.1	20	47.6	42
	Kobujoi	0	0.0	0	0.0	0	0.0	16	100	16
	Koyo-Ndurio	0	0.0	2	3.5	3	5.3	52	91.2	57
	Total	14	12.2	7	6.1	6	5.2	88	76.5	115
Chesumei	Kosirai	0	0.0	4	18.2	1	4.5	17	77.3	22
	Ngechek	25	58.1	6	14.0	2	4.7	10	23.3	43
	Total	25	38.5	10	15.4	3	4.6	27	41.5	65
Emgwen	Kilibwoni	0	0.0	34	58.6	2	3.4	22	37.9	58
Mosop	Kabisaga	0	0.0	0	0.0	15	78.9	4	21.1	19
	Kabiyet	0	0.0	0	0.0	10	71.4	4	28.6	14
	Total	0	0.0	0	0.0	25	75.8	8	24.2	33
Nandi Hills	Chepkunyuk	0	0.0	5	14.7	1	2.9	28	82.4	34
	Lessos	5	7.9	15	23.8	4	6.3	39	61.9	63
	Total	5	5.2	20	20.6	5	5.2	67	69.1	97
Total		44	12.0	71	19.3	41	11.1	212	57.6	368

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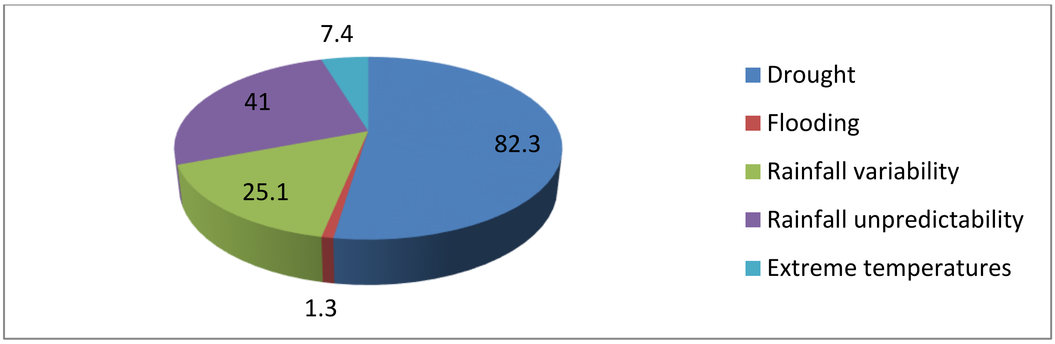

Figure 4-61: Main climate hazards experienced

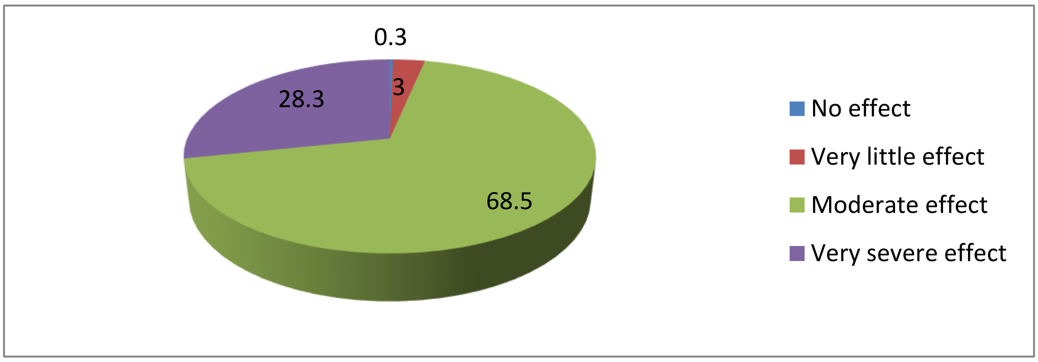

Figure 4-62: Effects of climate change on fodder/crops

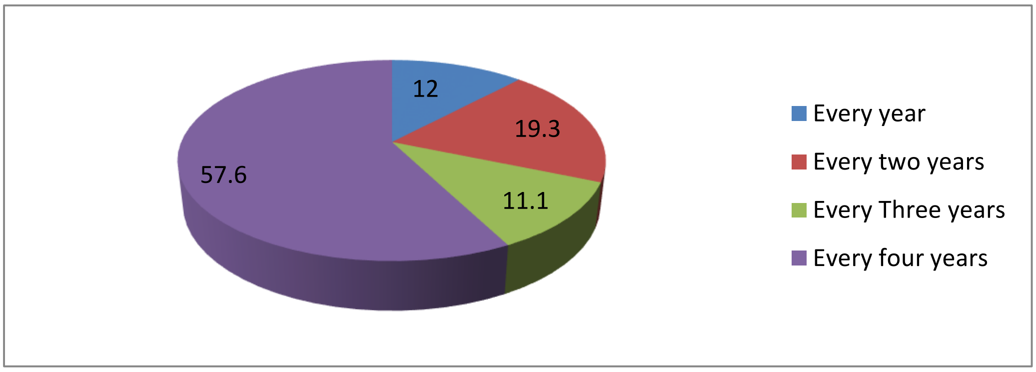

Figure 4-63: Frequency of climate change hazard occurrence

Table 4-38: Chi-Square test (Association with type of HH at α = 0.05)

Variable	Chi Square	P Value	Critical Value
Main climate hazards experienced	4.50	0.99	26.30
Effects of climate change on fodder/crops	4.18	0.688	26.30
Frequency of climate change hazard occurrence	5.05	0.956	21.02

(Source: Research Data, 2021)

4.7.3.2 Grazing Systems practiced by Household

During the data collection, respondents were asked to state the items owned in their household and the results presented in Table 4.39, Table 4.40, Figure 4-64 and Figure 4-65

The Table 4-39 shows that up to 63.9% of the respondents in Aldai sub county practised free range and paddocking grazing system, up to 30.3% practised semi zero grazing (paddocked). Similarly, 54.2% and 46.4% of the respondents in Emgwen and Nandi Hills sub counties practised free range and paddocking grazing system respectively followed by up to 28.8% (Emgwen) and 45.4% (Nandi Hills) who practised semi zero grazing (paddocked) in their farms. In Mosop Sub County, up to 87.9% of the respondents practised semi zero grazing (paddocked) with less than 13% adopting other grazing systems. In Chesumei Sub County, up to 45.6% of the respondents practised semi zero grazing (paddocked) followed by up to 30.3% who practised free range and paddocking grazing system. The study noted that most households in Nandi County had adopted either free range and paddocking (46.8%) or semi-zero grazing (41.8%) as a type of grazing system (Figure 4-64). Table 4-40, affirmed that drought (97.5% in Aldai, 85.3% in Chesumei, 100% in Emgwen, 54.5% in Mosop, and 59.6% in Nandi Hills). Overall (Figure 4-65), respondents in Nandi county show that drought (82.0%) is the leading climate hazard affecting their grazing practices whereas rainfall variability, rainfall unpredictability and extreme temperatures affected grazing practices up to 20.9%, 39.9% and 13.8% respectively.

FAO (2018) report notes that the semi-intensive/semi-grazing system is pervasive whereas the extensive system faces the challenge of dwindling grazing fields because of increasing human settlement and development. Table 4-41 shows computed χ^2 values were found to be greater than the critical chi square values between the type of HH and type of grazing system practiced by the household ($\chi^2 = 27.66$) and hence an indication of a statistically significant association.

Table 4-39: Type of grazing system practiced by the household

Sub County	Ward	Free range		Free range and paddocking		Semi-zero grazing (Paddocked)		Semi zero and zero grazing		Zero Grazing		Total	Chi Square test
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	
Aldai	Kaptumo	0	0.0	29	65.9	15	34.1	0	0.0	0	0.0	44	27.66
	Kobujoi	1	5.9	0	0.0	14	82.4	2	11.8	0	0.0	17	
	Koyo-Ndurio	4	6.9	47	81.0	7	12.1	0	0.0	0	0.0	58	
	Total	5	4.2	76	63.9	36	30.3	2	1.7	0	0.0	119	
Chesumei	Kosirai	0	0.0	3	12.5	19	79.2	1	4.2	1	4.2	24	
	Ngechek	11	25.0	19	43.2	12	27.3	1	2.3	1	2.3	44	
	Total	11	16.2	22	32.4	31	45.6	2	2.9	2	2.9	68	
Emgwen	Kilibwoni	6	10.2	32	54.2	17	28.8	0	0.0	4	6.8	59	
Mosop	Kabisaga	0	0.0	1	5.3	15	78.9	3	15.8	0	0.0	19	
	Kabiyet	0	0.0	0	0.0	14	100	0	0.0	0	0.0	14	
	Total	0	0.0	1	3.0	29	87.9	3	9.1	0	0.0	33	
Nandi Hills	Chepkunyuk	0	0.0	12	35.3	22	64.7	0	0.0	0	0.0	34	
	Lessos	4	6.3	33	52.4	22	34.9	2	3.2	2	3.2	63	
	Total	4	4.1	45	46.4	44	45.4	2	2.1	2	2.1	97	
Total		26	6.9	176	46.8	157	41.8	9	2.4	8	2.1	376	

Table 4-40: Type of climate hazards affecting grazing practices

Sub County	Ward	Drought		Flooding		Rainfall variability		Rainfall unpredictability		Extreme temperature		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	43	100	0	0.0	9	20.9	4	9.3	0	0.0	43
	Kobujoi	15	93.8	0	0.0	14	87.5	4	25.0	4	25.0	16
	Koyo-Ndurio	58	96.7	1	1.7	3	5.0	1	1.7	20	33.3	60
	Total	116	97.5	1	0.8	26	21.8	9	7.6	24	20.2	119
Chesumei	Kosirai	24	100	0	0.0	0	0.0	5	20.8	0	0.0	24
	Ngechek	34	77.3	1	2.3	16	36.4	14	31.8	2	4.5	44
	Total	58	85.3	1	1.5	16	23.5	19	27.9	2	2.9	68
Emgwen	Kilibwoni	59	100	1	1.7	4	6.8	29	49.2	0	0.0	59
Mosop	Kabisaga	10	52.6	0	0.0	0	0.0	16	84.2	0	0.0	19
	Kabiyet	8	57.1	0	0.0	0	0.0	12	85.7	0	0.0	14
	Total	18	54.5	0	0.0	0	0.0	28	84.8	0	0.0	33
Nandi Hills	Chepkunyuk	34	100	0	0.0	0	0.0	21	61.8	3	8.8	34
	Lessos	25	38.5	2	3.1	33	50.8	45	69.2	23	35.4	65
	Total	59	59.6	2	2.0	33	33.3	66	66.7	26	26.3	99
	Total	310	82.0	5	1.3	79	20.9	151	39.9	52	13.8	378

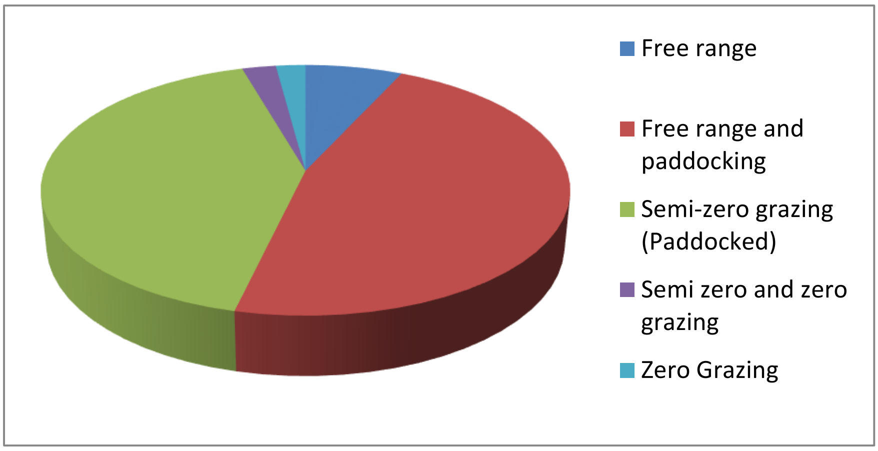

Figure 4-64: Type of grazing system practiced by the household

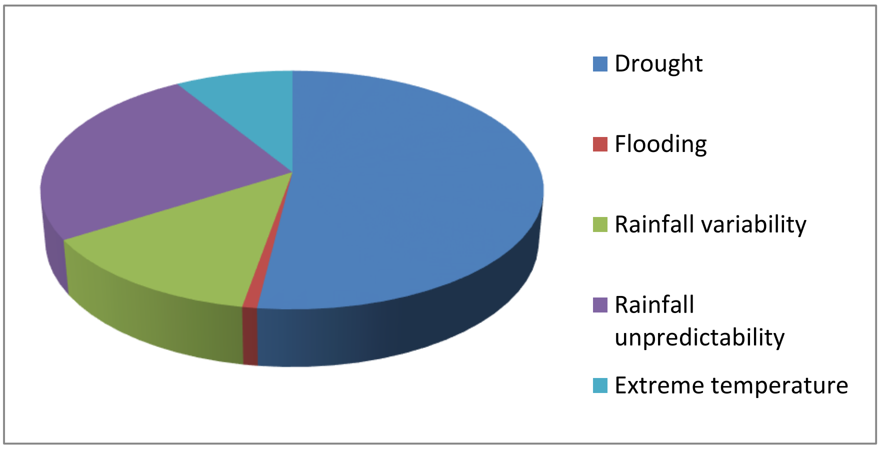

Figure 4-65: Type of climate hazards affecting grazing practices

4.7.3.3 Sensitivity of grazing systems to climate hazards

This section presents results on sensitivity of grazing systems to climate hazards (Drought, Flooding, rainfall variability, rainfall unpredictability and extreme temperatures) in Table 4.39and Figure 4-66.

Table 4-39 indicates that 73.6%, 89.3%, 38.6% and 55.5% of respondents in Aldai sub County showed that their grazing systems are moderately sensitive to drought, not sensitive to floods, slightly sensitive to rainfall variability and rainfall unpredictability and moderately sensitive to extreme temperatures respectively. In Chesumei sub county, 38.5%, 42.9% and 64.7% of respondents showed that their grazing systems are very sensitive to drought, not sensitive to floods, slightly sensitive to rainfall variability and rainfall unpredictabilitywhereas 42.9%

where not sensitive to moderately sensitive to extreme temperatures respectively. In Emgwen sub county, 61.0%, 50% and 64.7% of respondents showed that their grazing systems are very sensitive to drought, slightly sensitive to floods and rainfall unpredictability and all the respondents not sensitive to rainfall variability respectively. In Emgwen Sub County, all the respondents showed that their grazing systems were moderately sensitive to drought and rainfall unpredictability. In Nandi Hills Sub County, respondents showed that their grazing systems are very sensitive to drought (43.2%), rainfall variability (72.1%), rainfall unpredictability (65.1%) and extreme temperatures (67.9%) while 88.4% were no sensitive to floods. In overall, Figure 4-66 shows that in Nandi County, drought is moderately sensitive with floods being not sensitive to grazing systems while rainfall variability, rainfall unpredictability and extreme temperatures were all less than 50% slightly sensitive, moderately sensitive or severely sensitive.

The results are consistent with the findings by Wambugu et al. (2011), who in a study found that in 2009, when the country faced a severe drought, the dairy sub-sector experienced a decline in milk production due to inadequate water and pasture for the animals. However, the onset of the OND seasonal rains that year caused an increase in milk production because of improved availability of adequate water and fodder. The Table 4-42 shows computed χ^2 values to be greater than the critical chi square values between the type of HH and drought ($\chi^2 = 29.18$) and rainfall unpredictability ($\chi^2 = 27.25$) which were the main climate hazard affecting grazing practices and hence an indication of a statistically significant association.

Table 4-41: Sensitivity of grazing systems to climate hazards in Nandi County

Sub County	Climate change hazard	Not sensitive		Slightly sensitive		Moderately sensitive		Very sensitive		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Drought	7	5.8	12	9.9	89	73.6	13	10.7	121
	Flooding	92	89.3	9	8.7	2	1.9	0	0.0	103
	Rainfall variability	2	1.8	44	38.6	40	35.1	28	24.6	114
	Rainfall unpredictability	18	16.4	61	55.5	27	24.5	4	3.6	110
	Extreme Temperatures	24	28.2	17	20.0	39	45.9	5	5.9	85
Chesumei	Drought	1	1.9	12	23.1	19	36.5	20	38.5	52
	Flooding	3	42.9	1	14.3	2	28.6	1	14.3	7
	Rainfall variability	1	3.6	12	42.9	11	39.3	4	14.3	28
	Rainfall unpredictability	1	2.9	22	64.7	8	23.5	3	8.8	34
	Extreme Temperatures	3	42.9	0	0.0	3	42.9	1	14.3	7
Emgwen	Drought	1	1.7	12	20.3	36	61.0	10	16.9	59
	Flooding	1	25.0	2	50.0	1	25.0	0	0.0	4
	Rainfall variability	1	100	0	0.0	0	0.0	0	0.0	1
	Rainfall unpredictability	2	3.7	27	50.0	25	46.3	0	0.0	54
	Extreme Temperatures	0	Na	0	Na	0	Na	0	Na	0
Mosop	Drought	0	0.0	0	0.0	33	100	0	0.0	33
	Flooding	0	Na	0	Na	0	Na	0	Na	0
	Rainfall variability	0	Na	0	Na	0	Na	0	Na	0
	Rainfall unpredictability	0	0.0	0	0.0	33	100	0	0.0	33
	Extreme Temperatures	0	Na	0	Na	0	Na	0	Na	0
Nandi Hills	Drought	27	28.4	7	7.4	20	21.1	41	43.2	95
	Flooding	38	88.4	4	9.3	1	2.3	0	0.0	43
	Rainfall variability	3	7.0	0	0.0	9	20.9	31	72.1	43
	Rainfall unpredictability	1	1.2	5	6.0	23	27.7	54	65.1	83
	Extreme Temperatures	3	5.4	7	12.5	8	14.3	38	67.9	56

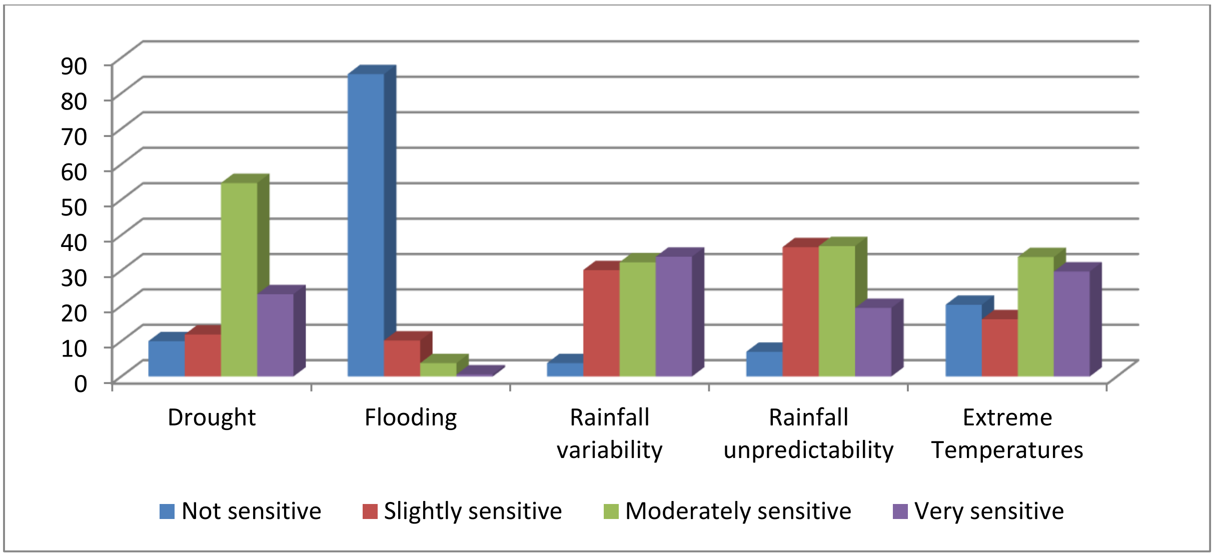

Figure 4-66: Sensitivity of grazing systems practiced to climate change hazards in Nandi County

Table 4-42: Chi-Square test (Association with type of HH at α = 0.05)

Variable		Chi Square	P Value	Critical Value
	Drought	29.18	0.180	26.30
	Flooding	20.24	0.110	26.30
	Rainfall variability	15.40	0.200	26.30
	Rainfall unpredictability	27.25	0.355	26.30
	Extreme temperature	22.06	0.421	26.30

(Source: Research Data, 2021)

4.7.3.4 Dairy Productivity Experience related to climate change

This section presents results based on changes in household dairy productivity experience related to climate change as shown in Table 4-43 and Table 4-44.

As shown in Table 4-43 and Figure 4-67, more than 92% of respondents in all wards of Nandi County agreed that there had been changes in milk production and body condition of animals due to climate change. Notably, more than 89% of all respondents in Nandi County indicated that climate change had resulted to changes in the amount of water available for the animals except Kosirai ward of Chesumei sub county, Kabisaga and kabiyet wards of Mosop Sub County who noted that these changes in amount of water available to the animal were not related to climate change. Moreover, more than 71% of respondents acknowledged that heat detected in animals was related to climate change except in Kosirai ward of Chesumei Sub County where majority of up to 68% did not associate the heat detected and climate change. Similarly, all the respondents in all wards in Nandi County noted that the growth of calves and heifers were affected by climate change.

Table 4-44and Figure 4-68 shows that the observed changes in milk production, the amount of water available for the animal, body condition of the animal, heat detected and growth of calves and heifers were negative in almost all the wards in the County implying that climate change had negatively impacted on dairy productivity. In addition, the findings of this study agree with Zewdu et al. (2014), who noted that variability in climate influenced the production in milk, such that as temperature increased, milk production declined notably. In addition, Mapiye et al. (2016) alluded that the low quantity and quality of feed resources affected the productivity of dairy animals in sub-Saharan Africa

Table 4-43: Changes in Household dairy productivity experience related to climate change

Sub County	Ward	Changes in milk production				Change in the amount of water available for the animal				change of the body condition of the animal				Heat detection				Growth of calves and heifers			
		yes		No		yes		No		yes		No		yes		No		yes		No	
		F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)
Aldai	Kaptumo	44	100	0	0.0	43	97.7	1	2.3	41	100	0	0.0	26	92.9	2	7.1	27	96.4	1	3.6
	Kobujoi	16	100	0	0.0	14	87.5	2	12.5	16	100	0	0.0	16	100	0	0.0	16	100	0	0.0
	Koyo-Ndurio	62	100	0	0.0	62	100	0	0.0	62	100	0	0.0	44	72.1	17	27.9	55	88.7	7	11.3
Chesumei	Kosirai	24	100	0	0.0	2	28.6	5	71.4	14	82.4	3	17.6	10	71.4	4	28.6	13	86.7	2	13.3
	Ngechek	43	100	0	0.0	18	100	0	0.0	32	100	0	0.0	15	100	0	0.0	18	100	0	0.0
Emgwen	Kilibwoni	57	100	0	0.0	45	100	0	0.0	46	100	0	0.0	34	100	0	0.0	45	100	0	0.0
Mosop	Kabisaga	19	100	0	0.0	1	5.6	17	94.4	19	100	0	0.0	6	31.6	13	68.4	16	84.2	3	15.8
	Kibiyet	14	100	0	0.0	2	14.3	12	85.7	14	100	0	0.0	11	78.6	3	21.4	13	100	0	0.0
Nandi Hills	Chepkunyuk	18	100	0	0.0	12	100	0	0.0	12	100	0	0.0	9	100	0	0.0	10	100	0	0.0
	Lessos	60	92.3	5	7.7	57	89.1	7	10.9	49	92.5	4	7.5	46	88.5	6	11.5	43	89.6	5	10.4
	Total	357	98.6	5	1.4	256	85.3	44	14.7	305	97.8	7	2.2	217	82.8	45	17.2	256	93.4	18	6.6

Table 4-44: Changes in Household dairy productivity experience as a result of climate change

Sub County	Ward	Changes in milk production				Change in the amount of water available for the animal				change of the body condition of the animal				Heat detection				Growth of calves and heifers			
		Positive		Negative		Positive		Negative		Positive		Negative		Positive		Negative		Positive		Negative	
		F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)	F (n)	P (%)
Aldai	Kaptumo	2	4.5	42	95.5	1	2.3	43	97.7	1	2.4	40	97.6	1	3.6	27	96.4	4	14.3	24	85.7
	Kobujoi	0	0.0	16	100	0	0.0	16	100	0	0.0	16	100	0	0.0	16	100	0	0.0	16	100
	Koyo-Ndurio	28	45.2	34	54.8	32	51.6	30	48.4	34	54.8	28	45.2	18	29.5	43	70.5	31	50.0	31	50.0
Chesumei	Kosirai	0	0.0	24	100	0	0.0	2	100	0	0.0	14	100	0	0.0	10	100	0	0.0	12	100
	Ngechek	0	0.0	43	100	0	0.0	18	100	0	0.0	32	100	0	0.0	15	100	0	0.0	18	100
Emgwen	Kilibwoni	0	0.0	56	100	3	7.0	40	93.0	0	0.0	44	100	0	0.0	33	100	0	0.0	44	100
Mosop	Kabisaga	11	57.9	8	42.1	0	0.0	1	100	2	12.5	14	87.5	0	0.0	3	100	2	50.0	2	50.0
	Kibiyet	6	46.2	7	53.8	0	0.0	3	100	1	8.3	11	91.7	1	20.0	4	80.0	5	62.5	3	37.5
Nandi Hills	Chepkunyuk	0	0.0	30	100	6	23.1	20	76.9	0	0.0	22	100	1	10.0	9	90.0	1	7.1	13	92.9
	Lessos	7	10.8	58	89.2	7	10.8	58	89.2	9	16.7	45	83.3	8	15.4	44	84.6	8	16.7	40	83.3
	Total	54	14.5	318	85.5	49	17.5	231	82.5	47	15.0	266	85.0	29	12.4	204	87.6	51	20.1	203	79.9

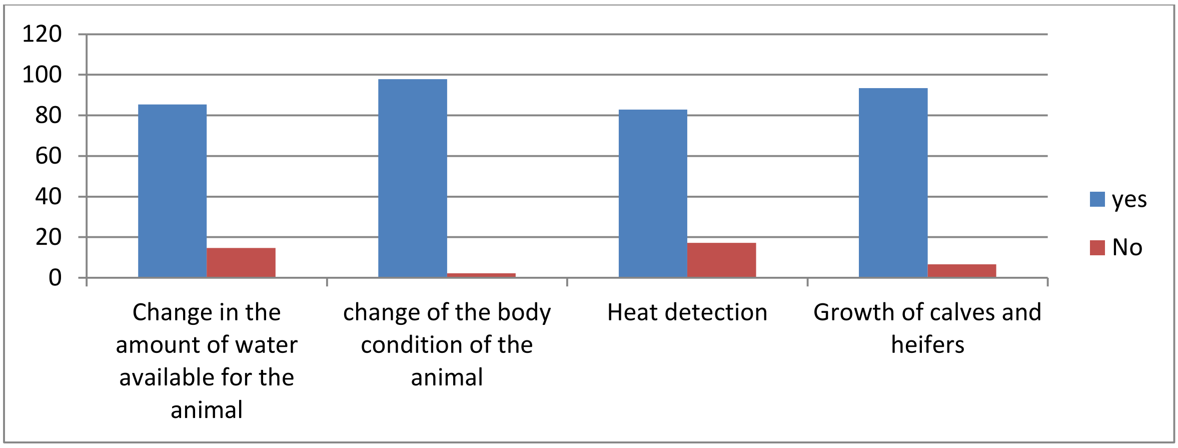

Figure 4-67: Changes in Household dairy productivity experience related to climate change

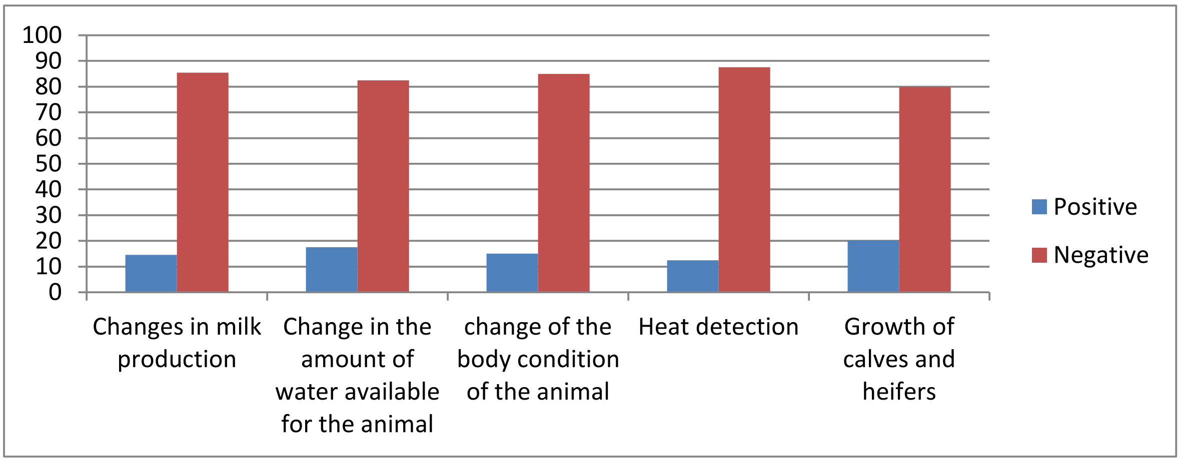

Figure 4-68: Changes in Household dairy productivity experience as a result of climate change

4.7.4 Dairy feed resources

This section presents results based on analysis sources of livestock feed, types of fodder/pasture and conservation/presentation of fodder for future use.

4.7.4.1 Source of Livestock feed

During the data collection, respondents were asked to state their source of livestock feeds in their household and the results presented in Table 4.45

As shown in Table 4-45, 86.9% of respondents sourced their animal feeds from their own farms (natural pasture) while 62.6% sourced their feeds from crop residue. Further, 39.4% indicated that they planted fodder whereas 19.2% and 16.2% noted that they sourced their feeds from communal land (natural pasture) or purchased fodder respectively. In Chesumei sub county, 71.6% sourced their feeds from their own farms (natural pasture, 44.8% planted their fodder or sourced from crop residue whereas only 7.5% sourced their feeds from either communal land or purchased fodder. In Emgwen Sub County, 80.7% sourced their fodder from their own farms with 43.9% planting their fodder while 36.8% using crop residue. In Mosop Sub County, 89.7% utilized crop residue as their source of feed while 51.7% used natural pasture from their own farms. In Nandi hills, 74.2% sourced their animal feeds from their own farms with crop residue accounting for 35.5% of feeds while planted fodder accounted for 29.0%. In overall, the study found that 76.5% of the household in Nandi County mainly depended on their own farms (natural pasture) as a source of feed followed by 49.9% from crop residue and 36.5% from planted fodder. The Table 4-45 shows calculated chi square values identifying the main source of livestock feed per subcounty to be natural pasture from communal land, own farm and crop residue were greater than the critical chi square values. Chi square test indicated that there is significant association between respondents and the main source of feed. However, respondents did not show significant association with planted and purchased fodder.

The FDG identified Kikuyu grass, Nandi Sateria and other natural grasses to form the bulk of natural pastures, maize stovers was the main crop residue while Napier grass and Rhodes grass formed the bulk of planted fodder. This result concurs with Njaruai et al. (2011b), who stated in a study that most of the households in Kenya devote 23-40% of household land to feed production of Napier and Rhodes grass and the rest under natural pastures or fallow. The FGD identified crops grown in Nandi County to include tea, maize, coffee, Sugar cane, vegetables, and fruits. Apart from dairy farming, other key activities were mainly tea picking and weeding with women noted to form the bigger labour force. In dairy farming, men were noted to ;be mainly involved in breeding, disease control and other seasonal activities like fodder planting, harvesting and storing whereas women were involved in daily activities such as feeding, watering and milking which agrees with studies (Njaruri *et al.*, 2012; Katothya, 2017) The FGD identified the natural pastures and fodder crops grown in Nandi County to comprise of Kikuyu grass, Nandi Sateria, and other Natural grasses are the most important in terms of providing feed for the cows. Moreover, it was noted that most farmers relied on natural grasses while planted grass such as Napier grass was the second most important fodder as many farmers had planted whereas the Rhodes grass was ranked third in terms of importance. The FGD also noted that dairy farmers utilized maize crops for their animals with a few of them planting maize for making silage while others use green maize stock after selling maize cob. Farmers also used dry stovers after harvesting maize.

Table 4-45: Main source of livestock feed per ward

Sub county	Ward	Natural pasture (communal land)		Natural pasture (own farm)		Planted fodder		crop residue		purchased fodder		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	5	13.2	27	71.1	23	60.5	12	31.6	10	26.3	38
	Kobujoi	1	7.7	13	100	7	53.8	9	69.2	2	15.4	13
	Koyo-Ndurio	13	27.1	46	95.8	9	18.8	41	85.4	4	8.3	48
	Total	19	19.2	86	86.9	39	39.4	62	62.6	16	16.2	99
Chesumei	Kosirai	0	0.0	18	78.3	13	56.5	8	34.8	3	13.0	23
	Ngechek	5	11.4	30	68.2	17	38.6	22	50.0	2	4.5	44
	Total	5	7.5	48	71.6	30	44.8	30	44.8	5	7.5	67
Emgwen	Kilibwoni	0	0.0	46	80.7	25	43.9	21	36.8	6	10.5	57
Mosop	Kabisaga	1	5.9	9	52.9	3	17.6	14	82.4	2	11.8	17
	Kabiyet	1	8.3	6	50.0	2	16.7	12	100	1	8.3	12
	Total	2	6.9	15	51.7	5	17.2	26	89.7	3	10.3	29
Nandi Hills	Chepkunyuk	1	3.1	31	96.9	6	18.8	8	25.0	2	6.3	32
	Lessos	5	8.2	38	62.3	21	34.4	25	41.0	7	11.5	61
	Total	6	6.5	69	74.2	27	29.0	33	35.5	9	9.7	93
Chi Square test		19.05		15.66		5.63		26.46		3.47		
Total		32	9.3	264	76.5	126	36.5	172	49.9	39	11.3	345

4.7.4.2 Types of Fodder/Pasture

This section presents results based on type of fodder/pasture used in their household and the results presented in Table 4.46, Table 4-47, Figure 4-69 and Figure 4-70

As shown in Table 4-46, up to 75.5%, 56.0%, 57.1% and 85.7% of respondents in Aldai sub county indicated that they planted Napier, Rhodes grass, lucerne and fodder trees respectively in less than 0.5acres of land respectively while maize (54.5%) and sorghum (65.5%) were planted on 0.5 to 2 acres of land. In chesumei Sub County, all households planted lucerne with majority of the respondents planting Napier (93.3%), Rhodes grass (64.3%), sorghum (88.9%), Kikuyu grass (72.7%) and fodder (80%) in in less than 0.5 acres of land. Similarly, in Emgwen Sub County, all households planted lucerne with majority of the respondents planting Napier (82.9%), Rhodes grass (60.7%), sorghum (71.4%), and Kikuyu grass (60.0%) in less than 0.5 acres of land. In Mosop Sub County, all households planted sorghum with majority of the respondents planting Napier (69.7%), Rhodes grass (50.0%), and Kikuyu grass (60.0%) in less than 0.5 acres of land while maize (79.3%) was planted in between 0.5 to 2 acres of land. In Nandi hills Sub County, all households planted fodder trees with majority of the respondents planting Napier (79.2%), sorghum (50.0%) and Rhodes grass (56.5%) in less than 0.5 acres of land while maize (56.5%) was planted in between 0.5 to 2 acres of land.

A test of significance was calculated (Table 4-46) compared acreage of fodder planted with types of fodder and found statistically significant association between acreage of fodder planted and maize, sorghum and lucerne i.e. computed chi square greater than critical chi square. Similar results were found for fodder trees and the number planted. According to the Laws of Kenya (2010), freehold ownership of land has no term limit while leasehold land ownership has a term limit. In customary land ownership tenure system, the land is inherited by the next of kin (Laws of Kenya, 2010). Customary land tenure bestows rights to communal land ownership. The land is owned by the local communities and administered in accordance with their customs laws (Laws of Kenya, 2010).

Table 4-47 shows the importance of these fodder where 57.4%, 58.0%, 54.5%, 82.8%, 73.3% and 77.1% indicated that Napier, Rhodes grass, maize, sorghum, lucerne and fodder trees respectively were important to dairy farming while 88.0% of respondents regarded kikuyu grass as very important to their dairy farming. In Chesumei sub county, (80.0%) and lucerne were considered important whereas Rhodes grass (71.4%), maize (81.3%), sorghum (55.6%), kikuyu grass (60.9%), lucerne (50.0%) and fodder trees (66.7%) were considered as very important for dairy farming. In Emgwen sub county, Napier (59.1%) was considered important whereas Rhodes grass (58.6%), maize (60.9%), sorghum (57.1%), kikuyu grass (60.0%), lucerne (62.5%) and fodder trees (100%) were shown be very important to dairy farming. In Mosop, Napier and maize were shown to be very important by all respondents. In Nandi Hills, Napier (66.7%), Rhodes grass (73.9%), maize (78.6%), sorghum (86.7%), Kikuyu grass (88.9%), and Lucerne (80.0%) were shown to be very important to dairy farming whereas all respondents noted that fodder Trees were very important. In overall, respondents considered Rhodes grass (57.7%), Maize (69.6) and Kikuyu grass (76.3%) as very important while Napier (55.6%), sorghum (55.0%), Lucerne (52.9%) and fodder tree (70.0%) as important to dairy farming in the county. Previous studies by Katiku et al. (2011) and Lukuyu et al. (2011) noted that the commonly utilized feed resources that formed the highest proportion amongst the smallholder’s dairy farmers in Kenya were natural pasture, Napier grass and crop residues.

Figure 4-69 shows that majority of farmers planted fodder in less than 0.5 acres of land for Napier (79.7%), Rhodes grass (57.3%), Sorghum (54.3%), Kikuyu Grass (49.4%), and Lucerne(71.9%) and fodder Tree (82.1%). Moreover, these respondents considered Rhodes grass (57.7%), Maize (69.6) and Kikuyu grass (76.3%) as very important while Napier (55.6%), sorghum (55.0%), Lucerne (52.9%) and fodder tree (70.0%) as important to dairy farming in the county (Figure 4-70).

The FGD noted that green maize, sorghum and natural pastures such as Kikuyu, Nandi sataria were very sensitive to changes in climate. Rhodes grass was classified as moderate sensitive to climate change while Napier grass was identified as a crop that could withstand changes in climate, i.e. less sensitive to climate change. Moreover, farmers indicated that maize Stover is also not sensitive to climate change and attributed their observation to the fact that the stovers were already dry and hence could not be affected by drought. The FGD noted that 20 years ago, natural pastures were mainly communal. However, communal lands are now overgrazed and very little fodder is available with the grass growth not beyond one foot. The land sizes have also continued to decrease and hence land available for paddocking natural pastures has continued to decrease which leads to over grazing. Natural resources available and accessibly and in Nandi County include swamps rivers and forest. However, the county government has put strict measures to control what is planted on the river catchment areas and prohibited farmers from ploughing up to the river banks. Other strict measures include control on the use of county communal grazing areas especially swamps and forest

Table 4-46: Acreage of fodder planted in Nandi County

Sub County	Fodder/Pasture		Napier	Rhodes grass	Maize	Sorghum	Kikuyu grass	Lucerne	Fodder Trees
Aldai	< 0.5 acres	Freq (n)	71	28	4	9	11	8	30
		Perc (%)	75.5	56	36.4	31	44	57.1	85.7
	0.5 to 2 acres	Freq (n)	20	20	6	19	3	6	5
		Perc (%)	21.3	40	54.5	65.5	12	42.9	14.3
	> 2 acres	Freq (n)	3	2	1	1	11	0	0
		Perc (%)	3.2	4	9.1	3.4	44	0	0
	Total	Freq (n)	94	50	11	29	25	14	35
Chesumei	< 0.5 acres	Freq (n)	42	18	7	8	16	5	4
		Perc (%)	93.3	64.3	46.7	88.9	72.7	100	80
	0.5 to 2 acres	Freq (n)	3	7	3	1	3	0	0
		Perc (%)	6.7	25	20	11.1	13.6	0	0
	> 2 acres	Freq (n)	0	3	5	0	3	0	1
		Perc (%)	0	10.7	33.3	0	13.6	0	20
	Total	Freq (n)	45	28	15	9	22	5	5
Emgwen	< 0.5 acres	Freq (n)	34	17	8	5	6	8	0
		Perc (%)	82.9	60.7	34.8	71.4	60	100	0
	0.5 to 2 acres	Freq (n)	5	10	10	1	3	0	0
		Perc (%)	12.2	35.7	43.5	14.3	30	0	0
	> 2 acres	Freq (n)	2	1	5	1	1	0	1
		Perc (%)	4.9	3.6	21.7	14.3	10	0	100
	Total	Freq (n)	41	28	23	7	10	8	1
Mosop	< 0.5 acres	Freq (n)	23	14	4	7	0	0	18
		Perc (%)	69.7	50	13.8	100	Na	Na	78.3
	0.5 to 2 acres	Freq (n)	10	9	23	0	0	0	5
		Perc (%)	30.3	32.1	79.3	0	Na	Na	21.7
	> 2 acres	Freq (n)	0	5	2	0	0	0	0
		Perc (%)	0	17.9	6.9	0	Na	Na	0
	Total	Freq (n)	33	28	29	7	0	0	23
Nandi Hills	< 0.5 acres	Freq (n)	42	13	11	9	5	2	3
		Perc (%)	79.2	56.5	35.5	50	25	40	100
	0.5 to 2 acres	Freq (n)	8	5	11	3	6	1	0
		Perc (%)	15.1	21.7	35.5	16.7	30	20	0
	> 2 acres	Freq (n)	3	5	9	6	9	2	0
		Perc (%)	5.7	21.7	29	33.3	45	40	0
	Total	Freq (n)	53	23	31	18	20	5	3
Chi Square			13.59	10.55	19.51	33.57	14.18	19.03	41.31

NB: For χ^2 test, df=8, α=0.05 and critical value =15.50 (Source: Research Data, 2021)

Table 4-47: Importance of fodder to dairy farming

	Sub County		Napier	Rhodes grass	Maize	Sorghum	Kikuyu grass	Lucerne	Fodder Trees
Aldai	Not Important	Freq (n)	2	0	0	0	0	0	2
		Perc (%)	2.1	0	0	0	0	0	5.7
	Important	Freq (n)	54	29	6	24	3	11	27
		Perc (%)	57.4	58	54.5	82.8	12	73.3	77.1
	Very important	Freq (n)	38	21	5	5	22	4	6
		Perc (%)	40.4	42	45.5	17.2	88	26.7	17.1
	Total	Freq (n)	94	50	11	29	25	15	35
Chesumei	Not Important	Freq (n)	2	1	0	0	0	0	1
		Perc (%)	4.4	3.6	0	0	0	0	33.3
	Important	Freq (n)	36	7	3	4	9	3	0
		Perc (%)	80	25	18.8	44.4	39.1	50	0
	Very important	Freq (n)	7	20	13	5	14	3	2
		Perc (%)	15.6	71.4	81.3	55.6	60.9	50	66.7
	Total	Freq (n)	45	28	16	9	23	6	3
Emgwen	Not Important	Freq (n)	0	1	1	0	0	0	0
		Perc (%)	0	3.4	4.3	0	0	0	0
	Important	Freq (n)	26	11	8	3	4	3	0
		Perc (%)	59.1	37.9	34.8	42.9	40	37.5	0
	Very important	Freq (n)	18	17	14	4	6	5	1
		Perc (%)	40.9	58.6	60.9	57.1	60	62.5	100
	Total	Freq (n)	44	29	23	7	10	8	1
Mosop	Not Important	Freq (n)	0	0	0	0	0	0	0
		Perc (%)	0	Na	0	Na	Na	Na	Na
	Important	Freq (n)	0	0	0	0	0	0	0
		Perc (%)	0	Na	0	Na	Na	Na	Na
	Very important	Freq (n)	1	0	1	0	0	0	0
		Perc (%)	100	Na	100	Na	Na	Na	Na
	Total	Freq (n)	1	0	1	0	0	0	0
nandi Hills	Not Important	Freq (n)	1	1	2	0	0	0	0
		Perc (%)	1.8	4.3	7.1	0	0	0	0
	Important	Freq (n)	18	5	4	2	2	1	1
		Perc (%)	31.6	21.7	14.3	13.3	11.1	20	100
	Very important	Freq (n)	38	17	22	13	16	4	0
		Perc (%)	66.7	73.9	78.6	86.7	88.9	80	0
	Total	Freq (n)	57	23	28	15	18	5	1

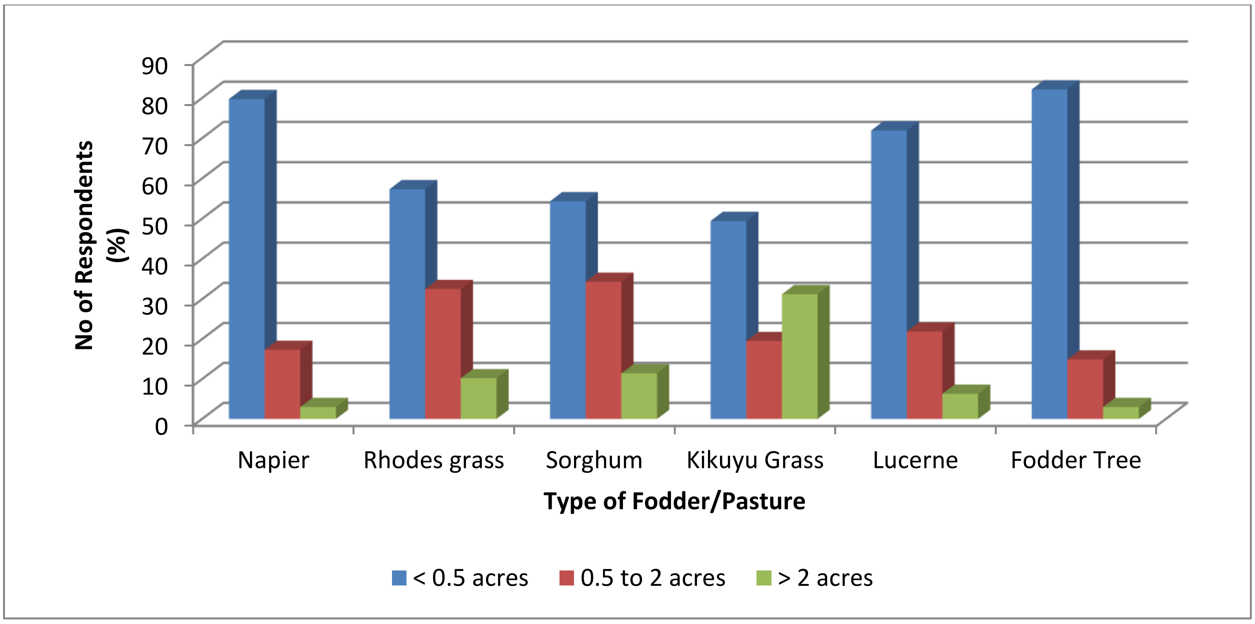

Figure 4-69: Type of fodder/pasture planted in acreage

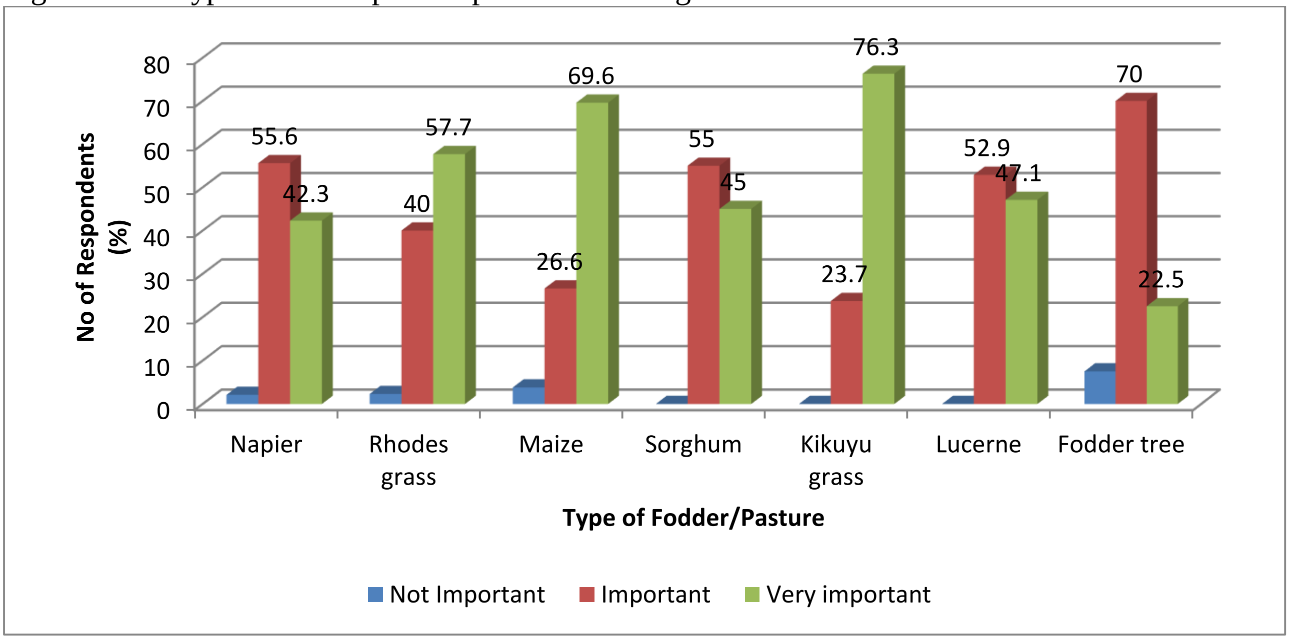

Figure 4-70: Importance of fodder/pasture to dairy farming

4.7.4.3 Fodder availability for future use

During the data collection, respondents were asked to state the type of fodder they preserve or conserve for future use and the results presented in Table 4.48 and Table 4.49.

Table 4-48: Conservation/Preservation of fodder for future use per ward

Sub County	Ward	Yes		No		Chi Square
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	
Aldai	Kaptumo	29	82.9	6	17.1	40.21
	Kobujoi	12	85.7	2	14.3	
	Koyo-Ndurio	59	96.7	2	3.3	
	Total	100	90.9	10	9.1	
Chesumei	Kosirai	15	78.9	4	21.1	
	Ngechek	39	90.7	4	9.3	
	Total	54	87.1	8	12.9	
Emgwen	Kilibwoni	48	87.3	7	12.7	
Mosop	Kabisaga	18	100	0	0.0	
	Kabiyet	11	100	0	0.0	
	Total	29	100	0	0.0	
Nandi Hills	Chepkunyuk	16	51.6	15	48.4	
	Lessos	44	67.7	21	32.3	
	Total	60	62.5	36	37.5	
Total		291	82.7	61	100	

NB: For χ^2 test, df=4, α=0.05 and critical value =9.49 (Source: Research Data, 2021)

Table 4-49: Type of fodder conserved/preserved

Sub County	Ward	crop residues		Hay		Silage		Wheat straw		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	25	96.2	9	34.6	4	15.4	0	0.0	26
	Kobujoi	12	100	4	33.3	2	16.7	1	8.3	12
	Koyo-Ndurio	56	96.6	9	15.5	24	41.4	3	5.2	58
	Total	93	96.9	22	22.9	30	31.3	4	4.2	96
Chesumei	Kosirai	14	93.3	6	40.0	3	20.0	0	0.0	15
	Ngechek	32	82.1	20	51.3	10	25.6	2	5.1	39
	Total	46	85.2	26	48.1	13	24.1	2	3.7	54
Emgwen	Kilibwoni	42	85.7	17	34.7	21	42.9	0	0.0	49
Mosop	Kabisaga	17	94.4	18	100	13	72.2	0	0.0	18
	Kabiyet	11	100	9	81.8	8	72.7	1	9.1	11
	Total	28	96.6	27	93.1	21	72.4	1	3.4	29
Nandi Hills	Chepkunyuk	13	81.3	5	31.3	2	12.5	0	0.0	16
	Lessos	32	72.7	18	40.9	15	34.1	0	0.0	44
	Total	45	75.0	23	38.3	17	28.3	0	0.0	60
Total		254	88.2	115	39.9	102	35.4	7	2.4	288

As shown in Table 4-48, majority of respondents conserved or preserved fodder for future use in Aldai (90.9%), Chesumei (87.1%), Emgwen (87.3%), Mosop (100%) and Nandi Hills (62.5%) sub counties of Nandi County. A test of significance was calculated (Table 4-48) to assess whether farmers conserved or preserved fodder for future use and found statistically significant association as computed chi square values were greater than critical chi square values. Table 4-49 show that most of the households in Aldai (96.9%), Chesumei (85.2%), Emgwen (85.7%), Mosop (96.6%) and Nandi Hills (75.0%) sub counties of Nandi county conserved/preserved crop residue. Significant percentage of respondents in Mosop Sub County was also noted to preserve hay (93.1%) and silage for future use. In overall, 88.2% of all respondents in Nandi County conserved or preserved crop residue while 39.9% conserved hay and 35.4% conserved silage.

The FGD noted that natural pastures were most available to the farmers in terms of access. Farmers noted that they could access natural pastures from their own farms or lease them from neighbours. Other ways in which farmers accessed natural pasture was through barter trade where a dairy farmer is allowed to graze the animals and in return pay by giving the owner of land the milk. The FGD also noted that Naiper grass were also easily available as farmers could easily get planting materials from neighbours. Availability of Rhodes grass was limited as they were mostly sold and sometimes farmers had to go great distances to access them whereas access to silage from Maize and Sorghum were limited since only few farmers make their silage. For maize Stovers, it was noted that they were readily available after maize harvest but limited by farmer's knowledge on processing and preservation.

In overall, 88.2% of all respondents in Nandi conserved or preserved crop residue while 39.9% conserved hay and 35.4% conserved silage and thus meant that crop residue mainly maize stovers is a major feed resource followed by conserved hay and silage during drought. Studies show that when treated crop residue could be a cheap source of feed resource (Owen and Jayasuriya, 1989) that can be used during feed scarcity (Salem and Smith, 2008) during dry season that is expected to exacerbate as result of climate change

4.7.5 Resilience and Adapatation

This section presents results based on analysis on resilience and adaptation.

4.7.5.1 Effects of climate change on dairy productivity

This section presents analysis on effects of climate change on Napier, Rhodes Grass, Maize, Sorghum, and Kikuyu Grass, lucerne and fodder trees in Table 4-50 and Figure 4-71.

As shown in table 4-50, Napier is slightly affected in Kaptumo (81.0%), Koyo Ndurio (100%), Kosirai (84.2%), Ngechek (92.0%) and Kilibwoni (90.7%) wards and very much affected in Kobujoi (75.0%), Chepkunyuk (63.0%) and Lessos (61.3%) wards. For Rhodes grass and maize, the study found that climate change had affected fodder slightly in Kaptumo (78.9%), Ngechek (77.3%) and Kilibwoni (86.2%) wards and very much affected fodder in Kobujoi (100.0%), Kosirai (66.7%), Kabisaga (100%), Kabiyet (100%), Chepkunyuk (70.0%) and Lessos (71.4%) wards. For sorghum, the study found that climate change had affected fodder slightly in Koyo Ndurio (100%), Kosirai (83.3%), Ngechek (100%) and Kilibwoni (57.1%) wards and very much affected fodder in Kaptumo (100%), Kobujoi (67.7%), Chepkunyuk (100.0%) and Lessos (83.3%) wards. For Kikuyu grass, the study found that climate change had affected fodder slightly in Koyo Ndurio (50%), and Ngechek (63.6%) wards and very much affected fodder in Kaptumo (100%), Kobujoi (100%), Koyo Ndurio (50%), Kosirai (66.7%), Kilibwoni (70.0%) and Lessos (88.9%) wards. For Lucerne, the study found that climate change had affected fodder slightly in Koyo Ndurio (100%), and Ngechek (100%) wards and very much affected fodder in Kaptumo (100%), Kobujoi (100%), Kosirai (100%), Chepkunyuk (100.0%) and Lessos (75%) wards. More than 90% of the respondents indicated that climate change had slightly affected fodder trees in Kaptumo, Kobujoi, Koyo-Ndurio, Kosirai, Lessos. Overall, the Figure 4-71 show that climate change had slightly affected Napier (87.8%), Rhodes grass (82.6%), maize (82.6%), sorghum (83.3%), Kikuyu grass (32.1%), Lucerne (74.5%) and Fodder trees (94.87%).

Table 4-50: Effects of climate change on fodder/pasture

Fodder/ Pasture	Category	Variable	Aldai			Chesumei		Emgwen	Mosop		Nandi Hills	
			Kaptumo	Kobujoi	Koyo-Ndurio	Kosirai	Ngechek	Kilibwoni	Kabisaga	Kabiyet	Chepkunyuk	Lessos
Nappier	Slightly Affected	Freq (n)	34.0	3.0	38.0	16.0	23.0	39.0	0.0	0.0	10.0	12.0
		Perc (%)	81.0	25.0	100	84.2	92.0	90.7	Na	Na	37.0	38.7
	Very Affected	Freq (n)	8.0	9.0	0.0	3.0	2.0	4.0	0.0	0.0	17.0	19.0
		Perc (%)	19.0	75.0	0.0	15.8	8.0	9.3	Na	Na	63.0	61.3
Rhodes Grass	Slightly Affected	Freq (n)	15.0	0.0	28.0	2.0	17.0	25.0	0.0	0.0	3.0	4.0
		Perc (%)	78.9	0.0	100	33.3	77.3	86.2	0.0	0.0	30.0	28.6
	Very Affected	Freq (n)	4.0	2.0	0.0	4.0	5.0	4.0	1.0	1.0	7.0	10.0
		Perc (%)	21.1	100	0.0	66.7	22.7	13.8	100	100	70.0	71.4
Maize	Slightly Affected	Freq (n)	15.0	0.0	28.0	2.0	17.0	25.0	0.0	0.0	3.0	4.0
		Perc (%)	78.9	0.0	10	33.3	77.3	86.2	0.0	0.0	30.0	28.6
	Very Affected	Freq (n)	4.0	2.0	0.0	4.0	5.0	4.0	1.0	1.0	7.0	10.0
		Perc (%)	21.1	100	0.0	66.7	22.7	13.8	100	100	70.0	71.4
Sorghum	Slightly Affected	Freq (n)	0.0	1.0	23.0	5.0	2.0	4.0	0.0	0.0	0.0	2.0
		Perc (%)	0.0	33.3	100	83.3	100	57.1	Na	Na	0.0	16.7
	Very Affected	Freq (n)	1.0	2.0	0.0	1.0	0.0	3.0	0.0	0.0	4.0	10.0
		Perc (%)	100	66.7	0.0	16.7	0.0	42.9	Na	Na	100	83.3
Kikuyu Grass	Slightly Affected	Freq (n)	0.0	0.0	1.0	4.0	7.0	3.0	0.0	0.0	0.0	2.0
		Perc (%)	0.0	0.0	50.0	33.3	63.6	30.0	Na	Na	Na	11.1
	Very Affected	Freq (n)	10.0	13.0	1.0	8.0	4.0	7.0	0.0	0.0	0.0	16.0
		Perc (%)	100	100	50.0	66.7	36.4	70.0	Na	Na	Na	88.9
Lucerne	Slightly Affected	Freq (n)	0.0	0.0	12.0	0.0	4.0	4.0	0.0	0.0	0.0	1.0
		Perc (%)	0.0	0.0	100	0.0	100	50.0	Na	Na	0.0	25.0
	Very Affected	Freq (n)	2.0	1.0	0.0	2.0	0.0	4.0	0.0	0.0	1.0	3.0
		Perc (%)	100	100	0.0	100	0.0	50.0	Na	Na	100	75.0
Fodder Trees	Slightly Affected	Freq (n)	14.0	1.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	1.0
		Perc (%)	100	100	90.9	100	Na	Na	Na	Na	Na	100
	Very Affected	Freq (n)	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Perc (%)	0.0	0.0	9.1	0.0	Na	Na	Na	Na	Na	0.0

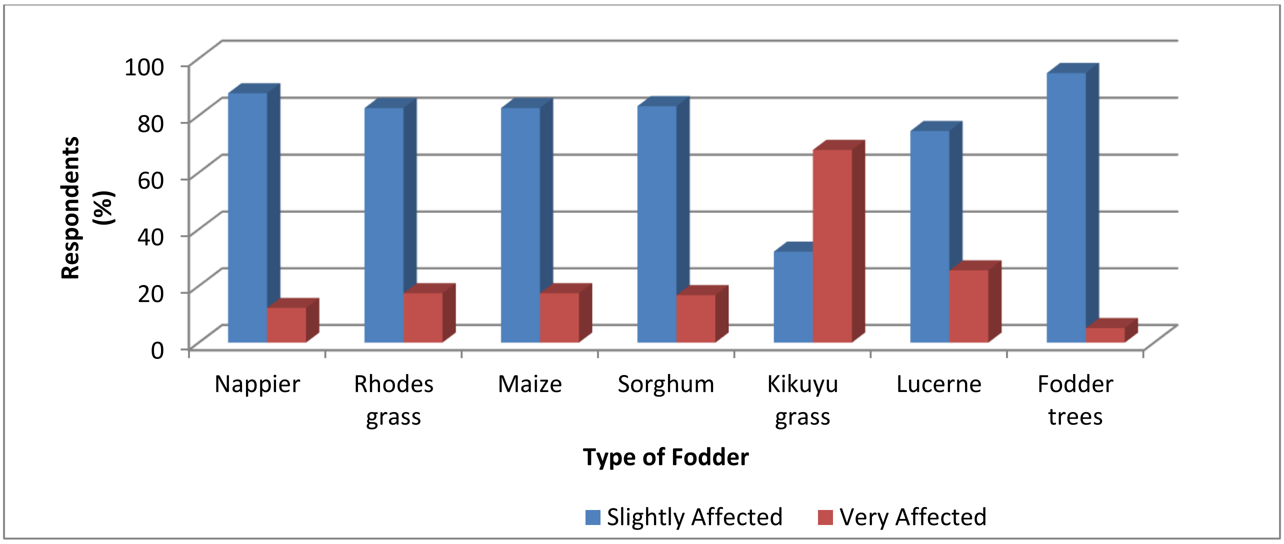

Figure 4-71: Effects of climate change on the type of Fodder/Pasture in Nandi county

4.7.5.2 Approaches used to address climate change

This section presents options used by household to deal with effects of climate change. As shown in Table 4-51, 18% of households in Aldai Sub County used conserved hay/silage, 42.3% bought commercial feeds, 85.6% used crop residue, and 27% sold their animals while less than 10% moved their animals to friends and relatives to avert the negative effects of climate change. In Chesumei Sub County, 59.4% of households used conserved hay/silage, 39.1% bought commercial feeds, 53.1% used crop residue, and 14.1% sold their animals while less than 5% moved their animals to friends and relatives to avert the negative effects of climate change. In Emgwen Sub County, 47.5% of households used conserved hay/silage 40.7% bought commercial feeds, 88.1% used crop residue, and 32.2% sold their animals while less than 5% moved their animals to friends and relatives to avert the negative effects of climate change. In Mosop Sub County, 93.9% of households used conserved hay/silage 84.8% bought commercial feeds, 90.9% used crop residue, and 51.5% moved their animals to friends and relatives while less than 5% sold their animals to avert the negative effects of climate change. In Nandi Hills Sub County, 45.3% of households used conserved hay/silage 25.3% bought commercial feeds, 62.1% used crop residue while less than 10% either sold their animals or moved their animals to friends and relatives to avert the negative effects of climate change. It was noted that in Nandi County, methods used to address negative experiences of climate change included use conserved hay/ silage (44.2%), buying of commercial feeds (40.9%), use crop residue (74.6%), moving of animals to other farms (8.8%) and selling of animals (17.4%).

Table 4-51: Methods used to address negative experiences of climate change

Sub County	Ward	Use conserved hay/ silage		Buy commercial feeds		Use crop residue		Move animals to other farms		Sell of animals		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	10	27.0	21	56.8	24	64.9	5	13.5	7	18.9	37
	Kobujoi	5	33.3	14	93.3	14	93.3	1	6.7	7	46.7	15
	Koyo-Ndurio	5	8.5	12	20.3	57	96.6	2	3.4	16	27.1	59
	Total	20	18.0	47	42.3	95	85.6	8	7.2	30	27.0	111
Chesumei	Kosirai	7	35.0	13	65.0	13	65.0	0	0.0	3	15.0	20
	Ngechek	31	70.5	12	27.3	21	47.7	3	6.8	6	13.6	44
	Total	38	59.4	25	39.1	34	53.1	3	4.7	9	14.1	64
Emgwen	Kilibwoni	28	47.5	24	40.7	52	88.1	2	3.4	19	32.2	59
Mosop	Kabisaga	18	94.7	17	89.5	17	89.5	8	42.1	1	5.3	19
	Kabiyet	13	92.9	11	78.6	13	92.9	9	64.3	0	0.0	14
	Total	31	93.9	28	84.8	30	90.9	17	51.5	1	3.0	33
Nandi Hills	Chepkunyuk	18	58.1	1	3.2	23	74.2	0	0.0	1	3.2	31
	Lessos	25	39.1	23	35.9	36	56.3	2	3.1	3	4.7	64
	Total	43	45.3	24	25.3	59	62.1	2	2.1	4	4.2	95
Total		160	44.2	148	40.9	270	74.6	32	8.8	63	17.4	362

4.7.5.3 Measures to prevent negative experience related to climate change

During data collection, respondents were asked to state whether they had measures to put in place to prevent the negative impacts of climate change. The results are presented in the Table 4-52 to Table 4-54.

The Table 4-52 shows that more than 60% of households in each ward in Nandi County had put measures in place in an event of a negative impact related to climate change. In particular, respondents in Aldai, Chesumei, Emgwen, Mosop and Nandi Hills sub counties showed 78.7%, 86.2%, 77.6%, 100% and 73.9% respectively that they had measures to help them avert negative climate change. In overall, 80.7% of respondents in Nandi County had put measures in place to avert similar negative experiences of climate change against 19.3% who had not measures in place. It is noted that these measures included adoption of new fodder types/ varieties, adoption of new planning methods, intercropping different fodder, conservation and preservation practices.

As shown in Table 4-53, significant adoption of new fodder types/varieties was noted to be 61.8% in Kaptumo, 92.9% in Kobujoi, 70.6% in Kosirai, 94.7% in Kabisaga, 100% in kabiyet, 90.5% in Chepkunyuk, and 57.1% in Lessos. Similarly, significant adoption of conservation and preservation practices was noted to be 85.7% in Kobujoi, 85.0% in Koyo Ndurio, 52.9% in Kosirai, 95.1% in Ngechek, and 79.4% in Lessos. The Table 4-53 also notes that adoption of new planning methods and intercropping different fodder was not recognised by majority of respondents in Nandi County as less than half of the respondents identified these approaches as a measure to prevent negative impact impacts of climate change. Overall statistics in Nandi County show that only 54.7%, 12.9%, 13.2% and 70.0% of respondents identified adoption of fodder types/varieties, adoption of new planning methods, intercropping different fodder and conservation and preservation practices respectively as measures put in place to to prevent similar negative experience related to climate change.

The Table 4-54 shows that significant percentage of more than 80% of all respondents in all sub counties indicated that they used disease control. However, only 75% of the respondents in Kobujois showed that they used compost making to reduce negative effects of climate change. A significant number of respondents in Kaptumo (72.1%), Kobujoi (62.5%), Koyo Ndurio (95.2%), Chepkunyuk (53.1%), and Lessos (84.6) had opted to use of water conservation. Planting of fodder trees was significantly adopted in Kaptumo (55.8%), Kabisaga (84.2%) and Kabiyet (64.3%) while reducing the number of animals was only being significantly practiced in Kabisaga (89.5%) and Kabiyet (100%). Moreover, Table 4-49 show that breeding using AI was also very popluar in Kobujoi (62.5%), Kosirai (100%), Ngechek (76.7%), Kilibwoni (71.2%), Kabisaga (100%), Kabiyet (92.9%), Chepkunyuk (75.0%) and Lessos (76.9%). The study also found that the use of biogas was also practised by a low percentage of respondents with none of the wards or sub counties exceeding 6%. A review by Rojas-Downing et al. (2017) showed that climate change adaptation, mitigation practices, and policy frameworks are critical to protect livestock production. The review found that diversification of livestock animals (within species), using different crop varieties, and shifting to mixed crop-livestock systems seemed to be the most promising adaptation measures. In addition, shifting to mixed crop-livestock systems can improve efficiency by increasing production with the use of fewer resources. On mitigation side, Rojas-Downing et al. (2017) noted that improvement of animal nutrition and genetics are important because enteric fermentation is a major GHG emitter in livestock production. However, the efficacy of these practices in reducing emissions is uncertain and more research is needed concerning effective mitigation practices related to enteric fermentation

Table 4-52: Existence of preventive measures to negative climate change

Sub County	Ward	Yes		No	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	35	94.6	2	5.4
	Kobujoi	15	100	0	0.0
	Koyo-Ndurio	35	62.5	21	37.5
	Total	85	78.7	23	21.3
Chesumei	Kosirai	17	81.0	4	19.0
	Ngechek	39	88.6	5	11.4
	Total	56	86.2	9	13.8
Emgwen	Kilibwoni	45	77.6	13	22.4
Mosop	Kabisaga	19	100	0	0.0
	Kabiyet	14	100	0	0.0
	Total	33	100.0	0	0.0
Nandi Hills	Chepkunyuk	21	84.0	4	16.0
	Lessos	44	69.8	19	30.2
	Total	65	73.9	23	26.1
Total		284	80.7	68	19.3

Table 4-53: Mitigation measures negative effect of climate change

Sub County	Ward	Adoption of new fodder types/ varieties		Adoption of new planning methods		Intercropping different fodder		conservation and preservation practices		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	21	61.8	14	41.2	9	26.5	13	38.2	34
	Kobujoi	13	92.9	2	14.3	1	7.1	12	85.7	14
	Koyo-Ndurio	3	7.5	4	10.0	7	17.5	34	85.0	40
	Total	37	42.0	20	22.7	17	19.3	59	67.0	88
Chesumei	Kosirai	12	70.6	4	23.5	0	0.0	9	52.9	17
	Ngechek	15	36.6	4	9.8	4	9.8	39	95.1	41
	Total	27	46.6	8	13.8	4	6.9	48	82.8	58
Emgwen	Kilibwoni	18	40.0	2	4.4	3	6.7	43	95.6	45
Mosop	Kabisaga	18	94.7	0	0.0	1	5.3	1	5.3	19
	Kabiyet	14	100	1	7.1	2	14.3	0	0.0	14
	Total	32	97.0	1	3.0	3	9.1	1	3.0	33
Nandi Hills	Chepkunyuk	19	90.5	2	9.5	1	4.8	13	61.9	21
	Lessos	24	57.1	4	9.5	10	23.8	37	88.1	42
	Total	43	68.3	6	9.5	11	17.5	50	79.4	63
Total		157	54.7	37	12.9	38	13.2	201	70.0	287

Table 4-54: Adoption of Climate Smart Agricultural technologies

Sub County	Ward	Compost making		Use of biogas		Water conservation		disease control		Planting of fodder trees		Reducing the number of animals		Breeding (using AI)		Total
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)
Aldai	Kaptumo	12	27.9	0	0.0	31	72.1	43	100	24	55.8	14	32.6	19	44.2	43
	Kobujoi	12	75.0	1	6.3	10	62.5	16	100	1	6.3	3	18.8	10	62.5	16
	Koyo-Ndurio	16	25.8	0	0.0	59	95.2	61	98.4	11	17.7	27	43.5	9	14.5	62
	Total	40	33.1	1	0.8	100	82.6	120	99.2	36	29.8	44	36.4	38	31.4	121
Chesumei	Kosirai	0	0.0	0	0.0	0	0.0	13	100	0	0.0	0	0.0	13	100	13
	Ngechek	3	7.0	2	4.7	12	27.9	41	95.3	15	34.9	13	30.2	33	76.7	43
	Total	3	5.4	2	3.6	12	21.4	54	96.4	15	26.8	13	23.2	46	82.1	56
Emgwen	Kilibwoni	5	8.5	4	6.8	14	23.7	57	96.6	11	18.6	21	35.6	42	71.2	59
Mosop	Kabisaga	0	0.0	0	0.0	4	21.1	19	100	16	84.2	17	89.5	19	100	19
	Kabiyet	0	0.0	0	0.0	5	35.7	14	100	9	64.3	14	100	13	92.9	14
	Total	0	0.0	0	0.0	9	27.3	33	100	25	75.8	31	93.9	32	97.0	33
Nandi Hills	Chepkunyuk	2	6.3	0	0.0	17	53.1	32	100	9	28.1	4	12.5	24	75.0	32
	Lessos	18	27.7	2	3.1	55	84.6	53	81.5	14	21.5	21	32.3	50	76.9	65
	Total	20	20.6	2	2.1	72	74.2	85	87.6	23	23.7	25	25.8	74	76.3	97
Total		68	18.6	9	2.5	207	56.6	349	95.4	110	30.1	134	36.6	232	63.4	366

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Past and projected precipitation remains bimodal and highly variable (increasing/decreasing) in both space and time, according to CORDEX model outputs. Computed percentage change for seasonal and annual precipitation was centered on 10% for baseline, -32.1% to 11.4% for RCP45 and -1.4% to 26.7% for RCP85. Notably differences between baseline and projected precipitation were noted for RCP45 (-19.5% to 11.0%) and RCP85 (-9.5% and 26.3%). Generally, precipitation distribution showed a SW to NE increase with SON/JJA season expected to receive highest/lowest amounts of precipitation. Analysis of projected maximum and minimum temperatures showed increasing trends. Computed percentage change for seasonal and annual maximum temperatures ranged between 1.0% and 3.8% for baseline, 2.77% and 4.12% for RCP45 and 3.60% and 5.77% for RCP85. Positive change between baseline and projected maximum temperatures were noted for RCP45 (between 1.31% and 2.22%) and RCP85 (between 1.8% and 2.6%). Computed percentage change for seasonal and annual minimum temperatures ranged between 2.47% and 9.35% for baseline, 7.5% to 10.8% for RCP45 and 3.60% to 5.77% for RCP85. Positive change between baseline and projected minimum temperatures were noted for RCP45 (between 3.9% and 5.5%) and RCP85 (between 2.14% and 3.86%) and decreasing from west to east. MAM season had the highest maximum and minimum temperatures with higher temperatures noted for RCP45 compared to RCP85.

Temporal analyses of NDVI indicate higher values between April and November and thus fodder availability. Highest/lowest NDVI and soil moisture content were noted for JJA/DJF seasons and thus high/low fodder availability. The percentage change for NDVI values during DJF, MAM, JJA, SON and ANN were found to be 6.0%, 1.96%, 2.13%, 4.16% and 2.53% respectively. The percentage change during DJF, MAM, JJA, SON and annual period ranged between 7.2% and 17.1% at 0-10cm depth and between 8.1% and 23.7% at 10-40 depth.

Milk production based on livestock population, dairy herd, lactating herd and sales showed positive trend with percentage change of up to 16%. Trend analysis of milk production shows positive change from 2007 to 2016 with highest/lowest values in April/December. Computed percentage change in milk production showed increases of up to 186%, 183%, 202%, 214% and 204% during MAM, JJA, SON, DJF and annual periods respectively.

A positive relationship was found between milk production and indicators of climate and fodder availability except NDVI at lag0 and lag1. The lowest/highest correlation coefficients were found in precipitation/minimum temperature at lag 0, 1 and 2. Autocorrelation analysis showed that all selected models based on different predictors had positive relationship with milk production. The best models (lowest (AICs) with at least four predictors identified precipitation, maximum temperature, minimum temperature and NDVI as the best predictors. On the contrary, the worst models (highest AICs) with at least four predictors composed of minimum temperature, soil moisture content (0-10cm), soil moisture content (10-40cm) and NDVI. The multi-regression analysis indicated that precipitation had significant contribution to dairy productivity. The study findings indicate that dairy productivity is highly sensitive to climate. Moreover, fodder availability which is also vulnerable to climate change significantly influences milk production.

Given the high spatial and temporal variability in these environmental factors, it is expected that the projected change will significantly challenge future dairy productivity especially in Nandi County of Kenya. Therefore, adequate measures including adoption of climate smart technologies to mitigate and adapt the extreme climate and fodder availability are necessary in order to sustainable enhance milk production.

The study found out that main climate hazards in Nandi County were drought (82.3%), rainfall unpredictability (41%), rainfall variability (25.1%), Extreme temperatures (7.4%) and flooding (2%). The effects of climate change on fodder crops were moderate in Aldai (92.2%), Chesumei (61.5%), Emgwen (78.0%), Mosop (93.9%) and severe in Nandi Hills (67.3%). An overall statistics for Nandi County show that 57.6% of respondents acknowledged that extreme climate events recurred after every four years.

Methods used to address negative experiences of climate change included using conserved hay/ silage (44.2%), buying of commercial feeds (40.9%), use crop residue (74.6%), moving of animals to other farms (8.8%) and selling of animals (17.4%). Households in Aldai (78.7%), Chesumei (86.2%), Emgwen (77.6%), Mosop (100%) and Nandi Hills (73.9%) had measures such as adoption of new fodder types/ varieties, adoption of new planning methods, intercropping different fodder, conservation and preservation practices to help them avert negative climate change.

5.2 **Recommendations**

The following recommendations are made so as to enhance coping strategies for climate variability by smallholder dairy farmers in Nandi County

5.2.1 National/County Government

In order to make weather information easily accessible and enhance its usability, the National government through KMD and the county government of Nandi need to establish more weather stations. This will improve on the accuracy of the available weather information. Moreover, dairy farmers should be empowered to adapt and mitigate against the effects of drought and emergence of new vectors and livestock diseases occasioned by extreme weather variability.

5.2.2 Research Community

There is need for the research community to make use of available weather and climate information to develop weather and climate products targeting milk production. There is also need to develop climate smart fodder varieties/production methods

5.2.3 Smallholder farmers

As a response to the effects of climate variability and change, dairy farmers should invest in fodder development and conservation in order to sustain their dairy herd productivity. Moreover, more farmers need to aadopt use of climate smart fodder varieties/production methods.

5.2.4 Policy Makers

Adequate mechanisms should be put in place to minimize losses and damages of the dairy herd and dairy herd productivity occasioned by increased frequency of extreme rainfall over the two sites. Moreover, policy makers need to not only promote use of climate smart fodder varieties/production methods but also mainstreaming climate change information into development planning, budgeting and implementation at national and county levels

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APPENDIX 1: MULTILINEAR REGRESSION ANALYSIS

Model	Intercept	PRE	TMX	TMN	Soilm 0_10	Soilm 10_40	NDVI	R2	p-value	AIC	ACF	D-W	S-W
model 1	0.57	0.02	-0.05	0.42	-10.82	21.51	-5.24	0.18	0.001	-18.89	0.81	0.31	0.94
model 2	-0.05	0.09	0.17					0.03	0.175	-6.66	0.92	0.12	0.91
model 3	-0.05	-0.03		0.23				0.05	0.043	-9.53	0.89	0.17	0.92
model 4	-1.36	-0.02			4.94			0.10	0.002	-8.30	0.94	0.10	0.90
model 5	0.25	0.05				-0.94		0.01	0.607	3.94	0.93	0.11	0.90
model 6	1.47	0.12					-2.22	0.02	0.228	1.93	0.92	0.12	0.91
model 7	-0.05	0.01	0.09	0.19				0.06	0.069	-8.38	0.89	0.17	0.92
model 8	-1.85	0.07	0.30		6.76			0.09	0.012	-12.38	0.91	0.13	0.91
model 9	-2.01	0.07	0.29			7.35		0.10	0.008	-13.32	0.91	0.13	0.92
model 10	-1.00	0.06	0.22				1.44	0.03	0.260	-5.22	0.92	0.13	0.91
model 11	-2.03	-0.03	0.22	0.23	7.41			0.13	0.003	-15.88	0.87	0.22	0.92
model 12	-2.24	-0.03	0.20	0.24		8.22		0.15	0.001	-17.43	0.86	0.23	0.93
model 13	0.78	0.02	0.03	0.23			-1.24	0.06	0.121	-6.65	0.89	0.17	0.92
model 14	-2.30	-0.03	0.16	0.25	-12.94	21.35		0.15	0.002	-16.43	0.84	0.26	0.93
model 15	0.82	0.02	0.02	0.40	9.67		-5.21	0.17	0.001	-18.21	0.83	0.28	0.93
model 16	-0.05		0.09	0.20				0.06	0.029	-10.37	0.89	0.17	0.92
model 17	-1.89		0.28		6.91			0.09	0.006	-13.73	0.92	0.12	0.91
model 18	-2.05		0.27			7.49		0.09	0.004	-14.63	0.92	0.12	0.91
model 19	-1.32		0.22				1.93	0.03	0.154	-6.92	0.92	0.12	0.90
model 20	-2.01		0.23	0.21	7.33			0.13	0.001	-17.80	0.87	0.21	0.92
model 21	-2.22		0.22	0.22		8.12		0.14	0.001	-19.32	0.86	0.23	0.93

model 22	0.69		0.03	0.23			-1.11	0.06	0.063	-8.60	0.89	0.17	0.92
model 23	-2.27		0.17	0.24	-12.98	21.30		0.15	0.001	-18.33	0.85	0.25	0.93
model 24	0.76		0.01	0.40	9.68		-5.11	0.17	0.000	-20.18	0.83	0.27	0.93
model 25	-1.33			0.26	4.79			0.09	0.004	-14.38	0.89	0.18	0.91
model 26	-1.63			0.27		5.90		0.11	0.002	-16.10	0.88	0.20	0.91
model 27	0.94			0.25			-1.49	0.06	0.026	-10.56	0.89	0.17	0.93
model 28	-1.91			0.28	-21.91	28.85		0.13	0.001	-17.41	0.85	0.26	0.92
model 29	0.80			0.41	9.68		-5.18	0.17	0.000	-22.18	0.83	0.28	0.93
model 30	0.13			0.40	-9.87	20.47	-4.54	0.18	0.000	-22.75	0.82	0.30	0.94
model 31	0.99					-0.14	-1.45	0.01	0.438	3.27	0.94	0.09	0.91
model 32	-0.31				5.02	0.74	-1.93	0.12	0.002	-8.21	0.94	0.10	0.90
model 33	-1.26				4.86	-0.32		0.11	0.001	-8.40	0.94	0.10	0.89
model 34	-0.42				4.88		-1.41	0.12	0.001	-9.87	0.94	0.10	0.89

APPENDIX 2: QUESTIONNAIRE

Questionnaire No. --------

Sub-county---------------------- Ward (location) -------------------- GPS coordinates ----------

FARM LEVEL QUESTIONNAIRE

Questionnaire to capture the existing and potential optimized adaptation and mitigation strategies

Introduction

This questionnaire is a tool for data collection in a study on climate change and fodder availability. The purpose of the study is to investigate the impact of fodder on smallholder milk productivity in Nandi County Kenya, under changing climate. Results from this study will assist farmers and programs operating in the Nandi County and in East Africa at large to plan and adapt to changing climate while increasing dairy productivity. All information you give is confidential and your name will not be written in the questionnaire to protect your identity. Your participation is voluntary and is highly appreciated. Thank you for your cooperation.

Instructions

This questionnaire consists of several sections; kindly answer all the questions by ticking or writing in the appropriate area. Please answer all questions in the relevant sections honestly and exhaustively.

Section I: - Household Information

1. Gender of Respondent (tick)

Male		Female	

2. Relationships of Respondent to household head --

00 = household Head 01=Spouse 02=Child, 03=Grandchild 04=Son/daughter-in-law 05=other unrelated (specify) ________________________

3. Type of household00=Male headed, 01=Female headed,07=Child headed

(age 16 or under)/Orphan08=other, (specify) ______________________

Section 2: -Respondent's Information

4. How many people are in your household? 01=1-3 01=4-6 02=>6
5. what is your age group of the head of household ______________

00=16-30 01=31-45 02=46-60 03=Above 60

6. Respondent's Highest level of education for the head of household ____________

00=No formal education 01=Primary 02=Secondary

03=collage education 04=Tertiary

7. What is the main occupation for the household head

00= Farmer 01=Business 02=Formal employment 04= other Specify____________

8. What is the main source of income in the household

00=Farming 01 =Formal employment 02=Business 03=other Specify----------------

Section 3: Wealth Status

9. What is the total size of households land in acres

00=0>1 acres, 01= 1-3 acres, 02= 3-5 acres, 03=5-10acres 04= 10-20acres

05 others specify -----------

10. Total land size allocated to dairy farming in acres

00=< 0.25 acres, 01= 0.25-0.5 acres, 02=0.5-2 acres, 03=2-5acres 03=5-10acres 04=>10 acres 05=others specify -------

11. No. of dairy animals owned Mature (Tick appropriately)

	00=1-3	01=4-6	03=7-9	04=> 10
Mature cows owned				
Young Cows				

12. Land tenure system

00=Secured have title deed, 01=Secured but family land, 02 =Rented 03 =squatter

13. Which of the following items does your household own at the present time?
00= Radio, TV 01=Cellphone, 02=Solar Panel, 03 =Vehicle, 04 =Tractor

Section 4: Climate Context

14. **Climate context** (related to livestock feed resource availability)
    i. What are the main climate hazards (dangers, threats) experienced in this area?

00=drought 01=flooding 02= rainfall variability 03= rainfall unpredictability 04=

extreme temperatures 05= other specify____________________

ii. What kind of effects does climate change has on your fodder/crops 00= No effect, 01= very little effect, 02= moderate effect, 03=very severe effects, 04 =other specify----------------

iii. How often does climate change hazards occur (dangers, threats) 00=every year 01=every two years, 02=every four years, 03 =other specify ------------------

15. What type of grazing system is practiced by the household?

00=free range grazing only 01 = Free range and paddocking 02= semi-zero grazing (paddocked) 03=Semi-zero and zero grazing 04=Zero grazing 05= other specify__________

Of the above grazing practices used by household, which type of climate threats below has affected you most? (You may select more than one)

00=drought01=flooding 02=rainfall variability03=rainfall unpredictability04=Extreme temperature 05= other (s) specify ____________________________

You can have more than one threat use tick appropriately

16. How sensitive is the grazing system practice used by household to the identified climate threat? (please select by ticking the climate threat and the corresponding sensitivity in the table below)

Type of climate threat **(please tick appropriate)**	00=Not sensitive	01=slightly sensitive	03=moderately sensitive	04=Very sensitive
00=drought				
01=flooding				
02=rainfall				
03=rainfall unpredictability				
04=Extreme temperature				
05=Other(s) specify ------------				

Section 5: Feed Resources

17. What is the main source of livestock feed in your household?

00 = Natural pasture on communal land 01= Natural Pasture on own farm 02 Planted Fodder 03= Crop Residue 04 =Purchased fodder

18. If your household has planted fodder/ pastures , which types have you planted (respond appropriately on the table below)

	Fodder/pasture type	Acreage 00=<0.5 01=0.5-2 02=>2	How important is the fodder to your Dairy farming. 00= Not important 01=important 02 =very important	How is the fodder/pasture type affected by climate change 00= Not affected 01=slightly affected 02=Very affected
1	Napier			
2	Rhodes grass			
3	Maize			
4	Sorghum			
5	Kikuyu grass			
7	Columbus/Sudan grass			
8	Lucerne			
9	Other specify			
10	Fodder trees	(No of trees). of tick appropriate 00=1-50, 01=50-100 02=101-150 03=>150 trees		

19. Do your household conserve/preserve fodder for future use (00=Yes 01=No)

20. If your answer is yes in the above question, which one among the following fodder do you conserve/preserve?

00=Crop residues 01=Hay 02= Silage 03= wheat straw, 04-Any other specify ______________

SECTION 6: DAIRY PRODUCTIVITY EXPERIENCE

21. What are your households dairy productivity related experiences as a result of climate change fill in the space provided

Type of climate change(drought, increased rain, unpredictability of rain)	Experiences	(00=Yes 01=No) select appropriate for each loss	Indicate whether the change is negative or positive 00=positive 01=negative	Comments e.g. change in milk production per cow increase or decrease by how much
	Changes in milk production			
	Change in amount of water available for animal			
	Change of the body condition for animals			
	Heat detection			
	Growth of calves and heifers			
	Other specify			

SECTION 7: RESILIENCE AND ADAPTATION

22. How does the household recover from negative experiences due to climate change (tick appropriately)

00=use conserved hay/silage 01= buy commercial feeds 02=use crop residue 03=move my animal to relatives/friends farms 04= I sell off some of the animals 05=others specify ---------____

Has the household put measures in place to prevent similar negative experiences related to climate change 00=Yes 01= No

23. If your answer in question above is yes which are these measures (tick appropriately)

01= Adopted of new fodder types/varieties

02=Adopted new planting methods
03= Intercropping different fodder
04= Conservation and preservation practices

24. If the household has adopted planting of new fodder types please name list below
_________________________ ________________________ __________________

25. If the household has adopted new planting methods, please list them
___
____

26. If the household uses intercropping different fodder types, please indicate the crops that you mixed____
___

27. If the household conserves and preserves fodder, list them
____
____

28. Are there other adaptation methods that the household uses to
    i. minimize the negative effects of climate change
    ____
    __
    ii. Maximize the positive effect of climate change
___
____

29. Do you use the following methods to reduce the negative effects of climate change? (please tick appropriately)

00=compost making, 01= use of biogas, 02 water conservation, 03 disease control (vaccination)

04 = Planting of fodder trees, 05=reducing the number of animals kept, 06= breeding (using AI)

APPENDIX 3: ACREAGE OF FODDER PLANTED IN NANDI COUNTY

Acreage of Napier planted per ward in Nandi County

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	34	79.1	8	18.6	1	2.3	43	100
	Kobujoi	10	83.3	0	0.0	2	16.7	12	100
	Koyo-Ndurio	27	69.2	12	30.8	0	0.0	39	100
Chesumei	Kosirai	19	90.5	2	9.5	0	0.0	21	100
	Ngechek	23	95.8	1	4.2	0	0.0	24	100
Emgwen	Kilibwoni	34	82.9	5	12.2	2	4.9	41	100
Mosop	Kabisaga	13	68.4	6	31.6	0	0.0	19	100
	Kabiyet	10	71.4	4	28.6	0	0.0	14	100
Nandi Hills	Chepkunyuk	18	81.8	4	18.2	0	0.0	22	100
	Lessos	24	77.4	4	12.9	3	9.7	31	100
Total		212	79.7	46	17.3	8	3.0	266	100

Acreage of Napier planted per Sub County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	71	75.5	20	21.3	3	3.2	94	100
Chesumei	42	93.3	3	6.7	0	0.0	45	100
Emgwen	34	82.9	5	12.2	2	4.9	41	100
Mosop	23	69.7	10	30.3	0	0.0	33	100
Nandi Hills	42	79.2	8	15.1	3	5.7	53	100
Total	212	79.7	46	17.3	8	3.0	266	100

Acreage of Rhodes grass planted per ward in Nandi County

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	14	70.0	5	25.0	1	5.0	20	100
	Kobujoi	1	50.0	0	0.0	1	50.0	2	100
	Koyo-Ndurio	13	46.4	15	53.6	0	0.0	28	100
Chesumei	Kosirai	5	71.4	1	14.3	1	14.3	7	100
	Ngechek	13	61.9	6	28.6	2	9.5	21	100
Emgwen	Kilibwoni	17	60.7	10	35.7	1	3.6	28	100
Mosop	Kabisaga	9	52.9	5	29.4	3	17.6	17	100
	Kabiyet	5	45.5	4	36.4	2	18.2	11	100
Nandi Hills	Chepkunyuk	8	100	0	0.0	0	0.0	8	100
	Lessos	5	33.3	5	33.3	5	33.3	15	100
Total		90	57.3	51	32.5	16	10.2	157	100

Acreage of Rhodes grass planted per sub county

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	28	56.0	20	40.0	2	4.0	50	100
Chesumei	18	64.3	7	25.0	3	10.7	28	100
Emgwen	17	60.7	10	35.7	1	3.6	28	100
Mosop	14	50.0	9	32.1	5	17.9	28	100
Nandi Hills	13	56.5	5	21.7	5	21.7	23	100
Total	90	57.3	51	32.5	16	10.2	157	100

Acreage of maize planted per ward in Nandi County

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	1	100	0	0.0	0	0.0	1	100
	Kobujoi	2	66.7	0	0.0	1	33.3	3	100
	Koyo-Ndurio	1	14.3	6	85.7	0	0.0	7	100
Chesumei	Kosirai	1	33.3	0	0.0	2	66.7	3	100
	Ngechek	6	50.0	3	25.0	3	25.0	12	100
Emgwen	Kilibwoni	8	34.8	10	43.5	5	21.7	23	100
Mosop	Kabisaga	2	11.8	13	76.5	2	11.8	17	100
	Kabiyet	2	16.7	10	83.3	0	0.0	12	100
Nandi Hills	Chepkunyuk	3	100	0	0.0	0	0.0	3	100
	Lessos	8	28.6	11	39.3	9	32.1	28	100
Total		34	31.2	53	48.6	22	20.2	109	100

Acreage of maize planted per sub county in Nandi County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	4	36.4	6	54.5	1	9.1	11	100
Chesumei	7	46.7	3	20.0	5	33.3	15	100
Emgwen	8	34.8	10	43.5	5	21.7	23	100
Mosop	4	13.8	23	79.3	2	6.9	29	100
Nandi Hills	11	35.5	11	35.5	9	29.0	31	100
Total	34	31.2	53	48.6	22	20.2	109	100

Acreage of sorghum planted per ward in Nandi County

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	2	66.7	0	0.0	1	33.3	3	100
	Kobujoi	3	100	0	0.0	0	0.0	3	100
	Koyo-Ndurio	4	17.4	19	82.6	0	0.0	23	100
Chesumei	Kosirai	5	83.3	1	16.7	0	0.0	6	100
	Ngechek	3	100	0	0.0	0	0.0	3	100
Emgwen	Kilibwoni	5	71.4	1	14.3	1	14.3	7	100
Mosop	Kabisaga	5	100	0	0.0	0	0.0	5	100
	Kabiyet	2	100	0	0.0	0	0.0	2	100
Nandi Hills	Chepkunyuk	4	100	0	0.0	0	0.0	4	100
	Lessos	5	35.7	3	21.4	6	42.9	14	100
Total		38	54.3	24	34.3	8	11.4	70	100

Acreage of sorghum planted per Sub County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	9	31.0	19	65.5	1	3.4	29	100
Chesumei	8	88.9	1	11.1	0	0.0	9	100
Emgwen	5	71.4	1	14.3	1	14.3	7	100
Mosop	7	100	0	0.0	0	0.0	7	100
Nandi Hills	9	50.0	3	16.7	6	33.3	18	100
Total	38	54.3	24	34.3	8	11.4	70	100

Acreage of Kikuyu grass planted per ward

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	5	50.0	2	20.0	3	30.0	10	100
	Kobujoi	5	38.5	1	7.7	7	53.8	13	100
	Koyo-Ndurio	1	50.0	0	0.0	1	50.0	2	100
Chesumei	Kosirai	10	90.9	1	9.1	0	0.0	11	100
	Ngechek	6	54.5	2	18.2	3	27.3	11	100
Emgwen	Kilibwoni	6	60.0	3	30.0	1	10.0	10	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	Na	0	Na	0	Na	0	Na
	Lessos	5	25.0	6	30.0	9	45.0	20	100
Total		38	49.4	15	19.5	24	31.2	77	100

Acreage of Kikuyu grass planted per Sub County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	11	44.0	3	12.0	11	44.0	25	100
Chesumei	16	72.7	3	13.6	3	13.6	22	100
Emgwen	6	60.0	3	30.0	1	10.0	10	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	5	25.0	6	30.0	9	45.0	20	100
Total	38	49.4	15	19.5	24	31.2	77	100

Acreage of Lucerne planted per ward

sub county	ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		total	
		freq (n)	perc (%)	freq (n)	Perc (%)	freq (n)	perc (%)	freq (n)	perc (%)
aldai	kaptumo	2	100	0	0.0	0	0.0	2	100
	kobujoi	1	100	0	0.0	0	0.0	1	100
	koyo-ndurio	5	45.5	6	54.5	0	0.0	11	100
chesumei	kosirai	2	100	0	0.0	0	0.0	2	100
	ngechek	3	100	0	0.0	0	0.0	3	100
emgwen	kilibwoni	8	100	0	0.0	0	0.0	8	100
mosop	kabisaga	0	na	0	na	0	na	0	na
	kabiyet	0	na	0	na	0	na	0	na
nandi hills	chepkunyuk	1	100	0	0.0	0	0.0	1	100
	lessos	1	25.0	1	25.0	2	50.0	4	100
total		23	71.9	7	21.9	2	6.3	32	100

Acreage of Lucerne planted per Sub County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	8	57.1	6	42.9	0	0.0	14	100
Chesumei	5	100	0	0.0	0	0.0	5	100
Emgwen	8	100	0	0.0	0	0.0	8	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	2	40.0	1	20.0	2	40.0	5	100
Total	23	71.9	7	21.9	2	6.3	32	100

Acreage of fodder tree plantedper ward

Sub County	Ward	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	11	91.7	1	8.3	0	0.0	12	100
	Kobujoi	1	100	0	0.0	0	0.0	1	100
	Koyo-Ndurio	18	81.8	4	18.2	0	0.0	22	100
Chesumei	Kosirai	4	80.0	0	0.0	1	20.0	5	100
	Ngechek	0	Na	0	Na	0	Na	0	Na
Emgwen	Kilibwoni	0	0.0	0	0.0	1	100	1	100
Mosop	Kabisaga	12	85.7	2	14.3	0	0.0	14	100
	Kabiyet	6	66.7	3	33.3	0	0.0	9	100
Nandi Hills	Chepkunyuk	0	Na	0	Na	0	Na	0	Na
	Lessos	3	100	0	0.0	0	0.0	3	100
Total		55	82.1	10	14.9	2	3.0	67	100

Acreage of fodder tree planted per Sub County

Sub County	< 0.5 acres		0.5 to 2 acres		> 2 acres		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	30	85.7	5	14.3	0	0.0	35	100
Chesumei	4	80.0	0	0.0	1	20.0	5	100
Emgwen	0	0.0	0	0.0	1	100	1	100
Mosop	18	78.3	5	21.7	0	0.0	23	100
Nandi Hills	3	100	0	0.0	0	0.0	3	100
Total	55	82.1	10	14.9	2	3.0	67	100

APPENDIX 4: IMPORTANCE OF FODDER PLANTED IN NANDI COUNTY

Importance of Napier to dairy farming per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	19	44.2	24	55.8	43	100
	Kobujoi	0	0.0	4	33.3	8	66.7	12	100
	Koyo-Ndurio	2	5.1	31	79.5	6	15.4	39	100
Chesumei	Kosirai	2	10.0	14	70.0	4	20.0	20	100
	Ngechek	0	0.0	22	88.0	3	12.0	25	100
Emgwen	Kilibwoni	0	0.0	26	59.1	18	40.9	44	100
Mosop	Kabisaga	0	0.0	0	0.0	1	100	1	100
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	0.0	6	24.0	19	76.0	25	100
	Lessos	1	3.1	12	37.5	19	59.4	32	100
Total		5	2.1	134	55.6	102	42.3	241	100

Importance of Napier to dairy farming per sub county

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	2	2.1	54	57.4	38	40.4	94	100
Chesumei	2	4.4	36	80.0	7	15.6	45	100
Emgwen	0	0.0	26	59.1	18	40.9	44	100
Mosop	0	0.0	0	0.0	1	100	1	100
Nandi Hills	1	1.8	18	31.6	38	66.7	57	100
Total	5	2.1	134	55.6	102	42.3	241	100

Importance of Rhodes grass per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	5	25.0	15	75.0	20	100
	Kobujoi	0	0.0	1	50.0	1	50.0	2	100
	Koyo-Ndurio	0	0.0	23	82.1	5	17.9	28	100
Chesumei	Kosirai	0	0.0	1	16.7	5	83.3	6	100
	Ngechek	1	4.5	6	27.3	15	68.2	22	100
Emgwen	Kilibwoni	1	3.4	11	37.9	17	58.6	29	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	1	11.1	1	11.1	7	77.8	9	100
	Lessos	0	0.0	4	28.6	10	71.4	14	100
Total		3	2.3	52	40.0	75	57.7	130	100

Importance of Rhodes grass per ward

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	0	0.0	29	58.0	21	42.0	50	100
Chesumei	1	3.6	7	25.0	20	71.4	28	100
Emgwen	1	3.4	11	37.9	17	58.6	29	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	1	4.3	5	21.7	17	73.9	23	100
Total	3	2.3	52	40.0	75	57.7	130	100

Importance of Maize planted per ward in Nandi County

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	0	0.0	1	100	1	100
	Kobujoi	0	0.0	0	0.0	3	100	3	100
	Koyo-Ndurio	0	0.0	6	85.7	1	14.3	7	100
Chesumei	Kosirai	0	0.0	0	0.0	3	100	3	100
	Ngechek	0	0.0	3	23.1	10	76.9	13	100
Emgwen	Kilibwoni	1	4.3	8	34.8	14	60.9	23	100
Mosop	Kabisaga	0	0.0	0	0.0	1	100	1	100
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	1	33.3	0	0.0	2	66.7	3	100
	Lessos	1	4.0	4	16.0	20	80.0	25	100
Total		3	3.8	21	26.6	55	69.6	79	100

Importance of Maize planted per sub county in Nandi County

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	0	0.0	6	54.5	5	45.5	11	100
Chesumei	0	0.0	3	18.8	13	81.3	16	100
Emgwen	1	4.3	8	34.8	14	60.9	23	100
Mosop	0	0.0	0	0.0	1	100	1	100
Nandi Hills	2	7.1	4	14.3	22	78.6	28	100
Total	3	3.8	21	26.6	55	69.6	79	100

Importance of sorghum planted per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	2	66.7	1	33.3	3	100
	Kobujoi	0	0.0	2	66.7	1	33.3	3	100
	Koyo-Ndurio	0	0.0	20	87.0	3	13.0	23	100
Chesumei	Kosirai	0	0.0	3	50.0	3	50.0	6	100
	Ngechek	0	0.0	1	33.3	2	66.7	3	100
Emgwen	Kilibwoni	0	0.0	3	42.9	4	57.1	7	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	0.0	0	0.0	3	100	3	100
	Lessos	0	0.0	2	16.7	10	83.3	12	100
Total		0	0.0	33	55.0	27	45.0	60	100

Importance of sorghum planted per Sub County

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	0	0.0	24	82.8	5	17.2	29	100
Chesumei	0	0.0	4	44.4	5	55.6	9	100
Emgwen	0	0.0	3	42.9	4	57.1	7	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	0	0.0	2	13.3	13	86.7	15	100
Total	0	0.0	33	55.0	27	45.0	60	100

Importance of Kikuyu grass planted per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	3	30.0	7	70.0	10	100
	Kobujoi	0	0.0	0	0.0	13	100	13	100
	Koyo-Ndurio	0	0.0	0	0.0	2	100	2	100
Chesumei	Kosirai	0	0.0	6	50.0	6	50.0	12	100
	Ngechek	0	0.0	3	27.3	8	72.7	11	100
Emgwen	Kilibwoni	0	0.0	4	40.0	6	60.0	10	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	Na	0	Na	0	Na	0	Na
	Lessos	0	0.0	2	11.1	16	88.9	18	100
Total		0	0.0	18	23.7	58	76.3	76	100

Importance of Kikuyu grass planted per Sub County

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	0	0.0	3	12.0	22	88.0	25	100
Chesumei	0	0.0	9	39.1	14	60.9	23	100
Emgwen	0	0.0	4	40.0	6	60.0	10	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	0	0.0	2	11.1	16	88.9	18	100
Total	0	0.0	18	23.7	58	76.3	76	100

Importance of lucerne planted per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	0	0.0	1	50.0	1	50.0	2	100
	Kobujoi	0	0.0	0	0.0	1	100	1	100
	Koyo-Ndurio	0	0.0	10	83.3	2	16.7	12	100
Chesumei	Kosirai	0	0.0	0	0.0	2	100	2	100
	Ngechek	0	0.0	3	75.0	1	25.0	4	100
Emgwen	Kilibwoni	0	0.0	3	37.5	5	62.5	8	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	0.0	0	0.0	1	100	1	100
	Lessos	0	0.0	1	25.0	3	75.0	4	100
Total		0	0.0	18	52.9	16	47.1	34	100

Importance of Lucerne planted per Sub County

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	0	0.0	11	73.3	4	26.7	15	100
Chesumei	0	0.0	3	50.0	3	50.0	6	100
Emgwen	0	0.0	3	37.5	5	62.5	8	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	0	0.0	1	20.0	4	80.0	5	100
Total	0	0.0	18	52.9	16	47.1	34	100

Importance of fodder tree planted per ward

Sub County	Ward	Not Important		Important		Very important		Total	
		Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	Kaptumo	2	12.5	8	50.0	6	37.5	16	100
	Kobujoi	0	0.0	1	100	0	0.0	1	100
	Koyo-Ndurio	0	0.0	18	100	0	0.0	18	100
Chesumei	Kosirai	1	33.3	0	0.0	2	66.7	3	100
	Ngechek	0	Na	0	Na	0	Na	0	Na
Emgwen	Kilibwoni	0	0.0	0	0.0	1	100	1	100
Mosop	Kabisaga	0	Na	0	Na	0	Na	0	Na
	Kabiyet	0	Na	0	Na	0	Na	0	Na
Nandi Hills	Chepkunyuk	0	Na	0	Na	0	Na	0	Na
	Lessos	0	0.0	1	100	0	0.0	1	100
Total		3	7.5	28	70.0	9	22.5	40	100

Importance of fodder tree planted per sub County

Sub County	Not Important		Important		Very important		Total	
	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)	Freq (n)	Perc (%)
Aldai	2	5.7	27	77.1	6	17.1	35	100
Chesumei	1	33.3	0	0.0	2	66.7	3	100
Emgwen	0	0.0	0	0.0	1	100	1	100
Mosop	0	Na	0	Na	0	Na	0	Na
Nandi Hills	0	0.0	1	100	0	0.0	1	100
Total	3	7.5	28	70.0	9	22.5	40	100