UNIVERSITY OF NAIROBI

PERCEPTIONS, CHALLENGES AND ADAPTATION STRATEGIES TO CLIMATE CHANGE AND VARIABILITY: THE CASE OF SMALLHOLDER DAIRY FARMING SYSTEMS IN SIAYA SUB-COUNTY, SIAYA COUNTY

By

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Dedication

This work is dedicated to my family for their support during my sojourn at ICCA and my parents (Mama Truphena Amunga and the late Papa Stanley Amakobe) for their love and care during my formative years.

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Abstract

An in-depth understanding of perceptions, challenges and adaptation strategies of Smallholder Dairy Farming Systems (SDFS) is crucial if appropriate interventions to increase adaptive capacities to climate change and variability (CCV) are to be undertaken. This study aims to determine adaptation strategies that have the potential to create resilient SDFS in Siaya Sub-County, Siaya County and probable up-scaling to similar agro-ecological zones. This arises from observations that CCV expressed as frequent droughts and floods is singled out as the main hindrance to agricultural production. The study uses mixed methods approach including household surveys, participatory methods, statistical data analysis and literature review. From the results obtained, it emerged that the climate of the study location had changed with droughts perceived as being the most frequent. Analysis of climate data showed long-term drying of all seasons except SON/D yet SDFS had not changed their planting exposing them to frequent crop failure. Correlation coefficient (r) analysis of rainfall data revealed that annual cumulative rainfall was strongly positively correlated ($r>0.5$) to JJA and SON/D but weakly positively correlated ($r=0.494$) to MAM implying MAM contribution to maize, beans, Napier and pasture production was on the wane. MAM/J and MAM had a very strong ($r=0.9$) positive correlation ($p=0.004$), while JJA and MAM/J had a weak ($r=0.487$) positive correlation ($p=0.004$) implying that the June precipitation strongly contributed to MAM aggregate rainfall effects. Similarly temperatures were perceived to have increased resulting in biome range shifts exhibited by invasive plant species initially associated with hotter regions of the County. Results from a binary longit regression model showed that invasive plant species, temperature, floods, frequency of drought and poor waste management had significant effect on incidences of livestock diseases ($p<0.05$). Tsetse flies and ticks were identified as major vectors ($p<0.05$) associated with prevalence and spread of livestock diseases with flare-ups for the former becoming more frequent. Some of the adaptation strategies observed included use of maize stovers as a livestock feed, water from shallow wells and roof catchment, high yielding Napier and pasture grass varieties, regular vaccinations, spraying, and bush clearing. Barriers to adaptation strategies identified and included: institutional barriers through consistent top-down approaches used to initiate and implement programs; out of reach technologies for SFDS; social barriers that impeded flow of related climate information; cultural practices that hindered timely land operation; religious barriers were attributed to some sects burning rearing of pigs and dairy goats that would otherwise enhance livelihoods. This study recommends that: SDFS should enhance adaptive capacities against CCV through diversification of livelihoods by expansion of enterprises to safeguard against asset erosion during times of extreme climate perturbations; multisectoral policies to steer institutions from "Path Dependency" be formulated to get rid of institutional rigidities; mechanisms to timely and adequately fund the sector be instituted; early warning weather system be developed; empirical studies of CCV effects on different fodders be conducted to enable targeted adaptation strategies aimed at increased resilience of SDFS.

Table of Contents **Page**

List of Tables

List of Figures

List of plates

List of Abbreviations and Acronyms

ACE	Action for Community Empowerment
ASFs	Animal Source Foods
ASDSP	Agriculture Sector Development Support Program
AGRA	Alliance for Green Revolution in Africa
ASDSP	Agriculture Sector Development Support Program
BAU	Business as Usual
CP	Conceptual framework
CCV	Climate Change and Variability
DJF	December-January-February
DMI	Dry matter intake
EbA	Ecosystem based Adaptation
ENSO	El Niño South Oscillation
FAO	Food and Agricultural Organization of the United Nations
FGDs	Focused group discussions
GCMs	General circulation models
GHGs	Greenhouse gases
GIS	Geographical Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
HH	Household
HHs	Households
ICIPE	International Centre for Insect Physiology and Ecology
ICPAC	IGAD Climate Prediction and Applications Centre
IPCC	Intergovernmental Panel on Climate Change
JJA	June-July-August
KALRO	Kenya Agricultural and Livestock Research Organization
KENTTEC	Kenya Tsetse and Trypanosomiasis Eradication Council
KMD	Kenya Meteorological Department
KNBS	Kenya National Bureau of Statistics
KI	Key informant

LGP	Length of growing period
LUMs	Land Use Maps
MAM	March-April-May
MAM/J	March-April-May/June
MPTs	Multipurpose trees
MMDCS	Mur Malanga Dairy Cooperative Society
NAMA	Nationally Appropriate Mitigation Action
NGOs	Non Governmental Organizations
NSD	Napier Stunt Disease
PAR	Participatory action research
PRA	Participatory Rural Appraisal
RCP	Representative Concentration Pathways
RVF	Rift Valley Fever
SACCO	Savings and Credit Cooperative Organisation
SCIDC	Sub-County Information and Documentation Centre
SDF	Smallholder dairy farms
SDFS	Smallholder dairy farming systems
SMD	Snow Mould Disease
SON	September –October-November
SON/D	September –October-November/December
SSA	Sub-Saharan Africa
SST	Surface Temperature
SRES	Special Report on Emission Scenarios
TDR	Transdisciplinary Research
THI	Temperature Humidity Index
UNCED	United Nations Conference on Environment and Development
USAID	United Tsetse Agency for International Development
WCDD&FMP	Western Kenya Community Driven Development and Flood Mitigation Project
WHO	World health Organization

Definition of Terms

Adaptive capacity - The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages in order, to take advantage of opportunities, or to cope with the consequences.

Biome - a large naturally occurring community of flora and fauna occupying a major habitat.

Biome Range Shift – Northward movement of species to higher elevations (latitudes) influenced by temperature increase.

Biophysical vulnerabilities – the inabilities of biological and physical environment to withstand extreme climate and weather events attributed to temperature and precipitation.

Climate Change and variability – Climate change refers to a change in the state of the climate that can be identified by changes in the mean or variability of its properties, and that persists for an extended period, typically decades or longer (minimum is 30 years) while climate variability refers to variations beyond individual weather events in the mean state and other statistics of the climate (such as standard deviations, the occurrence of extremes, etc.) on all spatial and temporal scales.

Long rains season – the traditional rainfall season occurring in the moths of March-April-May

Maladaptation - Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Resilience **-** the capacity for a socio-ecological system to absorb stress and maintain its function in the face of external pressure exerted to it by climate change and variability.

Short Rains Season - the traditional rainfall season occurring in the moths of September-October November

Socio-Economic – relating to or concerned with social and economic factors.

Smallholder Dairy Farming Systems – Mixed crop farming (crop and fodder production) dominated by *Bos taurus* breeds for milk production and income.

Vulnerability - the inability to resist a hazard or to respond when a disaster has occurred

CHAPTER ONE

INTRODUCTION

1.1: Background

Climate change and variability (CCV) poses the greatest threat to livestock production systems with dire consequences on food security, more so Animal Source Foods (ASFs). Smallholder Dairy Farming Systems (SDFS) characterised by mixed crop and livestock production is one of several production systems in East Africa, dominated by *Bos taurus* (exotic cattle) breeds for milk production (van den Bossche and Coetzer, 2008; Kabirizi et al., 2014; Thornton and Herrero, 2014). Under this system, *Pennisetum purpureum* (Napier grass) as a bulk fodder alongside other fodder legumes and food crops are cultivated under rainfed conditions hence highly susceptible to CCV (Kotir, 2011). Rising temperatures and frequent droughts due to altered precipitation patterns are expected to lead to increased production pressure on SDFS further aggravating food insecurity (Kotir, 2011; World Bank, 2013; FAO, 2014). Moreover, regional climate models predict that more areas in Sub Saharan Africa (SSA) will be more arid in future with dire consequences on rural livelihoods arising from significant crop and ASFs yield reductions attributed to altered Length of Growing Period (LGP) (Kotir, 2011; FAO, 2014).

It is further projected that reduced Length of Growing Period (LGP) along with increased frequency of failure of traditionally grown crops reaching maturity will trigger shifts from SDFS (mixed crop and livestock production) to more dominant livestock based food production that is likely to offset the food production balance (Mertz et al., 2009; Niang et al., 2014). For instance Anyamba et al. (2014) cite the case of Texas in the United States of America and Volga District of Russia, where the 2010-2011 drought associated with the La Niña weather phenomenon led to abandonment of cornfields in the former and 13.3 million hectares of grain area in the latter leading to serious food shortfalls. Similarly FAO (2014) attributed CCV to loss of 8% in maize production in Eastern Province of Kenya due to poor harvests caused by early cessation of the 2011 short rains. According to Williams and Funk (2011) and Niang et al. (2014) changing rainfall patterns impact water availability and when coupled with increased surface temperatures are bound to strain smallholder production systems with direct impacts on food security due to reduced yields hence low rural farm incomes (FAO, 2011; IPCC, 2014). For instance, wheat, maize and rice yields have been observed to reduce considerably under elevated temperatures and when taken as proxy of fodder availability then climate change without adaptation is projected to negatively impact SDFS at regional scales (IPCC, 2014). This will further be compounded by high risks of vector-borne diseases of cattle and fodder crop diseases envisaged to be favoured by a warming climate (Porter et al., 2014).

Elevated temperatures manifest as heat stress that affects all classes of cattle though *B. taurus* breeds are more susceptible compared to *B. indicus* (indigenous cattle breeds), as the latter are better adapted to high ambient temperatures common in SSA (van den Bossche and Coetzer, 2008). Heat stress is observed to adversely affect reproductive performance of *B. taurus*, beside overall low productivity expressed as a proxy of milk yield (*ibid*). Similarly high temperatures are also positively correlated to livestock disease incidences. For instance high occurrence of clinical mastitis, an economically devastating disease of dairy cattle is triggered by hot and humid weather conditions that are also a prerequisite for heat stress (Singh et al., 2012; Jingar et al., 2014). Besides, similar weather conditions aggravate infestation by cattle ticks leading to high tick borne disease occurrences (Singh et al., 2012).

Additionally, diseases such as Rift Valley Fever (RVF) associated with flooding as a result of intense precipitation are projected to increase due to CCV (FAO, 2013), that is already impacting farming systems yet SSA is singled out as one of the regions that CCV impacts will be most felt (IPCC, 2014). Adaptation strategies that assist SDFS to cope better with CCV now and in future are therefore deemed necessary hence this study in North Alego location of Siaya sub-county which represents a region of moderate agricultural potential (MOA, 2009).

1.2: Problem Statement

Africa is cited as having experienced 382 drought events in different areas (Shiferaw et al., 2014) over the past four decades hence a climate change vulnerability hotspot (Thornton, 2006). Such phenomena are projected to put more pressure on the already fragile SDFS reliant on rainfed agriculture, characterised by low adaptive capacities that jeopardise abilities of the farming systems to cope with climate shocks. This further increases the possibility of eroding farm incomes thus exacerbating food insecurity and in the process creating the “new poor” due to more households falling into poverty traps (Beddington et al., 2012; World Bank, 2013; Alliance for Green Revolution in Africa (AGRA), 2014; Carabine et al., 2014). Shongwe et al. (2011) point out that the frequency of hydro-meteorological hazards over the East African region have increased from an average of less than one in 1980s' to around 10 events per year between 2000 and 2006 with the number of flood events on the rise due to increased incidents of anomalously strong rainfall. At the same time Gautam (2006) in Shiferaw et al. (2014) observed that the East African region has undergone long term drying for the past five decades which is exhibited by increased frequencies of drought.

The Great Lakes region of Eastern Africa (under A1F1 and B1 scenarios) in which the study was conducted is singled out as one of the climate change vulnerability hotspots in relation to reduced LGP with catastrophic effects on SDFS due to reduced fodder quantities (Thornton et al., 2006). This view is corroborated by Carabine et al. (2014) and Niang et al. (2014) who indicated that: seasonal average temperatures in Eastern Africa have increased over the past 50 years; rapid warming of the Indian Ocean over the last 30 years has led to depressed long rains season with droughts and storm bursts becoming more frequent. Furthermore adverse impacts of climate change including depletion of aquifers and increased incidences of crop failure are inevitable in future (Kotir, 2011; Williams and Funk 2011; FAO, 2014); yet blue water would be ideal as an alternative source of both food and fodder production under irrigated systems.

The research therefore intended to gather and analyse climate data on perceptions, challenges and adaptation strategies adopted by SDFS due to CCV. This was necessitated by the need to identify and bridge adaptation gaps to adverse effects of climate change for rapid adoption of technologies which emphasize improved resource productivity that include: a reduction of ecological footprint associated with SDFS to achieve increased soil conservation and fertility; appropriate resource decoupling while increasing productivity per unit area with low generation of livestock waste. Besides no prior work on perceptions, challenges and adaptation strategies of SDFS to CCV covering the study location existed hence the study also acted as a baseline.

1.3: Research Questions

The research focused on how CCV impacts SDFS to attain increased adaptive capacities for enhanced food security. Consequently the following research questions guided the study:

1) What climatic factors are perceived as major challenges to SDFS in the study area?

2) What adaptation strategies are deployed in SDFS as a result of negative impacts of CCV?

3) What barriers hinder adaptation strategies of SDFS in the study area?

Hypothesis of the study

The following null hypotheses were designed to test corresponding specific objectives of the study:

a) There are no differences in perceptions of major climatic factors in SDFS ($\mathbf{H_{O1}}$)

b) There are no differences in adaptation strategies deployed by SDFS as a result of negative impacts of CCV ($\mathbf{H_{O2}}$)

c) There are no barriers hindering adaptation strategies amongst SDFS in the study location ($\mathbf{H_{O3}}$)

1.4: Objectives of the study

1.4.1: Overall Objective

The overall objective of the study was to increase adaptive strategies of Smallholder Dairy Farming Systems to adverse effects of Climate Change and Variability, in Siaya Sub-County

1.4.2: Specific Objectives

The specific objectives of the study were to:

1) assess perceptions of major climatic factors affecting SDFS in the study area and how these compare with the long term observed and established climate trends;

2) identify adaptation strategies deployed in SDFS due to negative impacts of CCV and factors that influence these adaptation actions; and

3) analyse barriers hindering adaptation strategies with a view of bridging adaptation gaps for increased resilience of SDFS to CCV in the study location.

1.5: Justification and Significance of the Research

Climate change whose effects include: erratic rainfall; reduced water quantity and quality; occurrence of frequent fires; flooding (leading to siltation of rivers, dams and lakes due to soil erosion) and temperature increase coupled with frequent diseases outbreaks is singled out as the main hindrance to agricultural production in Siaya Sub-County (GOK, 2013). Moreover, on global and regional scales, it is documented that farmers use indigenous knowledge, local knowledge systems and household level research to adapt and reduce negative effects of CCV (Mertz, 2009; IPCC 2014). Noting that complex impacts of climate change are observed to be localised and area specific (Thornton et al., 2007), analysis of area specific perceptions of major climatic factors and perturbations that affect SDFS will enable policy makers better understand, farmers' enhanced judgments of alternative adaptation strategies through informed choices and response measures that effectively ameliorate impacts of CCV.

Crops and livestock production characterised by low input and low output production methods are integrated into SDFS with heavy reliance on *P. purpureum* (Napier grass) as a bulk fodder (Kabirizi et al., 2014). Frequent droughts, floods and increased temperatures affect both quantity and quality of fodder translating to low dairy cattle performance associated with poor nutrition (FAO, 2011). Moreover, CCV is projected to lead to reduced LGP for crops and forages further contributing to reduced availability of fodder quantity and quality alongside reductions in the amounts of crop residues used as supplementary feeds for *B. taurus* breeds reared under SDFS (Knox et al., 2012; FAO, 2014; Niang et al., 2014; Thornton and Herrero, 2014). These scenarios have led to dynamic complexities with corresponding dynamic farming systems where SFDS test and adopt both indigenous and modern technologies that work best for increased productivity. For instance the "tumbukiza[1]" method of Napier grass production solely

[1] This is a Kiswahili word meaning "to put into a hole or pit" and is a system of planting Napier grass in pits fertilized heavily with cow manure. Round pits similar to those used when establishing bananas are the most common and on average are 60 cm in diameter and 60 cm deep, spaced at about 60 cm in rows of 60 cm apart. The sub-soil excavated from the second foot depth is discarded and the first foot of excavated top soil is mixed with manure and returned to the hole that is covered leaving a six inch space from the top to facilitate water harvesting. Each hole is then planted with 6 seed canes of Napier grass to a depth of 25 centimeters.

used for purposes of increasing in-field water harvesting hence lengthening fodder growing period due to increased soil moisture retention is one indigenous method that is smallholder farmer driven (Kabirizi et al., 2014). Understanding such SDFS led strategies are vital for researchers to devise best suited technologies that further ameliorate impacts of CCV on SDFS.

SDFS form one of the most important key livelihood strategies of rural communities in Kenya with dominance over the national milk sector accounting for 80% of total milk produced and a corresponding agricultural Gross Domestic Product (GDP) of 30% (FAO, 2011). Alongside CCV other factors that afflict SDFS include: poor agronomic practices; reduced fodder and crop residue yields; land fragmentation; declining soil fertility; increased incidences of pests and diseases; lack of capital (to aid adaptation measures); socio-cultural and religious factors; levels of infrastructural development; facilities that include ready markets, institutions, technology; early warning and early action system for timely dissemination of weather and climate information (Thornton et al., 2007; FAO, 2011; Beddington et al., 2012; Jayne and Muyanga, 2012; Antwi-Agyei et al., 2013; FAO, 2014). An understanding by both policy makers and researchers, of specific factors that affect performance of SDFS are crucial in establishing barriers that hinder adaptation strategies hence aid in bridging adaptation gaps that have a direct bearing on increased resilience hence better Household (HH) livelihoods.

1.6: Scope of the Research

This study was designed to gain insights on perceptions, challenges and adaptation strategies deployed by SDFS in the study location due to adverse effects of CCV that were then contrasted with long term climate data and trends. Climate change challenges and adaptation strategies were similarly determined and compared with those documented in existing literature sources to assist in determining points of convergence and divergence. The sampling technique was purposive and resulted to administration of questionnaires to households (HHs) practicing SDFS in North Alego Location of Siaya Sub-County due to very low densities of *Bos taurus* breeds in other locations implying that random sampling would have led to coverage of very extensive areas hence non-homogenous strata.

Farmers not practicing SDFS were not included in household surveys though their views were taken on board through Focused Group Discussions (FGDs) on perceptions of longterm climate trends, cropping and cropping calendar patterns. Transect walks were undertaken to establish biophysical vulnerabilities alongside adaptation measures associated with local knowledge systems. FGD Participants on long-term climate trends were restricted to members of the community who were resident in the area and were old enough in 1975 to discern adverse climate events from normal phenomena while the FGD group on cropping calendar patterns were those who had practiced farming for a minimum of ten years and considered successful by extension workers deployed in the study location.

1.7: Limitations of the study

Kadenge rainfall station had inconsistent rainfall data submitted to the KMD between 1968-2004 which ceased in 2005 prompting downloading proxy rainfall data from TAMSAT (Map Coordinate, Latitude-0.060287; Longitude-34.288296); which is an accepted procedure in the absence of quantified longterm ground observational rainfall records for relatively small domains (Lyon and Dewitt, 2012; Maidment et al., 2015). Annual rainfall data (1975-2014) representing a period of 39 years and monthly rainfall data covering a period of 31 years (1983-2014) was obtained from TAMSAT. This was deemed a long enough period to conclude that shifts in rainfall and hence climate for the study location had occurred. Besides there were no facilities that recorded daily minimum and maximum temperatures of the region causing use of long term temperature records for Kisumu station as proxy data (KMD, 2011).

Members of the Focused Group Discussions (FGDs) on longterm climate trends relied on recall memory which in some instances led to inconclusive discussions and longer sessions for themes under study; while Some households declined to be interviewed prolonging the duration of questionnaire administration due to increased distances between farms amidst limiting resource availability. Poor road infrastructural network in sections of the study location coupled with torrential short rains of October 2015 slowed down fieldwork leading to exclusion of SDFS that were located in impassable areas. Other factors included lack of production data from relevant Production Departments due to none availability of annual reports hindering determination of crop and fodder production and consumption trends on a cumulative basis. None demarcation of land and issuance of title deeds obstructed comparisons of acreage under fodder as a proportion of whole land parcels to determine intensification levels and technology transfer on SDFS as institutional inputs towards bridging barriers to adaptation. Quantification of biome range shift was not done as it was outside the scope of the study. Besides migration of invasive species is given in meters per year (m/year) under different climate scenarios (Garamvölgyi and Hufnagel, 2013) though other researchers for instance Schwartz (1992) in Garamvölgyi and Hufnagel (2013), estimated range shift of some of the plant species to be in the range of 10 to 40 km/century hence quantification of range shifts in the study location would have entailed a relatively long period of study requiring prior establishment of baselines.

1.8 Overview of Methodological Approach

This research is transdisciplinary entailing use of mixed research methods to accommodate different knowledge systems in order to bring results to fruition. Though each method has its own proponents coupled with strengths and weaknesses, it has been established that none of the methods when used singularly adequately addresses transdisciplnary problems (Hadorn et al., 2008). Quantitative aspects of this research have their origin in the doctrine of Positivism Philosophy also referred to as the scientific paradigm and is anchored on empirical research with focus on science as the only way to learn the truth (Scotland, 2012) through quantification. As such it is based on the premise that the researcher and the researched exist independently where "meaning solely resides in objects not in the conscience of the researcher, and it is the aim of the researcher to obtain this meaning" (Crotty, 1998, in Scotland, 2012).

Similarly, qualitative aspect of the study is based on Constructivist Philosophy which shifts focus on how people gain knowledge. It is grounded on the principle that people perceive and construct their world views through cognitive processes hence the researcher and the researched exist and interact, and through such interaction new knowledge is created (Turyahikayo, 2014). Results deduced by participants taking part in qualitative research are more subjective since each participant has a different view of a phenomenon under study that leads to the existence of multiple realities. Despite this, Constructivism upon which qualitative data is expressed in words and observations is an age old concept having been used in biological sciences (*ibid*). Positivism and Constructivism have a convergence point as scientific study and real world practical experiences are under focus (Bergold and Thomas, 2012).

CHAPTER TWO

LITERATURE REVIEW

2.1: Climate Change Scenarios and Predictions

Future global warming and to a large extend climate outlook is documented using climate model simulations anchored on Representative Concentration Pathways (RCPs) of radiatively important greenhouse gases (GHGs) and aerosols to obtain scenarios of plausible futures (van Vuuren et al., 2011). Based on Integrated Assessment Models (IAMs), the pathways are used to run new climate simulations under the framework of Coupled Model Intercomparison Project Phase 5 (CIMP5) and whose results form the basis of the climate system projections (*ibid*). There are four trajectories (RCP2.6 or RCP3-PD, RCP4.5, RCP6, and RCP8.5) relative to pre - industrial levels that describe four possible climate futures based on radiative forcing (RF W m^{-2}) values of GHGs near or the end of 2100 (van Vuuren et al., 2011; Wayne, 2013). RCP8.5 represents high emission scenarios devoid of policy intervention leading to High GHGs concentrations over time and is similar to A1F1 under the former SRES, RCP6 represents intermediate emissions influenced by technological inputs that target GHGs emission reductions and is similar to B2 scenario. RCP4.5 represents intermediate emissions equivalent to a future of ambitious low emissions similar to B1while RCP2.6 (RCP3-PD) represents low emissions where RF peaks to 3.1W m^{-2} and thereafter declines to 2.6W m^{-2} (Wayne, 2013). This particular RCP has no equivalent under the former SRES (*ibid*)

Data from Global Circulation Models (GCMs) is run across these RCPs for plausible climate futures (climate projections) that inform adaptation options for increased resilience of farming systems (ICPAC, 2016). For instance from the three RCPs (RCP2.6, RCP4.5 and RCP8.5) for 2020s, 2030s, 2050s and 2070s compared to reference period (1970 – 2000) project that the short rains, October-November-December (OND) will increase over most parts of the Greater Horn of Africa (GHA) under all the three scenarios while long rains March-April-May (MAM) and June-July-August-September (JJAS) will decrease with the exception of the Southeastern part of Lake Basin (*ibid*). Similarly maximum temperature will warm considerably during the MAM and JJA/S seasons compared to OND while minimum temperature is projected to exhibit a similar trend but at higher scales (*ibid*). These echo findings by Hulme et al. (2001), Thornton et al. (2006), van de Steeg et al. (2009), Knox et al. (2012) that temperatures will continue to rise at higher rates while there will be differences in rainfall variability across large regions in Africa; though East Africa will have a relatively stable rainfall regime due to evidence of longterm wetting. Carabine et al. (2014) though in agreement single out the months of August and September as exceptions that will be drier at the turn of the century of which, based on RCP scenarios is in tandem with ICPAC (2016).

However, GCMs have been observed to have coarse resolutions hence need downscaling to obtain higher regional resolutions that depend on availability of accurate historical weather and climate data to better predict weather and climate (Jones and Thornton, 2013). This is a major constraint in developing countries as longterm climate records are not available (AGRA, 2014), yet ground stations have continued to deteriorate and therefore inadequate data to complement satellite readings (Jones and Thornton, 2013). According to Funk et al. (2011) satellite readings are not in sync with *in situ* ground observation stations though they are accurate enough in determining areas that are relatively wet or warm from dry or cool ones. This observation is corroborated by Jones and Thornton (2013) who concur that MarkSim, a developed GCM downscaler for the tropics underestimates or overestimates annual rainfall variances over much of the areas tested giving rise to further uncertainties in weather and climate predictions (Porter et al., 2014). Jones and Thornton (2013) reported having used the MarkSim GCM to accurately predict areas of SSA where cereal production will be greatly affected by CCV hence likely to lead to shifts to predominantly livestock production systems. Thus despite shortfalls of GCMs it is generally agreed that they give good estimates of future impacts of CCV though poor in weather prediction (*ibid*).

While GCMs are useful in predicting future CCV, recent observations in rainfall changes have been determined using reconstructed longterm satellite based data due to lack of ground based observational records (Lyon and Dewitt, 2012; Maidment et al., 2015) and it is on this basis that MAM rainfall over the Eastern Africa region has been established to be in constant decline over the latter decades while precipitation over the Sahel has exhibited longterm wetting (Williams and Funk, 2011: Maidment et al., 2015).

2.2: Previous Work done in relation to the topic

2.2.1: Features and Importance of SDFS

SDFS are increasingly becoming important in provision of ASFs whose demand is bound to rise with population growth projected to reach 9.3 billion people by 2050 (Giovannucci et al., 2012). In order to feed the world, agricultural production has to increase by 60% from the base period 2005/2007 to 2050 of which 77% of this has to occur in developing countries (Alexandratos and Bruinsma, 2012). This calls for sustainable intensification of SFDS for increased production to meet future ASFs demand and attain food security in the face of continued land fragmentation (Giovannucci et al., 2012; Jayne and Muyanga, 2012).

Land fragmentation and increased rural-urban migration (Giovannucci et al., 2012) poses further threats to SDFS livelihoods due to erosion of farm labour; yet these systems consist of a majority of food produced in Africa where women account for 80% of food production (*ibid*), meaning that African farmers are predominantly women smallholders. According to *Boserup's hypothesis* intensification increases working time (Ringhofer et al., 2014) implying that in the absence of alternatives labour friendly technologies (for instance mechanization), high labour demand translates to increased inequalities as women being major producers of food are further strained as a result of additional chores *(ibid*). It is further argued that even in the prescience of mechanization, it is only men's well-being that is improved as they have more time due to rapid accomplishment of labour related tasks at the expense of women who manually carry out additional activities brought about by intensification (*ibid*) hence less time for social activities.

According to Atuhaire et al. (2014) SDFS align their operations to target specific niche markets but are bedeviled by constantly low productivity per unit area which confines them to subsistence production hence low productivity that hinders farm diversification. Giovannucci et al. (2012) observed that diversification is one of the means through which farmers can manage soils for increased fertility, use water efficiently to increase production per drop and maintain ecosystem functions through biodiversity conservation. This observation is similar Kristjanson et al. (2012) who opine that the most food insecure HHs make very little changes in farming practices amidst high rainfall variability and increased incidences of extreme events hence more vulnerable to impacts of CCV. This implies that most commodities produced on-farm by SFDS are consumed at home with low volumes taken to the market for sale signifying constant low farm incomes.

While many factors that constrain SDFS productivity have been identified, quality and quantity of fodder beside availability of by-products used as feed supplements are singled out as key (Thornton et al., 2009). Feed resources on these systems consist of natural pastures, improved pastures, cultivated fodder and fodder legumes, and crop residues (FAO, 2011; Wambugu et al., 2011) but owing to the mode of rearing livestock, natural pastures do not play a major role towards fodder provision unless for purposes of harvesting standing hay in exceptional circumstances since *B. taurus* breeds are hardly grazed on open pastures due low forage yields coupled with declining land sizes (Wambugu et al., 2011; Jayne and Muyanga, 2012). Besides, low investments in forage development at the family level hampers quality fodder production (FAO, 2011) which is made worse by seasonality of forage availability with dearth periods occurring during periods of prolonged droughts and flooding in lowlands (Porter et al., 2014).

In Kenya SDFS number more than one million and dominate milk production accounting for 80% of the national total (Wambugu et al., 2011) where dairy animals are stall fed using the cut and carry system complemented by commercial concentrates though use of inputs is still low. SDFS thus form one of the main sources of food and livelihood sustenance due to incomes from milk sales and employment creation across the value chain (FAO, 2011; Atuhaire et al., 2914).

2.2.2: Effects of Climate Change on of SDFS in Relation to Crops and fodder

Data of effects of CCV on various crops and their future performance under a warming climate is documented by use of various models and forms the basic indicators of future availability of crop residues that will be crucial for supplementary feeding on SDFS during fodder dearth periods (Knox et al. 2012; Thornton and Herrero, 2014). For example, Kotir (2011) and AGRA (2014) observed that rising temperatures and rainfall variability will alter suitability of land used for growing traditional food and fodder crops in many regions thus posing challenges to food security and fodder availability amongst SDFS who will be most affected due to their low adaptive capacities. Further, it has been observed that regions where crop losses are likely to be significant will shift to more dominant livestock oriented production systems, or totally abandon farming activities all together if severe crop losses become persistent (Thornton et al., 2009;

Anyamba et al., 2014; Niang et al., 2014). These scenarios are bound to put SDFS under continuous production strain with dire implications for HH food security and farm incomes.

Maize and beans are singled out as the most commonly grown crops on SDFS and whose yields though differently quantified are negatively correlated to rising temperatures (Schlenker and Lobell, 2010; Knox et al., 2012). For instance, Porter et al. (2014) documented that maize yields decline under temperature increases of 1ºC to 2ºC of local warming, while Thornton et al. (2009) approximated that this loss will be in the range of 10%-20% by 2055. Lobell et al. (2011) pegged this loss at 1.7% for each day spent above 30ºC under drought conditions. Elevated temperatures will therefore, affect crop yields translating to low availability of supplementary feeds (maize stover) (Porter et al., 2014) and bean husks (Kobayashi et al., 2016) used in SFDS since high temperatures coupled with high moisture stress will alter the LGP with probable failure of suitable cropping seasons due to increased soil moisture evaporation (Jones and Thornton, 2009; van de Steeg et al., 2009; FAO, 2014). Additionally, anticipated altered precipitation patterns will have effects on: soil erosion; soil fertility; crop and fodder damage due to increased floods, further worsening availability of crop residues and fodder alongside water which is crucial in all livestock and crop related production systems (Thornton et al., 2006; Kotir, 2011; FAO, 2014; Porter et al., 2014).

Thornton and Cramer (2012) reported that data on direct effect of CCV on cultivated fodders was scanty, with the assumption that forages are resilient. While extensively grown on SDFS and despite their similarity data on maize performance under a changing climate cannot be effectively taken as a proxy of forage availability, since the perennial growth nature of forages means that they are more exposed to weather variability and climatic extremes (water logging as a result of flooding and intermittent droughts) during off-season maize production periods, implying that they will be more affected.

2.2.3: Direct impacts of CCV *on Bos Taurus* breeds

Documentation of direct impacts of CCV on *B. taurus* breed of cattle exists but its effects on their productivity in the tropics and sub-tropics with the exception of the cool highlands is not well established, hence difficult to quantify (Thornton et al., 2009; Porter et al., 2014). Thornton

(2010) concluded that CCV has negative impacts on SDFS hence earlier postulation that rearing of heat tolerant animals will become more beneficial in a future warming climate (Kabubo-Mariara, 2008; Van den Bossche and Coetzer, 2008;Niang et al., 2014). But, according to Hoffmann (2010) selection for heat tolerant animal breeds will compromise dairy production since single trait selection forms the basis of high performance in *B. taurus* implying that milk yields and therefore productivity will be affected. Increased temperature has also been observed to be correlated to heat stress and on such occasions reduce feed intake exhibited as low cattle performance (Van den Bossche and Coetzer, 2008). West (2003) observed that increases in air temperature, Thermal Humidity Index (THI) and rectal temperature led to reduced Dry Matter Intake (DMI) and milk yields, with a five month loss of milk ranging from 300-900Kg for animals producing 33Kg of milk per day. Chauhan and Ghosh (2014) reported similar findings. Reduced DMI implies lower weight gains as a proxy of growth rates, increased mortality (Porter et al. 2014) and disruptions in reproductive patterns that range from 3-5% for every additional 1ºC rise in temperature due to reduced feed intake, translating to a productivity loss of 10-20% (Thornton and Cramer, 2012).

Other impacts of CCV on SDFS are attributed to emergence of vector-borne diseases mediated through spread of disease vectors and pathogens. According to Van den Bossche and Coetzer (2008) these impacts are difficult to quantify due to other non climatic stressors that play crucial roles in animal health management. However, other studies have tried to empirically quantify these impacts based on evidences of observed relationships between climatic conditions and biological behaviour of the vectors. Accordingly, Anyamba et al. (2014) confirmed the existence of a positive correlation between flooding, favourable temperatures and *Aedes* mosquito populations infected with the RVF virus following the 2010-2011 La Niña season in South Africa, which led to the most extensive and most widespread outbreak of RVF since 1970. Porter et al. (2014) reported similar trends of RVF outbreaks in the East Africa region that were positively correlated to the El Niño South Oscillation (ENSO) event during the same period. Additionally it is observed that climate change will lead to alterations of host pathogen range that will affect diversity and variations in disease abundance (*ibid*). In this respect, Mills et al. (2010) reported a northerly range shift of *Ixodes scapularis,* a vector responsible for babesiosis, Lyme disease and human granulocytic anaplasmosis that is bound to expand its range further north as it becomes less endemic in its traditional southern habitats; a phenomenon that will lead to increased emergence of diseases and pests in non-traditional regions.

2.2.4: Adaptation Strategies employed by SDFS

Production of ASFs in developing countries is reliant on rain fed agriculture and will be further constrained due to frequent droughts, intense floods, and rising temperatures with a direct bearing on fodder production (Jones et al., 2012; Munang et al., 2013) and call for urgent adaptation efforts for livelihood sustenance. Adaptation when used in the context of climate change policy implies human reactions designed to decrease damage related to extreme climate change events (Noble et al., 2014). Similarly it has been observed that there are no classified adaptation options though three broad categories exist; "soft", "hard" and Ecosystem Based adaptation (EbA) with the later being a hybrid of the first two (Jones et al., 2012; Munang et al., 2013; Noble et al., 2014).

Soft adaptation approaches entail non-structural options (information, policy, capacity building and institutional functions) that encourage behavioural change that enable affected vulnerable communities to deal better with climatic shocks, while hard adaptation options involve use of technologies and actions that require huge capital outlay (engineering, irrigation infrastructure) (Jones et al., 2012) implying that "soft" adaptation options can be easily reversed as opposed to "hard" ones. On the other hand, EbA is deployed to take advantage of nature in order to cushion affected communities against extreme climatic events through continuous and efficient delivery of ecosystem services (Jones et al., 2012; Munang et al., 2013). It has been observed for instance that when well deployed, ecosystem services can be used to diversify livelihoods through broadening resource-use options ("soft" adaptation) or flood regulation and storm surge protection ("hard" adaptation) (Munang et al., 2013).

The three broad adaptation options form the scope on which adaptation strategies are derived to address appropriate needs (Noble et al., 2014) by the at risk groups. According to Settele et al. (2014) adaptation strategies are necessary since it has been established that ecosystems are under constant threat from CCV and under RCPs (RCP2.3/3PD – RCP 6) there is bound to be large-scale biome shifts (Eigenbrod et al., 2015) implying changes in ecosystem composition

(Munang et al., 2013) while extensive extinction of ecosystems is projected to occur under RCP 8.5 (Settele et al., 2014) further constraining ecosystem functions with serious consequences on provision of food and fodder. Noble et al. (2014) concur and further state that human and natural systems have capacities to cope with adverse elements but with CCV adaptation will be needed to support coping mechanisms devised by the at risk communities. Adverse impacts of climate change have therefore necessitated the most at risk to adapt through broad dimensions though not all affected individuals have the same adaptation capacity since adaptation is influenced by socio-economic factors, institutions, infrastructure, natural resources and governance structures (*ibid*).

Several adaptation strategies exist though they are place and context specific (IPCC, 2014). For instance one of the adaptation strategies deployed due to increased environmental temperature on SFDS is shed modification that guards against effects of direct high solar radiation hence lowering heat stress (Mahajan et al., 2014). Shelters constructed for this purpose and depending on their complexity comprise of “hard” adaptation strategies since they can be complex and are capital intensive as they require large amounts as money to construct. This latter phenomenon is common on highly specialized dairy farms and is observed to contribute towards increased livestock productivity. For instance, Mahajan et al. (2014) observed that in studies contacted in Florida, lowering heat stress through construction of properly designed sheds only led to increased milk yield of between 10-19% in *B. taurus*, while in Argentina similar breeds under similar sheds exhibited lower afternoon rectal temperature and produced more milk. Wood et al. (2014) observed a similar trend while Mahajan et al. (2014) show that sheds when combined with sprinkler systems have better effects on milk yields; such advanced technology is beyond the reach of SDFS in SSA due to high poverty levels that curtail resource availability for creation of resilient systems, establishment of simple shelters (made of locally available materials) without any modification is widespread though no studies have been done with regard to milk yields when these structures are constructed under naturally growing trees for additional shading (soft adaptation strategy) (*ibid*).

Studies have established that adaptation responses of SDFS to CCV vary across regions and are influenced by the capacity of a community’s ability to perceive climatic changes and institute strategies that effectively counter associated negative impacts for sustained production (Codjoe and Owusu, 2011). According to IPCC (2014) adaptation is place and context specific with no single approach employed that appropriately reduces risks across board. As such, various methods with deviants from the long established traditional technological pathways for tackling CCV have emerged to the extent that local knowledge systems comprising holistic views of the environment are considered key resources in adapting to a changing climate (IPCC, 2014; Porter et al., 2014).

Further it has been noted that, local knowledge systems are not consistently used alongside the traditionally long established methods deployed to ameliorate negative effects of CCV leading to low effectiveness of adaptation strategies (IPCC, 2014; Porter et al., 2014). Additionally it has been observed that rapid CCV can render local knowledge systems ineffective leading to barriers that compromise adaptive capacities. This gives impetus for provision of additional information on climate impacts; its associated risks and adaptation options for increased resilience of SDFS (Porter et al., 2014). This line of thought is based on the premise that farmers make cropping decisions based on local perceptions but are unable to link long-term climatic changes to performance of agro-economic crops that comprise key livelihoods due to factors that include education levels (Rao et al., 2011).

Households (HHs) have thus been shown to make adaptation strategies based on the most recent climatic shocks rather than long established climate trends and are meant to cushion against anticipated extreme events hence ex-ante in nature (Bryan et al., 2013). Some of the strategies and activities SDSF engage in border on technology for instance change of crop type and variety and water harvesting, the rest are based on intuition arising from cognition and include; changing planting dates, use of farm by-products to feed livestock, soil and water conservation, deep tillage, change of fertilizers, crop and fodder diversification, increasing acreage under crops, and woodlot establishment (Nzeadibe et al., 2012; Below et al., 2013; Bryan et al., 2013; Tesfaye and Seifu, 2015). According to Bryan et al. (2013) technology in the form of early maturing hybrid crop varieties, planting drought tolerant crops, and rearing livestock breeds that withstand harsh environmental conditions are becoming common on SDFS. Of the studies on adaptation, Bryan et al. (2013) reported a considerable shift from cereal to livestock dominated production systems due to a surge in acreage under *P. purpureum*. Mertz et al. (2009) observed a similar trend while Niang et al. (2014) stated that SDFS are bound to predominantly shift to livestock activities as an adaptation strategy to adverse effects of CCV.

2.2.5 Negative Consequences of Adaptation Strategies

Adaptation strategies are cited as the best options available for increasing resilience on SDFS but not all adaptation strategies yield positive results that help in ameliorating adverse effects of CCV since some of the options lead to increased HH vulnerabilities (maladaptation). Such Maladaptations do not just arise from inadvertently poorly planned actions (Noble et al., 2014) but also from decisions that target short-term results at the expense of future threats (Magnan et al., 2016). For instance Lamhauge et al. (2011) cite an example of construction of well-engineered and climate proofed roads that withstand climate extremes and could foster new settlement into areas highly exposed to adverse impacts of future climate shocks thus increasing vulnerabilities of settled communities. Communities settling and farming in such areas that have leverage of superior infrastructure for ease of accessing other amenities can be considered an adaptation strategy in the short term but a maladaptation due to future adverse impacts of climate change (Shongwe et al., 2011).

Similarly Magnan et al. (2016) highlight cases of damming rivers upstream for irrigated crop and fodder production at the expense of humans and biota downstream which at times turn out to be maladaptive since vulnerabilities to drought of lower communities increase due to lack of sufficient water for irrigation, domestic use and diminished ecosystem provisioning services. In some cases damming of rivers for purposes of electricity production have ended up trapping fertile soils (silt) upstream consequently lowering farm productivity downstream (*ibid*). This is a further example of a case of construction of major infrastructure for economic purposes which, though done with good intentions ends up causing maladaptation downstream.

The same scenario is seen to apply in the case of Afar pastoralists of Ethiopia made destitute by flooding, displacement and loss of livestock from construction of a dam that is currently used to produce irrigated sugar (Magnan et al., 2016) instead of its intended original purpose which was for the production of irrigated pastures and water for the pastoralists especially during water scarcity periods. Many recorded cases of maladaptation therefore arise from hard adaptation options that are technology oriented with huge capital outlay.

2.2.6 Studies Related to Farmer Perceptions in Relation to Climate Change

Studies of farmer perceptions to CCV have been carried out and documented using various methods and approaches (for instance Mertz et al., 2009; Hartter et al., 2012; Kamanzi and Mapiye, 2012; Kasulo et al., 2012; Kalungu et al., 2013; Below et al., 2014; Tesfaye and Seifu, 2015), with different outcomes. For example, Hartter et al. (2012) and Below et al. (2014) from their studies of farmer perceptions deduced that local people's perceptions coupled with assessment of environmental factors was important in understanding adaptation responses for livelihood sustenance, while Kalungu et al. (2013) observed that not much was known about how farming households' agricultural practices had evolved based on perceptions and impacts of CCV despite existing scientific knowledge. But Codjoe and Owusu (2011) in the case of the Ghanaian Afram plains inferred that adaptation strategies implemented by farmers during periods of extreme climate perturbation formed part of the basis of future planning at higher governance levels further reinforcing observations that grassroots communities equally have important roles in knowledge creation (IPCC, 2014) with regard to CCV..

In these studies, analysis of data on farmer perceptions and adaptation strategies to CCV was done using diverse tools that included: household surveys using questionnaires for instance (Mertz et al., 2009; Codjoe and Owusu, 2011; Hartter et al., 2012; Kamazi and Mapiye, 2012; Kasulo et al., 2012; Kalungu et al., 2013), FGDs, Participatory Rural Appraisals (PRAs) and stakeholder workshops (Mertz et al., 2009; Codjoe and Owusu, 2011; Below et al., 2014), key informant interviews (Mertz et al., 2009), and transect walks (Kamazi and Mapiye, 2012), though tools such as livelihood mapping using seasonal calendars and land use maps are not mentioned despite their potential in real time tracking of environmental changes.

CHAPTER THREE

METHODOLOGY

3.0: Introduction

This chapter describes the research methodology employed in the study. It highlights a detailed outline of the study location, selection of the study population, data collection and analytical methods used for every strategic objective.

3.1: Description of the Study Area

Siaya Sub County is bordered by Busia County to the West and North West, Ugunja Sub County to the North, Gem to the East and Bondo to the South (figure 1). It lies approximately between latitude 0º 26´ South to 0º 18´ North and longitude 33º 58´ and 34º 33´ East (GOK, 2013). Siaya Sub County is one of the six sub-counties that make up Siaya County with 23.94% of the total County area (2,530km²) making it the largest

The Sub county has a fairly good road network (GOK, 2013) and according to Codjoe and Owusu (2011) a well-developed physical infrastructure is important and has the potential of aiding adaptation strategies amongst the rural poor due to its ability to contribute towards rapid access to social amenities that enable interactions of communities with appropriate state and financial institutions as the latter have a role to play in livelihood diversification hence the ability of the at risk communities to cope with climate shocks. Siaya sub-county has a current population 207,369 with a density of 342.3persons/km^2 which is relatively high, hence will need to produce more food to meet the burgeoning population amidst CCV (GOK, 2013).

The 2009 population census indicated the whole County comprised 2.2% of the total national population which is substantial when the rest of the counties are taken into consideration nationally (Runguma, 2014). Majority of the population in the county making up 65.3% is below 24 years old (figure 3. 2). It is observed that boys dominate in the 0-4, 5-9, 10-14 and 15-19 age brackets but this pattern reverses in the higher age cohorts. This phenomena is attributed to life expectancies which stand at 38.3 years for males and 43.6 years for females respectively (GOK, 2013) and has implications on provision of labour for agricultural production since it is a prerequisite for effective adaptation strategies in SDFS (Antwi-Agyei, 2013). One notable feature of the county is that it has a 79.75% literacy level which is high by Kenyan standards (GOK, 2013).

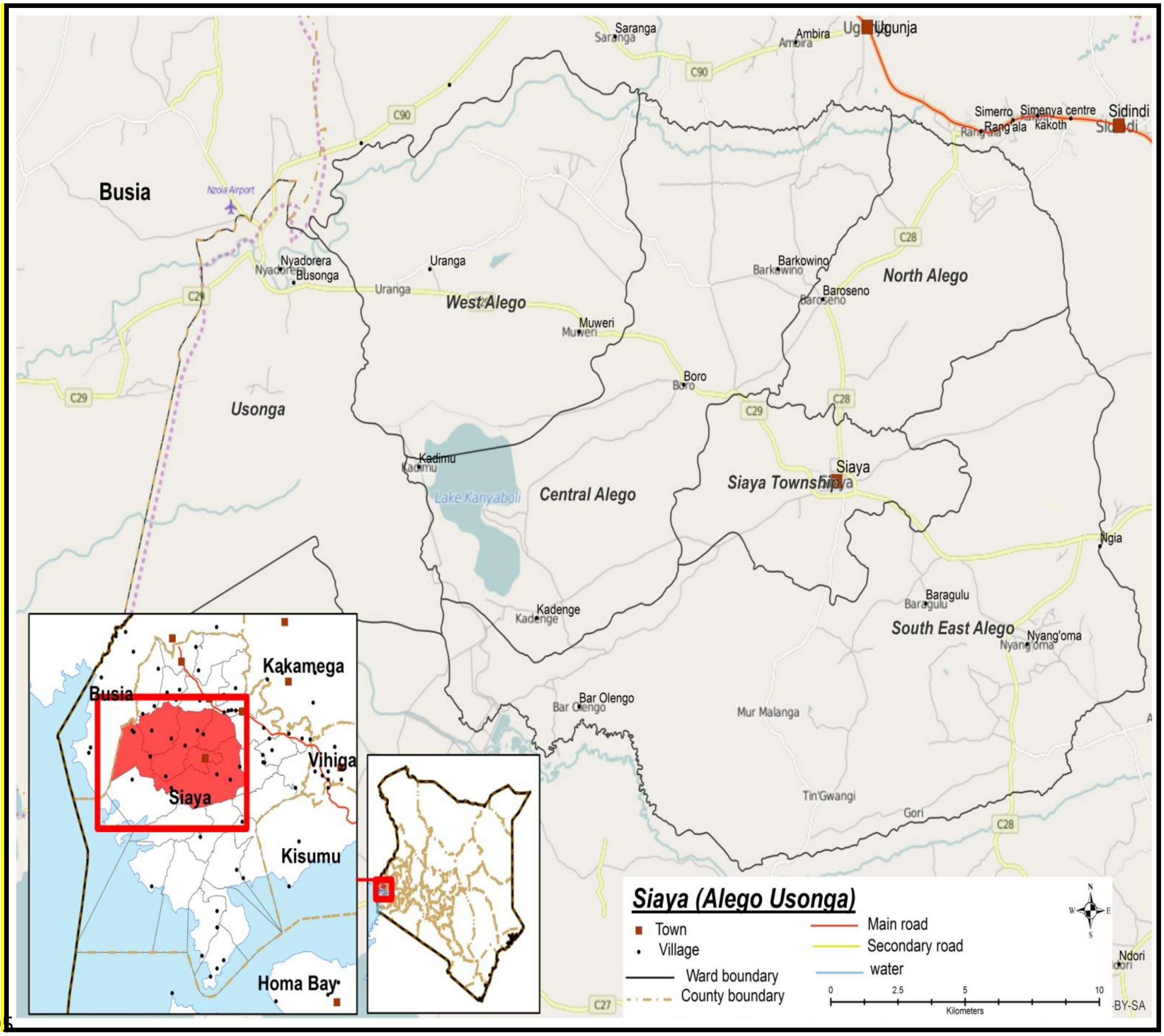


Figure 3.1: map of Siaya Sub-County showing the study location

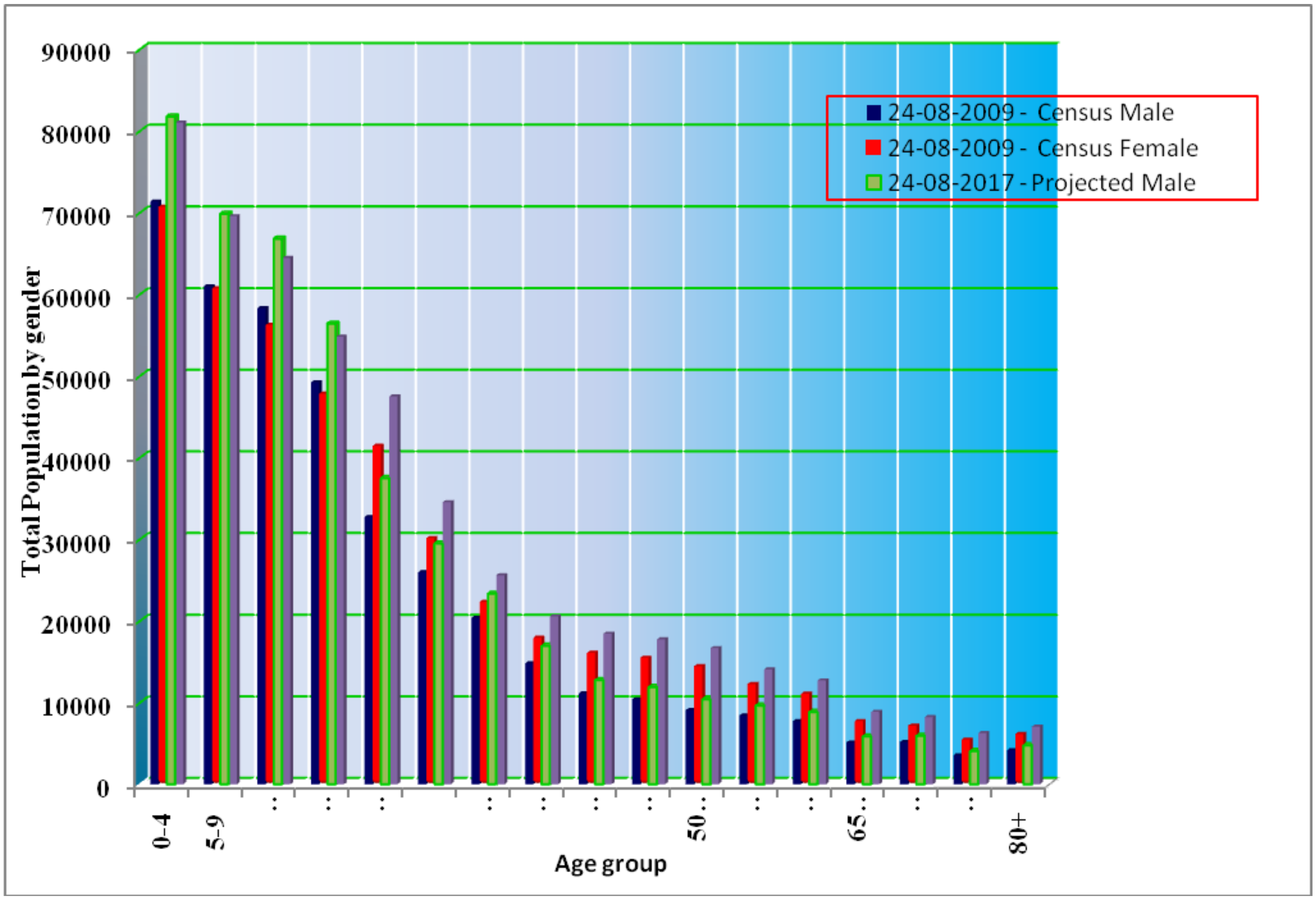


Figure 3.2: 2009 population census compared to 2017 projections by age and gender. Constructed from data population density by age cohorts provided in table 3 (GOK, 2013).

3:2 Biophysical setting/Environment

Siaya Sub County is well endowed with natural features and resources which when natured and properly conserved will contribute to the overall wellbeing of the population

3.2.1: Climate and Vegetation

Rainfall patterns of the study area are bi-modal with long rains occurring between March and June and short rains between September and December (MOA, 2009). Temperatures vary with altitude but on average range from 16.3°C to 29.1°C. Humidity is relatively high with mean evaporation range of 1,800mm to 2,200mm per annum (GOK, 2013) and when heat stress element is taken into account could pose a challenge in rearing of *B. taurus* breeds (West, 2003). The Sub County belongs to Agro-Ecological zone LM_2 hence a marginal sugarcane zone while small patches towards Rangala are transitional LM_1 (MOA, 2013).

The Sub County has hill top forested hills (Mbaga and Odiado) covered by various indigenous tree species interspersed with exotic ones (GOK, 2013) though its tree cover is low (2.8%) compared to the national requirement of 10% (GOK, 2013; Oloo et al., 2013). Several indigenous shrubs are also found though on the wane due to diminishing fallow land resulting from population pressure. *Tithonia diversifolia* (African sunflower) and *Lantana camara L*. (Obengele) shrubs dot fallow land (Oloo et al., 2013). However *L. camara L*. is a strong competitor (Simba et al., 2013) that smothers grasses leading to insufficient forage.

3. 2.2: Land Use and Resources

Siaya Sub-county is endowed with various natural resources that provide livelihoods for the rural people besides playing a major role in food security. Agricultural activities consisting of small scale rainfed farming are carried out on approximately carried out on approximately 47,800 Ha of arable land (Oganyo et al., 2016) with maize, sorghum, millet, beans, cowpeas, cassava, sweet potatoes, groundnuts and finger millet being cultivated on subsistence basis, though sugarcane, cotton, rice and groundnuts are considered as the major cash crops (GOK, 2013). Common livestock enterprises include dairy and indigenous zebu cattle breeds, sheep, goats, dairy goats, beekeeping, pigs and indigenous poultry; but the dairy cattle density is low as it makes only 10% of the total county cattle herd (GOK, 2013). This trend is consistent with the national data where in 2007, the former Nyanza province accounted for 5.9% of the total national dairy cows in milk and only 1.64% when the national *B. indicus* breeds in milk were included (FAO, 2011).

There are no major industries hence low employment rates but the informal agricultural sector plays an important role through hiring on-farm seasonal labour coupled with job opportunities created by farmer based marketing institutions such as agricultural based cooperatives (GOK, 2013). According to Wood et al. (2014), farmer oriented institutions raise the prospects of opportunities to access support initiatives such as markets for products and inputs that can spur production and adoption of technologies hence building adaptive capacities and resilience.

3.2.3: Water Resources

The Sub County has several rivers that form its drainage system into Lake Victoria of which Yala and Nzoia rivers are the main ones (GOK, 2013). Other water infrastructure consists of

Lake Kanyaboli, Lake Sare, water pans and dams (ibid). Ground water potential for deep boreholes and shallow well is high though this diminishes towards Lake Victoria where underground aquifers have high salinity, posing irrigation challenges, despite the fact that this region of the Sub County experiences water scarcity most (GOK, 2013). On the upper parts of the Sub county that border Ugenya, Ugunja and Yala, shallow wells are established at less than 45ft deep but this increases to about 75ft in the central parts of Boro and Karemo (*ibid*).

3.3.: Biophysical Vulnerabilities

Diminishing ground and tree cover as a consequence of deforestation due to brick making, house construction, and firewood harvesting for cooking purposes exposes the biophysical environment to factors that accelerate its deterioration. Low vegetative cover leads to increased surface runoff that has a bearing on: soil fertility as a consequence of soil erosion; recharge of aquifers hence water spring discharge; water carrying capacities of reservoirs as a result of rapid siltation; formation of gullies that reduce areas suitable for cultivation (Ochola, 2006; UNEP, 2006). Due to soil erosion water bodies in the County have high turbidity leading to high costs of water treatment (GOK, 2013; Oloo et al., 2013). This phenomenon is bound to worsen as the frequency of extreme climatic events including storm bursts and floods are projected to increase in future (Shongwe et al., 2011; Carabine et al., 2014; Niang et al., 2014; Porter et al., 2014).

This situation is made worse by invasive species such as *Lantana camara* whose growth habit has led to invasion of natural pastureland, smothering grasses relied on for grazing, with the risk of an upward surge in Trypanosomiasis, a vector borne cattle disease due to tsetse fly (*Glossina sp*) population build up since *L. camara* forms suitable breeding and resting sites for the vector (Simba et al., 2013), yet dairy breeds reared under SDFS are vulnerable to tropical diseases (van de Bossche and Coetzer, 2008).

3.2.5:Socio-Economic setting

The Sub County is heavily reliant on subsistence rainfed agriculture and therefore vulnerable to food insecurity due to CCV worsened by high poverty levels (Niang et al., 2014). Rural poverty is estimated to be 57.93% representing 400,599 people who live below the poverty line hence characterization of the county as a “wasteland dominated by poverty and underdevelopment” (Runguma, 2013). However Siaya County Profile (2014) describes the county as contributing to national economy through up-scaling of industrial crops such as sorghum, a major ingredient in beer production, as well as cotton, fruits and soya beans. However, Runguma (2014; pp. 147-149), based on field interviews and observations, has a contrary opinion and opines that the Sub County's economy is "gorogoro based[2]" due to perennial food shortages hence over reliance on the market for food purchases especially maize; yet this is the main staple of the inhabitants. Based on the latter argument, the Sub County with the exception of large scale rice production and milling by Dominion Farms Ltd in the reclaimed Yala swamp together with sugar (GOK, 2013) plays a very minor role in the national economic setting.

3.2.6: Socio-economic Vulnerabilities

The county experiences a wide range of socio-economic vulnerabilities due to high levels of unemployment whose consequence is migration of young, educated and able-bodied people to major towns and cities in search of better livelihoods (Runguma, 2014) resulting in the collapse of the social fabric. As a result women and the elderly take on additional and untraditional gendered roles (opening up of land for farming, taking care of livestock and looking after the young and sick) besides offering social protection (WHO, 2011; Runguma, 2014); long hours of exposure in unfamiliar environment have high possibilities of post traumatic stress disorder which not only is a disease by itself but also a precursor of other health complications that is a further stressor to women (WHO, 2011). Low food and fodder production is correlated to CCV hence high incidences of food insecurity that leaves farmers with no option but to supplement food deficits by direct purchases from markets (Runguma, 2014) that add to erosion of meager incomes leaving no surplus for investment in alternative economic activities.

3.3: Theoretical Framework

Article 39(a) of Agenda 21 (UNCED, 1992) recognizes that complex environmental problems cannot be solved using one single method, the hallmark of monodisciplinarity. This, therefore, calls for the need to incorporate various methodologies that emphasise integration of several disciplines to be able to achieve sustainable development. It has been envisaged that solving of complex environmental problems can be achieved by blending different scientific fields and

[2] This is a commonly used term in Kenya though mostly in the western parts of the country to denote a two kilogram tin.

knowledge alongside the inclusion of the at-risk communities through active participation of the most impacted societies with the objective of triggering full ownership of solutions derived through Transdisciplinary Research (TDR) processes (Kindon et al., 2007; Hadorn et al., 2008).

One of the methodologies in TDR, described as “a collaborative process of research, education and action explicitly oriented towards social transformation” (Kindon et al., 2007; p.9) is Participatory Action Research (PAR). It takes cognizance of the fact that knowledge exists on several planes and that grassroots communities have equal roles in knowledge production, hence the expression “those who have been most systematically excluded, oppressed, or denied, carry specifically revealing wisdom about the history, structure, consequences and the fracture points in unjust social arrangements” (Kindon et al., 2007; p.9). To effectively address TDR, PAR employs several methods of which; FGDs, diagramming, participatory mapping, transect walks, Geographical Information Systems (GIS), questionnaires, participant observations are documented as the most commonly used (Kindon et al., 2007; MacDonald, 2012).

Instances exist where PAR methodologies in TDR have been successfully used to solve environmental and societal problems that resulted to full ownership of solutions. For instance, Schelling et al. (2008) used TDR to solve health services problems amongst the “hard to reach” pastoralist communities of Chad by integrating; medicine (both human and veterinary), anthropology, epidemiology, social geography, microbiology disciplines, with incorporation of local community experiences and concepts. This approach not only managed to provide adapted health services for the pastoral communities but also achieved improved infrastructure and social amenities. Similarly Kiteme and Wiesmann (2008) used the same methodology to solve river management problems with TDR progressing from monodisciplinary to transdisciplinary approaches in the upper Ewaso Ng’iro North basin of Kenya, leading to integrated sustainable river basin management. As a result, Water Users Associations (WUAs) that are emulated across regions today emerged as one of the TDR milestones. TDR in this particular case led to strengthening of local institutions leading to attainment of program goals through; systems, target and transformational knowledge. But PAR just like any other method has its own weaknesses of which plurality of meaning, community involvement versus commitment to the research process and time for relationship building and its legitimization, are documented as major obstacles (MacDonald, 2012).

3.3.1: Conceptual Framework

The conceptual framework (CF) (figure 3.3) visualizes CCV as a complex phenomenon broken down into independent variables that form the basis of analysis of their effects on dependent variables in relation to perceptions, challenges and adaptation strategies on SDFS.

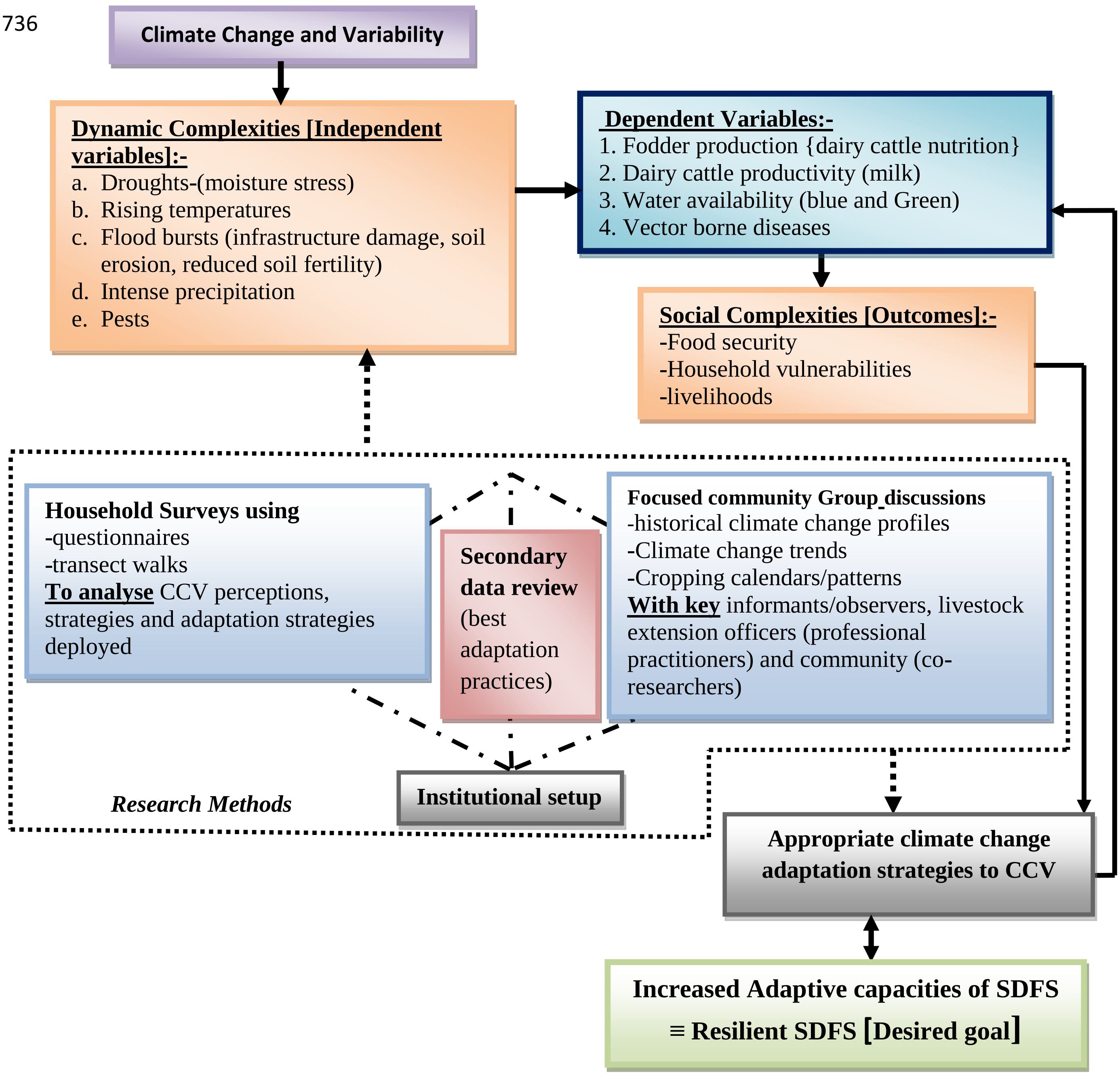


Figure 3.3: Conceptual framework

Independent variables depicted (figure 3.3) are conceptualized as causal factors (droughts, rising temperatures, flood bursts, intense precipitation and pests) while dependent variables (fodder production, dairy cattle productivity, water availability and vector borne diseases) impact food security and household vulnerabilities whose final outcome through appropriate adaptation strategies has a bearing on adaptive capacities of SDFS. An assumption is made that a positive intervention as a result of uptake of appropriate adaptation strategies leads to resilient SDFS with implications on food security and livelihoods. Effects of independent variables on is envisaged to be achieved through analysis and use of research methods (household surveys, FGDs, review of secondary literature and institutional roles) through TDR to achieve the desired goal. This entails for instance finding out perceptions, challenges and strategies deployed by SDFS on effects of drought on: water availability; fodder production; vector borne diseases; and dairy cattle productivity (expressed as a proxy of milk production) through household surveys. The CF is iterated and takes an approach of a process based framework that relates to how the variables influence each other together with their impacts on SDFS.

Based on CCV, the framework reflects the range of actors and institutions involved in the TDR process which in most instances are overly broad, diverse and can vary to such an extent, based on the relevance and significance of aspects under focus including the duration of the study and levels of resources at hand, to enhance activities such as field facilitation targeted towards enhancement of adaptive mechanisms. Besides FAO (2014) recognizes that management of natural resources under CCV is complex and requires involvement of a broad-spectrum of practitioners, perspectives and specialized knowledge to achieve resilient food production systems as a way of moving away from the business as usual (BAU) scenarios.

3.4: Methods

Introduction

The study adopted a methodology that comprised of qualitative and quantitative research (mixed) methods. Qualitative research was used to gather information on the study objectives through participatory tools that included seasonal calendars, transect walks and FGDs. FGDs were used to draw historical profiles (1975-2014) of perceived major climatic trends and how they related documented data from established climate centres. Structured questionnaires incorporating recall questions were administered on SDFS in order to generate quantitative data that was analyzed using Statistical Package for Social Sciences (SPSS) (Pallant, 2005). Results obtained from the study tools were presented using simple descriptive statistics that included tables, percentages, pie charts and graphs. For ease of clarity tools used to address each strategic objective were independently highlighted.

3.4.1: Primary sources of data

Primary data sources for the study included FGDs that explored major climatic trends since 1975 and elucidated decadal cropping calendars (2004 and 2014), structured questionnaires (appendix VI) and transect walks. Interviews with key informants from relevant National Government, County Government (including County Executive Committee Member for Agriculture, County Chief Officer, Sub-County Livestock Production Officer, Sub-County Agricultural Officer, Sub-County Water and Irrigation Officer, Sub-County Forest Services Officer, Sub-County Zoologist), Non Governmental Organizations (World Vision, ACE Africa, Siaya Bunge SACCO, and Send a Cow),Civil Organizations (Red Cross), Mur Malanga Dairy Cooperative Society (MMDCS) and participant observers (retired chiefs and teachers who were singled out as opinion leaders in the community) were held.

3.4.2: Secondary sources of data

A comprehensive literature review relevant to the study research questions and objectives was carried out. Statistical data (for instance livestock population, milk production trends, main sources of fodder, livestock disease trends), was collected from the County Information and Documentation Centre (CIDC) and socio-economic data (including human population density, infrastructural developments and networks, land use and resources, water resources, biophysical vulnerabilities and economic setting) from existing socio-economic projects carried out in the area to form part of the background information. Rainfall data for the area was downloaded from TAMSAT (Map Coordinate, Latitude-0.060287; Longitude- 34.288296) while long-term temperature data for Kisumu station was used as proxy temperatures for the study location. The period in question for rainfall data was 1975 - 2014 (40 years) for annual rainfall and 1983-2014 (31 years) for monthly rainfall.

3.4.4: Objective 1-Trends and Perceptions of Climate Factors Affecting SDFS

This objective was addressed using several tools:

3.4.4.1: FGD on Longterm Climatic Events

Members of this FGD were purposively chosen with the help of the area chief, Sub-county Livestock Production Officer and Sub county Agricultural officer. The group consisted of 7 members aged 60 years old and who were resident in the area but not necessarily practitioners of SDFS. This age bracket was chosen on the premise that FGD members at this age could still remember clearly profiles of major climatic shocks and that they were already knowledgeable enough by 1975 to discern normal climatic events from extreme ones. The aim of this was to establish, using recall questions, perceptions in trends of long-term climatic extremes and how they had impacted SDFS.

The recall questions covered the period 1975-2014 (40 years) and captured the following; perceived drought and flood years, perceived years of severe storms and winds, perceived years with very cold temperatures, perceived years with very hot temperatures, perceived years with extreme cold events during dry seasons, perceived years associated with pest invasion such as locusts and other debilitating vectors, changes in the composition of flora and fauna, perceived possible causes of these changes, perceived coping mechanisms deployed during extreme events.

3.4.4.2: Analysis of Rainfall data

Rainfall data downloaded from TAMSAT (satellite) (Map Coordinate: Latitude-0.060287; Longitude-34.288296) covering the period 1975 to 2014 was analyzed using descriptive statistics (mean, minimum and maximum parameters), correlations based on inter and intra season, pentad, and interdecadal scale variability in climate trends.

3.4.4.3: Presentation of FGD results on long-term Climatic Events

Results of this FGD were presented using a trend line that captured years of perceived extreme climate events that were compared to existing literature and long term annual minimum and maximum temperatures together with long term annual rainfall trends for the Sub County. This aided in determining whether perceptions as drawn by FGDs were in tandem with recorded climate data.

The trend line drawn was accompanied by a record of the proceedings, in instances capturing *verbatim* discussions attributed to respective FGD participants. Major trends in environmental changes associated to climate variability were also recorded alongside associated vulnerabilities in the study location.

3.4.4.4: FGD on Cropping Calendars

This FGD involved purposively selected 7 successful farmers selected by the area chief, Sub-county Livestock Production Officer and Sub county Agricultural officer to establish whether cropping patterns had changed over a span of 10 years (between 2004 and 2014) due to CCV and what aspect of climate caused the change, if any. The average number of years in farming for the group was 15.

3.4.4.5: Presentation of FGD results on Cropping Calendars

Outputs of this FGD were summarised using wheeled diagrams that compared the 2014 seasonal cropping calendar to that of 2004 to enhance visualization of changing cropping patterns as drawn by the FGD participants and to check for major differences attributed to CCV if any alongside changes in livelihood patterns. The wheels were also used to depict periods of household food in/security. Results from this FGD were further used to complement perceptions and adaptation strategies deployed to ameliorate effects of CCV from HH information gathered from questionnaires and FGDs on long-term extreme climatic events.

The low number of FGD participants provided an optimal environment for dialogue based on recall questions that related to past extreme climatic events and led to generation of useful and comprehensive information. This approach was based on the premise that FGDs are socially oriented processes that use group interviews to capitalize on communication between the research participants and the community for generation of information (Macdonald, 2012).

3.4.5: Objective 2 – Adaptation Strategies in SDFS

3.4.5.1: Sampling Technique

Purposive sampling was carried out to select SDFS (homogeneous sampling) that reared *B. taurus* breeds as a major source of income. This decision was taken as the study sample was a difficult-to-reach group (FAO, 2011) (in section 3.2.2 of this thesis). Selection of participants for the research therefore reflected the objective of investigation hence modeled more on a case study approach (Palys, 2008).

3.4.5.2: Study Sample

The study sample comprised of 100 purposively selected HHs practicing SDFS and was based on Kathuri and Pals (1993) in Waithavu (2012) observation that a sample of 100 respondents is ideal for a regional study.

Structured questionnaires were administered at household levels to generate quantitative data. Areas of interest included socio-economic aspects of the target group, perceived effects of climate change, impacts, challenges and strategies used to ameliorate adverse effects of CCV. Areas covered included: precipitation (perceived annual onset; perceived cessation; perceived length of dry spells, etc); temperatures (perceived length of hot and cold periods); perceived flood and drought periods; types of fodders grown; periods of low milk production; sources and availability of water; sources and trends in manual labour; changes in land use and livelihood strategies. Other aspects captured included edaphic factors such as soil fertility, soil erosion, their perceived probable causes and impacts.

3.4.5.3: Presentation of results from Household questionnaire survey

Quantitative aspects of data were analysed using Statistical Package for Social Science (SPSS) software for Pearson chi-square (χ^2) (Pallant, 2005) at 5% level of significance and one degree of freedom, to establish if there was any statistical significance in differences in perceptions and challenges in relation to precipitation and temperature on SDFS productivity. The association of farmers' perceptions to rainfall, temperature, fodder, disease incidences, and water availability in relation to changes in milk production were also explored using binary logistic regression and Pearson chi-square (*ibid*). Areas of interest in quantitative data analysis included farmers' perceived changes in CCV parameters in relation to fodder production, vector borne disease occurrences, presence and occurrence of parasites, and water availability. Independent variables included in the analyses were temperatures, floods, droughts, precipitation and pests while dependent variables were productivity of the *B. Taurus* breeds, fodder production, prevalence of vector borne diseases and parasitic infestations.

Categorical dependent variables were dummy coded using the integers 0 to denote a decrease of a dependent variable, 1 to denote a constant dependent variable and 2 to denote an increase in a dependent variable all in relation to independent ones. Socio-economic data was presented using descriptive statistics (percentages and frequency tables) generated using SPSS.

3.4.6 Transect Walk

A transect walk comprising of a member of Kenya Forestry Service (KFS) and the Sub-County Livestock Production Officer (SCLPO) was undertaken for one day to ground truth findings from the two FGDs and to check for consistencies in views expressed by participant observers. Gombe airstrip was taken as the start point, Hono Chiefs Camp as the Midpoint while Nyamila Primary School was the endpoint. The KFS member being well versed in taxonomy of higher plants was tasked to identify and give botanical names of trees identified by the first FGD in their vernacular language while SCLPO identified grasses of interest. Photography was also used to capture barriers to adaptation strategies and biophysical vulnerabilities.

3.4.6.1: Presentation of Results from the Transect Walk

Results obtained from the transect walk were presented in a tabular form and complemented the objective of the study alongside photographs that were used to capture barriers to adaptation strategies and biophysical vulnerabilities.

3.4.7 Land use Maps

Land use maps over the years (April 1975, April 1990, April 2000, April 2010 and April 2014) were used to check progression of: vegetation in Siaya Sub-County; built up area and patterns; bare soils, and change in size of available wetlands. April was taken as the month of choice since this was assumed to be the peak of farming activities due to MAM being the traditional long rains cropping season. These maps were also used to ground truth results of the first two specific objectives of study.

3.4.6: Objective 3 – Barriers to Adaptation and Resilience Building

This objective was meant to explore the presence of barriers that hinder adaptation strategies with to the aim of exploring possibilities of bridging gaps for increased resilience of SDFS due to adverse effects of CCV. This involved analysis of questionnaires administered at household level based on farmers' responses to factors hindering adaptation strategies. Other mechanisms used to establish existing barriers to adaptation included holding of interviews with: participant observers; key informants; representatives from formal and informal institutions. In addition to observations made during the transect walk to ground truth results obtained from objective one and two were also used. The information collected was complimented by literature review on the role institutions play in identifying and addressing adaptation barriers.

3.5: Data Analysis

Data analysis was carried out at various levels to achieve the overall objective of increasing adaptive capacities of SDFS to adverse effects of CCV, in Siaya Sub-County. Qualitative data obtained from FGDs and frequencies generated using SPSS from household surveys data was compared to long-term satellite data analysed using Excel software to draw conclusions on perceptions of CCV in the study location. Satellite rainfall data was analysed and presented as time series plots for; longterm annual, March-April-May/June (MAM/J), June-July-August (JJA), September-October-November-December (SOND), December-January-February, (DJA). The time series plots were compared to farmer perceptions of CCV and major climatic events.

Quantitative data analysis of results from modules related to challenges posed to SDFS by CCV in the administered household questionnaire coupled with adaptation strategies employed were similarly compared to tabulated results obtained from the transect walk to draw conclusions on challenges and adaptation strategies to CCV. Further analysis of the household questionnaire, transect walk results tabulation, interviews with participant observers and key informants were used to draw barriers to adaptation strategies which if breached will increase adaptive capacities of SDFS to adverse effects of CCV.

CHAPTER FOUR

RAINFALL TEMPERATURE TRENDS AND FARMER PERCEPTIONS

4.1: Introduction

Analysis of long-term climate data assisted in drawing conclusions on what aspects of climate of the study area have changed overtime besides understanding how these changes are perceived by SDFS including how they make predictions based on their experience and local knowledge. In this chapter data on long-term rainfall alongside proxy temperature trends for Kisumu station are presented alongside SDFS perceptions based on results obtained from FGDs and household surveys. Emphasis is on rainfall and temperature as these are the main elements necessary for fodder and crop production besides having an influence on the prevalence of both *Bos taurus* and fodder diseases (Kotir, 2011; Knox et al., 2012; Porter et al., 2014). Rainfall data plots were drawn to show: long-term annual; March-April-May (MAM); March-April-May-June (MAM/J); June-July-August (JJA); December-January-February (DJF); September-October-November-December (SOND) to demonstrate trends across seasons. Farmer perceptions are documented based on drought effects, rainfall intensity, floods and temperature.

4.1.1: Climate Trends

4.1.2: Precipitation

Results based on long-term rainfall (1975-2013) data for the study location indicated a longterm drying as annual rainfall data plots showed a negative gradient (figure 4.1). The same trend is exhibited for (1983-2013) (figure 4.2) though drying for the latter period is less as exhibited by the gradient. This same phenomenon is consistent with; March-April-May (MAM) (figure 4.3), March-April-May-June (MAM/J) (figure 4.4), June-July-August (JJA) (figure 4.5), and December-January-February (DJF) (figure 4.6) rainfall seasons. However September-October-November (SON) season (figure 4.7) was the exception as this period exhibited a long-term wetting which was further enhanced when the December rainfall was pulled to SON (figure 4.8). The long-term cumulative data plots (1975-2014) exhibited the steepest negative gradient followed by the 1983-2013 dataset further confirming persistent longterm drying over the period under study.

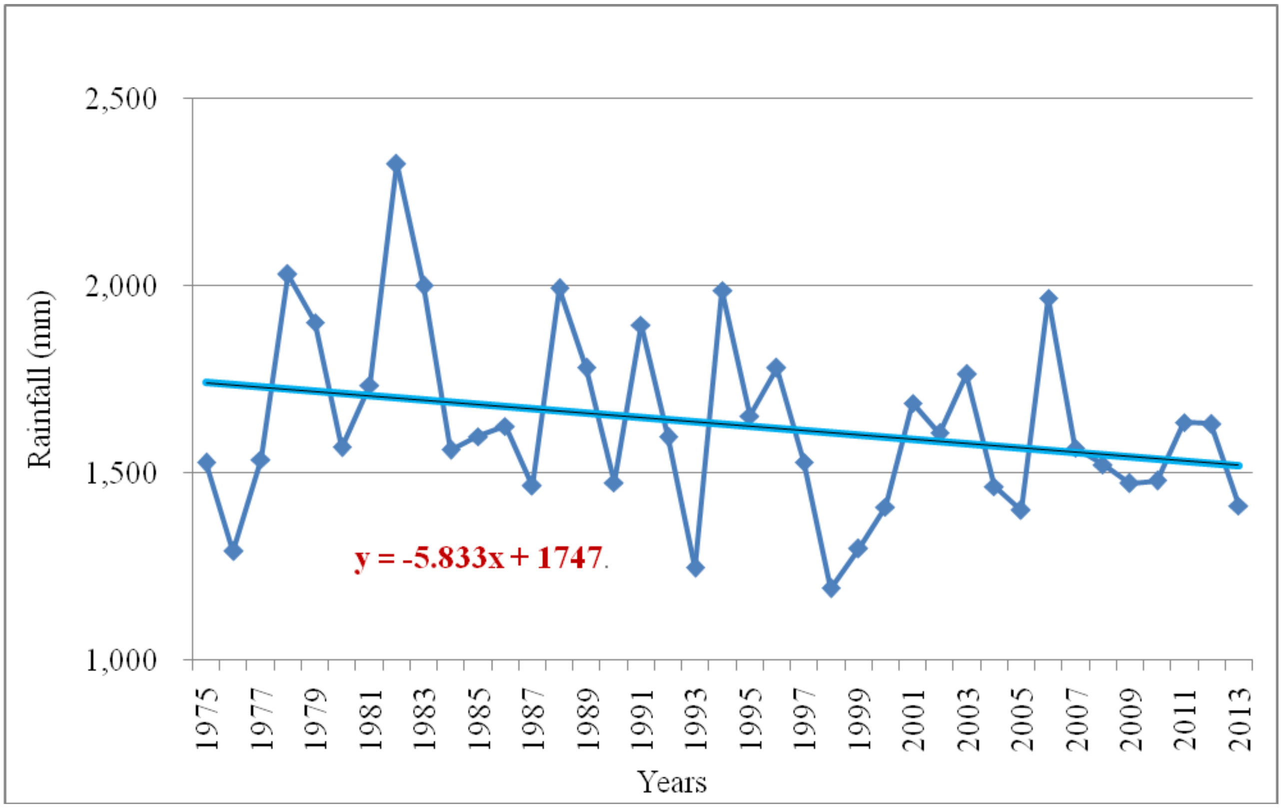


Figure 4.1: Trend in longterm cumulative annual Rainfall (1975-2013) Siaya Sub-County

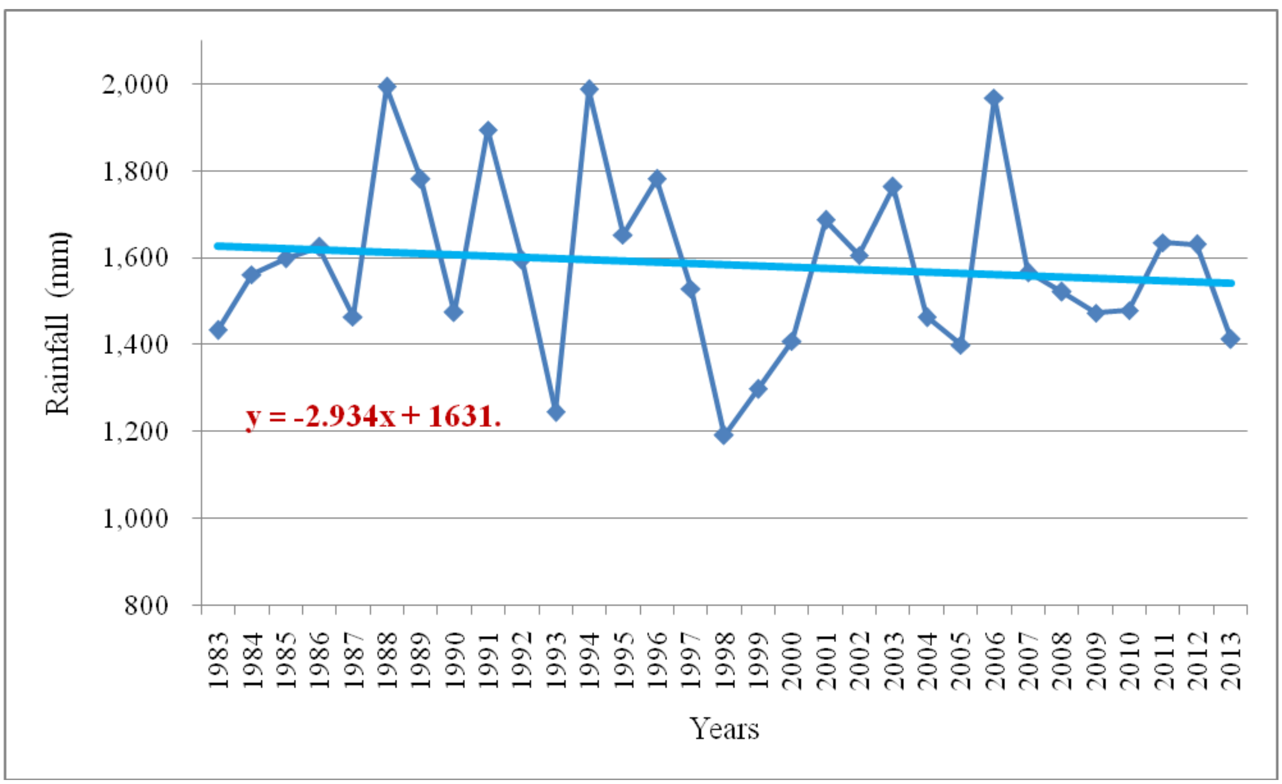


Figure 4.2: Longterm Annual Cumulative Rainfall (1983-2013) Siaya Sub County

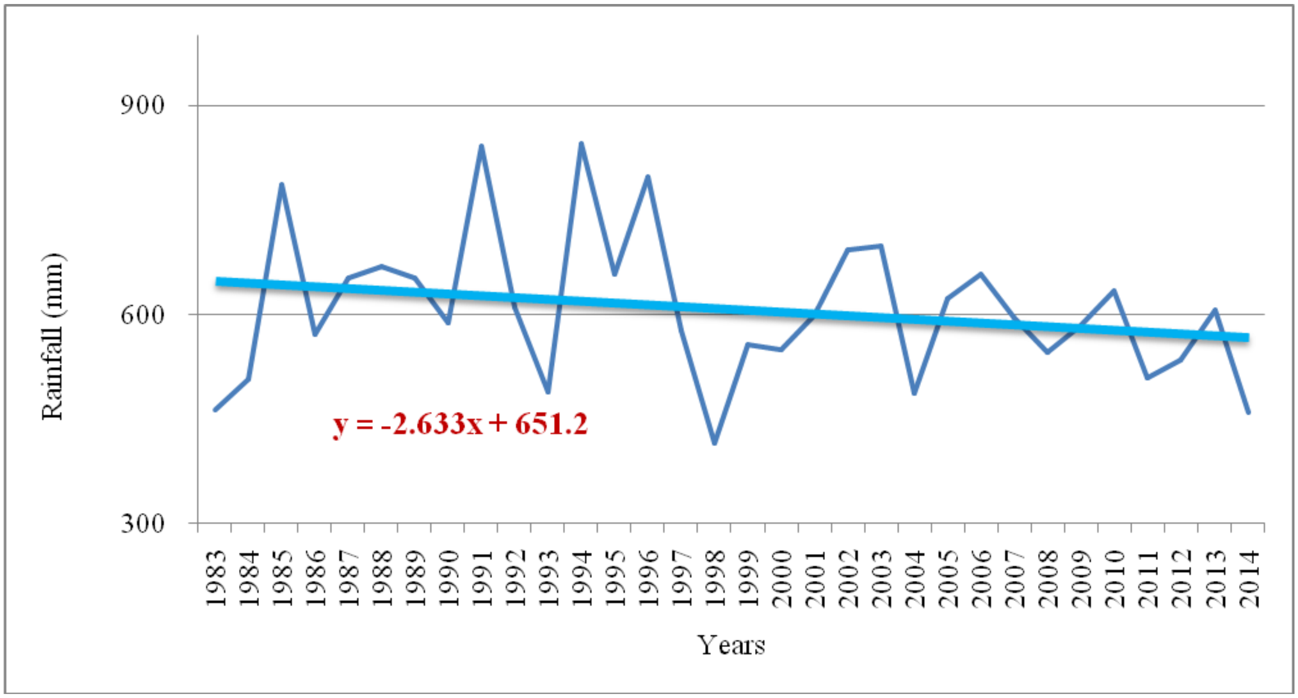


Figure 4.3: MAM rainfall for Siaya Sub-County

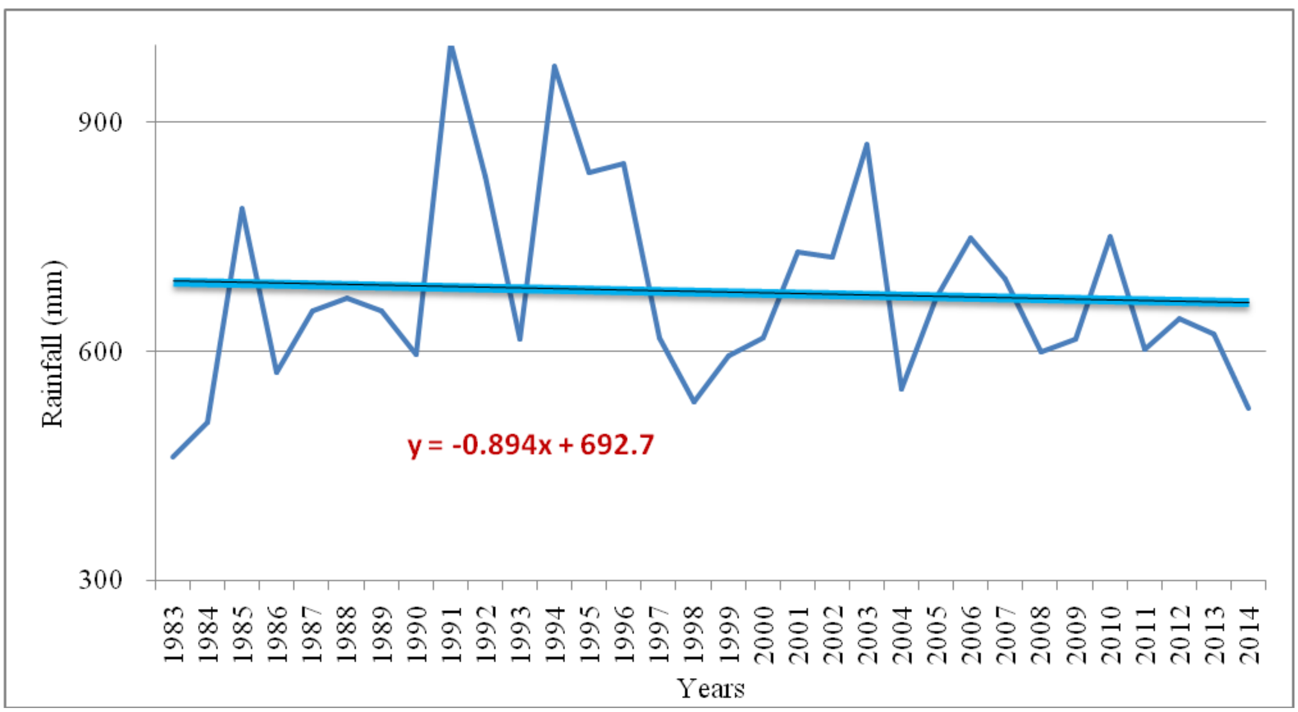


Figure 4.4: MAM/J Rainfall data plots for Siaya Sub-County

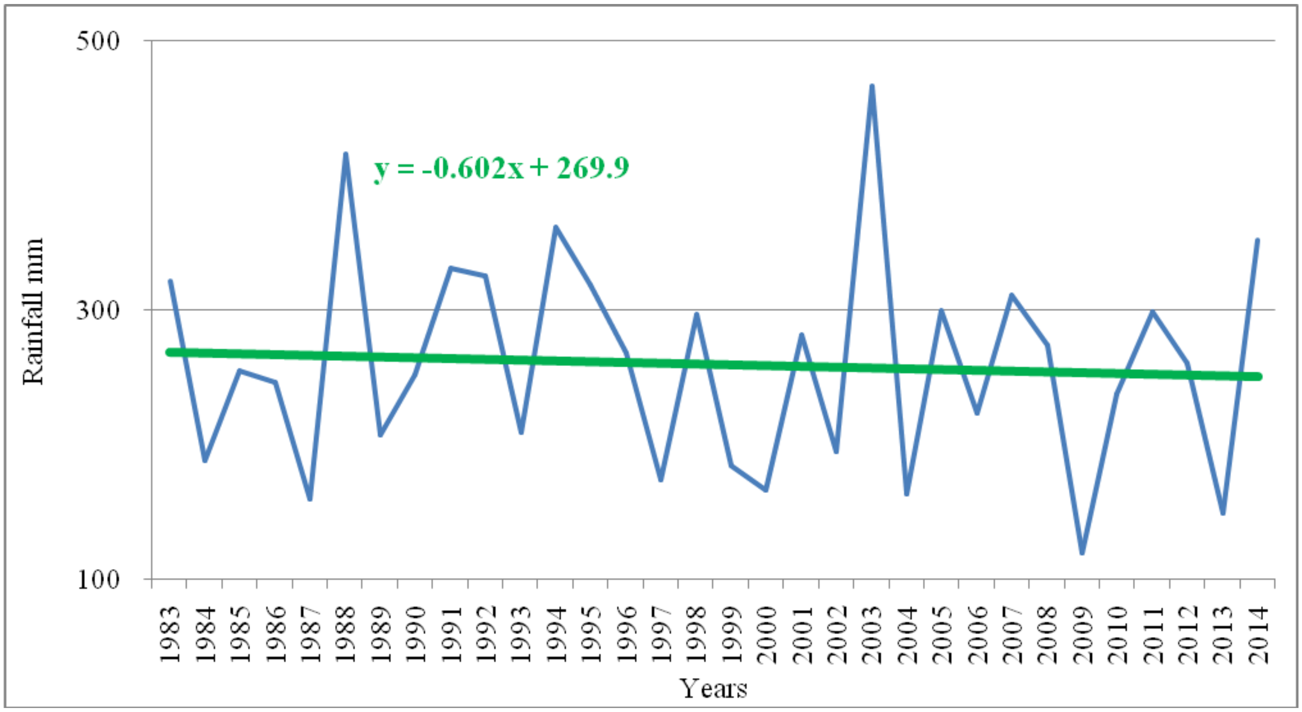


Figure 4.5: Longterm JJA Rainfall for Siaya Sub-County

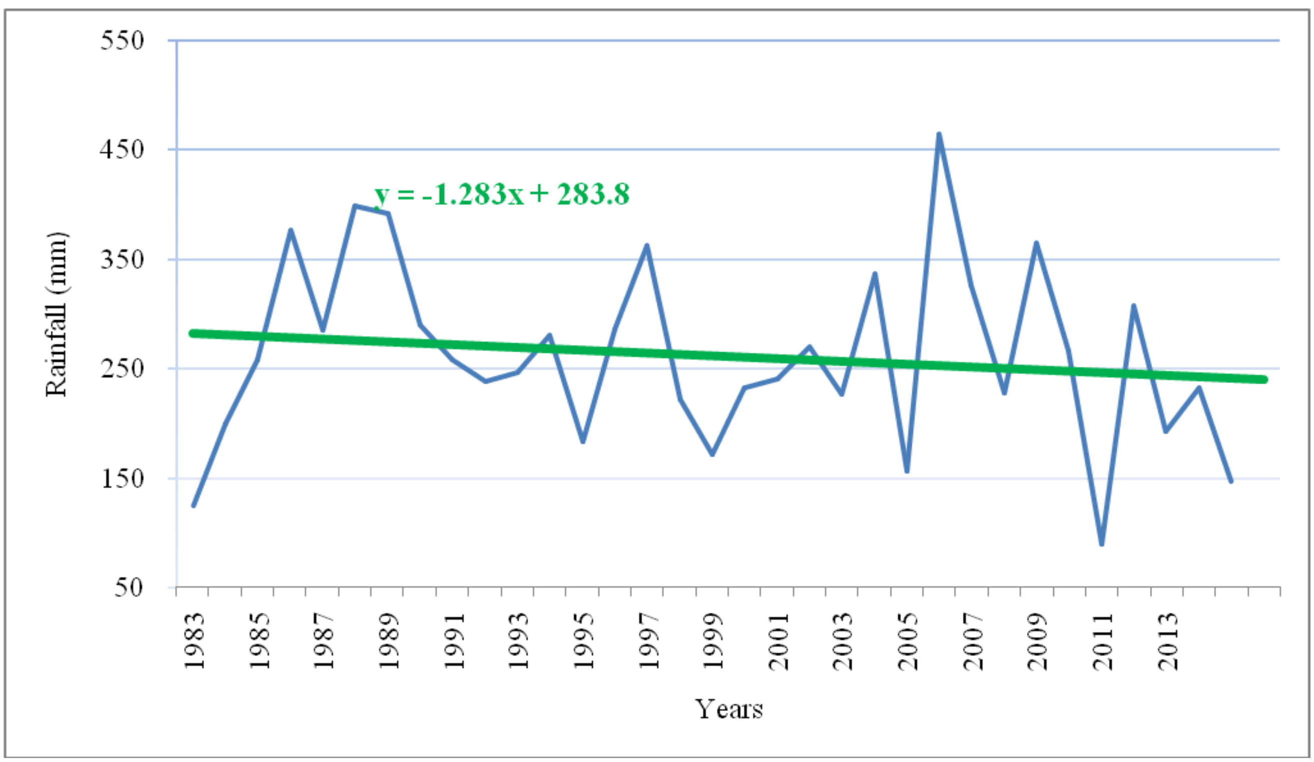


Figure 4.6: Longterm DJF Rainfall for Siaya County

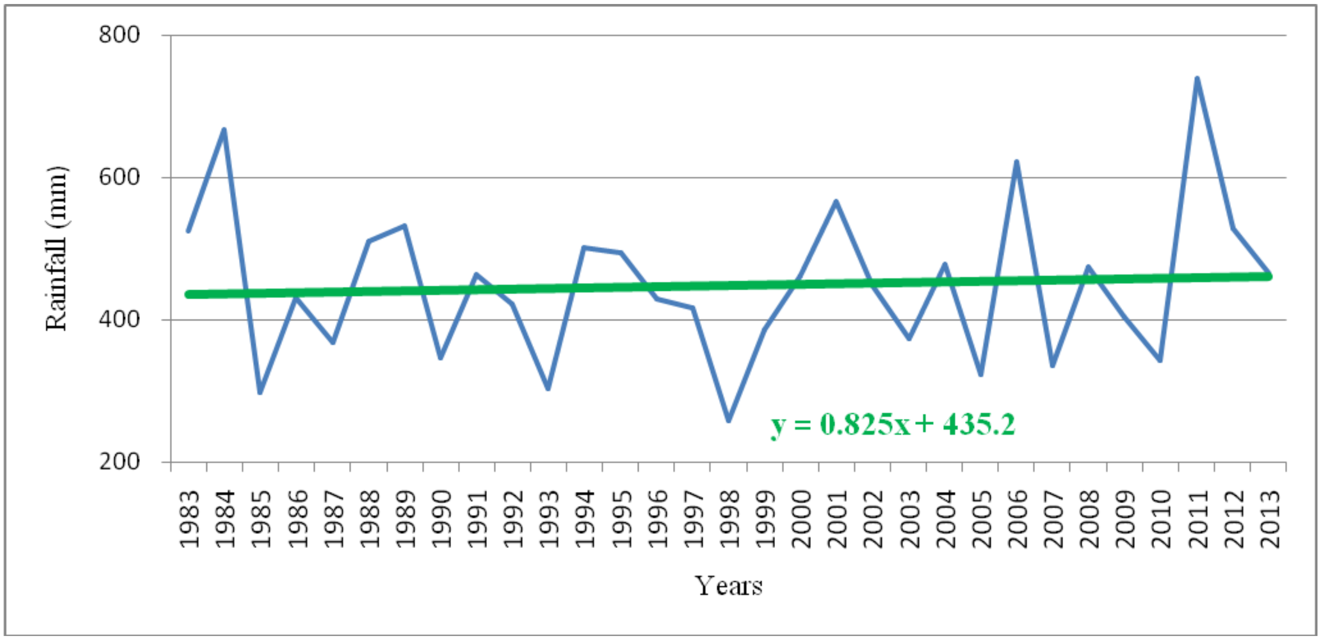


Figure 4.7: Longterm SON rainfall for Siaya Sub-County

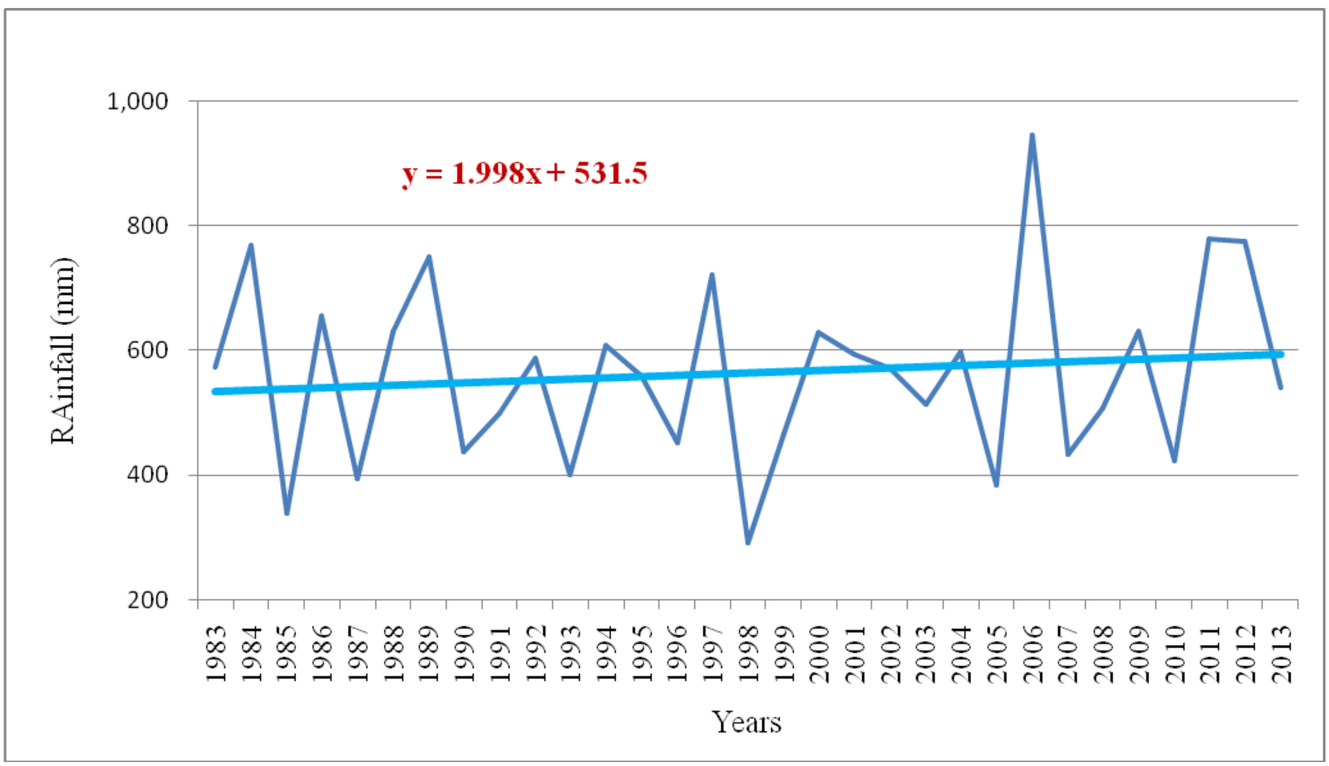


Figure 4.8: Longterm SOND rainfall for Siaya Sub-County

Further analysis of rainfall data revealed a longterm mean of 1638.44mm with a minimum of 1192mm and maximum of 2326mm for the period 1975-2014 (table 4.1) while the standard deviation was 241.813, which show a similar trend to the period 1983-2014 (table 4. 2). The minimum rainfall (1192mm) for the period was recorded in 1998 with implications of a La Niña effect having come out of the El Niño season the previous year (1997).

Table 4.1: Annual Cumulative Rainfall (1975-2013)

Rainfall	N	Minimum	Maximum	Mean	Std. Deviation
Annual cumulative	41	1192	2326	1638.44	241.813

Table 4.2: Longterm statistics (1983-2014)

Rainfall	N	Minimum	Maximum	Mean	Std. Deviation
Annual cumulative	33	1192	1999	1613.91	214.039

However, while interdecadal comparisons of standard deviations were insignificant (P=0.232; p=0.397), (table 4. 3 and Table4. 4), analysis of maximum rainfall showed steady declines (*ibid*) conforming to observed trends in longterm cumulative annual rainfall (figure 4.1).

Table 4.3: Interdecadal statistics

Year Groups	Minimum	Maximum	Mean	Std. Deviation
1975-1984	1291	2326	1747.80	310.792
1985-1994	1246	1993	1666.20	245.123
1995-2004	1192	1781	1538.30	197.115
2005-2014	1400	1968	1576.50	166.976

There is no difference between the means (p-value=0.232)

Table 4.4: Interdecadal statistics

Year Groups	Minimum	Maximum	Mean	Std. Deviation
1983-1992	1465	1999	1698.90	203.187
1993-2002	1192	1988	1538.90	254.054
2003-2012	1400	1968	1590.30	169.969
2013-2015	1413	1888	1659.33	237.992

There is no difference between the mean of rainfall between different decades (p-value=0.397)

Table 4.5: Seasons' Minimum, Maximum, Means and Standard Deviations

Season	Minimum	Maximum	Mean	Std. Deviation
MAM/J	525	1003	704.73	125.253
MAM	416	845	608.03	105.425
DJF	89	464	262.03	84.202
JJA	120	467	265.03	84.325
SOND	292	946	578.36	155.812

Similarly comparisons of inter-seasonal rainfall revealed that the June rainfall contributed positively to the MAM season since it considerably increased amounts of precipitation received when pooled to MAM (minimum 525mm, maximum 1,003mm with a mean of 704.73mm) as opposed to MAM season as a standalone (minimum 416mm, maximum 845mm and a mean of 608.03mm) (table 4.5). However though SOND recorded lower minimum rainfall compared to the MAM and MAM/J season, it had the second highest maximum rainfall but the highest when the influence of June rainfall was excluded from the MAM dataset (*ibid*) hence the only season that exhibited long-term wetting (figure 4.8). Likewise, SOND with the exception of 1993-1997 had the highest pentad standard deviation compared to the rest of the seasons (DJF, MAM, MAM/J, and JJA) implying high rainfall variability (Table 4.6).

Table 4.6: Pentad Statistics

Year groups	**Seasons**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
1983-1987	MAM/J	546	843	692.60	115.613
	MAM	462	787	596.00	128.520
	DJF	125	376	248.80	93.919
	JJA	160	322	234.20	63.089
	SOND	338	770	546.60	179.669
1988-1992	MAM/J	596	1003	805.40	145.710
	MAM	587	842	672.00	100.471
	DJF	238	398	315.00	74.947
	JJA	207	416	306.40	80.376
	SOND	437	751	581.60	121.290
1993-1997	MAM/J	615	972	776.40	156.227
	MAM	489	845	673.20	148.776
	DJF	183	362	271.40	65.106
	JJA	174	362	266.40	77.041
	SOND	400	721	548.40	127.390
1998-2002	MAM/J	533	729	639.20	85.072
	MAM	416	692	562.60	99.598
	DJF	171	270	227.20	36.162
	JJA	166	297	225.00	60.029
	SOND	292	630	510.80	136.516
2003-2007	MAM/J	550	871	706.40	117.087
	MAM	487	698	612.00	79.884
	DJF	156	464	301.60	117.332
	JJA	164	467	293.20	114.073
	SOND	384	946	575.20	222.813
2008-2012	MAM/J	598	749	641.60	62.572
	MAM	508	633	561.20	48.536
	DJF	89	365	251.00	103.839
	JJA	120	299	238.40	69.766

	SOND	423	779	623.20	158.884
2013-2015	MAM/J	525	800	649.33	139.378
	MAM	459	615	560.00	87.584
	DJF	147	232	190.67	42.548
	JJA	149	427	309.33	143.827
	SOND	541	824	719.00	154.981

There is no difference between the of rainfall means within different years (p-value>0.05)

When rainfall data was subjected to correlation coefficient(r) analysis it was deduced that annual cumulative rainfall was strongly positively correlated (r>0.5) to JJA and SOND but weakly positively correlated (r=0.494) to MAM an indication that MAM rainfall contribution to crop and fodder production for the region was on the wane. MAM/J and MAM had very strong (r=0.9) positive correlation (p-value=0.004) an indication that the June rainfall contributed strongly to the aggregate effects of the MAM season while MAM/J and JJA had a weak (r=0.487) positive correlation (p-value=0.004) which could be a pointer to high seasonal rainfall variability (Table 4.7).

Table 4.7 Pearson correlation coefficient

Correlations		**Rainfall**					
		Annual cumulative	**MAM/J**	**MAM**	**DJF**	**JJA**	**SOND**
Annual cumulative	Pearson Correlation	1	.620**	.494**	.195	.568**	.505**
	Sig. (2-tailed)		.000	.003	.277	.001	.003
MAM/J	Pearson Correlation	.620**	1	.900**	.168	.487**	-.074
	Sig. (2-tailed)	.000		.000	.349	.004	.684
MAM	Pearson Correlation	.494**	.900**	1	.235	.230	-.146
	Sig. (2-tailed)	.003	.000		.188	.199	.416
DJF	Pearson Correlation	.195	.168	.235	1	-.254	.225
	Sig. (2-tailed)	.277	.349	.188		.154	.208
JJA	Pearson Correlation	.568**	.487**	.230	-.254	1	.037
	Sig. (2-tailed)	.001	.004	.199	.154		.839
SOND	Pearson Correlation	.505**	-.074	-.146	.225	.037	1
	Sig. (2-tailed)	.003	.684	.416	.208	.839	

4.1.3: Temperature

Longterm temperature data of the study area was unavailable from TAMSAT as readings were not segregated into minimum and maximum temperature; hence use of synthesized minimum and maximum temperature data for Kisumu Station as proxy of long term temperature trends to compare perceptions of the study sample to temperature variations. According to KMD (2011), spatial temperature variations between the study site and that of Kisumu station are minimal. Additionally, the study location experiences a similar climatic regime as that of Kisumu station.

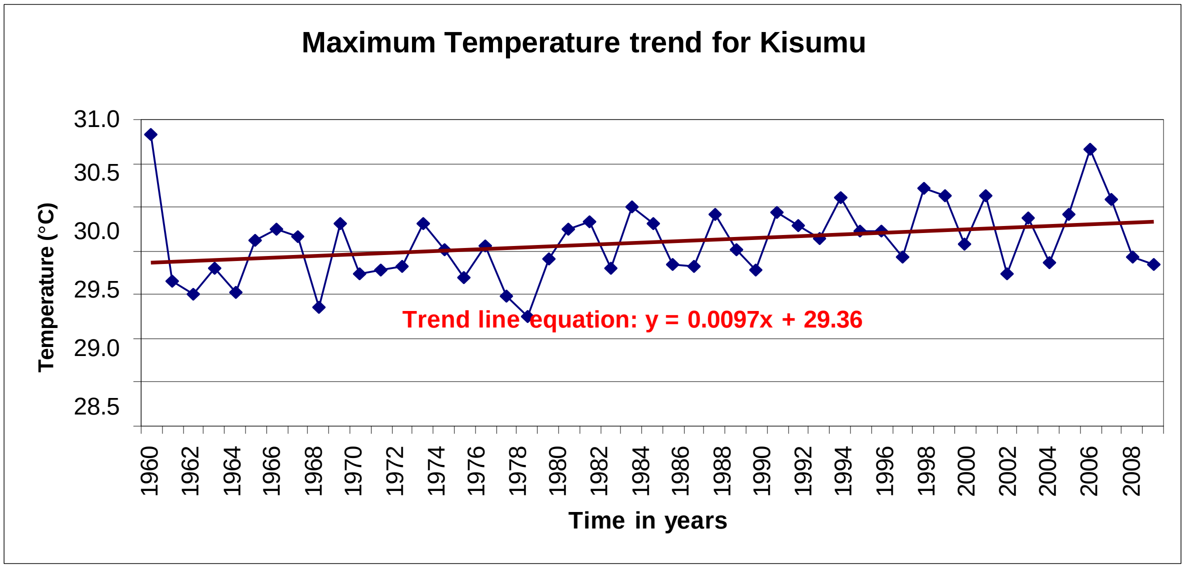


Figure 4.9: Trend in maximum temperature at Kisumu (Adopted from KMD, 2011 page 54)

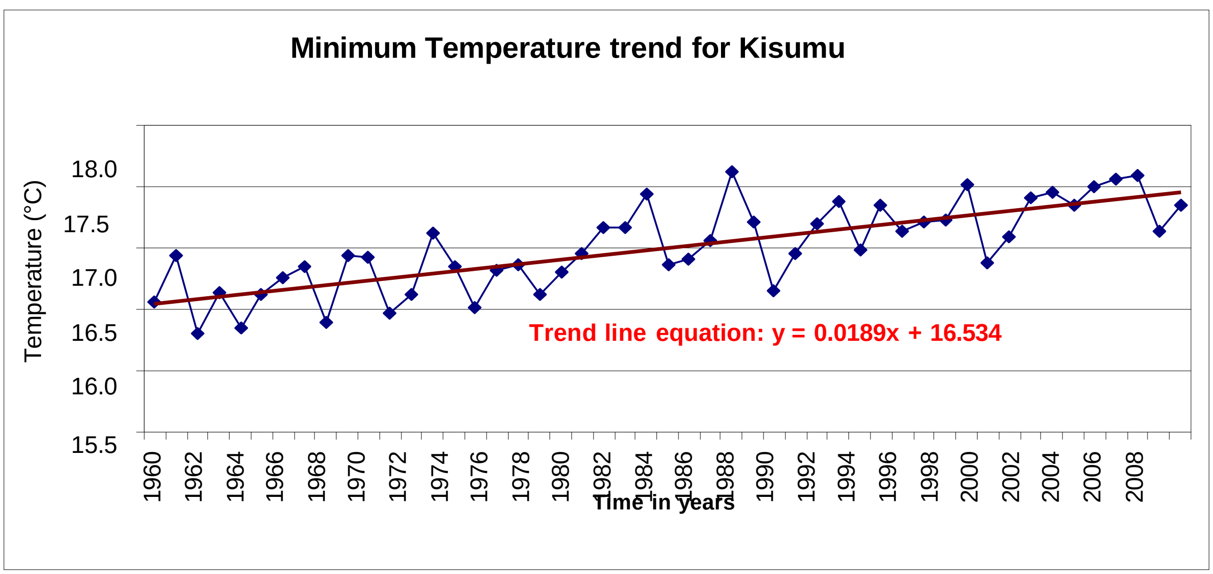


Figure 4.10: Trend in minimum temperature at Kisumu. (Adopted from KMD, 2011 page 54)

Proxy long-term maximum and minimum temperature trends (figure 4.9 and figure 4.10) for the study site show an increase in maximum and minimum temperatures overtime. However there is considerable increase in long term minimum temperatures as the trend line has a sharper ascent compared to the long term maximum temperature trend.

4.1.4: Floods and Droughts

Long term trends in floods and droughts are not comprehensively documented but the period 1961-1962 and 1997-1998 is recorded as having the worst flood events with the latter covering; a wider area, being most intensive and relentless (GOK, 2009). Other years that experienced major floods include 1937, 1947, 1951, 1957-1958 and 1978 *(ibid*). Interactions through FGDs and with key informants revealed that floods, with the exception of farms bordering rivers and those situated in low lying areas are rare. However areas that surround Usonga experience frequent flood events that result to massive loss of crops, livestock, and livestock displacement. According to one of the key informants,

> *"Flood damage with associated mitigation costs are on the rise and due to increased severity of these events more households are getting trapped in the poverty cycle as there is insufficient time to recover and recoup their assets before subsequent flood events* [Key Informant, 21st October 2015].

According to GOK (2009, p.28), of the 22 drought and flood events recorded countrywide in 36 years, 77.3% consisted of drought events while the rest were represented by floods that were solely confined to the former Western and Nyanza Provinces. Similarly Shiferaw et al.(2014) observed similar trends for the East African region which corresponded well with the trend line on major climatic events as drawn by FGD participants based on their perceptions for the period 1975 - 2014 (figure 4.9), where droughts were recorded as being most frequent followed by intense rainfall and floods.

Floods were linked to incidences of high *Glossina* (tsetse flies) challenge as years of extreme wet events gave rise to favourable environmental conditions for their breeding and spread. It was reported that during periods of floods (extreme wet events) the flies multiplied fast in swampy and riverine habitats (where they are mostly confined during dry seasons) followed by migration to other parts of the Sub County hence high flare-ups of Trypanosomiasis incidences to which exotic breeds have low resistance (GOK, 2015). This scenario is envisioned to play out more often in future for parts of East Africa where tsetse flies are endemic and are projected to have a future long term wetting (Hulme et al., 2001; Funk et al., 2011 Shongwe et al., 2011).

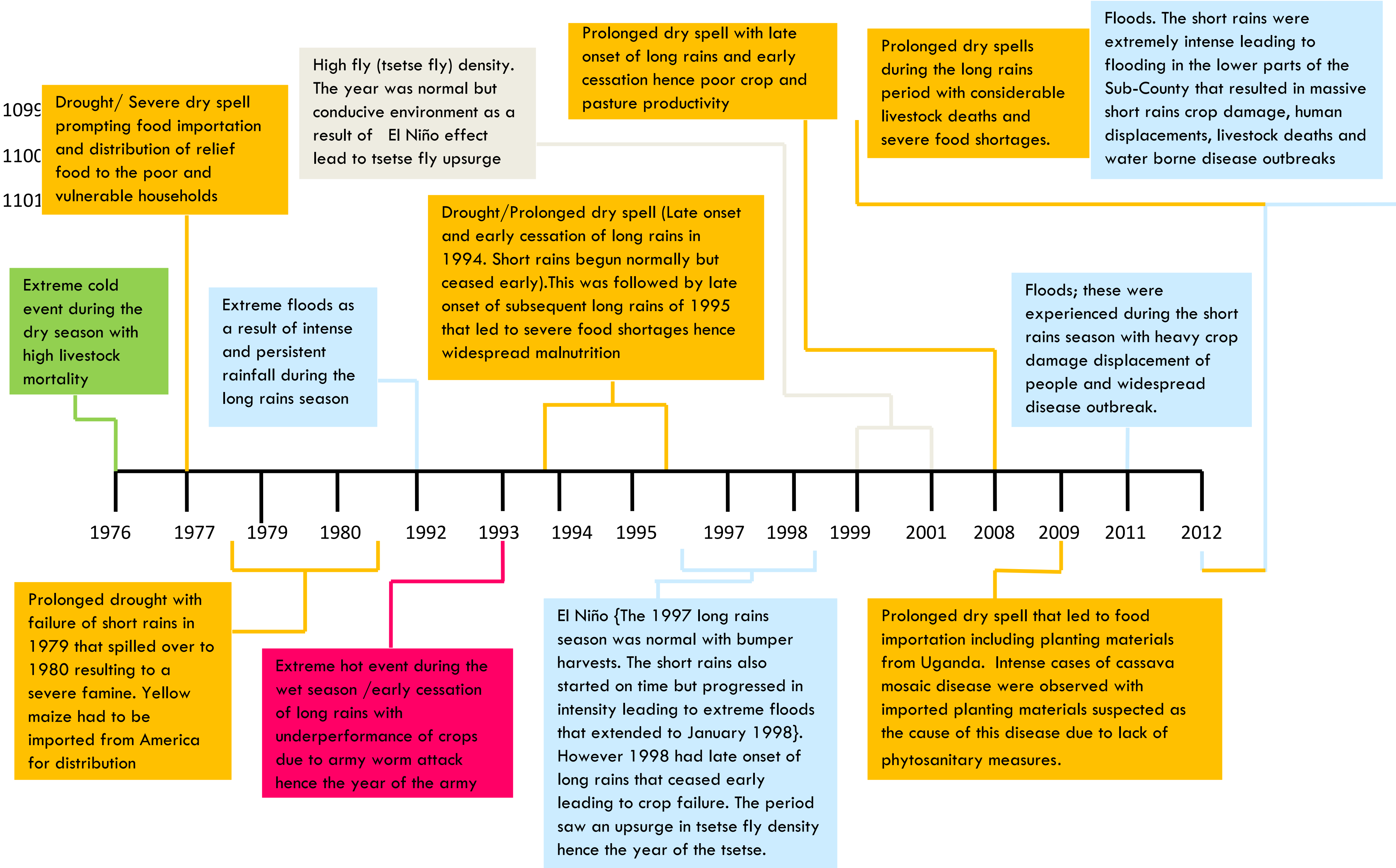


Figure 4.11: Trend line of major climatic events in Siaya Sub-County (1975-2014) based on FGDs and developed in October 2015. See table 4.8below for vernacular names of major climatic events. N=7

Table 4.8: Key to explanations of major climatic events and their vernacular names based on perceptions of FGD participants N=7

Year	Event	Name of event in local dialect	Explanations/Perceptions
1976	Extreme cold event during the dry season	Koch Oduya (the cold of the chicks)	The dry season was unusually cold and led to a lot of poultry mortality especially amongst chicks while cases of flu in human beings was high and child pneumonia was prevalent
1977	Prolonged drought	Amiyi Meru (Do I give you your mother)	Those who were able bought food from Uganda through lake Victoria, Kitale, Busia and Bungoma. Relief maize was distributed to the poor and the vulnerable though this was inadequate.
1979	Prolonged drought		Those who were able bought food from Uganda through lake Victoria, Kitale, Busia and Bungoma. Relief maize was distributed to the poor and the vulnerable though this was inadequate.
1980	Famine	The year of Goro-goro	Yellow maize had to be shipped in. It was an extreme drought that even wheat flour had to be used to make the traditional ugali dish (People used traditional vegetables such as Hariadho, dindi, nyabodhok (wild desmodium) Ayado (wild cassia species) Nyasigumba and nderma. This was an extension of failed short rains of 1979
1992	Extreme floods	Nyaldiema (Diarrhoea)	There were a lot of deaths due to outbreaks of water borne diseases the most notable one being cholera due to over flowing of pit latrines. Incidences of malaria due to high mosquito populations led to increased infant mortality. Hunger and malnutrition as a result of crop damage and failure was widespread while livestock deaths occurred due to pasture inaccessibility and drowning especially local poultry and small ruminants.
1993	Extreme hot event during the wet season	Yig kungu (the year of the army worm)	Rains came on time that allowed people to sow their farms but it ceased abruptly when the sown crops were being weeded paving the way for army worm attack that wiped out all the established fields. This led to severe famine during that year. There were deaths amongst indigenous livestock due to scarcity of grass on natural pastures.
1994	Prolonged dry spell	-	Late onset of rains (Rains begun in April and ceased early leading to crop failure)
1995	Drought	Mak Nungo Chuori (hold your husband's waist) or log dichiel (wash your hands once meaning having only one meal per day)	There was widespread malnutrition
1997	Extreme floods (El Niño rains).	Yig maugo (The year of the tsetse fly)	The long rains season was normal leading to bumper harvests. However onset of short rain in mid October was so intense and ceased in January of the following year. This led to massive flooding with substantial crop damage, livestock deaths, human displacement, property damage (houses were washed away) diarrhoea, malaria cases were also reported. Environmental conditions were

			conducive and there was an upsurge of tsetse flies that resulted in animal diseases.
1998	Extreme floods /Drought	The year of the tsetse fly (Yig Maugo)	Late onset of long rains as the spillover of el Niño rains into January led to delayed onset of long rains season. Tsetse fly infestation persisted till August (Rains begun in April and ceased in August leading to harvest losses)
1999	Normal season	Yig Maugo	This was reported to be a normal season but events triggered by the El Niño event made the environment conducive for persistence of tsetse infestation with dire consequences on livestock production activities.
2001	Normal Season	Yig Maugo	The seasons were normal leading to good conditions for thriving of the tsetse fly that saw un upsurge in tsetse fly population that curtailed SDFS production activities. This saw the coming on board of the OAU's Farming in Tsetse Controlled Areas Project (FITCA), that was taken over by PATTEC and currently KENTEC all aimed at tsetse suppression to pave way for sustainable land use activities and hence improved livelihoods.
2008	Prolonged dry spell	-	Late onset of rains and early cessation leading to crop failure
2009	Drought	-	Cassava mosaic disease intensifies due to importation of cuttings from Uganda
2011	Floods	-	These were observed during the short rains that were extremely intense with heavy crop damage displacement of people and widespread disease outbreaks in both human and livestock populations.
2012	Prolonged dry spells during long rains followed by extreme floods during short rains	-	The long rains season begun in late April and interfered with the planting calendar. This led to considerable crop failure as farmers who had adopted early planting regimes lost their crop. However the short rains came on time and were extremely intense leading to flooding in the lower parts of the Sub-County with massive crop damage, human displacements, livestock deaths and water borne disease outbreaks.

4.2: Farmer Perceptions

4.2.1: Perceptions of Droughts

Focused Group Discussions (FGDs) (Plate 4.1) revealed that droughts had increased as participants observed that frequencies of prolonged dry spells had increased leading to drying up of previously perennial rivers and streams. For instance, it was reported that Rivers Ralwala-Samajina and Magenga-Pundo-Ogongo in the Hono catchment had become seasonal due to climate change that in tern affected fish availability as one of the natural resources.

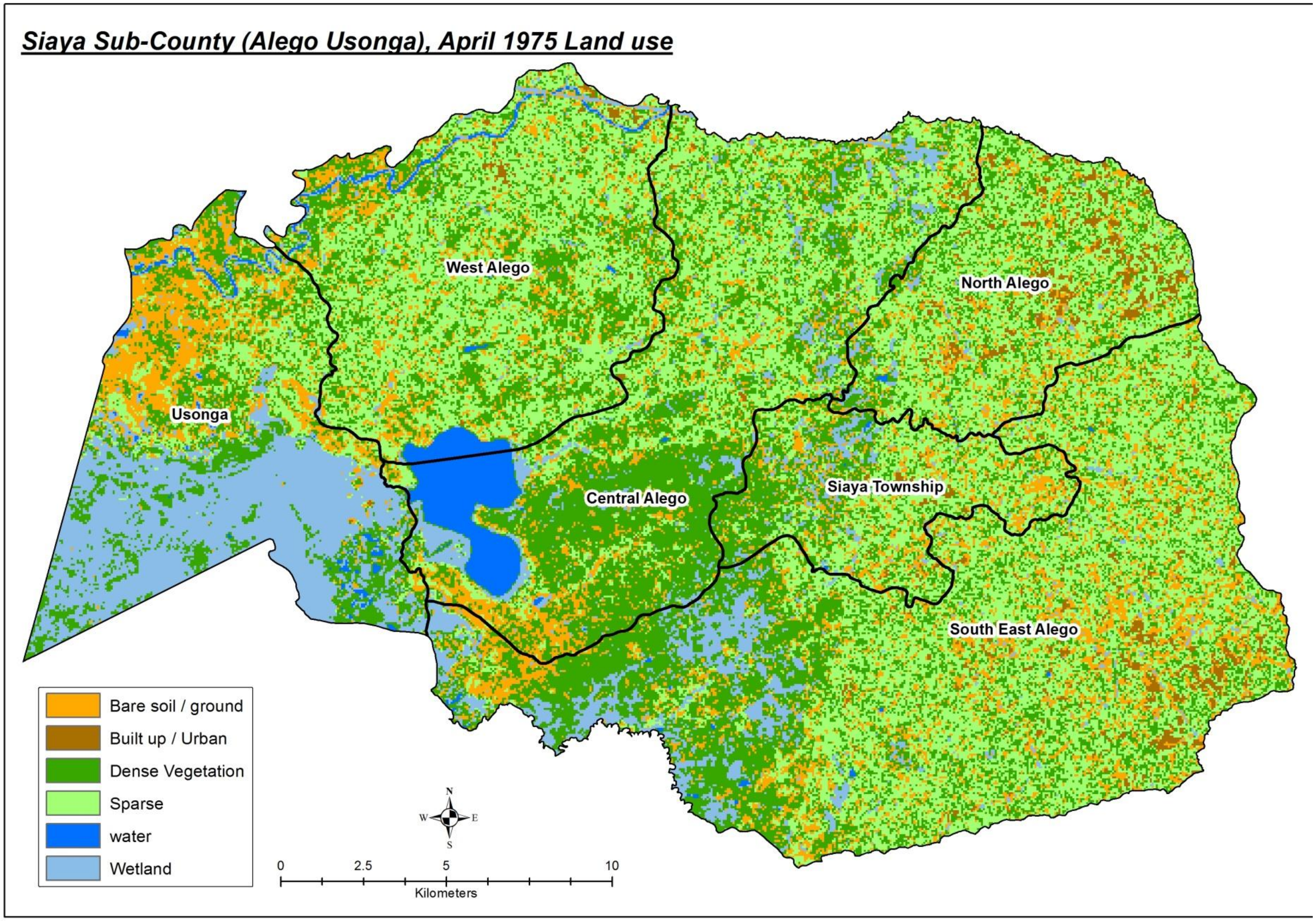
> *"River Magenga-Pundo-Ogongo had a lot of water before and a majority of the local population relied on it for fish while mud found along its banks was believed to have natural salts (saline soils) as livestock used to lick it just as grade ones lick commercial mineral supplements. The river is now dry and people no longer benefit from its once rich fish resources, prompting shifts to alternative sources of protein rich foods from markets hence impacting negatively nutritional status of the poor and vulnerable HHs"*, [FGD participant, 13th October 2015).

Plate 4.1: A focused group discussion in session, October 2015

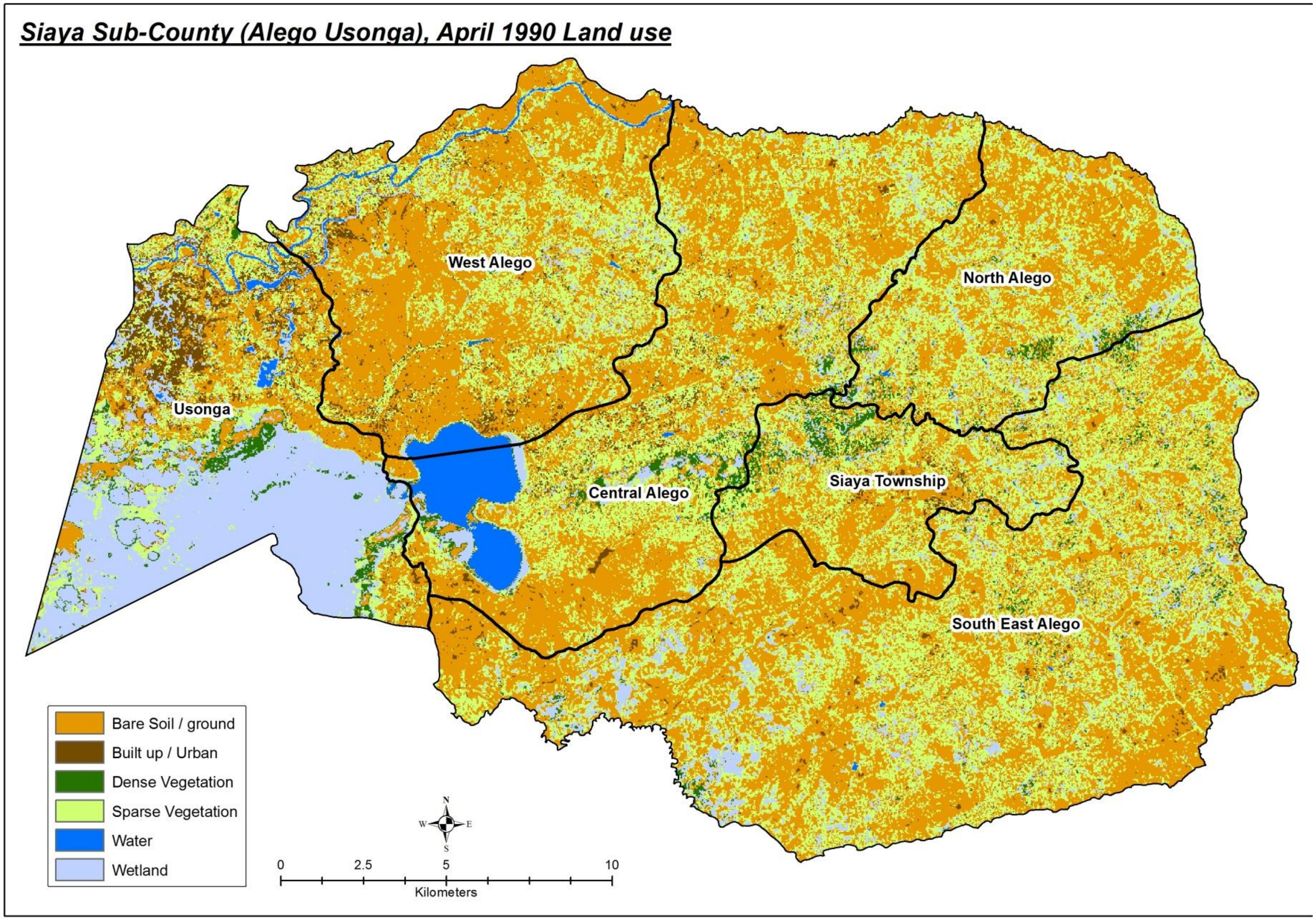
Frequent droughts have thus negatively impacted riverine ecosystems of the area leading to diminished provisioning services that further risks extinction of fresh water biota besides putting additional strain on water availability for both domestic and livestock use. This argument is made from observations of Land Use Maps (LUM) which indicate progressive reduction in the size of Yala Swamp (a wetland) paving way for farming activities and settlements.

Closely associated with perceptions of droughts were changes in vegetation cover as it emerged that majority of indigenous trees that grew in relatively wet patches (riparian areas) of North Alego location are currently hard to come by. FGD participants attributed this to low water table due to diminishing green water availability to recharge aquifers. Indigenous trees singled out as having been affected by CCV are *Ficus thorningi* (Pocho) and *Ficus cycomorus* (Ngowo) which according to the community served as indicators of shallow aquifers. This view was premised on observations that underground water exploitation where these trees grew was easy during times of extreme droughts (water scarcity) implying indicators of a shallow aquifer meaning that Shallow rooted plants are prone to and easily decimated by ravages of climate change,

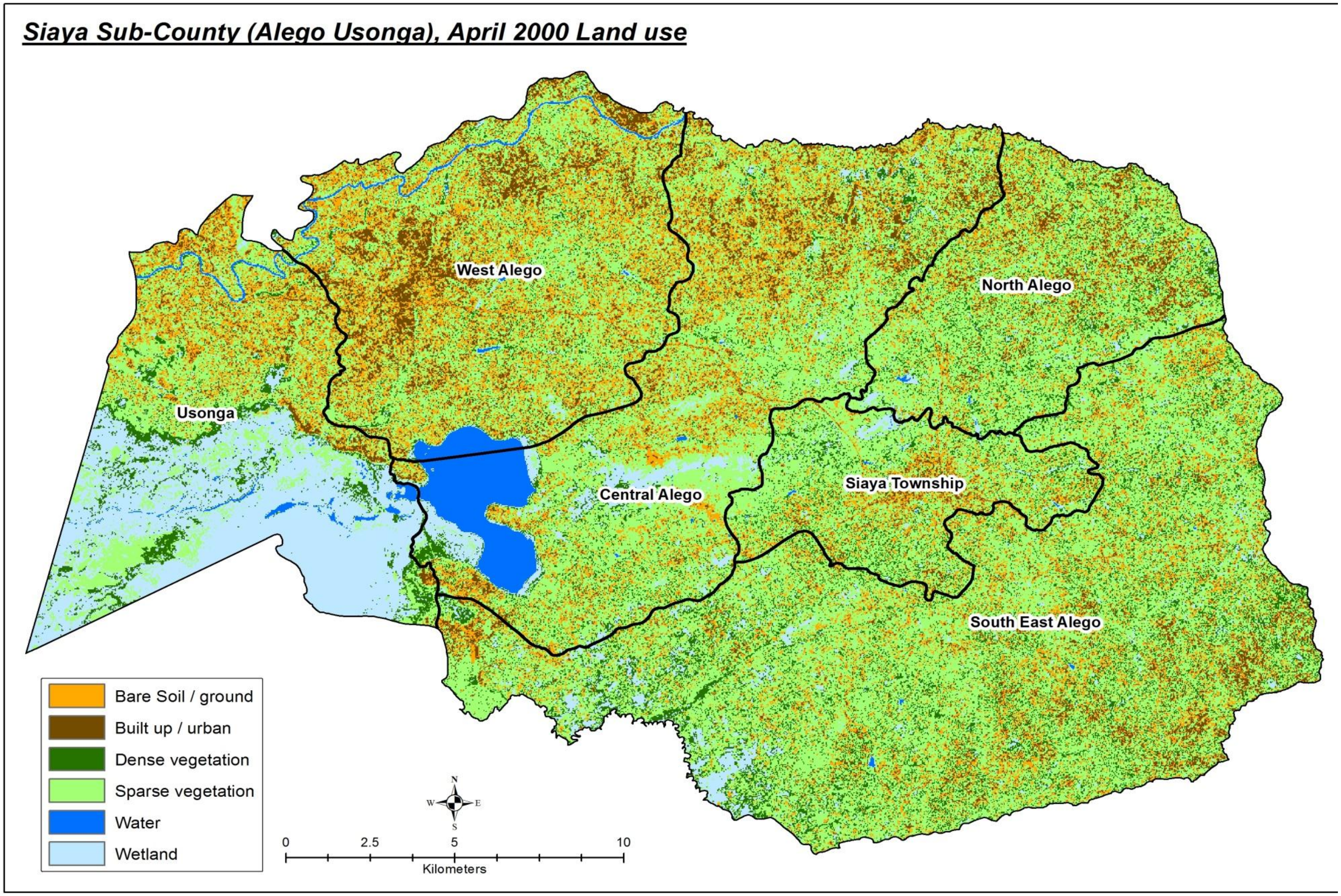
Other indigenous trees reported as being threatened due to CCV are: *Acacia polycantha* (Ogongo); *Milicia exclesia* (Olwa); *Terminalia mollis* (Opok); *Balanites aegyptica* (Othoo); *Albezia lebbeck* (Otur bum); *Euphorbia gandelebra* (Bondo); *Albezia koriara* (Ober); *Kingelia africana* (Yago); *Flueggea virosa* (Odok); *Diospyros abysinica* (Ochol); *Acacia lahai* (Alaktar); *Combretum molli* (Keyo). It was observed that the population of these trees has been on the decline since 1975 as the tree species listed are currently difficult to encounter growing in the wild. FGD respondents identified; *F. cycomorus*, *T. mollis*, *K. africana,* and *E. gandelebra* as the most threatened tree species yet they have numerous cultural uses apart from medicinal purposes. Besides CCV other causes perceived to be attributed to indigenous tree decline were: felling of trees for purposes of timber; charcoal burning; house construction; firewood; magenga (a cultural practice where bonfires at funerals are lit during night vigils); pest attack. This observation further corresponds well to land use maps that depict thinning vegetation overtime from 1975 to 2014 as shown in LUMs below


Siaya Sub-County (Alego Usonga), April 1975 Land use
West Alego
North Alego
Usonga
Central Alego
Siaya Township
South East Alego
Bare soil / ground
Built up / Urban
Dense Vegetation
Sparse
water
Wetland
N
W
E
S
0
2.5
5
10
Kilometers

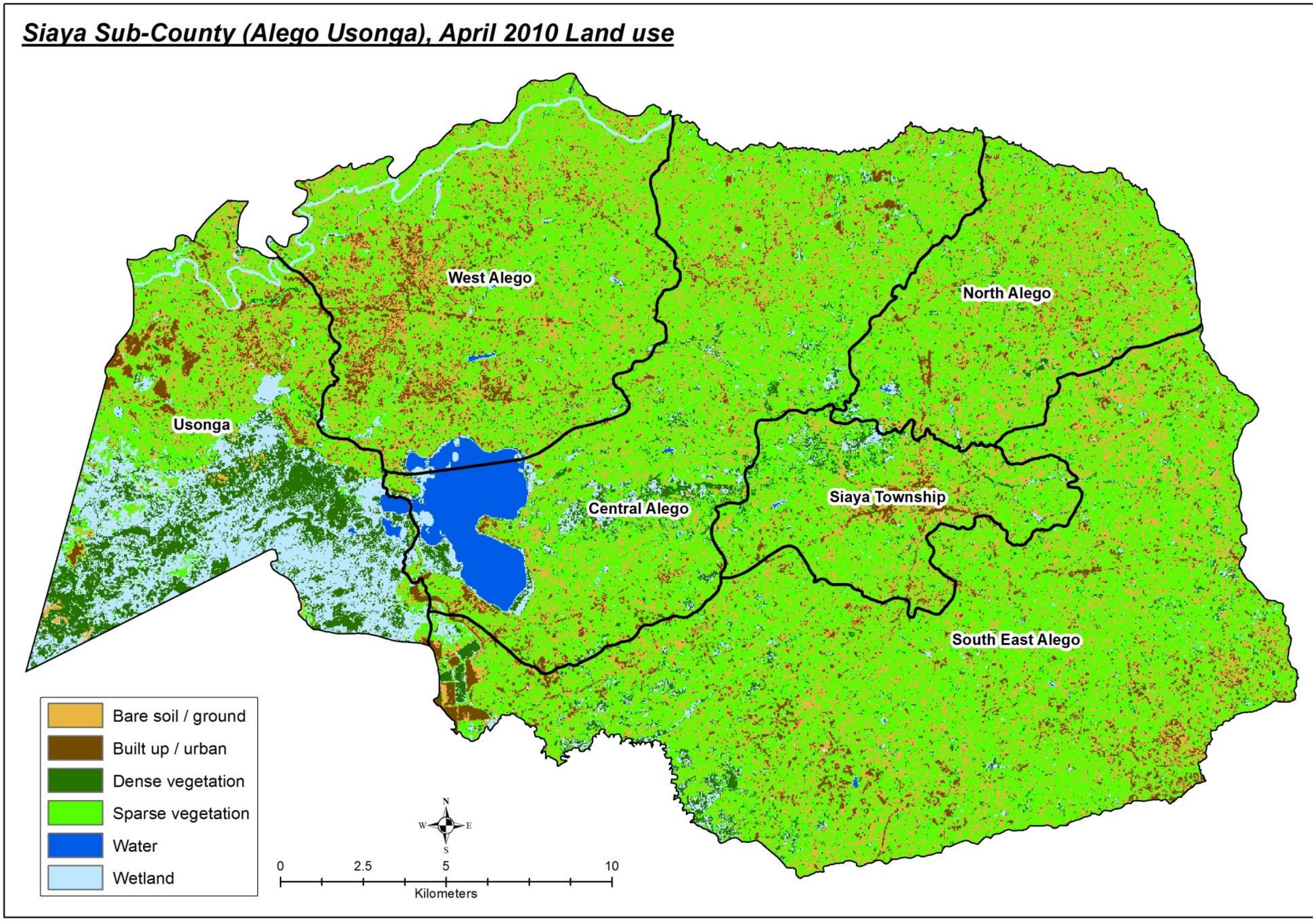
1148

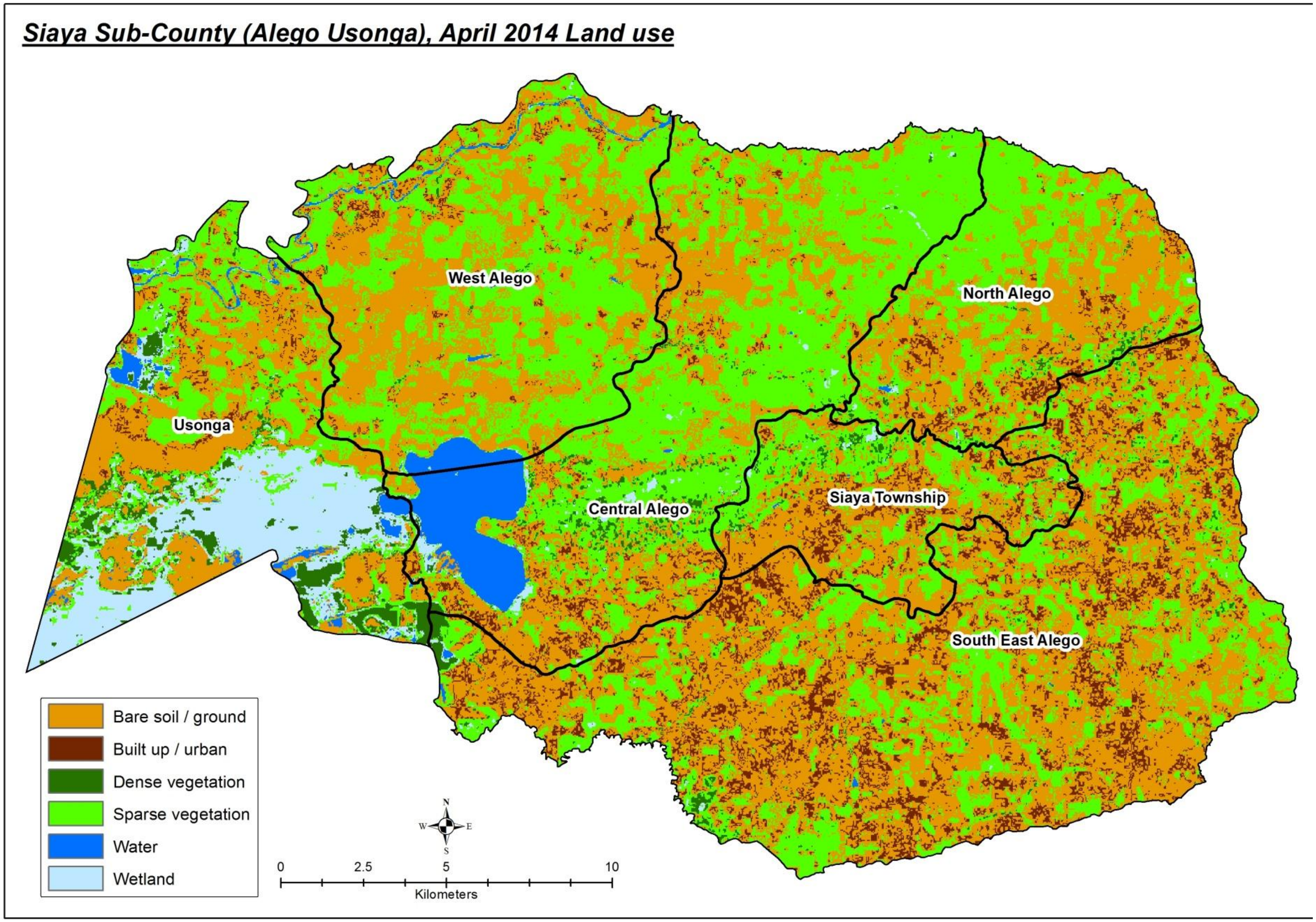

Siaya Sub-County (Alego Usonga), April 1990 Land use
West Alego
North Alego
Usonga
Central Alego
Siaya Township
South East Alego
Bare Soil / ground
Built up / Urban
Dense Vegetation
Sparse Vegetation
Water
Wetland
N
W
E
S
0
2.5
5
10
Kilometers

1149


Siaya Sub-County (Alego Usonga), April 2000 Land use
West Alego
North Alego
Usonga
Central Alego
Siaya Township
South East Alego
Bare Soil / ground
Built up / urban
Dense vegetation
Sparse vegetation
Water
Wetland
N
W
E
S
0
2.5
5
10
Kilometers

1151


Siaya Sub-County (Alego Usonga), April 2010 Land use
West Alego
North Alego
Usonga
Central Alego
Siaya Township
South East Alego
Bare soil / ground
Built up / urban
Dense vegetation
Sparse vegetation
Water
Wetland
N
W
E
S
0
2.5
5
10
Kilometers

1152 

Siaya Sub-County (Alego Usonga), April 2014 Land use
West Alego
North Alego
Usonga
Central Alego
Siaya Township
South East Alego
Bare soil / ground
Built up / urban
Dense vegetation
Sparse vegetation
Water
Wetland
N
W
E
S
0
2.5
5
10
Kilometers

From LUMs it is clear that on 17th April 1975 most of the plants were well developed and mostly forming dense vegetation with little bare ground (soils) implying very little planting activities and could be a pointer to the area having received a normal long rains season where planting was done early with early onset of rains. This trend is seen to progressively deteriorate over subsequent years. For instance in 1990, most of the farms were still bare ground during the same period implying little or no planting had taken place and could be an indicator of late onset of the long rains. At the same time mature tree density was low compared to 1975. The 2000 LUM taken over the same period shows further thinning of dense vegetation, increase in the built up area and more areas under bare ground which still indicates late onset of rains as more fields had not been planted. The 2010 image taken at the same time as that of1975 shows plants at a very young stage of growth on planted fields with virtually non existent dense vegetation. The same situation prevailed in 2014 as the image clearly indicates that by 17th April 2014, very little planting had taken place or if it had, there could be a possibility of massive crop failure from earlier planted fields based on observations that most ground consisted of bare soils. At this time dense vegetation was confined on the fringes of Yala Swamp. These observations correspond well with findings from FGDs

4.2.2: Farmer Perceptions of Rainfall patterns

Interactions FGDs affirmed that the community relied on indigenous knowledge passed on through generations from which prediction of possibilities of occurrences of rainfall were made. This knowledge comprised environmental and natural phenomena indicators that touched on wind, dry river beds, trees and bird behaviour. For instance it was reported that: *Ficus cycomorus* (Ngowo) would shed its leaves just before the onset of the long rains; *gigantean spp* (Akanda) would flower when rains were about; koga (a large dark bird of the eagle family) would intensify its chirping when rains were about; migration of the king stock bird (Ogunga) would happen just before the onset of rains; sparrows *(Passer melanurus* or opija) would swarm and summersault up in the skies at this time; streams that had been dry during prolonged dry spells would start spewing moisture in the morning and their river beds would suddenly become wet; whirlwinds (Kalausi) were intense and common just before the rains and caused a lot of grass thatched houses to burn especially for those households that carelessly handled open fires; intense winds would blow from east to west for approximately one and a half weeks and then change direction from west to east signaling onset of rains that would start pounding the area in less than a week of change of wind direction. These events are hardly observed now as one FGD member expressed.

> "*Rainfall was so reliable during the period prior to the late months of 1975 that we prepared our farms on time, practiced dry season planting and crops like sorghum were ratooned during the short rains season with considerable harvests realized, as ratooned crops matured early. Our rains were referred to as "Koth ma Kawango" a term used to imply Kakamega rainfall as wind patterns associated with rainfall came from that direction. This has become irregular and hailstones are now more common at night. These events are unusual and we cannot grasp these changes any more"*.
> [FGD participant, 13th October, 2015]

Subsequently it was reported that seasons have changed as rainfall intensity has reduced and is irregular thus frequent crop and fodder failure further impacting food security. In this study one KI observed that,

> *"Rainfall patterns of the study location have changed to the extent that short rains events are now more intense and reliable when compared to the long rains seasons hence chances of crop failure during the former are considerably low".*
> [Participant observer, 21st October, 2015]

In spite of these, perceptions of HHs practicing SDFS in respect to categorical precipitation variables (increasing decreasing, fluctuating, no change and unpredictable) were significant (χ^2=12.029, p=0.017). Such differences in perceptions to CCV occurring in the same locality could play a role on adaptation strategies and rates as variations in perceptions could result in longer adaptation processes (table 4.9).

Table 4.9 Perceptions of rainfall by SDFS N=100

Statement	Yes%
Early onset of long rains (rain starting earlier)	32%
Early Cessation of Long rains (rain ending earlier than normal)	34%
Late onset of long rains (rain starting later that normal)	64%
Late cessation of long rains (rain ending later that normal)	17%

Change in rainfall amount during the main rainy season (Fluctuating)	93%
Increasing rainfall in amount during main rain season (above normal)	25%
Decreasing rainfall in amount during main rain seasons (below normal)	43%
Shift in the timing of the onset of rain in the main seasons	82%
Long rains than normal (becoming more intense within seasons)	14%
Long rains than normal (becoming less intense within seasons)	38%
Early onset of short rains (rain starting earlier than normal)	12%
Late onset of short rains (rain starting later than normal)	50%
Early cessation of short rains (rain ending earlier than normal)	45%
Late cessation of short rains (rain ending later than normal)	10%
Short rains than normal (becoming more intense within seasons)	11%
Short rains than normal (becoming less intense within seasons)	27%
long term rainfall increasing	17%
Long term rainfall decreasing	70%
Rainfall has been fluctuating (seasons don't receive uniformly distributed rains)	88%
Floods are now more common	20%
Floods are now less common	69%
Flood intensity is increasing	23%
Flood intensity is decreasing	63%

4.2.3: Farmer Perceptions of Temperature trends

There was a general consensus amongst FGD participants that temperatures of the study location had increased. This perception was associated with environmental changes observed in relation to emergence of invasive noxious weeds attributed to biome-range shifts hence proxy bio-indicators of global warming. Specific noxious weeds singled out were *Mimosa pudica* (siro-siro) (plate 4.1), *Lantana camara* (Obengele), *Striga hermonthica* (hayongo) and *Occimum basilicum* (plate 4.2).

From discussions it emerged that *M. pudica* (siro-siro) an endemic species of the lower and drier regions (Bondo and Rarieda) characterised by high environmental temperatures is now common in the study location that was once devoid of it, as the area had relatively low temperatures. According to one FGD participant,

> "*The shrub is thorny, a non-livestock feed, smothers and kills grasses due to its growth habits, while its sharp thorns inhibit grazing of understory grasses*", [FGD participant 13th October 2015].

Similarly, it also emerged that weed population (invasive ruderal species) is on the rise with *L. camara, O. basilicum* and *Stachytarpheta sp.* (blue porter weed) showing signs of permanently establishing themselves on abandoned farmlands and disturbed sites (Plate 4.2). *L. camara* in some parts was observed to have formed single species ruderal communities implying a shift in ecosystem composition. These changes were attributed by farmers to increased temperatures amongst other climate change factors with detrimental effects on SDFS due to suppressed Maize, beans and Napier production. This correlated well with results from HH surveys as farmer perceptions of temperature trends were significant (χ^2=26.750, *p*=0.000). Further 84% of the respondents concurred that the temperature of the study location was increasing while 8% perceived it as decreasing.

Plate 4.1: A designated grazing pasture under heavy M. pudica infestation (brown patches). Note that grasses have been smothered and suppressed due to the allelopathic properties of the invasive weed.

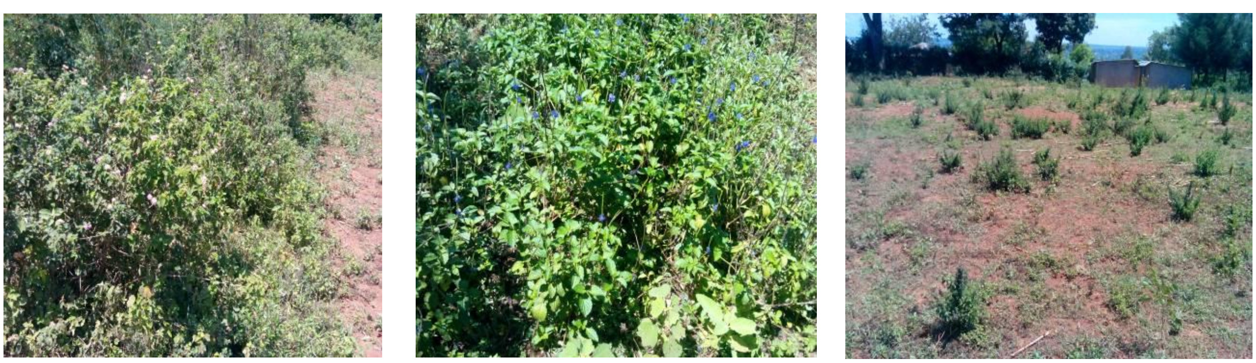


Plate 4.2: Ruderal species L. camara, Stachytarpheta spp and O. basilicum

4.2.4: Farmer Perceptions of effects of Temperature and Rainfall on Quantities of fodder

Farmer perceptions on quantities of fodder produced were varied (figure 4.10) though 94% of respondents surveyed concurred that temperature and rainfall had effects on feed availability for dairy cattle nutrition despite a high proportion of respondents differing on effects of rainfall on soil erosion, and temperature in relation to fodder production. This is an indication that although farmers were aware of CCV impacts on SDFS they did not keenly observes effects of each element on production variables.

Survey data revealed that 99% of households perceived the quantity of fodder fed as having effects on milk yields (figure 4.11) as there were significant differences in relation to quantities of fodder fed in relation to milk yields. Reduced quantity of fodder fed significantly led to decreased milk yields ($p < 0.05$) however increased fodder fed did not significantly lead to increased milk quantity and could be attributed to other factors such as quality of fodder, ambient temperature and genetic makeup of the breeds reared.

Table 4.10: Perceived effects of CCV on quantities of fodder produced (N=100)

CCV effects on fodder production	**Yes (%)**
Drought (reduced fodder production)	94
Floods (lead to stunted growth)	46
Floods (lead to fast growth)	3
Floods (low production due fodder crop damage)	41
Increased temperature(increased fodder production)	5
Increased temperature(low fodder production)	72
Increased temperature (higher fodder diseases)	37
Increased temperature (high weed density hence low production)	42
Increased temperature (rapid growth hence high production)	10
Rainfall fluctuation (leads to increased fodder production)	4
Rainfall fluctuation (leads to reduced fodder production)	74
Long rains than normal (lead to increased fodder production)	20
Soil erosion (affects soil fertility hence low fodder production)	53
Emergent invasive plants and fodder disease (affect production)	45

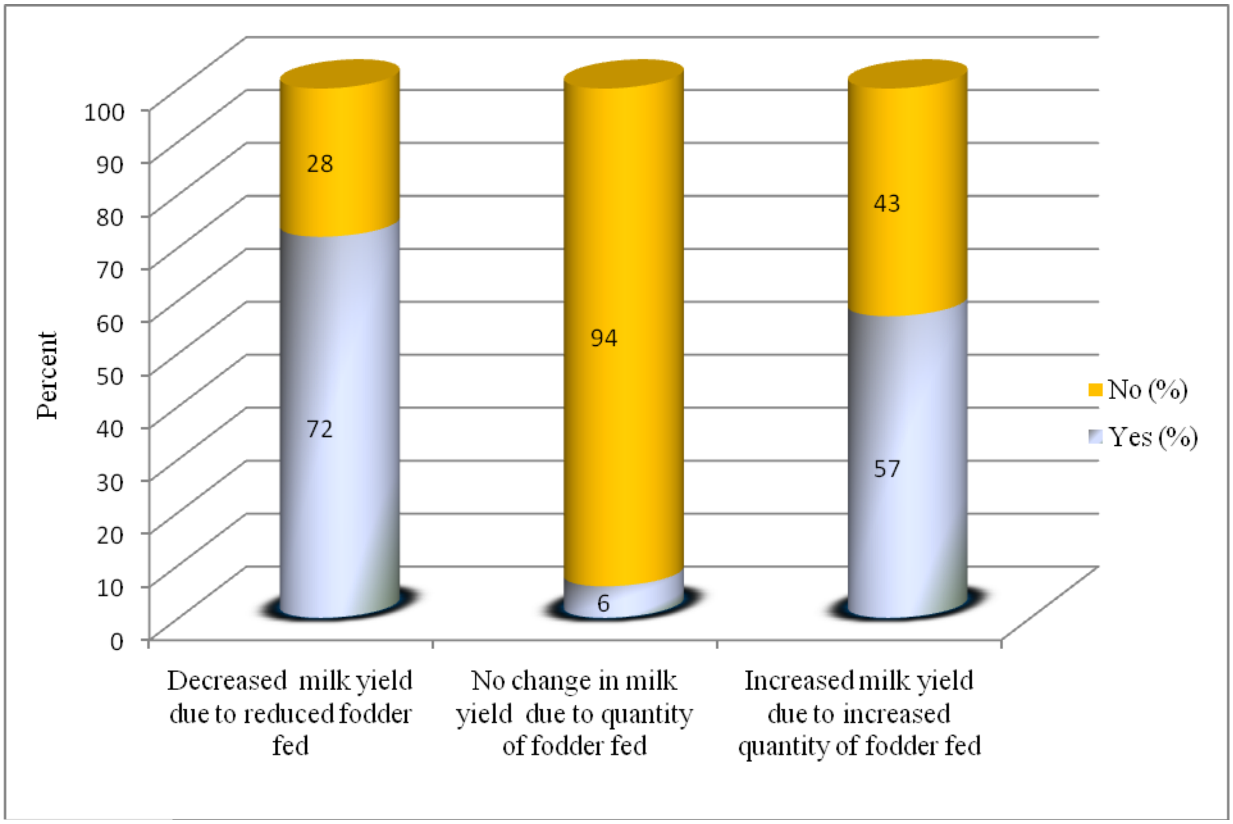


Figure 4.12: Quantities of fodder fed in relation to milk yields (N=100)

Fodder production specifically *P. purpureum* was observed to be the major bulk feed relied on by SDFS for optimum performance under the cut and carry system. A comparison of acreage under fodder over a span of 10years (2004 and 2014) was done and results indicated that the acreage under Napier increased by 93% between 2004 and 2014 (table 4.11). Similar increases were observed in respect to improved pastures, fodder legumes and natural pastures (*ibid*). At the same time, the number of fodder trees (MPTS) had increased by 50.7% over the same period.

Table 4.11: Acreage under various types of fodders

Acreage under Napier		Acreage under improved grasses		Acreage under fodder legumes		Acreage under Natural grazing		Number of Multipurpose trees	
2004	2014	2004	2014	2004	2014	2004	2014	2004	2014
60.3	116.4	1.75	8.99	1	6.65	5.9	10.4	1145	1726.25

The total population of dairy cattle under SDFS in the study location was low 298 and comprised of: 10% male and 17% female calves; 5% young bulls; 3% mature bulls; 9% bulling heifers; 19% dry cows; 37% cows in milk (figure 4.13). Based on the number of animals vis a vis the acreage under *P. purpureum*, farms practicing SDFS were overstocked since studies show that one dairy animal requires one acre of *P. purpureum* established under conventional system of fodder production for optimal production (Kibirizi et al., 2014). Multi Purpose Trees (MPTS) planted to provide plant based animal proteins, timber products, enhance soil fertility and soil conservation management were under-established since there were 1,726 trees against a requirement of 149,000 MPTS. According to Franzel et al. (2014) 500 fodder trees are required to sustain one dairy animal annually for increased productivity. This implies inadequate fodder and could contribute to poor performance of SDFS under projected future adverse effects of CCV.

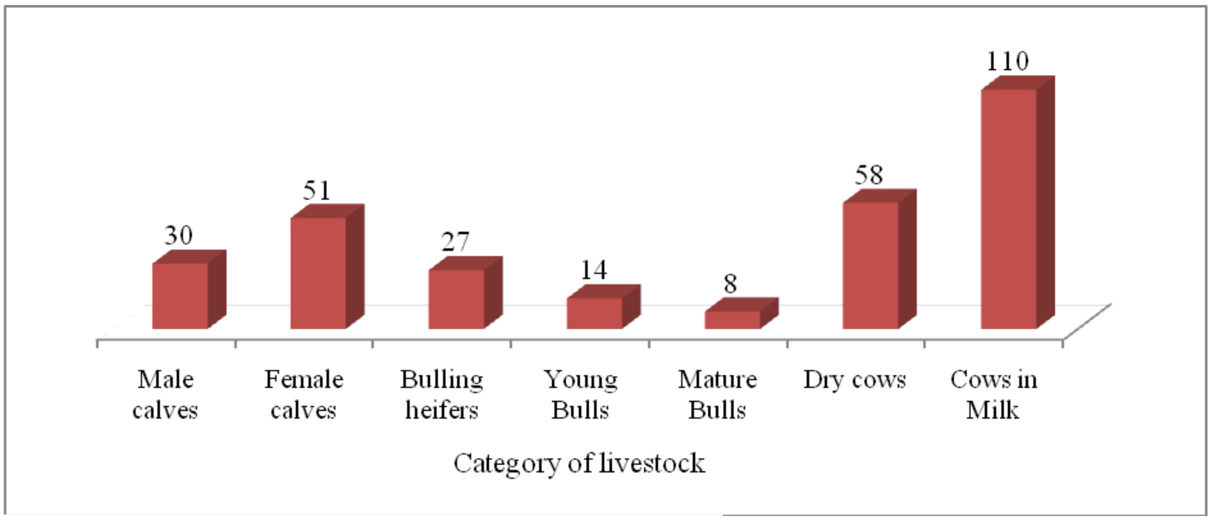


Figure 4.13:Dairy herd population by category(N=298)

SDFS in the study location therefore had inadequate fodder that curtailed feed conservation in times of plenty for use during periods of scarcity yet latter periods are predicted to become more frequent in future (Funk et al., 2011; Carabine et al., 2014). It was further deduced that milk supply to the dairy society increased tremendously between 1994 and 2014 but recent years exhibited high fluctuations coinciding with inter-seasonal climate variability that impacts water and fodder availability since peak milk supplies corresponded to MAM and SON seasons. Milk supplies to the dairy plant increased over time producers (figure 4.14) due to better marketing facilities as MMDCS employed milk collectors who went on bicycles to far flung areas of the Sub-County to collect milk from. It was further observed that the means ($\bar{x}$) of milk supplies to MMDCS by SDFS in the Sub-County varied significantly over the period 2014, 2004 and 1994 (p value<0.01).

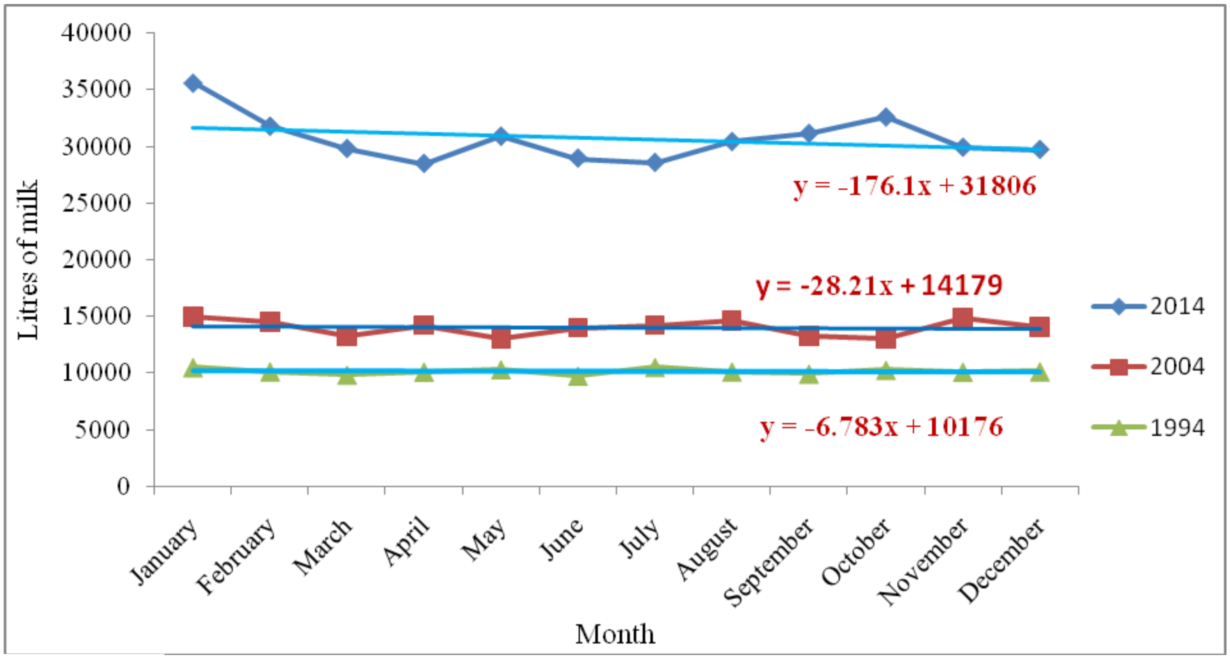


Figure 4.14: Monthly milk supply by SDFS to Mur Malanga Dairy Cooperative Society

An analysis of correlations and covariances also revealed that none of the sales in 2014, 2004 and 1994 were correlated (p values>0.05) as there was greater variation between sales over this period (table 4.5)

Table 4.12: Correlations/covariances of milk sales (1994, 2004, and 2014)

Correlations/Covariances				
		2014	2004	1994
2014	Pearson Correlation	1	.117	.431
	Sig. (2-tailed)		.716	.162
	Sum of Squares and Cross-products	44163386.729	1836652.854	2269336.583
	Covariance	4014853.339	166968.441	206303.326
2004	Pearson Correlation	.117	1	.253
	Sig. (2-tailed)	.716		.427
	Sum of Squares and Cross-products	1836652.854	5539530.729	472035.083
	Covariance	166968.441	503593.703	42912.280
1994	Pearson Correlation	.431	.253	1
	Sig. (2-tailed)	.162	.427	
	Sum of Squares and Cross-products	2269336.583	472035.083	627839.167
	Covariance	206303.326	42912.280	57076.288

4.2.5: Farmer Perceptions of Disease Challenges due to CCV

Farmers in the study location reported having faced myriad disease challenges posed by CCV as 77% of HH respondents perceived having experienced vector borne diseases with 58% attributing this to a combination of ticks, biting and tsetse flies while 79% affirmed that livestock disease incidences were on the increase. There was a correlation between increased disease burden and high vector build up attributed to: increased incidences of drought (47%); increased flood events (42%); high temperatures (39%); suitable habitats due to occurrence of invasive and ruderal plant species (34%); poor slurry management leading to suitable breeding grounds for disease vectors (32%).

Results from a binary logistic regression model showed that: invasive plant species; temperature; floods; frequency of drought; poor waste management had significant effect on incidences of livestock diseases ($p<0.05$). An increase in invasive plant species created suitable vector habitats (p=0.045). Increased temperatures (p=0.021), floods (p=0.037) and droughts (p=0.032) led to vector build up while poor waste management (p=0.027) contributed to suitable vector breeding sites that increased incidences of livestock diseases (table 4.13)

Table 4.13: Results of Binary Logistic Regression **(***Variables in the Equation)*

		B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**95% C. I. for EXP(B)**	
								Lower	**Upper**
Step 1[a]	Poor Waste Mgt Suitable Vector Breeding Sites	3.109	1.410	4.863	1	.027	22.401	1.413	355.072
	Drought Vector Build Up	1.185	.992	1.427	1	.032	3.270	.468	22.844
	Flood incidences Vector Build Up	3.344	1.604	4.348	1	.037	28.333	1.222	656.789
	Increasing Temperature Vector Build Up	3.396	1.476	5.290	1	.021	29.837	1.652	538.886
	Invasive Plant Species Suitable Vector Habitats	-.246	1.260	.038	1	.045	.782	.066	9.238
	Constant	-8.987	5.261	13.027	1	.000	.000		

a. Variable(s) entered on step 1: Poor Waste management, Drought, Flood incidences, Increased Temperature, Invasive Plant Species.

Incidences of livestock diseases= (.782 Invasive Plant species) + (29.837 Increased Temperature) + (28.333 Flood incidences) + (3.270 Drought) + (22.401 Poor waste management)

Similarly 78% of respondents attributed decreased milk yield to drought while 22% attributed it to increased milk yield. At the same time vector populations in relation to vector borne diseases were positively correlated to decreased milk yields. The 22% of HHs attributing drought to increased milks could possibly be to higher dry matter (DM) content in forages at this time hence dairy cattle are supplied with the adequate DM for both maintenance and production but this is open for further investigation.

A binary logistic regression model (table 4.14) showed that variation in tsetse flies and tick population had significant effect on the prevalence of vectors (p<0.05). Moreover, an increase in the population of tsetse flies (p=0.002) increased the prevalence of vectors on the farm at a larger magnitude as compared to an increase in tick population (p=0.012). Presence of biting flies (p=0.133) did not significantly affect presence of vectors but this did not imply that they had no implication on prevalence of livestock diseases as the model did not pick biting flies as having a significant effects on the presence of other vectors.

Table 4.14: Variables in the Binary Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1[a]	Tsetse	3.875	1.250	9.612	1	.002	48.178	4.159	558.123
	Ticks	-3.418	1.364	6.277	1	.012	.033	.002	.475
	Biting flies	2.638	1.756	2.257	1	.133	13.989	.448	437.092
	Constant	-6.084	2.124	8.201	1	.004	.002		

a. Variable(s) entered on step 1: Tsetse, Ticks, and Biting flies.

Prevalence of vectors on the farm = 0.002 + (48.178 Tsetse) + (.033 Ticks)

4.3: Relationship between Climate Trends and Farmer Perceptions

4.3.1: Droughts and Floods

Farmers in the study site related drought incidences to drying up of rivers that were once perennial with no tangible benefits as they obtained free fish from these rivers hence reliance on alternative sources of proteins that the poor and vulnerable families cannot afford with resultant increase in food insecurity expressed as malnutrition. Further droughts were also associated with aquifers becoming deeper resulting to drying up of indigenous trees that once served as indicators of high aquifers. These observations correspond well with long term annual rainfall trends which depicted long term drying, (figure 4.1 and LUMs) hence inadequate recharge of aquifers with implications on blue availability water for irrigated fodder. Further, land use maps (section 4.2.1) illustrate gradual expansion of bare ground and the built environment that have a bearing on underground recharge due to increased surface runoff as elicited by the rapidly shrinking wetland and thinning of dense vegetation. This observation is consistent with findings that CCV impacts food production systems with significant negative impacts in SSA (GOK, 2013; Porter et al., 2014; Niang et al., 2014) and that persistent and prolonged droughts accompanied by other precipitation anomalies will affect recharge of aquifers (Niang et al., 2014). Flood occurrences were observed to shift from the long to short rains seasons and were associated with low soil fertility due to increased runoff causing soil erosion hence reduced maize, beans and Napier grass productivity.

4.3.2: Rainfall

With regard to rainfall, farmers in the study location relied on indigenous knowledge and natural phenomena to predict onset of rainfall events that triggered timely land preparation and dictated farming activities which consisted of seasonal cropping calendars hence minimal losses that translated to food security. These phenomena are perceived to have changed hence conclusions that climate has changed as depicted by long term drying of the MAM, (figure 4.3), MAM/J (figure 4.4), DJF (figure 4.5) and JJA (figure 4.6) seasons. However the SOND season (figure 4.8), depicts long term wetting implying shifts in rainfall seasons coupled by their intensity. This further confirms findings that rainfall over the Eastern Africa Region has been on the decline for several decades (Shongwe et al., 2011; Williams and Funk, 2011; Carabine et al., 2014).

Although there was concurrence that the climate of the study location had changed a comparison of cropping patterns over a span of ten years (2004 and 2014) as portrayed by seasonal calendars (figures 4.15 and 4.16) had not changed in tandem, yet, the traditional cropping seasons show long term drying that would have necessitated a shift in planting dates of crop and fodder varieties.

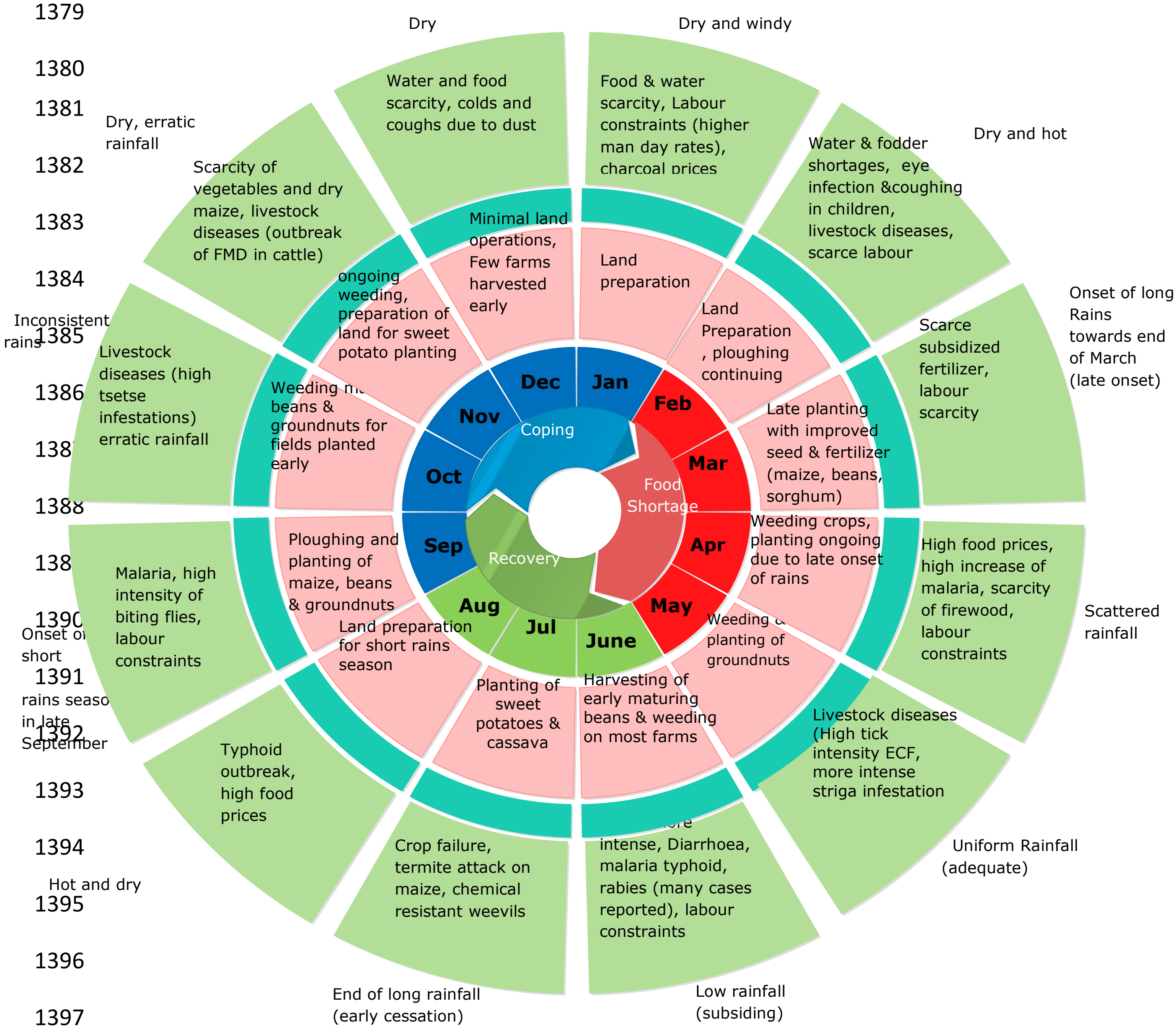


Figure 4.15: Cropping calendar (2014) drawn on 15th October 2015

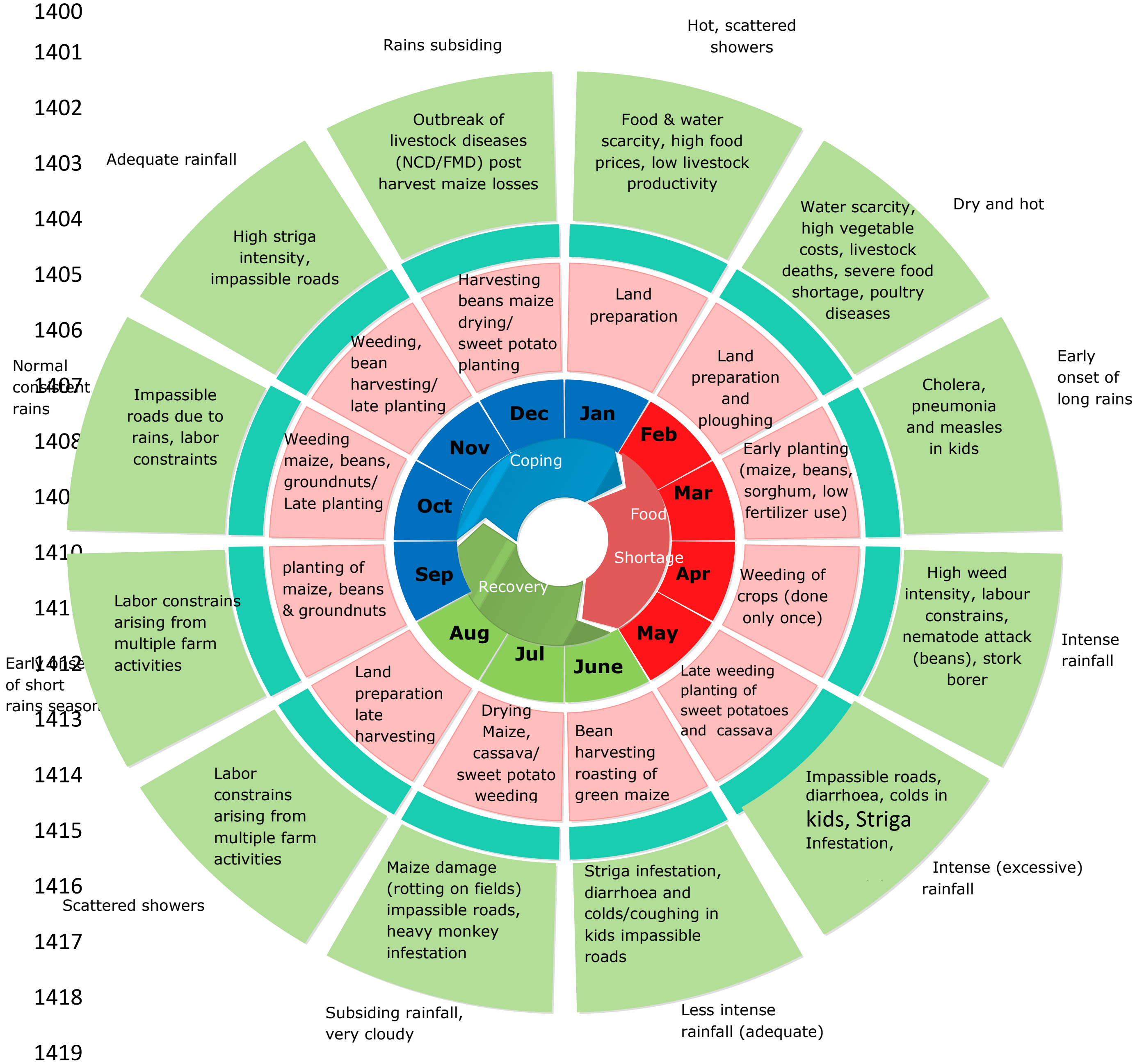


Figure 4.16: Cropping calendar (2004) drawn on 15th October 2015

In relation to rainfall, years of high *Glossina spp* (tsetse fly) challenge were also identified and their densities closely linked to extreme wet events that gave rise to favourable environmental conditions for their breeding and spread. It was reported that during extreme wet events the flies multiplied fast in swampy and riverine areas followed by migration to other parts of the Sub-County hence high flare-ups of Trypanosomiasis incidences of which *B. taurus* breeds have low resistance (GOK, 2015). This scenario is envisioned to play out more often in future in parts of East Africa projected to have a long term wetting (Hulme et al., 2001; Funk et al., 2011; ICPAC, 2016). From the cropping calendars it is deduced that the length of food shortages, recovery, and copping period has remained the same between 2004 and 2014 with little or no normal period of food supply yet adaptation strategies are geared towards prolonging the normal period, shorten the food scarcity, recovery and copping periods to create resilient systems.

4.3.3: Temperatures

Farmers perceived temperature trends to have increased and positively related this to emergence of invasive noxious plants and weeds like *Striga hermonthica* (hayongo) and *M. pudica* which are associated with regions that have elevated temperatures, increased populations of ruderal species alongside diseases such as black sigatoka of the *Musa spp* (Banana), cassava mosaic of *Manihot esculenta*, Napier Stunt Disease (NSD) and snow mold diseases that are positively correlated to low crop and fodder productivity. This perception corresponds well with recorded long term minimum and maximum temperatures (figure 4.9 and figure 4.10) implying longterm upward shifts in maximum and minimum temperatures have influenced proliferation and spread of invasive weeds. Field observations revealed that *M. pudica* is a non-native species of the study location and due to favourable environmental conditions (high temperatures and reduced rainfall quantities) that aid in breaking its seed dormancy (Ajorlo et al., 2014), had rapidly established itself and currently threatens grass species mix relied on by SDFS during fodder dearth periods.

This observation is attributed to allelopathic properties of invasive species (Ajorlo et al., 2014) that leads to reduced quantities of standing hay relied on by SDFS during prolonged dry spells under the cut and carry system. Hence non-native invasive species influenced by CCV degrade and destroy ecosystems by altering resource availability, disturbance regimes or habitat structure (Moorhouse and Macdonald, 2015).

4.3.4: Transect walk

A transect walk to ground truth findings from the FGDs on major climatic trends coupled with results from HH surveys, KIs, and cropping calendars to fill in biophysical gaps revealed that non SFDS contributed to increased vulnerabilities of the overall biophysical environment further straining SFDS (table 4.15). Farming systems in the study area were mixed small scale ranging from predominantly peri-urban agricultural influence (Gombe–start point) to purely rural setting agricultural production (Nyamila – endpoint). Gombe and Hono were observed to have approximately 45% and 70% of land fallow while Nyamila had close to 90% with dense stands of *Rhynchelytrum repens* (red top grass) and *Tagetas minuta* (Mexican marigold) which are proxy bio-indicators of infertile soils arising from nutrient depletion (Mairura et al., 2007). Natural pastures were observed to be under heavy invasion of *Hyparrhenia rufa*, a tufted perennial increaser I grass species that was bound to further lower livestock carrying capacity yet this grass has been found to host NSD causative agent (Obura et al., 2011) and could further impact SDFS arising from the possibility of NSD causative agent being easily transmitted to Napier grass.

Similarly it also emerged that invasive ruderal species population was on the increase with *L. camara, O. basilicum,* and *Stachytarpheta sp.* (porter weed) showing signs of permanently establishing on abandoned farmlands and disturbed sites. *L. camara* in some areas was observed to have formed single species ruderal communities implying a shift in ecosystem composition. These changes were attributed to increased soil erosion leading to low soil fertility amongst other climate change factors with detrimental effect on SDFS since, besides being an invasive ruderal plant; *L. camara* forms favourable resting sites for *Glossina sp* (tsetse flies) that could lead to spikes in Trypanosomiasis cases.

Despite soil erosion being singled out as a major source of low soil fertility and apart from trash lines present on cultivated farms, there were no visible soil conservation structures such as retention ditches and terraces. This further exacerbated biophysical vulnerabilities as gullies were observed to have formed in areas with steep slopes while reel erosion was present on newly tilled land. Areas surrounding rivers Riat in Nyalgunga and Samajina in Hono were heavily eroded as depicted by the presence of gullies and protruding rock-outcrops.

Table 4.15: Results of Transect Walk of the study location (North Alego)

Feature of Interest	Start point	Mid point	End point
	Gombe	**Hono**	**Nyamila/Nyalgunga**
Land Use	Farmlands (Peri-urban farming)	Farmlands (Rural setting with some Peri-urban farming influence)	Farmlands (Rural farming) Poverty levels in this area based on observations of housing, social amenities and farm infrastructure were high and would warrant further studies by social scientist.
Farming system	Small scale mixed agriculture with prominent peri-urban settlements. Around 45% of farms were estimated to be fallow with dense bush (ruderal species) encroachment. Brick making activities were prominent	Small scale mixed agriculture with about 70% of land estimated to be fallow. Dominated with mango trees and dense bush (ruderal species) encroachment.	Small scale mixed agriculture with close to 90% of land estimated to be fallow. Dominated with dense bush (ruderal species) encroachment. Low density of dairy breeds due to low frequency of Napier fields encountered.
Crops grown	Maize, beans, bananas (both local and exotic varieties), cassava, sweet potatoes, tomatoes, Napier grass, small scale dairy production, indigenous livestock. Some farms had plots under Integrated Pest Management system (IPM) (Stimulo- deterrent technique).	Maize, beans, bananas (both local and exotic varieties), cassava, sweet potatoes, sorghum, chewing cane, small scale horticultural production along river Samajina, Napier grass, small scale dairy production, indigenous livestock. Some farms had plots under Integrated Pest Management system (IPM) (Stimulo-deterrent technique).	Mono-cropped fields of maize and beans on very few farms, bananas (majorly local varieties), cassava (mixed varieties), low densities of avocado, mango trees and sweet potatoes, sorghum stovers, Napier grass strips implying less intense dairy production activities, indigenous livestock. The area had very low tree cover.
Natural vegetation	Indigenous and exotic trees dominated by *Markhamia lutea*, Eucalyptus, Jacaranda, avocados, Cypress, *Cassia sp*, *Spathodea campanulata*, *Leucaena sp*, *Croton sp*, *Mangifera indica*, *Albezia coriaria*, *Euphorbia turicalli*, *Psidum quajava*, natural grasses with dense stands of *Lantana camara* and *Mimosa pudica* on abandoned (fallow) farms.	Indigenous and exotic trees dominated by *Markhamia lutea*, eucalyptus, jacaranda, avocados, *Croton sp*, *Tarmarindus indica* Cypress, *cassia sp*, *Spathodea campanulata*, *Leucaena sp*, *Croton sp*, *Mangifera indica*, *Albezia coriaria*, *Euphobia turicalli*, *Psidum quajava*, *Sesbania sesban*, *Erythrina abyssinica*, *Ficus sp* natural grasses dominated with *Cymbopogon sp.* (lemon grass) and *Hyparrhenia rufa* with dense stands of *Lantana camara* and *Mimosa pudica* on abandoned (fallow) farms.	Indigenous trees interspersed with few exotic species, dominated by *Markhamia lutea*. *Eucalyptus sp*, avocados, *Cassia sp*, *Croton sp*, Albezia *coriaria*, *Euphobia turicalli*, Psidum *quajava*, *Erythrina abyssinica*, *and Ficus sp* natural grasses dominated with *Cymbopogon sp.* (lemon grass) and *Hyparrhenia rufa* as an increaser species with dense stands of *Lantana camara* and *Mimosa pudica* on abandoned (fallow) farms and natural grazing fields.
On farm water management	None. The upper parts were relatively flat while farms neighbouring rivers had very gentle slopes. Prominent standing pools of water during rains (soil hardpan) were observed, eucalyptus trees planted on cropland	None. The area had a higher slope percentage compared to the start point. The terrain was hilly hence higher surface runoff, eucalyptus trees planted close to river Samajina	None. The area had the highest slope compared to the rest of the transect walk sampling points. The terrain was hillier hence more surface runoff compared to other sampling points.
Soil erosion	Reel erosion on farms with gentle slopes and those adjacent to rivers was observed	Reel erosion prominently was visible on newly cultivated lands; some farms are heavily eroded due to protruding rock outcrops while gullies are present on farms bordering rivers and streams.	Soil erosion was more prominent on cultivated sites especially on farms surrounding river Riat in Nyalgunga. The soils though loamy looked depleted as reflected by observed crop

			performance and dominance of *Rhynchelytrum repense* (rose top) grass (a bio-indicator of exhausted soils)
Soil conservation measures	There were no visible soil conservation structures	A majority of farms had no soil conservation structures; some farms have trash lines to control surface runoff while very few have terraces.	Soil conservation structures are nonexistent though a few farms have trash lines to control surface runoff despite the area having very steep slopes. Gullies are more prominent.
Cropping problems	Maize and bean crop population was low due to poor plant spacing, a high rate of maize off types was observed, around 35% of crops were planted against contours, crop diseases (bananas are under black sigatoka attack, some cassava stems are under cassava mosaic disease attack), Napier grass was poorly managed, widespread and heavy Napier stunt disease observed, some Napier fields had snow mold disease and leaf rust. Natural pastureland was under heavy *M. Pudica* infestation.	Maize and bean crop population was low due to inappropriate plant spacing, a higher percentage of maize off types was observed, around 40% of crops was established against contours, crop diseases (bananas are under black sigatoka attack, some cassava stems are under cassava mosaic disease attack), Napier grass was poorly managed, widespread and heavy Napier stunt disease observed, some Napier fields had snow mold and leaf rust disease. Natural pastureland was under heavy *M. Pudica*, *Occimum sp* and *Stachytarpheta sp* (blue porter weed) infestation.	Maize (local varieties) and beans were mono-cropped with very low plant population, ploughing along contours was common at around 65% on observed farms, diseases of bananas, cassava and Napier grass more prominent, natural pastureland was also under heavy *M. Pudica* , *Occimum sp* and *Stachytarpheta sp* (blue porter weed) infestation.
Probable Interventions	Proper plant spacing to maximize crop yields, planting along contours, use of trash lines, terracing, cutoff drains, crop diversification, establish high value crops (horticulture), use of certified seeds and clean planting materials, encourage bush control, regular weeding and heavy manuring of fodder crops, establishment of improved pastures, use of Napier stunt disease tolerant cultivars, institute controlled grazing measures, encourage water harvesting for small scale irrigation to promote off season crop production and woodlot establishment. Finally encourage rotational grazing through proper farm planning, mechanical removal of noxious weeds from areas set aside for grazing and rehabilitation of soils on brick making sites used for brick making.	Proper plant spacing to maximize crop yields, planting along contours, replace trash lines with terraces, intensify use of cutoff drains, diversify crop enterprises, intensify establishment of high value crops (horticulture), use of certified seeds and clean planting materials, encourage bush control, regular weeding and heavy manuring of fodder crops, establishment of improved pastures, use of Napier stunt disease tolerant cultivars, institute controlled grazing measures especially on farms neighbouring river Samajina, encourage water harvesting for small scale irrigation to promote off season crop production, promote woodlot establishment, discourage planting of eucalyptus on riparian sites to conserve the ecosystem. Finally encourage rotational grazing through proper farm planning and mechanical removal of noxious weeds from areas set aside for grazing.	Proper plant spacing to maximize crop yields, encourage cultivation along contours, establish terraces on farms, introduce improved fallow systems to build up soil organic matter, intensify use of cutoff drains, diversify crop enterprises, introduce high value crops (horticulture), use of certified seeds and clean planting materials, encourage bush control, regular weeding and heavy manuring of Napier strips, establishment of improved pastures, use of Napier stunt disease tolerant cultivars, institute controlled grazing measures especially on farms neighbouring river Riat, encourage water harvesting for small scale irrigation to promote off season crop production, promote woodlot establishment, Finally encourage rotational grazing, proper farm planning and mechanical removal of noxious weeds from areas set aside for grazing.

CHAPTER FIVE

ADAPTATION STRATEGIES

5.1: Introduction

Adaptation actions are place and context specific and are crucial if the affected communities are to improve livelihoods through enhanced food security and livelihood diversification aimed at creation resilient systems amidst CCV hence reduced vulnerabilities. This chapter presents adaptation strategies employed by SDFS in the study location based on perceived challenges identified and adverse impacts posed by CCV besides institutional roles in development and strengthening adaptation strategies for increased farm incomes and farmer wellbeing.

From the HH surveys 79% of the SDFS were female while 29% were male. Of the study sample: 7% were aged between 26-35years; 14% were between ages 36-45; 34% were aged between 46 and 55years; 29% were between 56-55; 16% were aged 66 years and above (table 5.1). The study sample had attained various levels of education (*ibid*) while HH sizes varied and ranged from 1 to over 10 (table 5.2).

Table 5.1: Cross tabulation of age group vis-à-vis education levels

Age Group	**Education Level (N=100)**						**Total**
	No Education	**Primary School**	**Secondary School**	**High School**	**Middle Level College**	**University Level**	
26-35	0	6	0	0	1	0	7
36-45	1	10	3	0	0	0	14
46-55	4	16	7	1	3	3	34
56-65	5	15	3	0	3	3	29
> 66 years	3	8	3	0	1	1	16
Total	**13**	**55**	**16**	**1**	**8**	**7**	**100**

Sources of labour in the HHs varied (Table 5.3) just as the type of housing which is considered crucial when harvesting rainwater using roof catchment for use during scaarcity or to increase HH per capita water consumption (Table 5.4) . At the same time 54% of the SDFS relied on rivers for provision of water (Table 5.5) while 47% had been in practice for between 6 to 10years (Table 5.6) while 89% produced milk for both home consumption and cash income (Table 5.7).

Table 5.2: Household Size. (N=100)

HH Category	**%**
1 - 3	9
4 - 7	64
8 - 10	18
Over 10	9

Table 5.3: Sources of Labour (N-100)

Source of Labour	**%**
HH labour	75
Hired from within the Location	18
Hired from within the Sub-County	1
Hired from within the County	2
Hired from outside the County	4

Table 5.4: Type of Housing (N=100)

Source of Labour	**%**
Permanent	32
Semi-Permanent	59
Grass thatched	9

Table 5.5: Sources of Water (N=100)

Source of Labour	**%**
River	54
Shallow well	36
Piped	10

Table 5.6: Number of Years in SDFS (N=100)

Category in Years	**%**
≤ 5	35
6 - 10	47
11 - 15	9
≥ 16	9

Table 5.7: Purpose of milk production *(N=100)*

Reason	**Percent (%)**
Household use alone	5
Household and cash income	89
Not yet milking	6

5.2: Adaptation Strategies

Observations from the study location revealed that adverse impacts of CCV had necessitated adoption of adaptation strategies by a considerable number of SDFS to lower associated risks for increased resilience leading to lower vulnerabilities. All the four categories of adaptation (autonomous, planned, anticipatory and reactive) were observed. Autonomous adaptation strategies seemed to be farmer driven and included: use of maize stovers for supplementary feeding; establishment of shallow wells for provision of water all year round and in the process reducing frequent distances to traditional water sources; use of roof catchment for rain water harvesting; heavy manuring of fodder fields to address soil fertility problems. Interactions with SDFS revealed a close linkage of spontaneous adaptation strategies due to low ecosystem provisioning services (reduced resource availability) but not to changes in climate.

Planned adaptation strategies were observed to include introduction of: high yielding fodder crop varieties (Napier and improved grasses) tolerant to drought and flooding; high yielding grass varieties to supplement Napier grass; establishment of Napier grass under "tumbukiza" system to increase in field water retention; irrigated fodder production during prolonged dry spells; soil conservation structures; regular vaccinations against notifiable diseases. Some of these strategies such as introduction of high yielding fodder varieties were stakeholder driven based on changing natural resources availability.

Similarly anticipatory adaptation strategies included: introduction of fodder trees for improved animal nutrition, soil nitrogen fixation and provision of fuel wood; regular spraying against vector borne diseases of economic importance; establishment of Napier in furrows for increased of retention rain water; modification of zero grazing units for temperature regulation.

Reactionary adaptation strategies comprised of: bush clearing to alter breeding and resting sites for disease vectors; establishment of fodder along contours to minimize surface water runoff hence soil erosion control for increased fodder production. Other adaptation measures included use of: liquefied petroleum gas (LPG) for cooking (15%) hence saving on fuel wood; energy saving devices in meal preparation (42%); clean energy sources for lighting (71%). A summary of adaptation strategies and some of the motivating factors are given in table 5.8.

Table 5.8: Adaptation strategies and motivating factors

Strategy	Motivating Factor (Driver of behaviour)				
	Negative impacts of CCV	Negative impacts of CCV and available financial capital	Negative impacts of CCV and to raise income to support living costs	Available financial capital to raise additional income to support living costs	No strategy/ others
Shifted to higher yielding fodder varieties	5	4	1	5	85
Introduced new fodder varieties tolerant to flooding, high temperatures and drought (South African Napier variety)	42	1	4	4	49
Established high yielding grass species (hay production)	30	1	3	3	63
Produced fodder under irrigation (Fields near streams)	10	2	1	0	87
Used maize stovers (supplementary feeding during periods of fodder scarcity)	55	5	8	2	30
Cross bred dairy cattle (off-springs tolerant to increased temperatures)	5	1	18	3	73
Planted fodder crop along contours (soil erosion control)	40	5	4	5	46
Practiced soil conservation measures (trashlines)	19	8	4	2	67
Sunk shallow well for provision of water all year round	17	19	1	3	60
Used roof catchment for additional water supply	20	34	10	5	31
Planted fodder trees for additional fodder and firewood	14	3	2	9	72
Modified dairy unit for optimal temperature regulation	4	1	0	0	95
Regularly sprayed against diseases vectors	59	13	16	7	5
Regular vaccinations against common livestock diseases	48	12	17	9	14
Bush Clearing (altering suitable habitats for disease vectors)	24	2	9	1	64
Planted Napier in furrows for water retention	27	24	7	3	27
Planted Napier under tumbukiza (in field water retention)	12	9	7	4	68
Heavily manured fodder fields (soil moisture retention and increase soil fertility	36	15	3	1	45
Used of slurry to generate cooking gas (methane)	0	0	0	0	0

At the community level adaptation measures employed during food dearth periods included use of: root crops (cassava and sweet potatoes); preserved vegetables; wild vegetables such as *Basella alba* (Nderema), *Ludwigia stoloniferia* (Nyasigumba), *Acalypha volkensii* (Dindi), *Asystasia mysorensis* (Atipa) and *Sesamum angustifolium* (Onyulo); preserved mushrooms; dependency on extended families for cash handouts especially for those households with family members that migrated to other regions in such of alternative livelihoods. However, use of wild vegetables was reported to be on the decline due to opening up of virgin land that hosted abundant populations of wild vegetables, invasion of the study location by noxious weeds due to biome-range shifts and breakdown of traditional knowledge systems attributed to outmigration. Additionally food importation from areas with surplus occurred though this was solely for well off families as poor and the vulnerable HHs relied on relief handouts. Major foods brought in included cereals and root crops (cassava and sweet potatoes). Besides, some of these cereals and root crops alongside Napier were used as planting materials from areas such as Uganda and due to lack of phytosanitary measures were attributed to emergence of new plant diseases that exacerbated vulnerabilities of people reliant on them as a major source of food besides infection of Napier fields with diseases such as NSD.

5.3: Institutional Roles in Adaptation Strategies

Government and non-governmental actors were present in the study location (table 5.10) and supported SDFS by initiating discrete projects and programs that included extension and research services hence a platform for adoption of planned and anticipated adaptation strategies based on a wide technological menu. However despite the existence of supportive institutions, adoption rates based on various motivating factors were low thus making SDFS more vulnerable to climate perturbations (table 5.8). Moreover institutional adaptation processes comprised simple planned technological interventions rather than encompassing broader disciplines for increased adaptation strategies while at the same time avoiding maladaptation. According to Niang et al. (2014) functional local based institutions, education, infrastructure and economic levels of a community amongst others can at times contribute to low adaptive capacities.

Table 5.9: Grassroots institutions and their areas of intervention

Name of institution	**Type of institution**	**Areas of intervention/action**
ICIPE	International Research Organization	Stimulo-deterrent technology for striga and stem borer suppression using high value fodder crops and legumes aimed at increased food security - (technology development and transfer)
KALRO	Regional research organization	Fodder and crop production (livelihood diversification),
Red Cross	Civil organization	Disaster risk reduction, livelihood diversification, food security and asset restocking
MMDCS	Private institution	Marketing and provision of farm inputs (livelihood diversification)
Send-a cow	Private institution	Livelihood diversification
World Vision	Private institution	Livelihood diversification, disaster risk reduction (through provision of non food items), soil fertility management, technology transfer, provision of dairy cows and goats, local poultry, beekeeping, pig production, table banking, value addition
ACE Africa	Private institution	Child development, community health and well being, community livelihoods (crop and livestock diversification, provision of hammer mills and soya processors for nutritional supplements to boost immunity HIV positive members of the community)
One acre fund	Private institution	Farm inputs (food security)
GIZ	Private institution	Financial and technical support
USAID	Private institution	Financial and technical support
Siaya Bunge SACCO	Private institution	Asset loans (Motorcycles, fridges, solar lamps and coca cola products). Interest free loans to the disabled, fish and fruit sellers are also targeted
Agriculture Sector Development Support Program (ASDSP)	Public	Integration of indigenous and modern climate knowledge for an agreed on seasonal forecasts packaged as advisories to value chain actors (women and youth) engaged in production and marketing of fish, poultry and mangoes), identification of areas at risk of degradation using GIS for rehabilitation, promotion of climate smart technologies for the three value chains acceptable to the vulnerable(youth and women), capacity building in NRM (climate change planning and management, carbon sequestration, carbon trading (REDDS) ecosystem management)
Ministry of Devolution and Planning (Directorate of Special Programmes-(WKCCD&FMP)	Public	Flood mitigation, implementation of micro and macro projects aimed at livelihood improvement, soil conservation, agro-forestry, tree nursery establishment, conservation of water catchment areas, provision of grants to groups for expansion of retail businesses, provision of dairy goats, pigs, improved indigenous birds, horticulture, marketing infrastructure, fish farming, drought tolerant crops and small scale irrigation.
KENTTEC	Public	Tsetse fly suppression using moving targets, provision of artificial insemination services at subsidized costs and provision of dairy cows.
Ministry of Agriculture, Livestock and Fisheries	Public	Extension and training, monitoring food security situation, disease control, food safety and quality control, crop and livestock products production and consumption trends, technology development and sector policies
National Environmental Management Authority	Public	Environmental management through Environmental impact assessment and audit, waste management, environmental pollution and enforcing of the EMCA 1999.
Kenya Forest Service	Public	Natural resource management

Public institutions represented at the grass root level comprised devolved agencies that included various ministries under National governments and the County with distinct roles ranging from general extension services to infrastructural development aimed at strengthening local capacities. However it was observed that given the vastness of the Sub County extension services were sparse since areas of responsibility, coupled with limited personnel, transport and facilitation curtailed the frequency of extension agents' contact with SDFS for provision of services and support to socio-economic projects aimed at realization of profit maximization

Further institutional activities did not directly address CCV but some of the outputs had a direct bearing on adaptation strategies derived and employed by the SDFS. For instance research institutions comprising regional and international organizations provided high yielding fodder and fodder legume varieties under several production systems that included Ecosystem based Adaptation (EbA) through use of Stimulo-deterrent diversionary techniques for the control of *Busseola fusca* (maize stalk borer) and suppression of *Striga hermonthica* (witchweed) aimed at increased cereal production while at the same time providing improved fodder for SDFS. Private organizations (NGOs, Civil Society and Cooperatives) spearheaded establishment of high yielding pasture grasses and additionally distributed in-calf dairy cows and goats to female headed vulnerable households with the objective of attaining increased adaptive capacities hence resilience to CCV through enterprise diversification. Civil society institutions led by the Red Cross were involved in disaster risk preparedness and recovery efforts before (ex-ante) and after (ex-post) adverse weather and climate events by providing financial, humanitarian and technical assistance. Moreover agricultural based cooperatives accorded SDFS improved market access alongside provision of loans and credit facilities for farm-inputs that contributed towards adaptation strategies and increased benefits accruing thereof (figure 5.1).

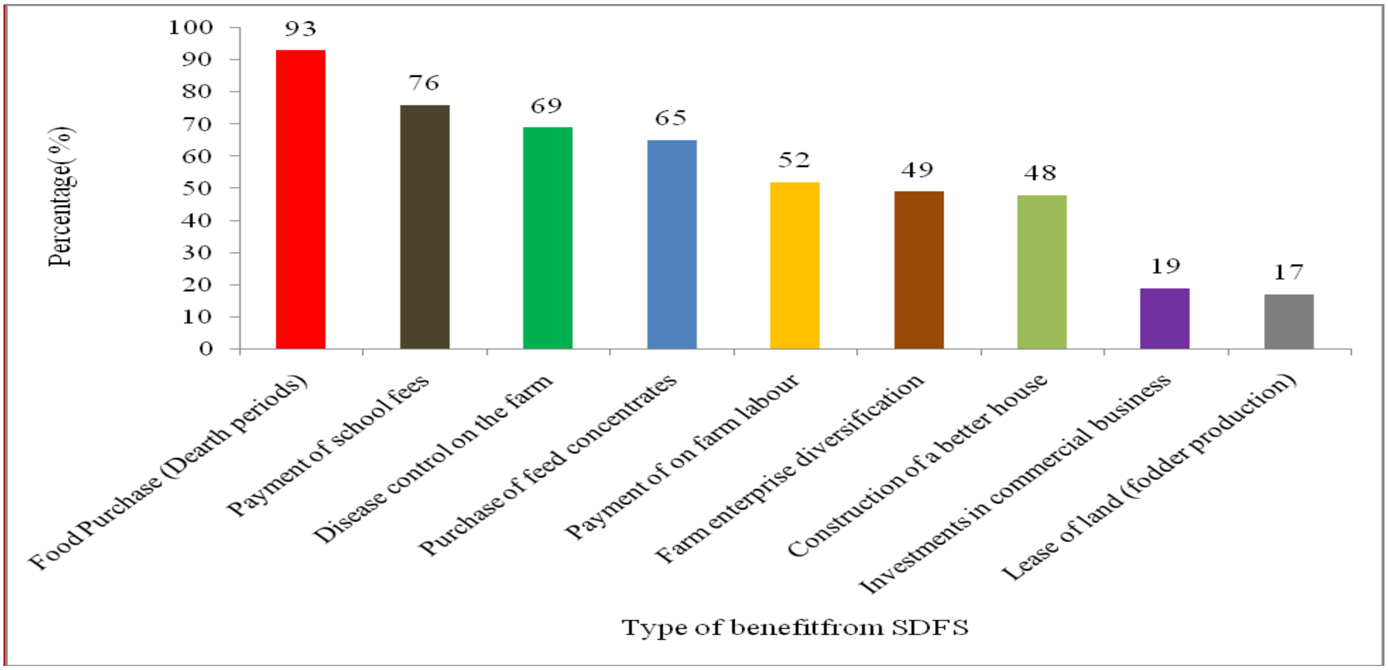


Figure 5.1: Benefits accruing from SDFS

Key institutions alongside other information channels served as sources of adaptation strategies (Table 5.10).

Table 5.10: Sources of information that contributed to adaptation strategies (N-100)

Source	**Yeas (%)**
NGOs	66
Community meetings (Barazas)	49
Community Based organizations (CBOs)	47
Radios	44
Livestock Production Officers (LPOs)	40
Neighbours	37
General Extension Officers (Services)	21
My own Judgement	17
Family Members	16
Newspapers	9
Faith Based Institutions (FBOs)	6
Traditional Knowledge	6
Cultural Knowledge Passed Down	1
Kenya Meteorological Department	1

From the table 5.10, NGO's were rated the highest as key sources of information bearing on adaptation strategies (66%) while cultural knowledge and seasonal weather forecasts from KMD were ranked the least. Livestock Production Officers (LPOs), general extension service providers and KMD when combined ranked lower than NGO’s as sources of adaptation strategies *(ibid*) yet their mandates formed key pillars from which other relevant stakeholders anchored their activities. Though radios were present in most households only 44% of the respondents indicated that some of the adaptation strategies adopted were derived from packages broadcast through electronic media. This together with low scores pegged on use of print media (newspapers) (*ibid*) were thought to be associated with low awareness of impacts of CCV on farming communities amongst the general public and the mode of language of dissemination. According to Antwi-Agyei et al. (2013), education levels of the target consumers of CCV knowledge is important for rapid adaptation strategies. Traditional and cultural knowledge were similarly ranked low but this could have been associated with socio-cultural institutions that dictate social norms since 71% of SDFS HHs being female headed and with additional tasks could have contributed to a likelihood of their inability to access and use traditional knowledge systems through interactions with the wider community.

CHAPTER SIX

BARRIERS TO ADAPTATION

6.1: Introduction

There are many factors that contribute to barriers to adaptation strategies that if not appropriately addressed lead to limitations of successful adaptation with detrimental effects to food security and livelihoods of SDFS. Barriers to adaptation presented in this chapter range from individuals, community, coupled with institutional aspects based on results obtained from HH surveys, FGDs interviews with KI, PO and stakeholders carrying out activities aimed at livelihood improvement.

6.1.1: Adaptation Barriers based on SDFS Perceptions

Various barriers to adaptation strategies in relation to CCV were identified and results presented in a tabular form (figure 6.1). The most outstanding barriers to adaptation as ranked by the respondents were: weak government support to address adaptation strategies to CCV (80%); inadequate extension services (86%); forward and advanced weather predictions to aid future planning (75%); easy to understand, timely weather and climate information dissemination (72%); lack of seasonal timely weather and climate information (71%); lack of knowledge on blending scientific and local knowledge to support CCV adaptation strategies (69%); lack of knowledge on causes of CCV (67%); lack of livestock insurance schemes against CCV (64%); none availability of fodder cultivars tolerant to diseases (62%). The rest of the barriers identified had scores of 39% or less hence considerably negligible since they can be easily surmounted (highly mutable hence soft barriers) as opposed to hard barriers. Some of the perceived barriers identified were also influenced by several factors related to institutional, policy, technological, cultural, social and religious factors that in some instances could give rise to maladaptation.

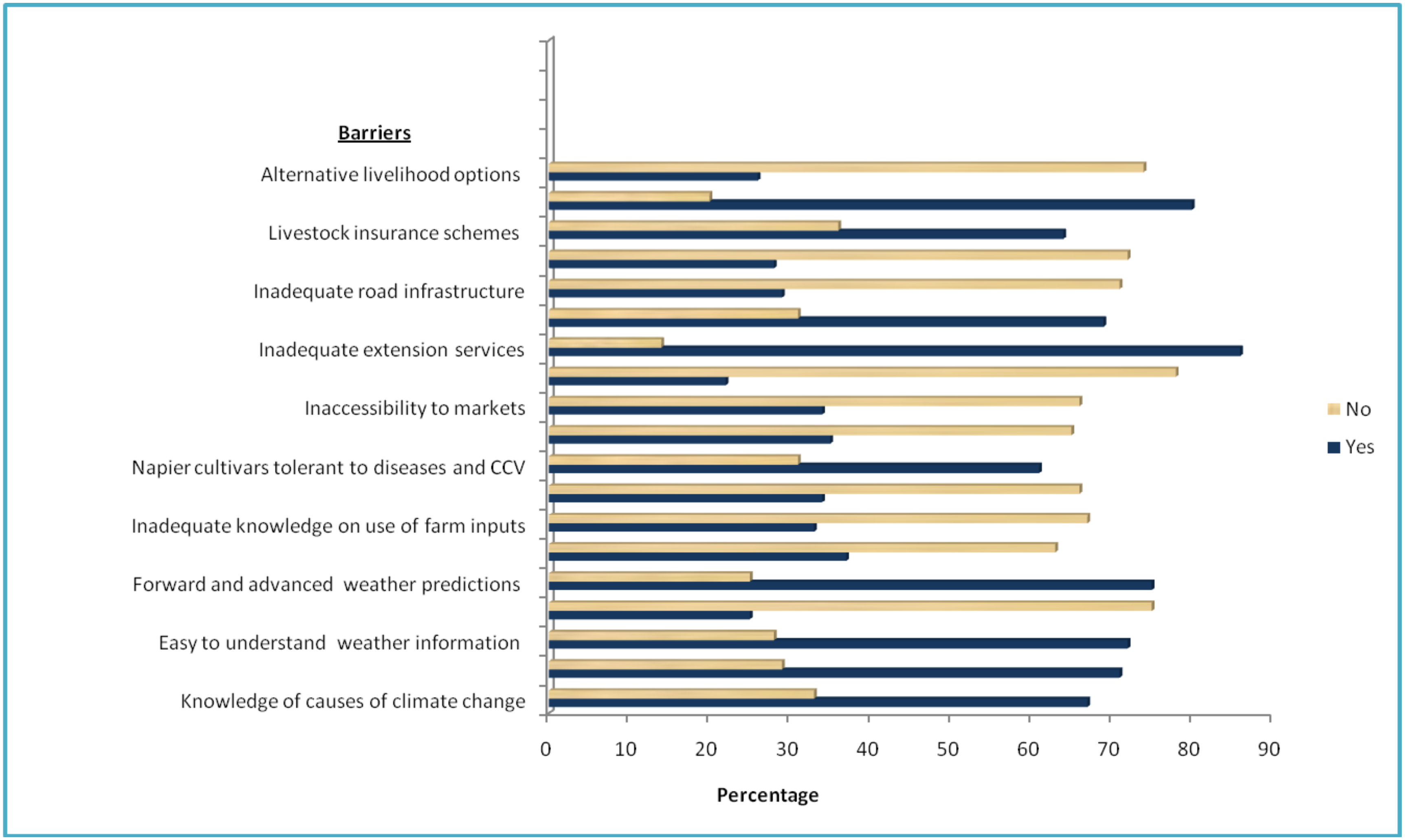


Figure 6.1: Perception of barriers to adaptation strategies

6.1.2: Institutional barriers

Institutional barriers were related to the implementation mode of key programs and projects by government agencies that lacked transdisciplinarity besides being top-down heavy. This denied the intended beneficiaries the opportunity to participate in sharing experiences and knowledge in their areas of immediate concern that if addressed would have solved the most pressing problems related to SDFS both in the short and longterm. For instance, construction of a 120,000 litre capacity monthly milk processing plant (plate 6.1a and 6.1b) by one of the institutions aimed at motivating more HHs to venture into SDFS through improved market facilities did not address factors that would lead to increased milk production (see figure 4.14 for instance); the new plant might not have been a priority amongst SDFS since they had an old plant that never operated beyond half of its installed capacity. Similarly the site of the new plant was far removed from the initial milk cooling plant prompting the MMDCS to retain the agro-vet store at its initial location with additional overhead costs. Defraying resultant additional costs might have implications on the profit margins of SDFS and could deter other interested farmers from diversifying their livelihoods. Furthermore there is a possibility of maladaptation in future if new HHs intending to diversify their livelihoods to SDFS are not provided with disease tolerant *P. purpureum* cultivars for planting due to widespread Napier Stunt Disease (NSD).

Plate 6.1a and 6.1b: the modern MMDCS milk processing plant whose capacity is under-utilized

The same approach was used when putting up a *Mangifera indica* (mango) and livestock feed processing plants without adequate involvement of stakeholders on issues of production of raw materials for sustainability of the said plants, and without reference to various climate model outputs that predict future impacts of CCV on farming systems in SSA (for example, Hulme et al., 20001; Funk et al., 2011; Carabine et al., 2014) that would opened avenues for crucial decisions concerning other alternative options. All these point to none mainstreaming of CCV in planning processes linked to inadequate skills hence poor institutional adaptation planning as reflected in low ownership of capital projects by the community. This latter observation is consistent with views expressed by Kindon et al. (2007).

Likewise another public institution with a climate change component exclusively targeted the vulnerable (youth and women) engaged in fish, local poultry and mango value chains. Value chain actors were to benefit from seasonal weather and climate information with the postulation that higher incomes from the value chains will lead to employment of poor and vulnerable families resulting to higher incomes hence poverty reduction. While this mode of targeting could in effect lead to increased incomes, exclusive provision of climate data to value chain actors alone could be detrimental and therefore an adaptation barrier to other producers including SDFS since all agricultural based enterprises are sensitive to CCV.

Institutions in the agricultural sector were observed to play an important role of capacity building to enhance SDFS skills while at the same time acting as a link between research organizations and farmers to rapidly cascade modern technologies developed through research and research trials. But according to field findings extension services expressed as proxy of institutional support appeared inadequate giving rise to low ranking as sources of adaptation strategies (see table 5.10). One reason for this could be lack of adequate knowledge and skills of effects of CCV on farming systems that limits adaptation strategies menu hence inefficient flow of important information for adoption by SDFS (*ibid*). Consequently weak institutional capacity formed a barrier to adaptation strategies with a strong likelihood of maladaptation as SDFS were more likely to end up worse-off due to lack of advance information on intra-annual, intra-season rainfall variability besides adaptation options.

6.1.3: Constitutional/Policy Barriers

The Kenya government has from time to time declared through public policies and acts of parliament its objectives and intentions of achieving and preserving national values and norms in the interest of its citizenry. Some of these intentions encompass provision of public goods and services such as extension and training that would otherwise be underfunded and underprovided for by the private sector since such services entail massive cash injections with no direct and tangible benefits in terms of accrued revenue and profits. Article 176 (1) of the constitution of Kenya (GOK, 2010) created devolved units of governance that delegated powers to county assemblies for enactment of necessary pieces of legislation relating to devolved units as per article 185 (2) of the fourth schedule. While intentions expressed in GOK, (2010) were deemed good for the Country's future posterity, provisions under article 185 (2) were observed to have affected extension services delivery hence a barrier to climate change adaptation strategies.

According to one key informant the county government had concentrated on revenue generating service delivery sectors through higher funds allocation at the expense of production ones charged with provision of public goods; yet as stated production (public good) sectors require considerable funding with no direct returns to the County Government as benefits are directly transferred to individual HHs or farmer groups in from of increased food security and incomes. Underfunding of the production sector was therefore pointed out to have affected the frequency of farm visits by field extension officers. No direct advisories on CCV were issued through such extension messages or interventions that would go a long way in strengthening productive capacities of SDFS and indirectly address adaptation strategies to CCV. One major reason for this skewed funding is that service sectors comprise low hanging fruits (dispensaries, schools, roads, markets and metallurgy sheds) that are highly visible once in place at the expense of production sectors that have low visibility.

> *"We no longer visit farmers as often as we did before devolution. Our motorcycles are now old and frequently breakdown yet we are not facilitated to repair them. Also issuance of fuel from the County Government is irregular leading to over reliance on NGO's working in our wards for facilitation but this only happens whenever they have activities touching on livestock production. In times of emergencies we are left with no option but fuel our motorcycles and indirectly pass the cost to the farmer*" [One of the livestock extension officers, 30th October 2015].

This implies that SDFS located in areas of low NGO concentration are at a disadvantage and risk engaging in maladaptive practices due to infrequent interaction with extension officers as was observed in the Nyalgunga/Nyamila block during the transect walk (table 4.3).

Policy was also observed to contribute to other adaptation barriers. For instance the country only had a Climate Change Bill at the time of study. While the National Climate Change Response Strategy (NCCRS) (2010) advocates for integration of adaptation and mitigation strategies into existing economic and development policies of which the Kenya National Climate Change Action Plan (NCCAP), 2013 was put in place to guide its implementation, these documents were not legally binding since they were not policy statements. Other policy documents covering the agricultural sector for instance; the Agriculture, Fisheries and Food Authority Act (AFFA) No. 13 of 2013, Crop Production Act 2013 and Sessional paper No. 2 of 2008 are all silent on climate change adaptation. Failure to mainstream climate change and adaptation policies in the afore-mentioned policies implies BAU which is likely to contribute to adaptation barriers.

6.1.4: Socio-cultural and religious barriers

Socio-cultural norms appeared to be strongly embedded in the community and seemed inherently sensitive as respondents interviewed strongly defended their culture that emanated from ancestral beliefs. However, expert interviews revealed that socio-cultural beliefs are not explicit but are salient and could constrain adaptation strategies if not addressed.

> *"There are socio-cultural practices still being observed in the community that impede food and fodder production. For instance during planting (komo or golo kodhi) some HHs still observe the tradition where older members of the family (parents) planted first followed by the firstborn son in that order to the youngest and during harvesting periods (keyo,) the daughter in-law could not harvest before the mother in-law; while when establishing a new home from ones father's homestead, the firstborn son moves first followed by the second borne in that order but the last born remains in the original homestead"* [Key informant discussion, 3rd November, 2015].

The sentiments expressed have effects on adaptation actions in families still observing this socio-cultural tradition as young people who are able and wish to prepare their farms for early planting must wait for the older people to plant first hence high probability of crop failure on fields planted late during years of early onset and early cessation of rainfall (see table 4.9). In some instances this necessitates the young and able to offer assistance to the elder siblings to fast track land preparation for timely planting in order to avoid food insecurity in their HHs. Likewise the young and able cannot move to their designated pieces of land in time where they are bound to exercise freedoms in the choice of enterprise investments. This could be an indicator to the absence of the young and educated taking part in SDFS hence a possibility of this target group migrating out of the Sub County to settle elsewhere.

> "*In this community it is a taboo for a daughter in-law to own a bull whether indigenous or exotic for purposes of breed improvement or an improved cockerel to crossbreed indigenous birds. If this must happen then the bull or cockerel must be kept by the father in-law who thereupon takes full control and can make disposals without further reference to the daughter in-law"* [Key informant discussion, 3rd November, 2015].

These sentiments had a direct bearing on adaptation strategies since cultural practices could be a hindrance to adoption of technologies that increase productivity. Socio-cultural beliefs therefore constitute barriers and ought to be given due considerations while devising adaptation strategies.

Religious barriers were observed not to be widespread but dependent on which denomination or sect one belonged to and its area of spread. For instance one of the key informants from one of the key institutions reported that some of the program's earmarked beneficiaries pulled out on learning that part of the packages they were to benefit from consisted of dairy goats as their religious sect did not advocate for rearing and consuming dairy goat milk. Similarly, in another location the intended beneficiaries pulled out as the dominant sect did not approve of rearing of pigs and consumption of pork. Religion in this case was cited as a barrier to adaptation strategies since small ruminants especially goats and pigs are more versatile and prolific when compared to the large ruminants and can withstand effects off CCV better hence contributing to food security and livelihood diversification hence resilience.

6.1.5: Technological Barriers

Technology is considered one of the most important adaptation strategies that can be deployed by SDFS to sustain production amidst CCV (Thornton and Herrero, 2013) hence one of the four key agricultural adaptation pathways (Antwi-Agyei et al., 2013). Some of the critical areas that are of importance for technological development in SDFS include: use of irrigation systems to advance production of irrigated fodder and fodder crops; fodder conservation in the form of hay and silage; introduction of new disease, drought and flood tolerant fodder varieties; increased use of farm by-products; devising early warning systems; dissemination of accurate and easy to interpret forward seasonal weather prediction for advance planning. Infield water and soil management techniques are also critical if fodder production quantities are to be increased (Beddington et al., 2012). While most of these technologies existed in the study location not all SDFS had access to the full range of adaptation options due to cost implications. This implies that technologies that aid adaptation must be affordable, readily available and be able to offer tangible benefits in the short and long term to enhance rapid and universal uptake of adaptation strategies across various farming systems.

One of the technologies deployed in the study location for instance was Stimulo-deterrent diversionary technique for suppression of *S. hermonthica* (witchweed) and control of *B. fusca* (maize stem borer) that proved effective in the short-term; as its effectiveness was reported to diminish with time when *P. purpureum* (Napier grass) as a trap crop got infected with NSD. This diminishing effectiveness might be attributed to ineffective emission of the pull cues though there are no studies related to what pull cue densities are required for effective functioning of this technique. NSD together with other diseases of Napier were observed to be widespread (see table 4.14, plate 6.2a and plate 6.2b) hence impacting the effectiveness of this technology. At the same time *desmodium intortum* (green leaf desmodium) was observed not to thrive well during periods of moisture stress considerably shedding its leaves and could have a bearing on its effectiveness in production of the push cues. Provision of clean planting materials is therefore a prerequisite if SDFS are to adopt high fodder yielding technologies. It was also observed that plot sizes (10M X 10M) on which this technology was established (see plate 7a) were small in comparison to HH sizes thus yields from these trials may not spur rapid multiplication of this technology. Likewise, none availability and high cost of *D. intortum* seeds to SDFS could also be an adaptation barrier to adoption of integrated fodder and cereal crop production strategies on SDFS.

While cultivars tolerant to a myriad of Napier diseases (NSD, leaf rust and snow mold) were developed under ideal conditions on research stations, their multiplication was not cascaded down to target beneficiaries since there was no Napier bulking and multiplication site that placed SDFS within reach of improved high yielding fodders. This created a technological barrier since farmers interested in establishing high yielding fodders had to travel to distant regional research centres for acquisition of disease tolerant cultivars. Besides, newly introduced cultivars were observed to be vulnerable to disease attack. For instance the improved South African cultivar tolerant to NSD established well when first planted but was observed to be prone to leaf rust disease on its first ratoon implying low fodder yields with subsequent cuttings (plates 6.3a, 6.3b). This could deter SDFS from planting improved disease tolerant cultivars which in itself is a barrier to adaptation strategies.

Plate 6.2a: Stimulo-deterrent technique with trap crop (P. purpureum) under NSD attack

Plate 6.2b:Napier field under full blown NSD attack. (Note the low herbage yield)

Plate 6.3a: Improved South African Napier cultivar tolerant to NSD on first establishment

Plate 6.3b: The first ratoon of the same cultivar under heavy leaf rust disease attack.

CHAPTER 7

SYNTHESIS AND DISCUSSION

Rainfall and temperature data analysis coupled with responses from FGDs, HH surveys and stakeholders interviews clearly indicate that the climate of the study location has changed thus exposing SDFS to a myriad of challenges and new risks that could hinder productivity. Major climatic factors perceived to have changed by the study sample included rainfall and temperature which are the main elements that determine performance of maize, beans, improved grasses and Napier, a bulk fodder under the cut and carry system. As highlighted in literature review, effects of increasing temperatures on beans and maize productivity (Knox et al., 2012) are well documented. Though its direct impacts on Napier grass are unknown (Thornton and Cramer, 2012), fodders were observed to be more negatively affected due to their perennial growth habit. This is projected to worsen in future as altered LGP is inevitable (Kotir, 2011) and may lead to reduced lower yields (FAO (2014), farmers reducing acreage under crops or abandoning some crop enterprises all together (Anyamba et al., 2014).

Furthermore temperature was observed to be directly linked to shifting ranges of invasive plant species, increased populations of ruderal plants that impact ecosystems with resultant low ecosystem provisioning services (Settele et al., 2014) beside forage production and flare ups of vector borne diseases (Porter et al., 2014). Increased environmental temperature (high ambient temperatures) was also observed to have direct effect on the *Bos taurus* breeds manifesting as heat stress with dire consequences on their productivity through low reproductive performance expressed as a proxy of low milk yields (van den Bossche and Coetzer, 2008). Another aspect of increased temperature was THI (West 2003) that also contributed to low livestock productivity as it was directly linked to low DMI directly translating to low animal weight gains (West, 2003; Chauhan and Ghosh, 2014). Crop and fodder diseases mediated through climate change were positively correlated to low crop and fodder productivity with black sigatoka of the *Musa spp* (Banana), cassava mosaic of *Manihot esculenta*, Napier stunt and snow mold disease being singled out as examples. This perception in increasing temperature corresponded well with recorded long term minimum and maximum temperatures (figure 4.7 and figure 4.8) implying long term upward shifts.

However the study sample had various perceptions on direct effects of increased environmental temperatures on *B. taurus* breeds reared hence negating Hypothesis1 **(H_{O1}**) since; only 5% of the respondents recorded having modified their zero grazing units as an adaptation strategy to adverse effects of increased environmental temperatures. This is was further enhanced by varied responses from typologies of increased temperature implying that not all SDFS equally perceived effects of temperature in relation to climate change (Table 4.10).

As regards rainfall, farmers in the study location relied on indigenous knowledge passed down to them orally for prediction of rainfall events hence timely land preparation and farm operations depicted resulting in minimal crop and fodder losses leading to enhanced food and fodder security. These natural phenomena were perceived to have changed with conclusions that the climate of the study location had changed as depicted by long term drying of the MAM, (figure 4.3), MAM/J (figure 4.4), JJA (figure 4.5) and DJF (figure 4.6) seasons. However SON/D (figure 4.8), showed a long term wetting implying shifts in rainfall seasons coupled by rainfall intensity as affirmed by farmers and one of the KI.

Following these observations and despite there being unanimity that the climate of the study location had changed, there were no major changes in planting patterns between the years 2004 and 2014 as elicited by cropping calendars drawn by 7 successful farmers (figures 4.15 and 4.16); yet this would have required shifts in planting dates of maize, beans, improved grass, and Napier varieties (Knox et al., 2012; Thornton and Cramer, 2012) since FGDs revealed that crop failure during the normal cropping season (MAM/J) had become a normal phenomena due to the erratic nature of rainfall. This confirmed findings by Williams and Funk (2011), Shongwe et al. (2011) and Carabine et al. (2014) that rainfall over the Eastern Africa Region has been on the decline for several decades further negating hypothesis1 **(H_{O1})** that there are no differences in perceptions of major climatic factors in SDFS**.**.

Floods and drought events were poorly documented with literature pointing to 1961 - 1962 and 1997 - 1998 as the worst flood periods ever recorded (El Niño events) (GOK, 2009). Other notable flood years on record included 1937, 1947, 1951, 1957-1958 and 1978. Nonetheless, a trend line (figure 4.11) drawn illustrating major climatic events between 1975 and 2014 showed that drought events were on the increase followed by floods (figure 4.11). Flood years were associated with an upsurge of debilitating disease vectors (tsetse flies) with resultant flare-ups of trypanosomiasis yet *Bos taurus* breeds reared on SDFS have low resistance (van den Bossche et al., 2008). Floods and rainfall intensity during the short rains seasons were positively associated with increased soil erosion leading to low soil fertility. For instance a transect walk (undertaken to ground truth findings from FGDs, KI and other key stakeholders) revealed dense stands of *Rhynchelytrum repens* (red top grass) and *Tagetus minuta* (Mexican marigold) (Table 4.15) which are bio-indicators of nutrient depleted soils (Mairura et al., 2007) further increasing bio-physical vulnerabilities of SDFS to CCV (plate 4.2).

Closely associated with drought were changes in vegetation cover for trees associated with shallow aquifers whose indicators were *F. thorningi* and *F. cycomorus* implying poor recharge of aquifers by green water yet the study location is predicted to undergo long term drying (ICPAC, 2016) especially during the traditional crop and fodder growing season (MAM/J) which will further strain SDFS due low yields of blue water expected to served as an alternative source for irrigated crop, pasture and fodder production. Drying up of vegetation was supported by LUMs (section 4.2.1) taken on the same date but different years (17th April; 1975, 1990, 2000, 2010, and 2014) which showed progressive thinning of dense vegetation (drying up of the study location) accompanied by drastic reduction in the size of wetlands (Yala swamp) paving the way for increased agrarian activities as one of the strategies to increase crop and fodder production. These activities however have a bearing on ecosystem provisioning services (Moorhouse and Macdonald, 2015) resulting from altered ecosystem composition further negating hypothesis (**H_{O1}**) and reinforces observations made by Niang et al., 2014 that persistent and prolonged droughts accompanied by other precipitation anomalies will affect recharge of water aquifers.

Adaptation strategies existing in the study location emanated from perceptions of CCV by the SDFS and were aimed at ameliorating CCV associated risks for increased adaptive capacities. Though all the four categories of adaptation strategies existed SDFS did not link their actions directly to CCV but instead diminishing ecosystem provisioning services (reduced resource availability) appeared to be the trigger. For instance sinking of shallow wells for provision of water all year round was linked to drying up of rivers and not to frequent prolonged drought events due to CCV. Similarly, spontaneous feeding of maize stovers soon after harvesting maize was done due to their availability and not scarcity of fodder since it turned out that SDFS were overstocked (section 4.2.3) and struggled to feed their dairy cattle for increased productivity. This was also was reflected by the low number of MPTS that would otherwise serve as a source of protein based fodder for dairy cattle. These efforts though indirectly aimed at better adaptation strategies negate hypothesis 2, (**H_{O2}**) since differences in adaptation strategies deployed by SDFS as a result of negative impacts of CCV existed.

Institutions working in the study location implemented discrete activities in form of projects and programs that served as alternative sources of adaptation strategies as they played a role in ameliorating adverse effects of CCV. For instance use of EbA by deploying Stimulo-deterrent diversionary technique to control *Busseola fusca* (maize stalk borer) and suppression of *Striga hermonthica* (witchweed) indirectly addressed plant pests and vectors mediated through CCV and the control of invasive species due to biome-rage shifts (Settele et al., 2014). This technique though established on small demonstration plots contributed to fodder production through Napier as a pull cue as well as fodder legumes (*Desmodium intortum)* as a push cue hence providing forages rich in proteins while at the same time contributing towards cereal output on SDFS. Key institutions thus served as sources of adaptation strategies (table 5.10) as NGOs' were rated the highest sources of information bearing on adaptation strategies (66%), Livestock Production Officers (LPOs), general extension services and KMD were ranked lower yet they are viewed as lead agents due to their mandates. This be could be a pointer of low technical know-how on adverse effects of CCV. Other farmer led adaptation strategies included *"Tumbukiza"* technology for increased infield water harvesting and retention (section 1.5 and Table 5.8) implying that SDFS embraced various adaptation strategies further negating **$H_{O2.}$** However a typology of adaptation strategies (table5.8) showed that SDFS looked at adaptation strategies through a narrow lens of disease control, and use of maize stovers as supplementary feed.

Various adaptation strategies were employed by the larger community during food dearth periods that included use of: root crops (cassava and sweet potatoes); preserved vegetables; wild vegetables (section 5.2) and preserved mushrooms. Well off families relied on extended families for cash handouts especially for those households with family members that migrated to other regions in search of alternative livelihoods. However, use of wild vegetables was observed to be on the decline due to opening up of virgin land that once hosted abundant populations of wild vegetables, gradual drying up of indigenous vegetation as confirmed by the LUMs, invasion of the study location by noxious weeds due to biome-range shifts and breakdown of traditional knowledge systems as a result of outmigration. The community also imported food from areas with surplus though this was solely for well off families as poor and the vulnerable HHs relied on relief handouts from Government agencies and relief based civil organisations.

Some of the adaptation strategies employed to manage risks associated with adverse effects of CCV were observed to increase vulnerabilities of SDFS through maladaptation hence exposing them to more climate related risks. For instance, major foods brought in during dearth periods included cereals, pulses and root crops (cassava and sweet potatoes) together with planting materials (cassava cuttings, sweet potato vines, banana suckers and Napier cuttings) thought to be better varieties from areas as far as Uganda, but lack of phytosanitary measures ended up disseminating new plant diseases and pests (section 5.2) wiping out crops and fodder that were traditionally relied on. Disease cited as being introduced through these adaptation strategies included black sigatoka of the *Musa spp*. Cassava mosaic diseases of *Manihot esculenta*, and Napier related diseases such as NSD, Snow Mould and Napier Rust Disease. Nonetheless, observations made with regard to maladaptation were as a result of the community's attempt to adapt to adverse effects of CCV further negating $\mathbf{H_{O2}}$.

Several sources were observed to give rise to adaptation barriers thus negating $\mathbf{H_{O3}}$ (that there were no barriers hindering adaptation strategies). For example there was observed to be lack of transdisciplinarity some key institutions whose decisions were consistently top-down resulting to hard adaptation strategies not being wholly owned by the SDFS. The fact that enhanced milk marketing channels by MMDCS resulted to tripling of milk deliveries to the cooling plant (Figure 4.14) did not warrant construction of a new milk processing plant in a hard to reach location since the old plant still performed at half of its installed capacity (figure 4.14). Construction of a new cooling and processing plant was observed to have introduced new overhead costs with a bearing on SDFS incomes hence an adaptation barrier that is likely to deter more SDFS wishing to diversify their livelihoods. Besides, the old plant was strategically located in the midst of town and dispensed other products and services through its agro-vet division to the general public hence a larger catchment, therefore a superior advantage over the location of the new plant and could be an adaptation barrier; since reduced earnings could deter other farmers shifting to SDFS as an alternative source of farm income and livelihood diversification.

This consistent top-down approach was also exhibited in the construction of an animal feed and mango processing plants (section 6.1.2, plate 6.1a and plate 6.1b) without putting into consideration sources of raw materials for both processing units and references to future climate outlook from climate model predictions. This mode of implementation thus locked in huge capital that would have been used to fast-track adaptation strategies to increase resilience through increased farm productivity. This therefore represented a case of an institution with responsibilities that it lacked capacity to execute and whose mode of implementation restricted views from major stakeholders on what needed to be done to bridge observed production gaps hence an institutional barrier to adaptation

Closely associated with institutional barriers were lags in policies resulting from constitutional dispensation. While section 185 (2) of the constitution provided for the County Assemblies to play oversight roles to County Governments, lack of clear policies formulated at both levels (National and County Government) were observed to have led to over-concentration on sectors whose overall outputs comprised low hanging fruits. For instance there was emphasis on service sectors that focused on construction of schools, health facilities, roads and related infrastructure at the expense of production sectors that have low visibility. The Agriculture sector was such an example of high hanging fruit yet it crucial in alleviation of food insecurity with potential the of catalysing the growth cottage industries through raw materials and by-products generated from crop and livestock production activities. This further negates $\mathbf{H_{O3}}$.

Extension services in the study location were observed by one of the KI to have been curtailed due to low funding hence low technical staff-farmer interaction yet some of the extension services outputs though not directly addressing CCV have a bearing on adaptation strategies. Such low visibility public service goods therefore require huge injection of public funds on a timely basis due to the nature of agricultural based enterprises, a situation that was observed to have been worsened by untimely and irregular release of funds by the National Treasury to the

County Government. Further, the sector was observed to have no immediate revenue returns that would attract funding from other stakeholders and can only therefore be undertaken by the National or County Governments under clear policy directions. But at the time of the study no Climate Change Policy was in place hence a barrier to adaptation strategies further negating $\mathbf{H_{O3}}$. According to IPCC (2014) Increased crop and livestock productivity has a strong bearing on food security and livelihoods at HHs and regional scales but given increased pest and disease damage coupled with flood impacts on food system infrastructure, there is need more so gender oriented policies to guide strengthening of institutions at all governance levels.

Technological barriers equally hindered adaptation strategies and were observed to be closely related to costs of acquisition. For instance to counter and reverse diminishing quantities of Napier as a bulk fodder due to NSD infestation, one of the Regional Research Organisations had imported and multiplied a Napier cultivar that was tolerant but lack of bulking sites close to the study location hindered its uptake by SDFS. Additionally, while base station readings alluded to the cultivar's resistance to other diseases, it was observed that it was prone to Napier Leaf Rust Disease on its first ratoon implying lower DM yields on subsequent cuttings and could form a barrier to adoption of this technology. Stimulo-deterrent diversionary technique also existed under EbA but the tiny sizes of plots on which it was established coupled with the cost of the push cue could hinder its adoption as rapid multiplication of several plots per HH for increased productivity would be required. This further negates $\mathbf{H_{O3}}$ hence the statement by Giovannucci et al. (2012; Pp38) that "many new technologies are unknown, unaffordable, and inaccessible to smallholder farmers who form the majority of producers in most of Africa".

Social, cultural and religious barriers were also identified as forming part of institutional barriers. Preference of the community to observe hierarchy in land operations (*golo kodhi*) and property ownership strongly embedded in culture could be a precursor of well educated, strong bodied young population moving out in search for alternative livelihoods hence erosion of community values. The same cultural aspects were also linked to low breed improvements since for instance daughters-in law had no free will to keep improved bulls or cockerels for upgrading indigenous stock while still sharing the same compound with their parents-in law as this was considered a taboo. Such practices meant to preserve the culture of the community orally passed down and practiced through lineage are a barrier to adaptation. Communities in Northern Burkina Faso have similar practices where cultural barrier are observed to limit livelihood diversification (Nielsen and Reenberg, 2010) hence a cultural barrier that increases vulnerabilities. Though not widespread, religious barriers were observed to exist and were confined to areas with dominant sects (section 6.1.4). For instance one religious sect did not allow its members to rear pigs for pork consumption while in another site, members were prohibited from keeping dairy goats and utilizing its milk yet these two classes of livestock are known for their prolificacy amidst CCV and once adopted would go a long way in enhancing food security. Social barriers were also observed to exist and were related social order. A majority of SDFS were women (79%) with additional tasks (WHO, 2011; Giovannucci et al., 2012) amidst existing social norms that limited interactions with the wider society hence a barrier to adaptation due to inability to participate in social systems where information flow regarding adaptation strategies existed.

Creation of Resilience of SDFS

Based on the nature of resource availability and main livelihood strategies observed, farming systems in the Sub-County can be described basically as “Hanging in” (subsistence) as elicited by cropping calendars implying low adaptive capacity exhibited by considerable periods of food scarcity (figure 4.15 and figure 4.16). One of the initial steps to building resilience is by aiming to reduce the length of the period SDFS experience food scarcity by shortening the recovery and copping cycle in order to lengthen duration of food sufficiency (Figure 4.15 and 4.16). This necessitates initiation of mechanisms that gradually move the farming systems from “Hanging in” to “stepping up” (subsistence to Semi-commercial farming). This can be achieved by focusing on key aspects that increase both crop and livestock productivity in order to realise adequate yields for HH consumption and surplus for sale during times of favourable market prices. In this respect, *ex-ante* and *ex-post* activities that minimize SDFS losses related to climatic shocks should be targeted so as to meet the overall objective.

Ex-ante activities that contribute towards building resilience should include diversification of crops and fodder aimed at increasing food security and livestock feed resource base. To achieve maximum benefits, crops and livestock fodder of choice should include: those that thrive well in a broad range of conditions such as low soil moisture and high temperature (drought tolerant) besides being disease tolerant; early maturing and high yielding varieties that equally perform well during periods of excess precipitation. These need to be established on a spatio-temporal basis so as to take advantage of rainfall variability. In this aspect it is important to consider *asynchronous crops* and fodder varieties that withstand plant stress resultant from climate shocks. Established pastures and livestock fodder are perennial in nature and require proper agronomic practices (weeding and heavy manuring to increase soil organic matter/carbon) for optimal performance alongside reducing land under fallow for provision of adequate forage. Similarly altering fodder crop cycles for poor performing established fields to improve livestock nutrition should be given attention as part of ex-*ante* phase. Likewise, mature fodders should be harvested during times of plenty, conserved for use during dearth periods and freshly harvested fields weeded and fertilized for vigorous re-growth during precipitation seasons. This argument is premised on observations that plant nutrient mobilization during growing seasons tends to lower feed quality with a bearing on livestock productivity. Maintenance of soil conservation structures to increase infield water harvesting (reduced surface runoff) therefore boosting soil moisture content while at the same time minimizing soil erosion should also be a key area of focus. Water harvesting facilities that maximize roof catchment systems should be established during this time to cater for shortfalls during prolonged drought events.

Ex-Post activities geared towards increasing resilience appear to be limited should nevertheless; include proper postharvest handling of cereals, pulses and conserved fodder to minimize crop and fodder related losses to ensure food security and income generation during times of climatic shocks. During periods of *ex-ante* and *ex-post* activities animal disease control that includes regular vaccinations against notifiable diseases, spraying of livestock against ectopic parasites by use of recommended equipment coupled with helminths control should be emphasized.

Management of slurry through conversion of methane (CH_4) to carbon dioxide (CO_2) (Plate 7.1) serves to reduce vector breeding sites while at the same time contributing to environmental conservation via provision of alternative sources of cooking fuel thus exerting less pressure on trees and forests for provision of firewood. Environmental temperature regulation through modified zero grazing stalls and livestock sheds are also a prerequisite.

Plate 71: Biogas plant- source of Methane for lighting and cooking (Adopted from Carabine et al., 2014)

All *Ex-ante* and *ex-post* operational activities hinge on disaster risk management that revolves around easy to interpret and accurate weather forecasts for use by SDFS. This is necessary in order to inculcate early warning and early action systems that would determine the choice and scale of farm operations so as to minimize climate and weather related shocks, and in the process creating of opportunities for resilient SDFS. To achieve resilience of SDFS based on *ex-ante* and *ex-post* operations necessitates integration of technologies that require multi-sectoral approaches, involvement of transdisciplnary teams, strong institutional support, hinged on climate focused adaptation policies mainstreamed across all sectors.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1: Conclusions

This study was designed to gain insights on perceptions, challenges and adaptation strategies to CCV on SDFS in Siaya Sub-County with the aim of identifying existing adaptation gaps that can be bridged for increased adaptive capacities.

The study established that the climate of the study location has changed as SDFS through HH surveys, FGDs, KI with a blend of indigenous knowledge perceived CCV to have affected ecosystems' provisioning services such as availability of fish due to frequent droughts affecting water volumes in rivers coupled with recurrent crop failure especially during the traditional long rains cropping season. Droughts constrained water availability for both domestic use and livestock production besides altering vegetation as depicted by LUMs. Other elements of climate perceived to have changed were rainfall amounts and intensity hence reduced flood events and increased frequency of droughts leading to crop failure especially during the long rains period which when taken as proxy of fodder production implied low forage availability translating to poor livestock nutrition and productivity.

Minimum and maximum temperatures of the study location were observed to have also increased and corresponded well to observations in biome range shifts of noxious weeds and presence of ruderal plants on disused and abandoned farms. This observation correlated well with longterm rainfall and temperature data of the location for all seasons with the exception of SON/D that exhibited longterm wetting Despite these, it was ascertained from cropping calendars that land preparation coupled with sowing dates for crops had more or less remained the same though use the of commercial fertilizers had increased courtesy of fertilizer subsidies.

Land holdings under pasture production were observed to be small leading to overstocking with direct implications on dairy productivity. This was further corroborated by nonexistent of fodder conservation techniques and structures which are pointers to challenges in fodder availability most of the year that is made worse during periods of prolonged dry spells. Proceeds from SDFS cushioned famers against adverse impacts of CCV making them less vulnerable since benefits accrued were used to on food purchases during periods of extreme scarcity, payment of school fees, enterprise diversification, to leasing of land for fodder production.

Though respondents were in agreement that the climate of the study location had changed wide differences in perceptions of rainfall and temperature trends existed and could affect adaptation rates due to different worldviews held by SDFS. A similar observation was made in relation to effects of CCV on fodder production despite a general concurrence that it affects the quality and quantity of feed availability with direct effects on milk production. Findings from the study also showed that SDFS faced challenges posed by CCV including vector borne diseases exacerbated by increased density of ticks and tsetse flies. However based on a binary longit regression model a weak correlation between disease incidences and biting flies, which are mechanical pathogen transmitters was established and could be the cause of observed poor waste management leading to more suitable breeding sites. Additionally a high disease burden was attributed to flood and drought incidences coupled with increased temperatures and invasive ruderal plant species that formed suitable resting sites for disease vectors in particular tsetse flies.

Adaptation strategies existed but their adoption levels were low exacerbating vulnerabilities of farming systems due to climate perturbations despite the presence of grassroots institutions whose activities, though not directly addressing CCV, some of the activities executed had a direct bearing on adaptation strategies. Government institutions had mandates that formed key pillars upon which other actors anchored their activities but were ranked poorly as sources of adaptation strategies when compared to NGO's. This observation was linked to visibility and frequency of conduct with the study sample at the grassroots level. Governance processes emanating from the constitution and policies in place were some of the identified sources of adaptation barriers linked to low funding of extension services. Low funding curtailed frequent interactions between extension agents and actors in SDFS further posing risks of failure due to a limited menu of adaptation strategies. The Agricultural sector due to low visibility was poorly funded as the County leadership concentrated on implementing programs that were low hanging fruits at the expense of extension services. Further institutional rigidities exhibited by the top-down model of targeting and activity implementation pointed to low awareness of CCV at the policy level hence contributed to limited approaches to adaptation efforts which, alongside lack of inclusion of bottom-up approaches was seen as a barrier to adaptation.

Technological barriers were also found to exist in the form of costs of acquisition coupled with their effectiveness to withstand impacts of CCV. For instance improved *P. purpureum* cultivars tolerant to NSD in Stimulo-deterrent diversionary technique trials were seen to be vulnerable to Napier leaf rust disease. Other adaptation barriers that curtailed adaptation strategies were emanated from socio-cultural and religious institutions due to the structure of family networks and extended kinship that had inherent norms passed down through ancestral lines. Adaptation barriers emanating from socio-cultural practices affected farming activities of would be early adopters, enterprise diversification and to some extend contributed to outmigration of educated and skilled labour at the expense of investments and developments at home.

8.2: Recommendations

Adoption of adaptation strategies on SDFS will rely on accurate climate and weather information dissemination based on early warning and early action systems and circulation of accurate information, sound policies, strong institutions, and robust extension and research services. Recommendations highlighted below target to a large extend SDFS actors in Siaya Sub-County, Devolved Governments, the Central Government, research and the scientific community.

8.2.1: Recommendations for SDFS

Adaptation strategies in the study location may be limited by low education levels, moderately large households catered for mainly by women who are burdened by other production activities. SDFS should therefore strive to enhance adaptive capacities against CCV through diversification of livelihoods including expansion of farm enterprises in order to guard against asset erosion in times of extreme climate perturbations that are projected to become more frequent in future. Other areas of focus should include: increased use of locally available materials for composting to improve soil health; improving indigenous tree cover through establishment of household woodlots; shifting to traditional and early maturing crops; servicing of existing soil conservation structures to reduce surface runoff and soil erosion; improving waste management to limit breeding sites for disease vectors; expansion of water harvesting structures; maximize on profits by the uptake of off-season farm production through small scale irrigation hence intensification; bush clearing to enhance agricultural extensification hence altering favourable resting and breeding sites for tsetse flies and other disease vectors.

8.2.2: Recommendations for County (Devolved) Government

Agriculture is one of those public service good sectors that were devolved and which require huge injection of capital without commensurate returns in form of revenue directly to the County Government but to farmers through increased food security and farm incomes. In this respect the County Government should ensure that sector annual work plans and budgets are honoured and adequately funded on a timely basis for smooth implementation of planned activities aimed at promoting *ex-ante* and *ex-post* climate shocks coping strategies. This will result in fast tracking and cascading down proven climate smart technologies such as small scale irrigation systems for increased food and fodder production beside promoting rapid uptake of biogas production for lighting and cooking for enhanced carbon sequestration through reduced use of firewood.

There is also need for the County Government to increase extension: farmer ratio through recruitment and facilitation of more frontline extension workers alongside training of the same by integrating climate change in the training curriculum. This will enable relevant climate and technological information that will lead to increased adaptive capacities through access of key inputs for increased production hence resilient systems. Besides, policies formulated at the County Government level should target increased input subsidies in the livestock production sector since initial investments costs are prohibitive for most farmers. These policies should facilitate access to; microfinance institutions, markets, increased value addition to crop and livestock produce and climate change adaptation strategies. Formulated policies should advocate for the formation of a coordination body to ensure that all areas of the county are evenly covered by extension agents and relevant stakeholders.

8.2.3: Recommendations for the National (Central) Government

Devolution of the Agricultural sector limits the role of the Central Government in terms of day to day extension activities of devolved units apart from policy formulation and implementation of donor funded projects whose funding is done solely through the Treasury. As a result gaps exist between the two levels due to absence of effective coordinating mechanisms to ensure efficient extension services geared towards food security. It is therefore imperative that multisectoral policies that steer institutions away from the long established "Path Dependency" are formulated and implemented in order to break institutional rigidities that promote the Business as Usual

(BAU) culture amidst competing policies. Such policies should allow stakeholders greater lateral through hybridized bottom-up and top-down approaches (panarchical model) for ownership, governance and enhancement of adaptation strategies aimed at increasing resilience of SDFS to CCV. These policies need to emphasize formulation of sector based Nationally Appropriate Mitigation Actions (NAMAs) to ensure implementation of climate change related programs through increased centralized multisectoral targeting and funding. The policies must emphasize mainstreaming of CCV curriculum development to equip extension personnel with the necessary adaptation skills for increased climate related information dissemination and training of SDFS for adequate preparation prior to and after major predicted climate shocks to reduce *ex-ante* and *ex- post* losses. The policies should up-scaling of the most successful CCV adaptation strategies and models at Sub-County levels to other regions.

8.2.4. Recommendations for Research and the Scientific/Academic Community

Little is still known of how exactly CCV will impact SDFS more so fodder production due to over concentration of studies on effects of climate change on food crop based enterprises. This has prompted use of crop production parameters and data as proxy of fodder availability. Most crops used as proxy for forage availability are mainly annual in nature while forages are perennial implying that the latter are likely to be more negatively impacted due to the length of exposure to vagaries of weather. Empirical studies on CCV effects on various fodders therefore need to be conducted to enable targeted adaptation strategies on SDFS. Areas of further research include: effects of altered LGP on biomass production of *P. purpureum* alongside other alternative forages that will thrive best under adverse effects of CCV; differences in yields of *P. purpureum* grown under different soil amended treatments; *P. purpureum* cultivars that are likely tolerate best plant diseases especially the devastating Napier Stunt Disease (NSD) amidst rising temperatures, reduced soil moisture, increased presence of invasive ruderal and noxious plant species. The same approach should be extended to *Chloris gayana* (Rhodes grass) due to its potential for hay production and *Setaria sphacelata* (Nandi Seteria) for its ability to withstand heavy and repeated defoliation.

There is also need for research into the economic unit of production for crops and forages used in Stimulo-deterrent diversionary technique to spur its uptake for increased fodder and crop residue production. This is based on the observation that this technology was still under trial on 10X10M plots and could deter SDFS adopting it based on total cereal yields. Besides, deviations from yield ceilings on farms ought to be determined and compared to base station readings.

While analysis of long term rainfall data with the exception of the SON/D season indicated that there is long term drying, the farming community has stuck to its traditional planting dates with corresponding frequency of high crop failure. There is therefore need to compare crop and fodder production during the MAM/J season to SON/D with a view of shifting major crop and fodder production activities to the latter, together with early maturing disease tolerant fodders and hybrid crops to determine adjustments in planting dates from the long established traditional MAM period aimed at minimizing crop and fodder crop losses due to CCV.

Other areas that call for additional study include designing of zero grazing units that effectively regulate heat due to projected increase in temperatures coupled with affordable and readily available Livestock Protection Net Fences (LPNFs) for control of disease causing vectors that are also projected to become common in future. likewise, there is need to reconstruct longterm rainfall data for the region, set up more ground rainfall and temperature observation stations to complement satellite based date for accurate fodder crop modeling to better future predictions under different scenarios. Finally designing of a cost effective early warning early action weather and climate system will be necessary to increase levels of *ex-ante* and *ex-post* weather and climate perturbations decision making at the local level for resilient SDFS.

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APPENDICES

Appendix I: Focused Group Discussion Guide for long term extreme climate events

S/No	Names of Participants	Age	Contacts (Optional)	Village

Guiding Questions

1. In your views, do you think that climate has changed since 1975 to date? Yes [ ] No [ ]

2. If yes, what aspects of the climate do you think that have changed?

3. Using recall memory from 1975 to date can we think of years that had :-

a. Extreme droughts that caused famines?
b. Extreme floods that caused deaths and crop failure?
c. Intense rainfall that caused deaths and led to population of high fly density?
d. Late onset and late cessation of rains that caused harvested crops to rot?
e. Early Onset and early cessation of rains that caused crop failure?
f. Extreme cold events during the dry season that caused people to become sick?
g. Extreme hot events during the wet season that caused crops not to grow well?
h. High pest infestation during the rainy season that caused crop damage and livestock diseases?
i. High pest infestation during the dry season that led to diseases?
j. Rainfall cessation before crops matured that caused famine?
k. Rainfall cessation long after crops had matured that interfered with harvests?
l. Extremely high temperatures that led to uncontrolled fires?
m. Extremely cold temperatures that led to human and livestock death besides crop failure?

4. In your views what are the trends of these events?

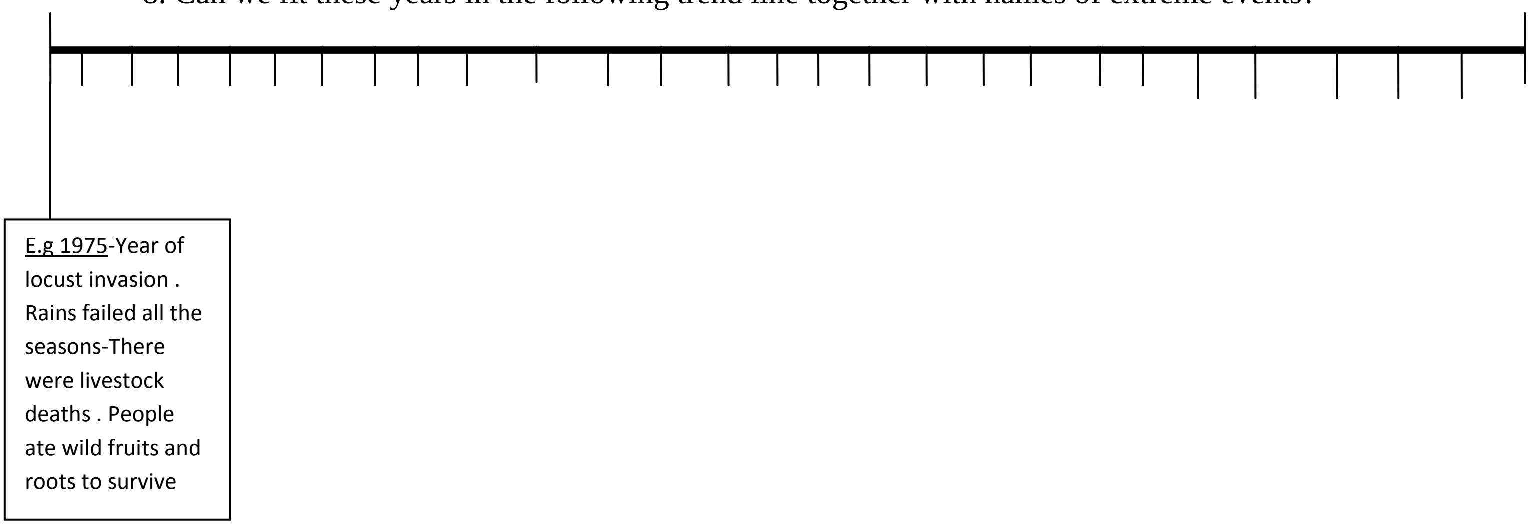
Code	Indicator	Tick upon reaching consensus
0	Reducing	
1	Constant	
2	Increasing	

5. Were the extreme events that you have isolated given any vernacular names? Yes [ ] No [ ]

6. If yes what were these events' names and their meanings? Please list them

7. What did people do to survive these extreme events? Pleas list them.

8. Can we fit these years in the following trend line together with names of extreme events?



8. Using the same trend line can we identify years that had conspicuous environmental changes? for instance abundance of a tree such as Ober and the progression of such an indicator to date? or intensity of a fly such as the Tsetse to denote its infestation trends over the years etc.

10. How do you think that these changes have affected livestock production activities in the locality more so the SDFS? Please list them.

11. In your views, what do you think that should be done to make the community more resilient to climate change and variability?

Appendix II: Focused Group Discussion guide for seasonal calendars

S/No	Names of Participants	Years in Farming	Contacts (Optional)	Village

Guiding Questions

1. In your views, do you think that climate has changed since 1975 to date? Yes [ ] No [ ]

2. If yes, what aspects of the climate do you think that have changed?

3. Have these changes affected your crop production in any way? Yes [ ] No [ ]

4. If yes, can you please draw a seasonal cropping calendar as shown on the next page indicating what farming activities you carried out year 10 years ago and today showing who did what?

5. In your views what are the trends in crop production 10 years ago and now?

Code	Indicator	Tick upon reaching consensus
0	Reducing	
1	Constant	
2	Increasing	

5. What do you attribute these changes to? Please list them

6. Are any particular seasons given any local names? Yes [ ] No [ ]

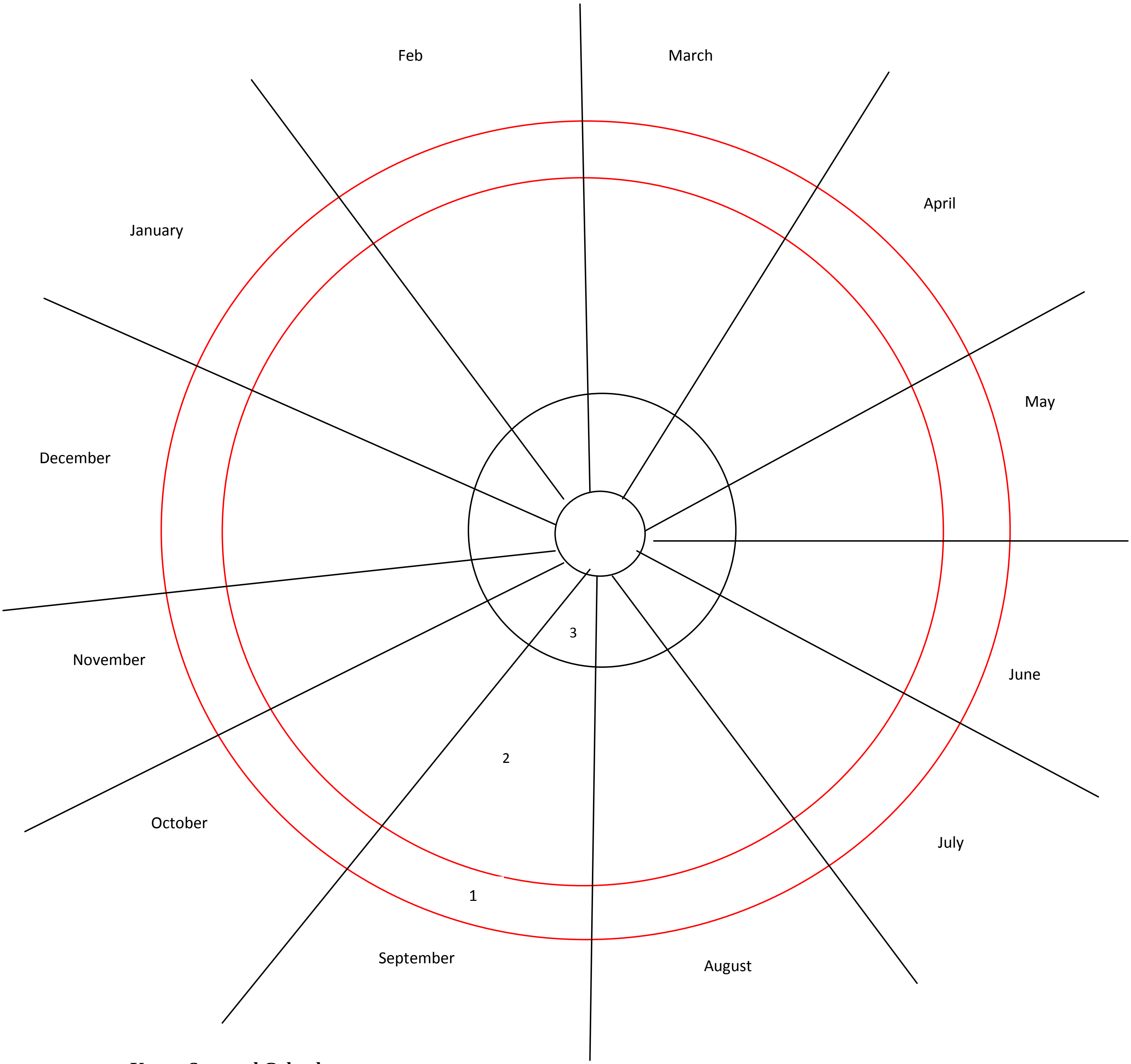
7. If yes, please list them

8. What do you do in the event of food shortages? Pleas list them.

9. On average, how many months in a year constitute periods of severe food scarcity ?

10. What are these months? Please list them

11. In your views, what do you think that should be done to make the community more resilient to climate change and variability to enable profitable farming activities?



Key to Seasonal Calendar

S/No	Event	Example
1	Prevailing weather	a. Heavy rainfall, b. Dry and windy, c. hot and windy, d. drizzles, f. irregular rainfall, g. onset of long/short rains etc
2	Land operations	1. Land preparations, 2.1st ploughing, 3. 2nd ploughing, 4.planting, 5.1st weeding, 6.2nd weeding, 7.top dressing, 8.crop harvesting, 9.shelling maize etc
3	Challenges	A. malaria outbreak B. labour scarcity C. Eye infections D. pneumonia in kids E. food scarcity F lack of firewood G Livestock diseases etc

Appendix III: Household questionnaire survey tool

Questionnaire No:

Date: / / Date/Month/Year

General Information

Demographic and Socio-economic Characteristics of Respondents

Village:	Ward:
Sub-location:	Name (optional)

1. **Personal Information**

1.1 What is your gender? Male [ ] Female [ ]

1.2 Which age group do you think you belong to? (Please tick the appropriate bracket)

a. 18 – 25 years [ ]
b. 26 – 35 years [ ]
c. 36 – 45 years [ ]
d. 46 – 55 years [ ]
e. 56 – 65 years [ ]
f. Over 66years [ ]

1.3 Which cluster does your household fall under? (Please tick the appropriate bracket)

a. 1 – 3 [ ]
b. 4 – 7 [ ]
c. 8 – 10 [ ]
d. More than 10 [ ]

1.4 What is your level of education? (Please tick the appropriate bracket)

a. No Education [ ]
b. Primary School [ ]
c. Middle School (JSE) [ ]
d. Secondary School [ ]
e. High school [ ]
f. Vocational [ ]
g. Middle level college [ ]
h. University [ ]
i. If informal or any other please specify____
____

j. Type of Housing – Semi-permanent [ ] Permanent [ ] Grass thatched [ ] if other please specify____

1.5 What do you use to cook? (Please tick the appropriate bracket)

a. Fire wood [ ]
b. LPG (commercial gas) [ ]
c. Charcoal [ ]
d. Gas from slurry [ ]
e. Kerosene [ ]
f. If none of the above please specify________________________________

1.6 Have you installed any energy saving cooking devices? Yes [ ] No [ ]

If yes, please specify____

1.7 What do you use for lighting? (Please tick the appropriate bracket)

a. Kerosene [ ]
b. Solar power [ ]
c. Electricity [ ]
d. Gas from slurry [ ]
e. If none of the above please specify________________________________

1.8 What is your major source of water? (Please tick the appropriate bracket)

a. River [ ]
b. Shallow well [ ]
c. Borehole [ ]
d. Roof catchment [ ]
e. Tapped water [ ]
f. Dam [ ]
g. Water Pan [ ]

2. Respondent's response to SDFS

2.1 For how long have you been a smallholder dairy farmer? (Please tick the appropriate bracket)

a. Less than 5 years [ ]
b. 6– 10 years [ ]
c. 11 – 15 years [ ]
d. over 16 years [ ]

2.2 What is your source of farm labour? (Please tick the appropriate bracket)

a. Household labour [ ]
b. Hired from within the location [ ]
c. Hired from within the sub-county [ ]
d. Hired from the county [ ]
e. Hired from outside the county [ ]

Is the hired labour regular/reliable Yes [ ] No [ ]

2.3 Land holding under fodder

Total acreage of land	Acreage under cultivated fodder (Napier)	Acreage under improved grasses (Rhodes etc)	Acreage under fodder legumes	Acreage under natural grazing	Number of multi-purpose trees

	Last 10 years	current	Last 10 years	current	Last 10 years	current	Last 10 years	current	Last 10 years	current

2.4 Do you have any land under irrigation? Yes [ ] No [ ] (tick the appropriate bracket)

If yes, please specify the acreage irrigated for pasture production purposes_________________

2.5 Do you Lease any land for pasture production? Yes [ ] No. [ ] (tick appropriate bracket)

If yes, please specify the acreage leased and reasons_____________________________________

____

2.6 Dairy herd structure

Total number	**Calves**		**Bulling heifers**	**Young bulls**	**Mature bulls**	**Mature cows**	**Cows in milk**
	M	**F**					

2.7 Are they all housed and stall fed all year round? Yes [ ] No [ ]

2.8 If no, state the periods they are not housed and the reasons why_______________________

____

____

2.9 Do you produce milk for:-

a. Cash income alone [ ]
b. Subsistence (household use) alone [ ]
c. Both a. and b. [ ]
d. Not yet in production [ ]

2.10 Where do you sell your milk if it is for cash income?

a. Neighbours (farm gate) [ ]
b. Local shopping centre [ ]
c. Dairy cooperative society (Mur Malanga) [ ]
d. a and b [ ]
e. a and c [ ]
f. b and c [ ]

2.11How do you handle your slurry/manure?

a. I collect it in a covered slurry pit [ ]
b. I collect it in an open slurry pit [ ]
c. I apply it directly to the field [ ]
d. I do not manage it at all [ ]

3. Perceptions of climate change and variability

3.1 In your view, do you think that climate has changed over the last 21 years? Yes [ ] No [ ]

3.2 What do you think has been the trend in rainfall since 1994 to date in this area?

a. Increasing [ ]
b. Decreasing [ ]
c. Fluctuating [ ]
d. No change [ ]

e. Unpredictable [ ]
f. I don't know [ ]

3.3 What do you think has been the trend in temperature since 1994 to date in this area?
a. Increasing [ ]
b. Decreasing [ ]
c. Fluctuating [ ]
d. No change [ ]
e. Unpredictable [ ]
f. I don't know [ ]

3.4 How do you perceive these changes in rainfall and temperature?

Code	**Perceptions**	**Tick**
A.	Early onset of long rains (rain starting earlier than normal)	
B.	Early cessation of long rains (rain ending earlier than normal)	
C.	Late onset of long rains (rain starting later than normal)	
D.	Late cessation of long rains (rain ending later than normal)	
E.	Change in amount of rainfall during main rain season (fluctuating)	
F.	Increasing rainfall in amount during main rain season (above normal)	
G.	Decreasing rainfall in amount during main rain seasons (below normal)	
H.	Shift in the timing of the onset of rain in the main seasons	
I.	Long rains than normal (becoming more intense within seasons)	
J.	Long rains than normal (becoming less intense within seasons)	
K.	Early onset of short rains (rain starting earlier than normal)	
L.	Late onset of short rains (rain starting later than normal)	
M.	Early cessation of short rains (rain ending earlier than normal)	
N.	Late cessation of short rains (rain ending later than normal)	
O.	Short rains than normal (becoming more intense within seasons)	
P.	Short rains than normal (becoming less intense within seasons)	
Q.	Long term rainfall increasing	
R.	Long term rainfall decreasing	
S.	Rainfall has been fluctuating (seasons don't receive uniformly distributed rains)	
T.	Floods are now more common	
U.	Floods are now less common	
V.	Flood intensity is increasing	
W.	Flood intensity is decreasing	
X.	Temperature of the area decreasing	
Y.	Temperature of the area increasing	

3.5 In your view, do you think that the above mentioned changes have had any effect on the quantities of feed produced for your dairy cows? Yes [ ] No [ ]

3.6 If yes in what ways do you think climate change and variability has contributed?

Code	Challenges	Tick
A.	Drought leading to reduced fodder production	
B.	Flooding of fodder field leading to reduced production due to stunted growth	
C.	Flooding of fodder field leading to increased production due to fast growth	
D.	Floods leading to low production due to washing away of fodder crop	
E.	Increased temperature leading to increased fodder production	
F.	Increased temperature leading to reduced fodder production	
G.	Increased temperature leading to increased fodder diseases hence low production	
H.	Increased temperature leading to increased weeds hence low fodder production	
I.	Increased temperature leading to rapid fodder growth hence high production	
J.	Rainfall fluctuation leading to increased fodder production	
K.	Rainfall fluctuation leading to reduced fodder production	
L.	Long rains than normal leading to increased fodder production	
M.	Floods leading to soil erosion that affects soil fertility hence low fodder production	
N.	Emergent of invasive weeds and new fodder disease that affect production	

3.7 In your view do you think that the quantity of fodder fed has any effect on milk yields?

Yes [ ] No [ ]

If yes in what way does this happen?

Code	Challenges	Tick
0	Leads to decreased milk yield due to reduced fodder fed	
1	Leads to no change in milk yield due to quantity of fodder fed	
2	Leads to increased milk yield due to increased quantity of fodder fed	

3.8 Do you experience any vector borne diseases of livestock on the farm? (Tick one)

Yes [ ] No [ ]

3.9If yes, what do you think are the causes of these diseases? (Tick one)

a. Ticks [ ]
b. Biting flies [ ]
c. Tsetse flies [ ]
d. Ticks and biting flies [ ]
e. Ticks and Tsetse flies [ ]
f. Biting flies, Tsetse flies and ticks [ ]
g. Not aware [ ]

3.10 Do you think that incidences of livestock diseases are on the increase? (Tick one)

Yes [ ] No [ ]

3.11 If yes what in your opinion do you attribute this to?

Code	Challenges	Tick

A.	Drought leading to increased build up of vectors	
B.	Flooding of farms leading to build up of vectors	
C.	Increased temperatures leading to rapid multiplication of vectors	
D.	Encroachment of invasive plants that create suitable nesting habitats for the vectors	
E.	Inadequate handling of slurry/manure creating suitable breeding sites for vectors	

3.12 Do you think that an increase in vector population during drought contributes to:-

Code	Challenges	Tick
0	Decreased milk yield	
1	No change in milk yield	
2	Increased milk yield	

3.13 Do you think that an increase in vector population during floods contributes to:-

Code	Challenges	Tick
0	Decreased milk yield	
1	No change in milk yield	
2	Increased milk yield	

3.14 Do you think that an increase in vector population due to high temperatures contributes to:-

Code	Challenges	Tick
0	Decreased milk yield	
1	No change in milk yield	
2	Increased milk yield	

3.15 Do you think that increased vector borne diseases contribute to:-

Code	Challenges	Tick
0	Decreased milk yield	
1	No change in milk yield	
2	Increased milk yield	

3.16 When do you experience water shortages for livestock production the most? (Tick one)

a. During droughts [ ]
b. During floods [ ]
c. During periods of intense rainfall [ ]

3.17 Do you think that water shortage due to drought contributes to:-

Code	Challenges	Tick
0	Decreased milk yield	
1	No change in milk yield	
2	Increased milk yield	

4.0 Existing Adaptation Strategies and possible motivating factors on SDFS

4.1 What adaptation strategies have you put in place as a result of the limiting factors we have discussed? (Please tick appropriately)

Adaptation Strategies	**Possible Motivating Factors**		
	Negative impacts of CCV	Available financial capital	To raise additional income to support living costs
Shifted to higher yielding fodder varieties			
Introduced new fodder varieties tolerant to flooding, high temperatures and drought			
Established high yielding grass species for hay production			
Use of maize stovers for feeding during fodder scarcity			
Cross bred dairy cattle for off-springs that are tolerant to increased temperatures			
Planted fodder crop along contours			
Used irrigation for fodder production			
Carried out soil conservation measures			
Sunk shallow well for water provision all year round			
Used roof catchment for additional water supply			
Planted fodder trees for provision of fodder and firewood			
Modified dairy unit for optimal temperature regulation			
Regularly spray against diseases vectors			
Regularly vaccinate all livestock against common livestock diseases			
Bush clearing to alter habitats suitable for disease vectors			
Planted Napier in furrows for water retention			
Planted Napier under tumbukiza for water retention			
Heavily manure fodder fields to retain soil moisture and fertility			
Use slurry to generate cooking gas (methane)			

4.2 How did you get to know that the strategies you picked and adopted were good for supporting your adaptation options to CCV? (Please tick as appropriate)

Code	**Media**	**Tick**
A.	Radio	
B.	Newspapers	
C.	Television	
D.	Family Members	
E.	Neighbours	
F.	Faith Based Institutions	
G.	Community Based Organizations	
H.	Non Governmental Organizations	
I.	Community meetings (Barazas)	
J.	Livestock Production Officers	
K.	Extension Services	
L.	My own judgment	
M.	Our traditional knowledge that also forecasts weather events	

N.	Cultural knowledge passed down from our ancestors	
O.	Kenya Meteorological Department's seasonal forecasts	

4.3 Can you specify any other source not mentioned above?________________________________

4.4 Are you a member of any farming organization? Yes [ ] No [ ]

4.5 If yes please state its name____

4.6 What benefits do you get from being a member of the stated organization? (Tick appropriate)

Code	Benefit	Tick
A.	I get dairy feeds at subsidized prices	
B.	I get dairy concentrate on loan	
C.	It is my sole milk outlet	
D.	I take to them surplus milk for sale	
E.	I get annual dividends from being a member	
F.	I get credit facilities to expand (diversify) my farming enterprises	
G.	I get drugs and acaricides at subsidized prices	
H.	I get general farm inputs on credit	
I.	I get school fees loans	
J.	I Get emergency loans	

Please specify if there any other benefits____
____

4.7 Do you think that engaging in smallholder dairy production has contributed towards improving your resilience towards CCV? Yes [ ] No [ ]

4.8 If yes in what way?

Code	Livelihood options	Tick
1.	I have used the proceeds to diversify my farm enterprises	
2.	I have used the proceeds to pay for school fees	
3.	I used the proceeds to build a better house	
4.	I use the proceeds to buy food during periods of scarcity	
5.	I use the proceeds to lease land for increased fodder production	
6.	I use part of the proceeds for disease control on the farm	
7.	I use the proceeds to pay for on farm labour (employment creation)	
8.	I used the proceeds to open up a commercial business	
9.	I use the proceeds to buy feed concentrates	

5.0 Barriers to adaptation

5.1 Can you please state factors that limit optimal production of your dairy enterprise in light of CCV? (Please tick appropriate response)

Code	Barrier	Tick
A.	Knowledge of causes of climate change	
B.	Lack of timely weather and climate information	
C.	Lack of easy to understand, timely weather and climate information dissemination	
D.	Lack of knowledge on soil fertility improvement	
E.	Lack of forward and advanced weather predictions to aid in future planning of SDFS	
F.	Lack of knowledge on better fodder husbandry practices	
G.	Inadequate knowledge on use of farm inputs	
H.	Inadequate knowledge on alternative fodder production systems	
I.	Non availability of tolerant cultivars of Napier grass to diseases and CCV	
J.	Inadequate knowledge on adaptation options	
K.	Inaccessibility to markets	
L.	Lack of credit for uptake of adaptation strategies	
M.	Inadequate extension services	
N.	Lack of knowhow on blending scientific and local knowledge systems to support CCV strategies	
O.	Inadequate road infrastructure	
P.	Land tenure systems (lack of title deeds as collateral for credit)	
Q.	Lack of livestock insurance schemes against CCV	
R.	Weak Government support to address adaptation strategies to CCV	
S.	Lack of alternative livelihood options to reduce vulnerability due to CCV	

Appendix IV: Transect walk guide

Feature of Interest	Start point	Mid point	End Point
Land Use			
Farming system			
Crops grown			
Natural vegetation			
On farm water management			
Soil erosion			
Soil conservation measures			
Cropping problems			
Probable Interventions			