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Climate Change Effects and the Resulting Adaptation Strategies of Smallholder Farmers in Three Different Ecological Zones (Kilifi, Embu and Budalangi) in Kenya

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Abstract
Smallholder farmers in Kenya are faced by effects of climate change which results to loss of crop and livestock productions. Consequently, smallholder farmers suffer crop and livestock losses, causing devastation and food insecurity situation. This study provides findings on the effects, adaptation approaches carried out by smallholder farmers of Embu, Kilifi and Budalangi to climate change. The study objectives were achieved through use of survey design. Mixed approach of quantitative and qualitative data analysis was applied. Sampling included multi stage sampling. Three study sites were chosen based on different ecosystem conditions in Kenya. Linear regression was used to demonstrated crops and rainfall trends. Mean temperatures noted to increase slightly and greater variations in the mean seasonal rainfalls in all the three study areas. Declining trend of crop yields was noted for Kilifi ($R = -0.032$). The research findings evidently showed that climate change is impacting on smallholder farmers and farming systems in the study area..
Keywords: Smallholder farmers; climate change and adaptation strategies

1. Introduction

Climate change is happening despite the international efforts to limit greenhouse gas emissions, due to the past and present emissions (Gerber et al., 2013; IPCC, 2007a). Unavoidable impacts are expected to affect agriculture which highly depends on climatic aspects such as heat, sunlight and water (Iglesias et al., 2011). The impacts of climate change are likely to affect agriculture through accelerating crop failure, declining livestock and fish production, consequently reducing food supply by smallholder farmers (Obuoyo et al., 2016). Some of the major challenges come from the greater prevalence of drought and floods, heavy rainfall, storms, outbreak of diseases, pests and weeds. Eventually, heavy rainfall and increased incidences of drought disrupt agricultural activities and pose great risk to food production. In other words, drought frequency and duration are some of the factors which affect agricultural productions (Hosseinizadeh et al., 2015). In many cases, weather patterns brought about by climate change will be new in the farmers' experience; for example, floods in areas such as Embu may cause rapid crop failure due to ineffectiveness of fertilizers and herbicides, difficult of traction and cultivate flooded fields while delaying the planting season of crops (Jarvis et al., 2008). Livestock production is not spared too, declines in pasture growth results to poor productivity thus shortage of milk, meat, eggs and other livestock products (Smucker et al., 2007). This outcome leads to food insecurity situation due to limited supply of agricultural products and hunger continues to persist in most areas of the country.

The agricultural sector in Kenya accounts about 21 - 23.5 % of country's GDP, provides 80 % of employment opportunities and 70% of raw materials in the country (NEMA, 2011). The sector is the primary source of food consumed by rural and urban populations. Consequently, the sector is one of the key pillars that support national economy and social welfare (Nyikal and Kosura, 2005). Agricultural land in Kenya faces more risk of degradation under climate change scenario. In reality, poor agricultural practices such as over grazing, mono-cropping and poor farming methods will promote soil erosion, nutrient depletion, sedimentation, salinization and siltation of aquatic ecosystems. The degraded agricultural lands undermine crop and livestock productivity which predisposes farming households to food and income insecurity (Rao et al., 2011). Due to underlying factors, promotion of good farming practices that are compatible with changing climatic conditions should be encouraged (Iglesias et al, 2011). International Panel on Climate Change advocates for adaptation to the effects of climate change in agricultural sectors, so as to minimize potential risks and exploit opportunities (IPCC, 2007b). It is important for Kenya smallholder farming communities to adapt to climate change because they contribute the biggest percentage of agricultural production.

1.1 Vulnerability of smallholder farming systems to climate change

Smallholder farming systems in Kenya often involve farm power that is either manual or animal, although it can also be based on smallholder machinery. Smallholder farming in Kenya is also highly reliant on climatic patterns. The farmers depend largely on the rainfall and temperature conditions. This means that changes in precipitation and temperature will have consequential effects to both crop growth and livestock productivity (Khanal, 2009). Since smallholder farming is generally practiced by the rural producers who farm using family labour, the farm provides the principal source of income. Most of the Kenyan smallholder farmers produce maize and additional quantities of potatoes, beans, peas, sorghum, cassava, banana, oilseeds, vegetables, tree fruits, etc (Ojwang' et al., 2010). However, these farmers are faced with a number of challenges.

Vulnerability of developing countries on composite indicators reflects exposure, sensitivity and adaptive capacity to climate change. Vulnerability assessments indicate that poorest countries and populations will be the first and most affected by extreme climatic events (ADB - IFPRI, 2009). Africa continent is agro-ecologically disadvantaged because of its predominant location to the tropics and with most of its farming systems depending on rainfed agriculture (Howden et al., 2007). Under these circumstances, it's economic and social activities are subjected to the effects of climate change. Moreover, increasing population per capita in Africa is expected to decline more of agricultural production and subsequently resulting to food insecurity and major blow to the economy (Mendelsohn et al., 2000)

The agricultural sector is the main stay of the Kenya's economy. Over 80% of the population in rural areas derives their livelihoods from agricultural related activities (GoK, 2010). Due to these reasons, the Government of Kenya (GoK) has continued to give agricultural sector a high priority as an important tool for promoting national development.

In Kenya, agriculture is largely vulnerable to climate change. Increase of precipitation is likely to result to crop failure through flooding, soil and wind erosion. Other factors such as temperature, soil characteristics and the use of production input factors such as fertilizers and chemicals for determining agricultural output. Climate change provides a profound challenge for the future of smallholder agricultural production by posing direct threats to these systems and the livelihoods that they sustain (AMCEN-AU and UNEP, 2012). From the recent studies on Kenya population, it shows that 57% of population lives in poverty and rely on the climate-sensitive economic activities (Ojwang' et al., 2010). Kenya's land is covered by 12% of high potential area for farming and 5.5% as medium potential which supports crops and diary livestock keeping (Mariara and Karanja, 2007).

Kenya can expect more droughts and more floods than it has seen in the past (Ojwang' et al., 2010). A decrease in rainfall in the Arid and semi-arid Lands (ASALs) would spread drought conditions in arid areas thus increasing desertification, disrupting agro-pastoral production systems and causing severe food insecurity for both crops and livestock farmers (Nyikal and Kosura, 2007). Increase of temperature and rainfall amounts in pastoral lands would have positive effect on pasture growth. Similarly, corresponding increase in rainfall in the high potential areas would have both negative and positive such as causing landslides on steep slopes, floods, increased maturation period for crops, increased incidence of fungal diseases in potatoes, maize and beans (Deressa et al., 2010).

1.2 Adaptation of smallholder farming systems to climate change

Adaptation to climate change in agriculture offers opportunities to potentially and substantially reduce many of the adverse impacts and enhance beneficial impacts without leaving residual damage (Rosegrant et al., 2008). Adaptation in agriculture may be autonomous, anticipatory, planned, private or public and reactive as distinguished by IPCC (IPCC, 2007b). The main purpose of adaptation to climate change in agriculture is to effectively manage the potential risks while exploring opportunities presented in the coming decades and future.

Adaptation involves making appropriate adjustments, measures, changes, practices and strategies to moderate potential risks and to benefit from opportunities associated with climate change (Levina and Tirpak, 2006). Accordingly, sustainable adaptation in smallholder agriculture practices should promote food production while ensuring conservation of natural resources such as water, soil and other natural resources (Liniger et al., 2011). In that manner, smallholder farmers practices should pursue sustainable agricultural approaches that maximizes on socio- economic benefits accrued from land while maintaining ecological integrity. For instance, some of these strategies are practical and sustainable in smallholder crop agriculture. These practices include; but not limited to crop rotation, fallows, crop diversification, conservation tillage, organic agriculture, fertilizer management, integrated pest management, manure management, agro forestry, reforestation, rainwater harvesting and improved drainage, irrigation systems, restoration of natural vegetation, mixed cropping, no till production and avoid deforestation (Winterbottom et al., 2013). Furthermore, suitable adaptation strategies have proved to improve, restore the structure and functioning of degraded soils while increasing infiltration rates and restoration of water and nutrients in the soils (Thornton and Lipper, 2013; Vermeulen et al., 2012).

Adaptation to climate change in livestock production in Kenya cannot be ignored because it's an important economic activity in ASALs. Kenya lost 70% of the total livestock due to droughts in the worst drought ever to hit the country in 1991-1992 (Huho and Ang'awa, 2008). Realization of need for adaptation in livestock should aim at reducing livestock loss and improving livestock production systems. Likewise, measures such as introduction of fodder banks, improving water management, controlling of animal diseases and nutrition significantly reduces livestock loss (Makar, 2012). Other major considerations include improving the health of herd, achieved by increasing use of high quality legume forage, such as Calliandra, as protein supplements during dry seasons and drought (Howden et al., 2007). Diversification of livestock may safeguard pastoral livelihoods whilst encouraging usage of the optimal stocking rate, stratified production, migration and diversification of yield productions in Kenya could provide adaptable solutions effects of climate change.

1.3 Challenges of adaptation to climate change in smallholder system

The greatest challenge of the smallholder agriculture is to develop mechanisms that would help farmers cope up and adapt to climate change. The first step to consider in adaptation to climate change is to improve farmer's adaptive capacity to various climate change impacts. However, adaptation is a process that involves technical, financial and management adaptation options available to them (Kurukulasuriya et al., 2011).

As been noted, poverty is the ultimate cause of land degradation in Kenya. Poor farmers have no wealth to invest in sustainable farming methods. In fact, land is the main source of wealth to the poor farming communities (Huho and Ang'awa, 2008). Poor land use practices affect the quality of land to produce viable yields. Lack of funding, secure land rights and will undermine progress of adaptation and development in vulnerable poor communities especially the smallholder farming in Kenya and other Sub-Saharan African regions. Although no specific estimates are available for the funding needs for adaptation in the agricultural sector, they are likely to be large in relation to total current aid flows to other sectors (Muller, 2009).

Market access is important issue when it comes to agriculture, especially in trading of agricultural inputs and access to information. In smallholder farming system, intensification and higher yields beyond the household needs will be realized only if market access exists or can be established. This depends on sufficient infrastructure, information, skills and organisation (Cooper et al., 2009).

Off-farm employment can restrict the availability of on-farm labour and time required for adaptation efforts in the farms whereby little resources will be available for farming activities (Cooper et al., 2009).

Climate change impacts are likely to affect infrastructure required for agricultural development. Despite overall annual rainfall increases, appropriate infrastructure is not available to capture rain water. In lower Coastal lying areas, salt-water intrusion as a result of sea level rise in coastal areas is likely to occur (IPCC, 2007a). Another anticipated problem is the damage to irrigation systems and other agricultural infrastructure may result due to flooding during the rainy season. Rural areas are spatially dispersed, which affect the costs of transport, the quality of public services and the reliance on subsistence production. Climate change policy is also needed for better planning and reaction to disasters; both long term and short term programs should be availed to smallholder farmers to adapt and mitigate climate change. Other non climate stressors include health related stress such as diseases like HIV-AIDS and cancer (Heidi, 2012). Human resources may be constrained by diseases both in pastoralists and crop farmers and making them unavailable for farming activities.

1.4 Statement of the Problem

Climate change continues to occur and effects continue to worsen. Smallholder farmers in Embu, Kilifi and Budalangi rely on natural precipitation for crop and livestock production. Unpredictable climatic conditions expose them to climatic events, which results to crop and livestock losses. Smallholder farmers lack adequate capacity to adapt to climate change. Consequently, smallholder farmers are faced up with agricultural production losses which lead to devastation and food insecurity. Few studies explore information provided on how they cope up with the losses caused by effects of climate change in these study areas.

1.5 Justification

Research on climate change, its effects on agricultural production and adaptation has focused largely on large scale farming systems in Kenya. Consequently, gaps exist in knowledge of climate change effects and adaptation approaches on the smallholder farming systems in Kilifi, Budalangi and Embu. Knowledge on effects of climate change faced by farmers in these study areas is inadequate and how they cope up with these effects. The results from this study will enhance understanding and knowledge sharing of adaptation strategies in smallholder systems.

1.6 Scope of the study

The study was carried out in Budalangi, Kilifi and Embu counties in Kenya. Selection was based on the distinctive ecosystems that enabled visualization of different adaptation strategies in smallholder farming systems in Kenya. Kilifi was selected because of it lies adjacent to the sea (coastal lowland areas). Embu was chosen because of its relatively high-medium agricultural potential while Budalangi was selected due to its flood prone conditions experienced in Budalangi and found in Lake Victoria Basin. Sampling unit in this study included smallholder farmers who grow subsistence crops and not more than two cash crops on small production units of less than 1 acre. The target locations (villages) were selected randomly from all the areas identified within 20km radius.

1.7 Objectives of the study

To evaluate the effects of climate change and adaptation approaches put forward by the smallholder farmers in Kilifi, Budalangi and Embu Counties in Kenya.

1.7.1 Specific Objectives

- To identify the effects of climate change on crop production
- To find out effects of climate change on livestock production
- To describe the adaptation strategies adopted by the smallholder farming systems
- To assess the challenges faced by smallholder farmers in adapting to the effects of climate change

2. Methodology

2.1 Study areas

The study was undertaken in three areas of Kilifi, Embu and Budalangi in Kenya to differentiate among three ecosystems experiencing different agro-climatic conditions as tabulated in Table 2.1.

Table 2. 1: Study area characteristics

Study areas characteristics	Kilifi	Budalangi	Embu
Agro-ecological zones	Coastal lowlands	Lower midlands (Lake Basin)	Upper midlands
Rainfall patterns	Bimodal	Bimodal	Bimodal
Rainfall amounts	200mm-500mm, 1200-1500mm	1070mm-2200mm	1000mm-2500mm
Temperatures	20-35 ^{O}C	14-30 ^{O}C	17.7-20.7 ^{O}C
Soils	Luvisols & ferrasols	Ferrasols	Nitosols
Soil fertility	Low chemical fertility	Low chemical fertility (strongly weathered)	Deep & medium to high fertility
Farm size (acres)	0.98-1.5	0.96- 1.9	0.5- 1

Kilifi County is in the Coastal lowlands on coordinate scale of 3.00230 S and 39.81670 E. The study sites were selected from Tezo and Matsangoni wards of Kilifi North constituency in Kilifi County. The population size of Kilifi North is estimated to be 154, 632 persons per Km2 (Infotrack, 2016).

Embu County is located on the South Eastern slopes of Mt. Kenya. Embu County is found on coordinates 0.53880 S and 37.4596 0 E in the upper midlands of Mount Kenya region. Two wards, Gaturi South and Kirimari from Manyatta constituency in Embu County provided study sites. Population size of Manyatta constituency is estimated to be 154, 632 persons per Km2 (Infotrack, 2016).

Budalangi constituency is located in Busia County. Budalangi is located on the lower midland of Lake Basin (Lake Victoria). Budalangi is found on coordinates 0.46080 N and 34.1115 E. Bunyala Central and Bunyala North wards of Budalangi constituency provided study sites. Budalangi is found on the low lying swampy tract of Western Kenya prone to flooding. It embraces the Yala/ Nzoia lowlands, which is broken by irregular water channels and flash floods. The population size of Budalangi is estimated to be 66, 723 persons, many who live in the flood plain regions (Infotrack, 2016).

Selection of three study areas enabled visualization of different adaptation strategies in smallholder farming systems in Kenya. The three study areas in Kenya are further shown in Figure 3.1, Figure 3.2, Figure 3.3 and Figure 3.4.

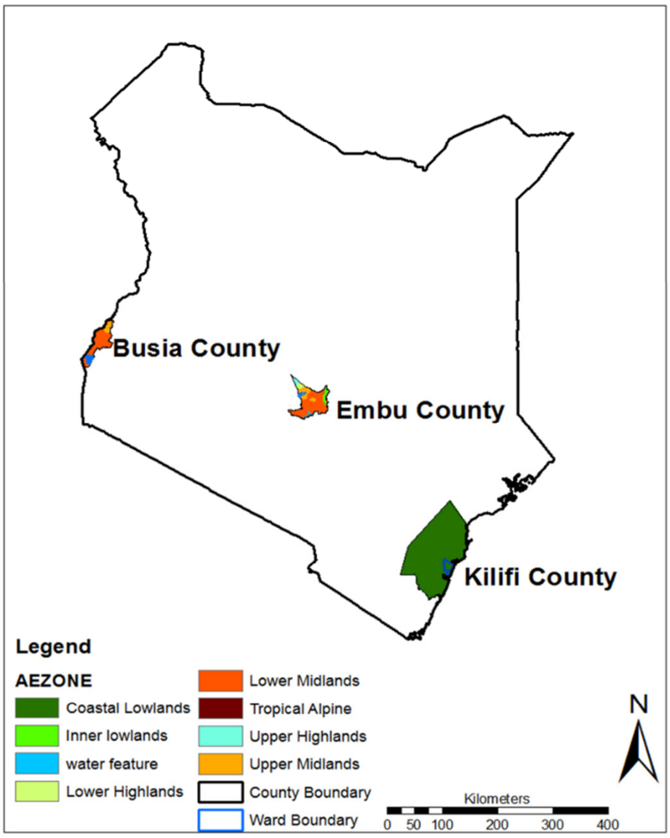

Figure 2. 1: A map of Kenya showing three counties within which study took place. Source: Diagram generated using GIS.

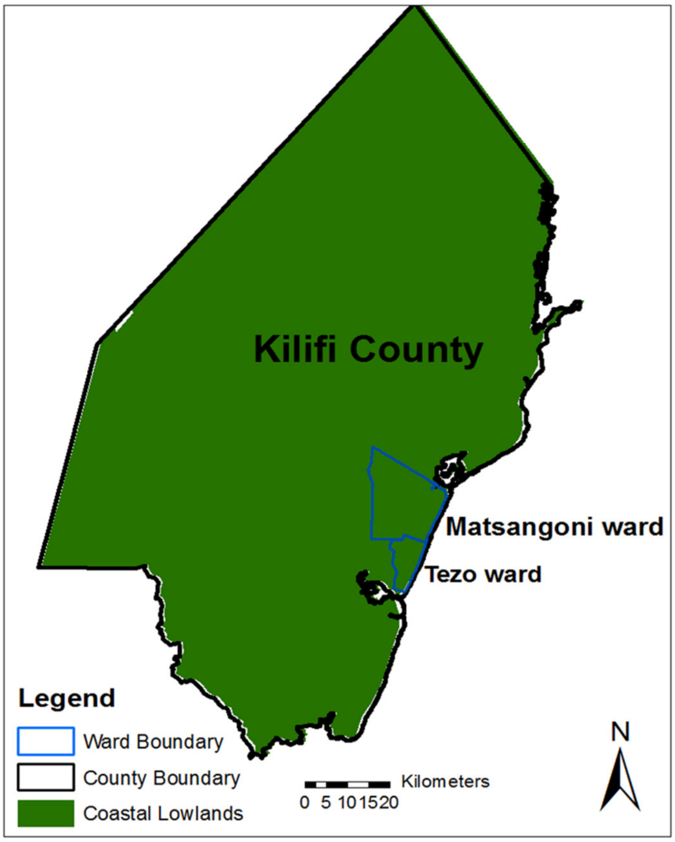

Figure 2. 2: A map of Kilifi County showing wards within which study sites were located (Tezo and Matsangoni wards).Source: Diagram generated using GIS.

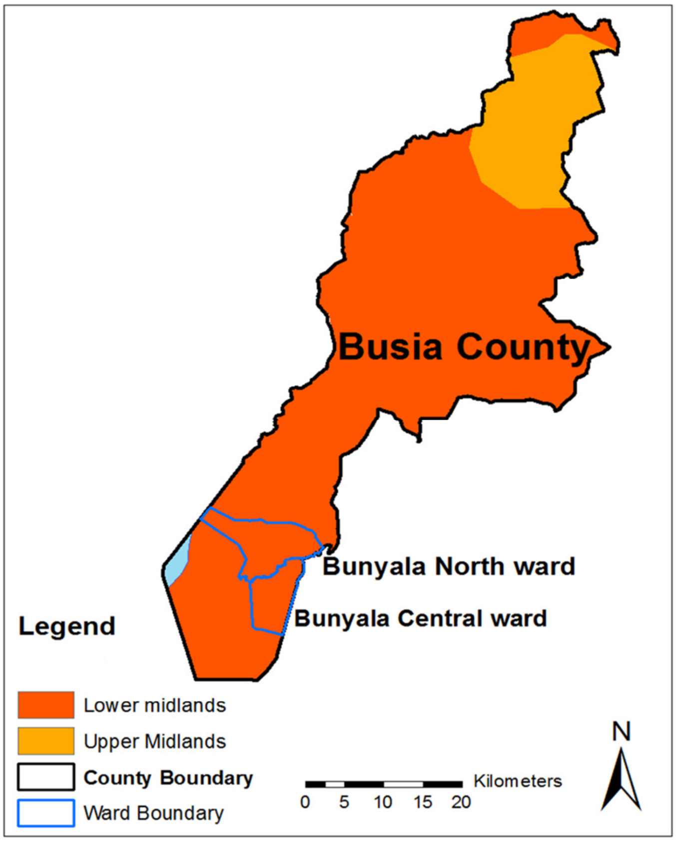

Figure 2. 3: A map of Busia County showing wards within which study sites were located (Bunyala North and Bunyala Central ward).Source: Diagram generated using GIS.

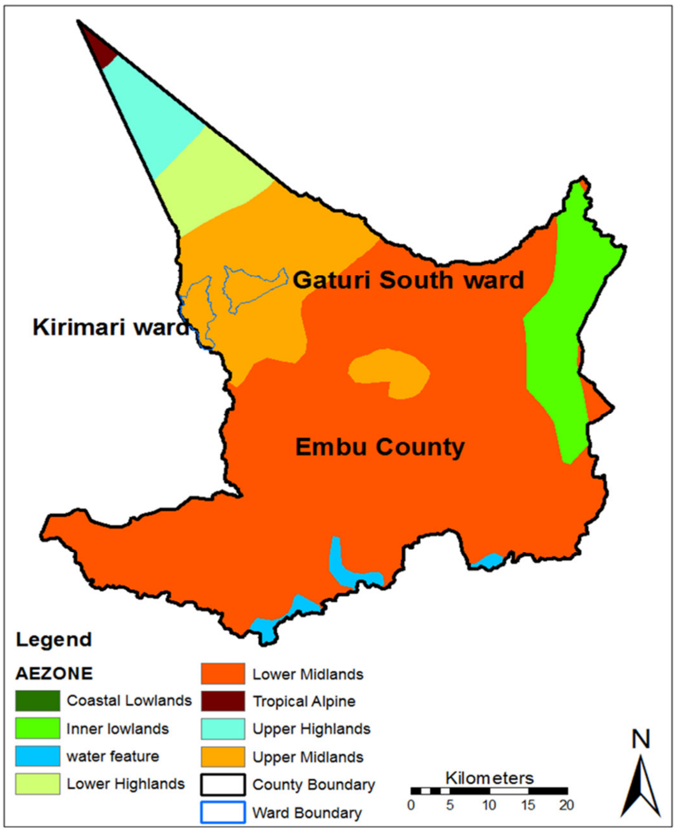

Figure 2. 4:A map of Embu County showing wards within which study sites were located (Kirimari ward and Gaturi South wards).Source: Diagram generated using GIS.

2.2 Research design

The research questions of this study were answered using mixed approaches. To achieve this, mixed method of quantitative approach and qualitative methods were used. Interviews and households' responses were based on perceptions. Additionally, both primary and secondary data sources were used. Primary data originated from a household survey, key informant interviews and FGDs. While secondary data sources included review of literature and information from available relevant organizations.

2.3 Sampling

Multi stage sampling was used to select target study sites and households. First, purposive sampling was used to identify constituency and wards. Then, three villages were randomly selected from the wards. Lastly, households were randomly selected in the villages. Three stages of sampling are shown in Table 2.2.

Table 2. 2: Sampling procedure

1st stage sampling			2nd stage sampling	3rd stage sampling
Purposive sampling			Random sampling	Random sampling
County	Constituency	Wards	Villages	Households
Embu	Manyatta	Gaturi South	Kangaru	27
			Nginyirua-Kamiri	27
		Kirimari	Kathigari	28
Kilifi	Kilifi North	Tezo	Ufuoni	31
			Kaereni	31
		Matsangoni	Kakunjuni	31
Busia	Budalangi	Bunyala North	Nambegele	33
			Nanjomi	32
		Bunyala Central	Mombaka	32

Purposive sampling was used to identify key informants. Key informants included experts in fields of agriculture and environment. Snow balling was used to identify the local elders (60 years and above) in the villages.

2.4 Research instruments

2.4.1 Questionnaires

A target sample size was primarily 300, each site expected to produce 100 filled questionnaires. Overall, the first survey yielded 82 responses from Embu, 97 in Budalangi and 93 in Kilifi, amounting to 272 households. The second follow up survey yielded 90 responses, 30 questionnaires from each study areas as summarized in Table 2.3.

Table 2. 3: Response rate of questionnaires

	Embu	Kilifi	Budalangi
1st survey	82	93	97
2nd survey	30	30	30

The questionnaires were coded instead of using real names of the participants to encourage participation. However, despite implying anonymity and confidentiality, it was difficult to achieve 100% response rate.

2.4.2 Interviews

Additionally, semi structured in-depth interviews were used to provide further information and detailed historical overview of climate change events that could have been omitted in the questionnaires. The participants involved Agricultural extension officers, District agricultural officers, Non-Governmental Organizations (NGOs) representative and village elders to establish impacts and efforts they have put in effort to help the smallholder farmers in adapting to climate change.

2.4.3 Focus group discussions

Focus group discussions (FGDs) were used for triangulation of the information provided by the farmers and interviews. It involved various stakeholders such as agricultural officers, climate expert, extension officers, farmers' representative and agricultural based NGOs representative. Moreover, FGDs were also helpful in providing community responses and recommendations that can help smallholder farmers adapt to climate change.

2.4.4 Transact walks and direct observations

Transect walks and direct observations were also applied in this study. Observation provided a clear view of climate change indicators and employed by the researcher as a verification tool of the data provided in other survey methods used. Aspects of observation were recorded through notes taking and photography.

2.5 Data collection

First, reconnaissance survey was carried out in each area to determine study location site and to sample out the representative farming households. Thereafter, selection and training of research assistants followed. The training was essential to ensure recording and reliability of the data. The questionnaires were in English, hence it was important to have research assistant who can translate, interpret and assist the interviewees in providing valid responses. After the selection process, the researcher contacted the administrative personnel, i.e. County agricultural officers in Kilifi, Embu and Budalangi that allowed the research team to start the field work activities. Target numbers of questionnaires to be filled were 100 for each study area. The questionnaires entailed open ended detailed questions so as to provide characteristics of the farms, effects faced due to climate change, module of adaptation strategies and challenges facing the farmers. Specific, precise and standardized questions were asked to the selected respondents and filled for by the researcher and research assistants. The surveys were rolled out as recorded in Table 2.4.

Table 2. 4: Data collection exercise

Areas	**1st survey Timings**	**2nd Survey Timings**
Embu	5/9/2012	3/5/2013
Kilifi	10/10/2012	12/7/2013
Budalangi	25/1/2013	23/6/2013

Farmers were asked if they understood the term climate change, if, so, the process of answering the questions continued. If not sure about the term 'climate change' an explanation was made by the researcher and the assistants. The respondents were asked to compare the current occurrences to their childhood memories just to make sure that their responses were based on long time views and not just present happenings of the climatic conditions.

2.6 Climate data

The climate data for this study was collected at Kenya meteorological department (KMD) headquarters. The data comprised of monthly maximum-minimum temperatures and rainfall records, which was computed, organized and generated annual means and trends. For the temperatures, linear trend equations of y=ax+b were used, whereby 'y' represent annual temperatures, and 'x' represent the change in temperatures in.

Linear regression equation y = ax+b
y = annual temperatures (0C)
x = changes in temperatures (0C)
a = intercept
b = constant

Precipitation data was classified into annual and seasonal precipitation. Then, mean annual rainfalls were calculated from monthly data and trends determined by linear regression. Again, seasonal data of monthly rainfall only focused on the long rains seasons of March, April and May (MAM); for short seasons, were October, November and December (OND). Likewise linear trends and equation of y=ax+b

Linear regression equation y= ax+b
y= mean rainfalls (mm)
x = changes in the precipitation (mm)
a = intercept
b = constant

2.7 Production data

Maize data was obtained from the Ministry of Agriculture (MOA) annual reports. Data on the maize production for long period was available for Kilifi, which was used to demonstrate the trends of crop production from 1977-2012. Linear correlation coefficient (R) was used. Furthermore, R squared (R2) was used to represent variation of maize production and annual rainfall then presented using scatter plot. However, some years were missing data, so, forecast and trend lines of Microsoft Excel was used to fill in missing data. Also, livestock production data for long period of study areas was not available.

2.8 Data analysis

In the first place, survey data was entered into computer statistical application of IBM SPSS version 20. Then, it was coded, sorted. Frequency analysis, cross tabulation, non-parametric tests were run and presented using descriptive statistics in form of frequencies, tables, graphs and charts of SPSS and Microsoft Excel.

3 RESULTS

3.1 Attributes of crop and livestock farming

3.1.1 Attributes of crop farming

The summary statistics of the crops data collected and key variables considered in the analysis are presented in

Table 3.1 and 3.2.

Table 3. 1: Main crops grown in Kilifi, Embu and Budalangi

Sub-county	Total no. of farmers sampled	Main crops	Total no. of farmers	% . Total no. of farmers
Kilifi	82	Maize	81	98.8
		Coconuts	42	50
Embu	93	Maize	93	100
		Beans	82	88.2
		Bananas	75	80.6
Budalangi	97	Maize	91	93.8
		Beans	81	83.5
		Rice	37	38.1

Note: Respondents were allowed to provide more than one response to main crops grown, thus the total exceed 100%

From the Table 3.1, main crops in Kilifi included maize and coconuts. Whereby, 98.8% of farmers in Kilifi grew maize and 50% also grew coconuts. In Embu, all respondents cultivated maize (100%), beans (88.2 %) and bananas (80.6%) as main crops. Farmers in Budalangi grew maize (93.8%), beans (83.5%) and rice (38.1%) as main crops. Beside these main crops, farmers also grew additional crops as shown in Table 3.2.

Table 3. 2: Other crops grown in Kilifi, Embu and Budalangi

Sub-county	Total no. of farmers sampled	Other crops	Total no. of farmers	% . Total no. of farmers
Kilifi	82	groundnuts	27	32.1
		cashew nuts	20	23.8
		Mangoes	35	42.7
		Bananas	12	14.3
		green grams	12	14.3
		Pawpaws	12	14.3
		Sugarcane	6	7.1
		citrus fruits	3	3.6
Embu	93	sweet potatoes	53	57.0
		Mangoes	34	36.6
		Pawpaws	32	34.4
		Avocadoes	28	30.1
		Sugarcane	27	29.0
		arrow roots	23	24.7
		Pumpkins	14	15.1
		Citrus fruits	8	8.6
		Yams	7	7.5
		Coffee	7	7.5
Budalangi	97	Cassava	23	23.7
		Millet	36	37.1
		Sorghum	16	16.5
		Vegetables	14	14.4
		Cowpeas	14	14.4
		Sweet potatoes	10	10.3
		Soya beans	2	2.1

Note: Respondents were allowed to provide multiple responses to crops grown, thus the total exceed 100%

Findings tabulated in Table 3.2 shows that the farmers in Kilifi grew mangoes (42.7%), groundnuts (32.1%) and cashew nuts (23.8 %), among others as additional crops. Similarly, farmers in Embu also diversified their main crops with crops such as sweet potatoes (57%); mangoes (36.6%) paw paws (34.4%) and others as shown Table 3.2. The farmers in Budalangi also planted millet (37.1%), cassava (23.7%), sorghum (16.5 %) and others as surplus crops as indicated in Table 3.2.

3.1.2 Attributes of livestock farming

The study also assessed livestock type kept by farmers. Farmers interviewed also practiced livestock farming as shown in Table 3.3.

Table 3. 3: Livestock kept in Kilifi, Embu and Budalangi

Study area	Type of livestock kept	% of respondents
Kilifi	Poultry	42
	Goats	33
	Cattle	22
	Sheep	3
Embu	Goat	32
	Cattle	30
	Poultry	22
	Rabbits	8
	Pigs	6
	Sheep	2
Budalangi	Cattle	32
	Poultry	28
	Pigs	19
	Goats	17
	Sheep	4

From the Table 3.3, poultry was the most preferred livestock kept by 42% of Kilifi respondents, followed by goats (33%), cattle (22%) and least were sheep (3%). Whereas in Embu, goat farming was kept by 32 % of farmers, cattle (30%) followed closely; then, poultry (22%), rabbits (8%), pigs (6 %) and least common was sheep (2%) according to Table 4.3. In Budalangi, cattle keeping were preference for many farmers at (32%), poultry (28%), pigs (19%), goats (17%) and sheep (4%) as demonstrated in Table 3.3.

3.1.3 Input use

Fertilizers

Commonly used fertilizers in the areas sampled were either organic and inorganic fertilizers, or combination of both as illustrated in Table 3.4.

Table 3. 4: Percentage of farmers using different type of fertilizer applications in the farms

Regions		Type of fertilizer		
	Inorganic (%)	Organic (%)	Both (%)	None (%)
Kilifi	33.7	31.7	14.6	20
Embu	8.6	33.3	55.9	2.2
Budalangi	13.4	21.6	10.4	54.6

Applications of inorganic fertilizer use by farmers interviewed were relatively low, in Kilifi (33.7%) as compared to farmers in Budalangi (13.4%) and Embu (8.6%). Although 33.3 % of Embu farmers interviewed opted use of organic fertilizers, 55.9% of farmers used both inorganic and organic fertilizers. It was quite surprising that 54.6% of farmers in Budalangi neither used inorganic nor organic fertilizers (Table 3.4).

Pesticides

Some of the households applied pesticides in their farms as shown in Figure 3.1.

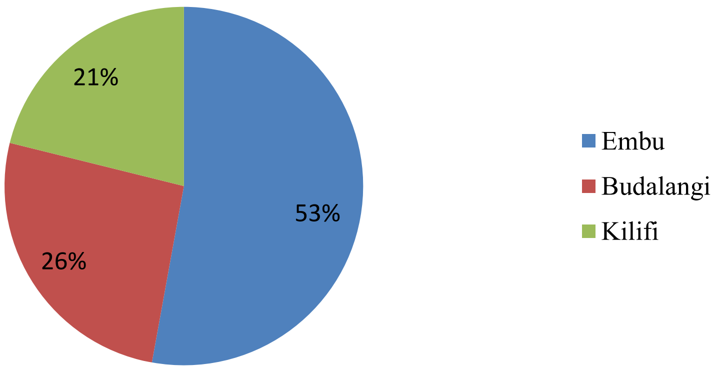

Figure 3. 1: Pesticide use by households in Kilifi, Embu and Budalangi

Application of pesticides in Embu was highest at 53%, followed by Budalangi at 26% and lowest use in Kilifi (21%) as indicated in Figure 3.1.

Farm equipment
Farmers in the studied areas also used farm equipments specifically tractors for ploughing of their lands (Figure 3.2).

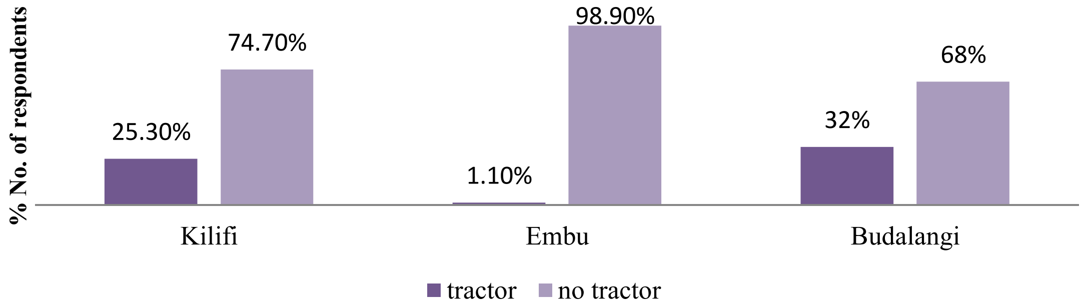

Figure 3. 2: Tractors use by farmers of Kilifi, Embu and Budalangi

Low use of tractors for ploughing was reported, Budalangi (32%), Kilifi (25.3%) and lowest in Embu (1.1%) as stipulated in the Figure 3.2.

Farm labour
Family labour was the most common source of labour observed from the fieldwork surveys as shown in Figure 3.3, followed by temporary and permanent labour.

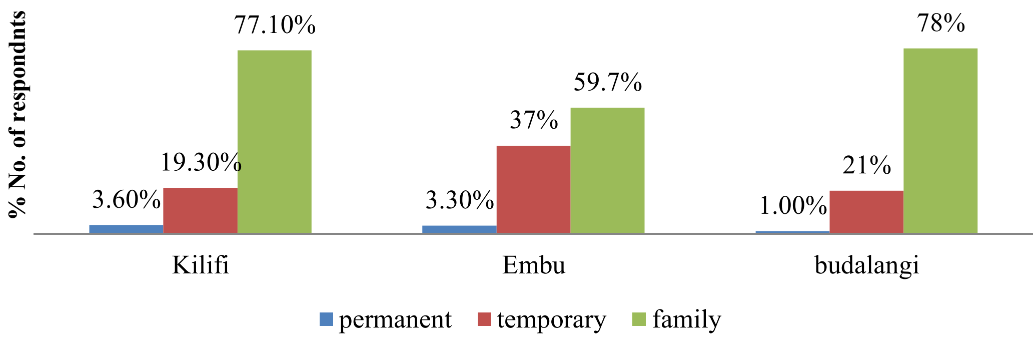

Figure 3. 3: Labour use by the smallholder farmers in Kilifi, Embu and Budalangi

3.1.4 Returns of the farm

Farm income
Income generated from the farms was recorded and it was evident that most farmers earned below Ksh. 10,000 per harvest, as seen from Figure 3.4. The households from Kilifi who earned below Ksh. 10,000 per harvest stood at 84.5 %. Meanwhile, farmers who earned below ksh 10,000 per harvest comprised 60.2% and 63% in Embu and Budalangi respectively. Small number of farmers, (only 11 out of 272) sampled across the regions earned above Ksh.50, 000 per harvest.

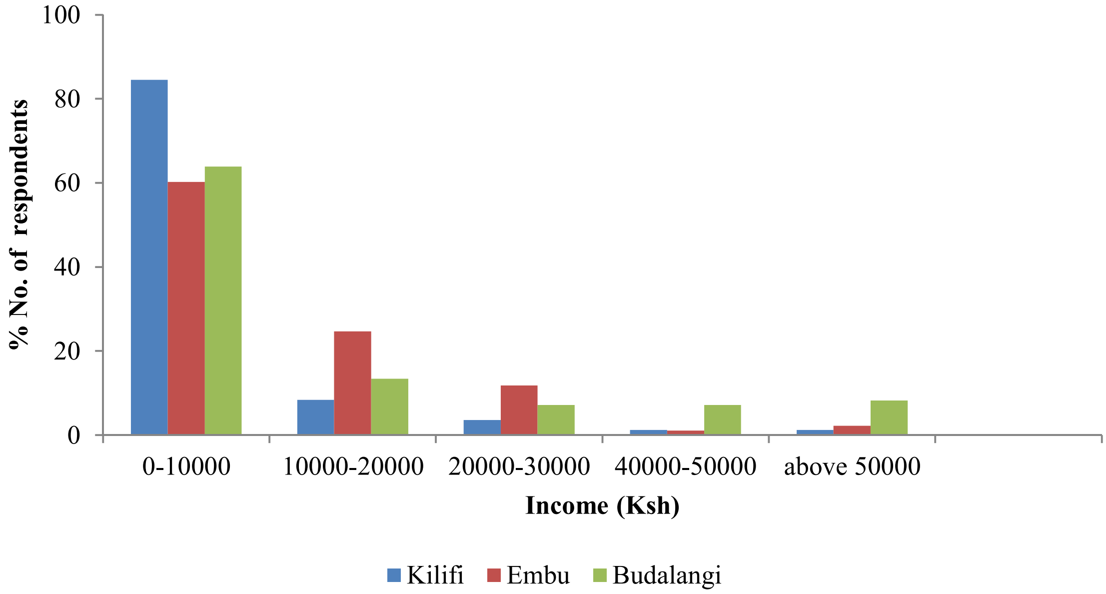

Figure 3. 4: Farm income in Kilifi, Embu and Budalangi

Respondents were further asked to describe their satisfactions based upon their income generated from the farms. The results were summarized in Table 3.5.

Table 3. 5: Satisfaction based on income generated by the smallholder farmers in Kilifi, Embu and Budalangi

Regions	Satisfaction		
	satisfied (%)	not satisfied (%)	Somehow satisfied (%)
Kilifi	25	52.5	22.5
Embu	25.8	52.7	21.5
Budalangi	5.2	56.7	38.1

Furthermore, to establish relationship between farm income and satisfaction levels, comparison of mean analysis was done using SPSS version 20. The results were obtained and generated in Table 3.6.

Table 3. 6: Comparison of means of farm income with satisfaction levels in Kilifi, Embu and Budalangi

Income and satisfaction levels		Mean income & Satisfaction
Pair 1	Farm income Kilifi	Less 10,000
	Satisfaction Kilifi	Not satisfied
Pair 2	Farm income Embu	Ksh.10,000- 20,000
	Satisfaction Embu	Not satisfied
Pair 3	Farm income Budalangi	Ksh10,000- 20,000
	Satisfaction Budalangi	Not satisfied

Pair 1 concluded that farmers in Kilifi earned below income of Ksh. 10,000 represented and were not satisfied.
Pair 2 concluded that most farmers in Embu earned income ranging from Ksh. 10, 0000- 20,000 and most farmers are not satisfied too.
Pair 3 concluded that farm income of Budalangi farmers earn farm income range of Ksh. 10,000-20, 000, however, farmers are not satisfied too.

3.2 Effects of climate change on crop production

This section answers objective one of the study. First, linear trend analysis of climatic variables i.e. temperature and rainfall was done. Secondly, R- squared was used between rainfall and crop data in Kilifi to observe variations and presented using scatter plots. Lastly, survey data carried out in the field was analyzed to identify effects of climate change on crops faced by smallholder farmers.

3.2.2 Trends analysis of temperature and rainfall in Embu, Budalangi and Kilifi

Variability in rainfall and temperatures was analysed for a period of 36 years obtained from Kenya Meteorological Department (KMD) headquarters to determine changes in the climatic conditions. Climatic data was only available for Embu, so datasets for Malindi were used to represent Kilifi and Kisumu for Budalangi.

3.2.3 Annual temperature variability

Variations in annual maximum and minimum temperature of Embu, Kisumu (for Budalangi) and Malindi (for Kilifi) were taken for 36 years and presented in Figure 3.5.

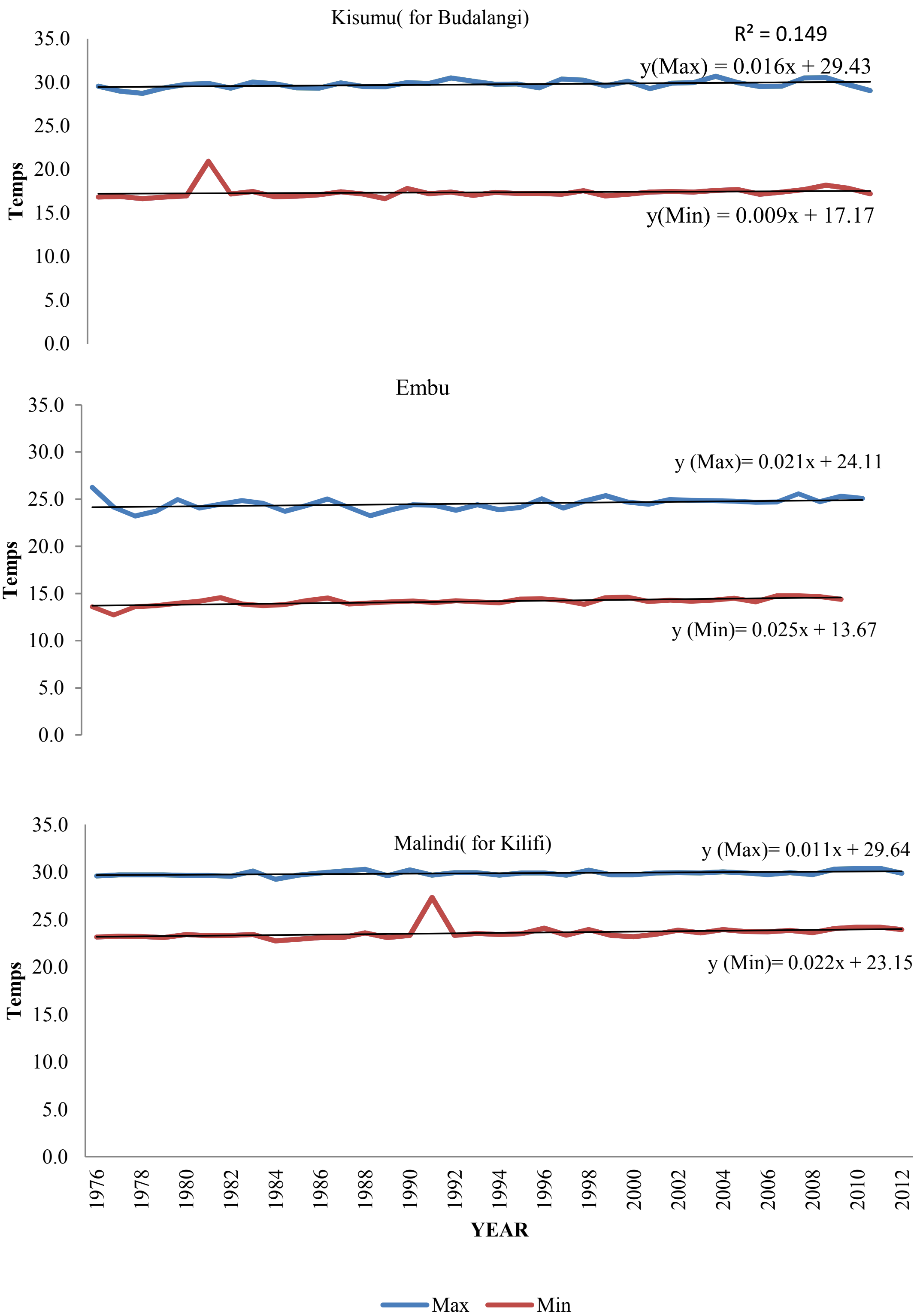

Figure 3. 5: Mean maximum and minimum temperatures of Embu, Kisumu (for Budalangi) and Malindi (for Kilifi) (Source; KMD, 2013)

The mean annual maximum and minimum temperatures for Embu were slightly rising at rate of 0.02^{O}C for maximum and 0.03^{O}C for minimum as observed in Figure 3.5. Likewise, both the mean annual maximum and minimum temperatures of Kilifi were increasing at rate of 0.01^{O}C and 0.02^{O}C respectively (Figure 3.5). Moreover, increasing trends of 0.02^{O}C and 0.01^{O}C were also noted in Budalangi for both maximum and minimum temperatures respectively (Figure 3.5). Increase in minimum temperatures is significantly higher than maximum temperatures in Embu and Kilifi, while, Budalangi, temperatures is increasing for minimum and maximum temperatures.

3.2.4 Annual and monthly rainfall variability

There was notable annual rainfall variability at all study locations from year to year as shown in Figures 4.6, 4.7 and 4.8.

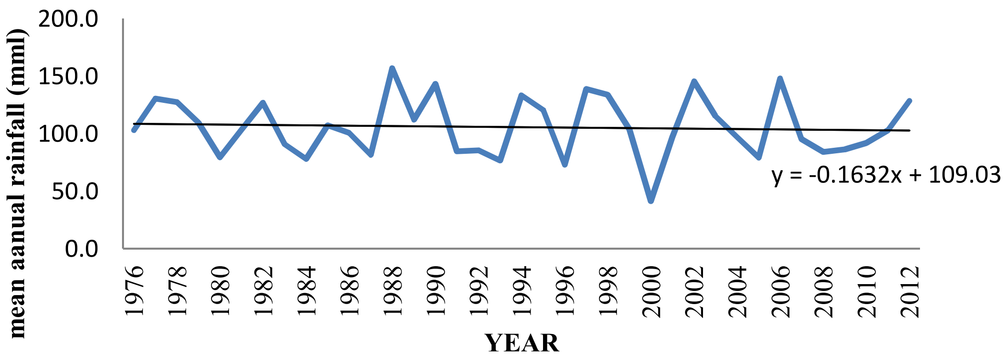

Figure 3. 6: Trend of observed rainfall in Embu (Source; KMD, 2013)

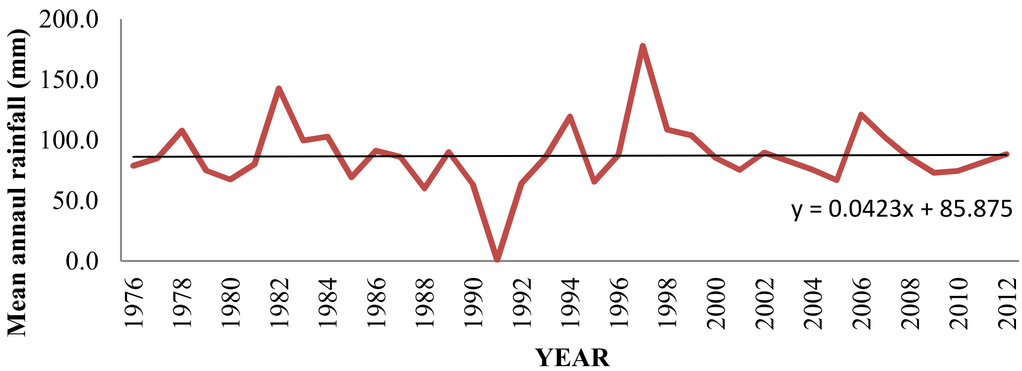

Figure 3. 7: Trend of observed rainfall in Malindi (for Kilifi) (Source; KMD, 2013)

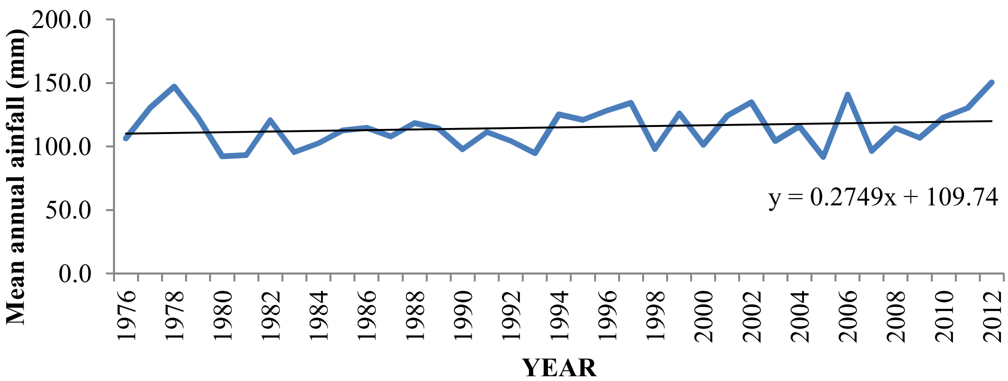

Figure 3. 8: Trend of observed rainfall in Kisumu (for Budalangi) (Source; KMD, 2013)

Mean annual rainfall in Embu is decreasing at rate of 0.16mm (Figure 3.6), as compared to Kilifi and Budalangi which is increasing at rate of 0.04mm (Figure 3.7) and 0.27mm (Figure 4.8) respectively. Decreasing fluctuations of annual rainfall amounts were noted for Embu while increasing variability of rains were observed for both Kilifi and Budalangi.

3.2.5 Seasonal rainfall variations

There was decreasing trend of rainfall observed during long rains of March (M), April (A) and May (M), and positive anomalies during the short seasons, October, November and December (OND) as shown in Figures 3.9, 3.10, and 3.11.

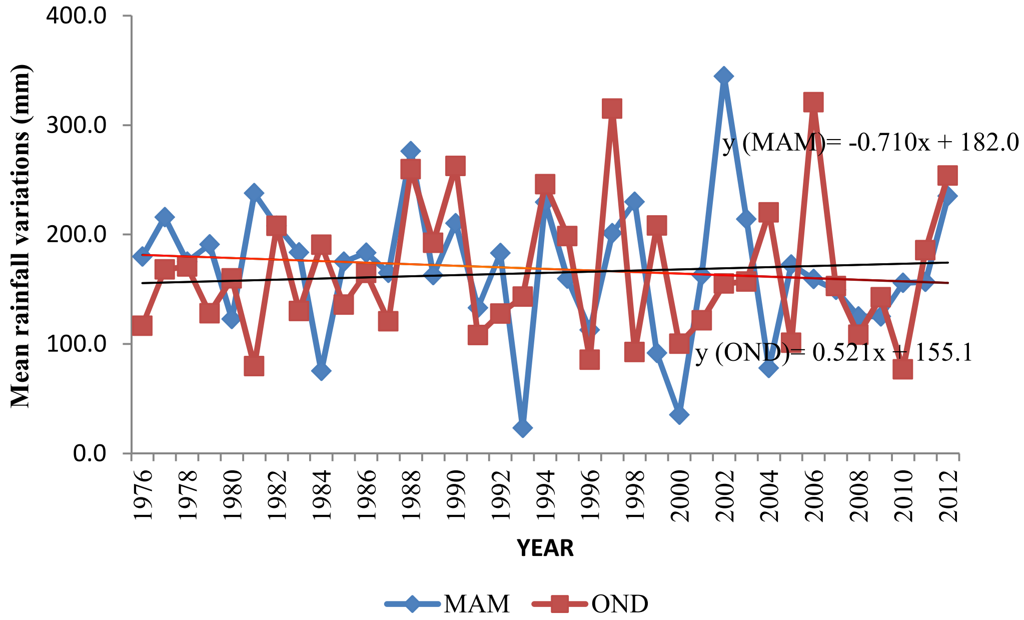

Figure 3. 9: Seasonal rainfall trends of Embu (Source: KMD, 2013)

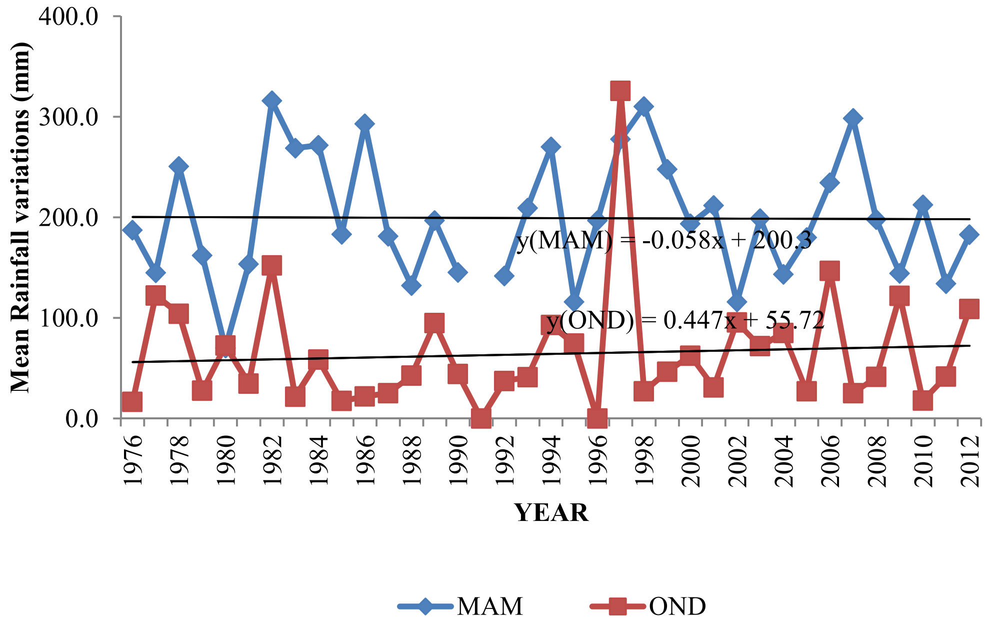

Figure 3. 10: Seasonal rainfall trends of Kisumu (for Budalangi) (Source: KMD, 2013)

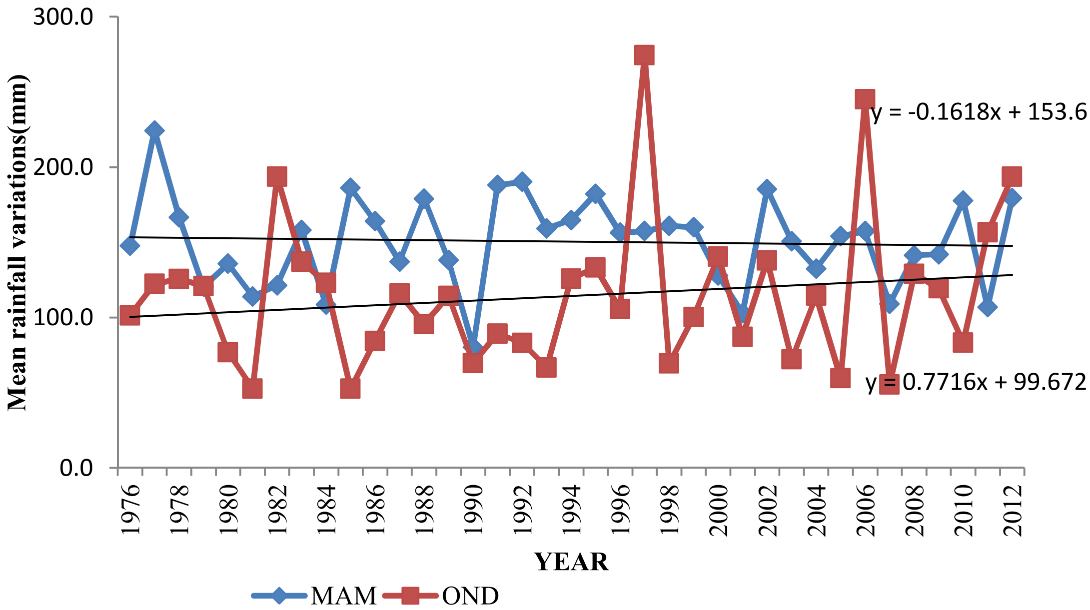

Figure 3. 11: Seasonal rainfall trends of Malindi (for Kilifi), (Source; KMD, 2013)

From Figures 3.9, 3.10, 3.11, declining rainfall trend during the long rains (March, April and May) was observed in Embu at rates of 0.71mm and 0.16mm in Kilifi (for Malindi). However, small variations were also observed in Budalangi (represented by Kisumu) at 0.06mm. Furthermore, an increasing trend of rainfall during short rains season (October, November and December) was also noted in all study areas; Embu at 0.52mm (Figure 3.9), Kisumu at 0.44mm (Figure 3.10), Malindi (for Kilifi) at 0.77mm (Figure 3.11). Overall, amount of rainfall showed high seasonal variability. Also to note, long rains seasons are experiencing reduction in precipitation amounts while in short rains season the precipitation amounts seem to be increasing in all study locations (Figures 3.9, 3.10 & 3.11).

3.2.6 Farmers' awareness of climate change

Farmers' awareness about climate change was remarkable in sampled areas as summarized in Figure 3.12.

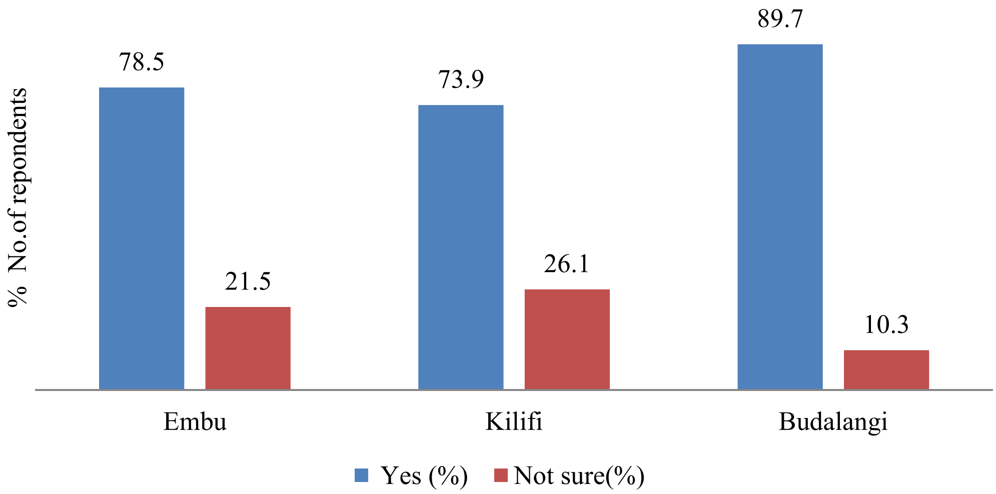

Figure 3. 12: Farmers' awareness of climate change

Farmers interviewed were quite confident that climate change is taking place according to the results presented in Figure 3.12. The results clearly indicated that most of the farmers broadly understood happenings of climate change, over two third perceived changes in Embu (78.5%), Kilifi (73.9%) and Budalangi (89.7%), (Figure 3.12).

3.2.7 Effects of climate change on crop yields/production

This section of the study sought to identify the effects of climate change on crops according to data collected from the field surveys and recorded maize data (Ministry of Agriculture reports).

Crops production

Decline in crops production was a major effect of climate change experienced by all farmers in the study areas as represented in Figure 3.13.

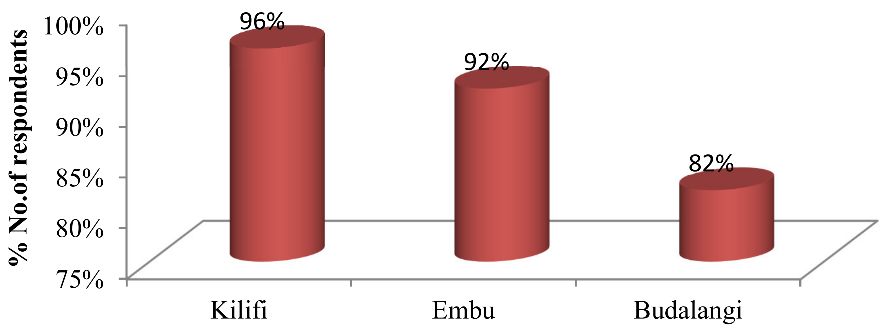

Figure 3. 13: Crops decline in Kilifi, Embu and Budalangi

Farmers interviewed reported high crops production decline, Kilifi (96%), followed by Budalangi (92%) and Embu (82%).

So as to countercheck the farmers' responses, maize yield trend for Kilifi (Figure 3.14), was used to compare with recorded survey data (Figure 3.13). Results are presented in Figure 3.14.

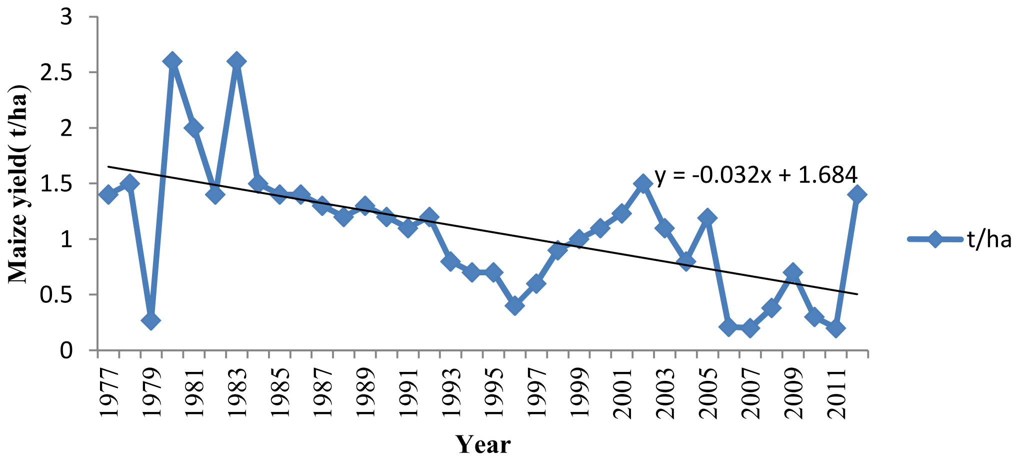

Figure 3. 14: Maize yield trend –Kilifi (1977-2012)

Overall, production in maize showed a declining trend of 0.032t/ha. Correlation coefficient was used to establish any relationship between rainfall distribution and crop yields as shown in Figure 3.15.

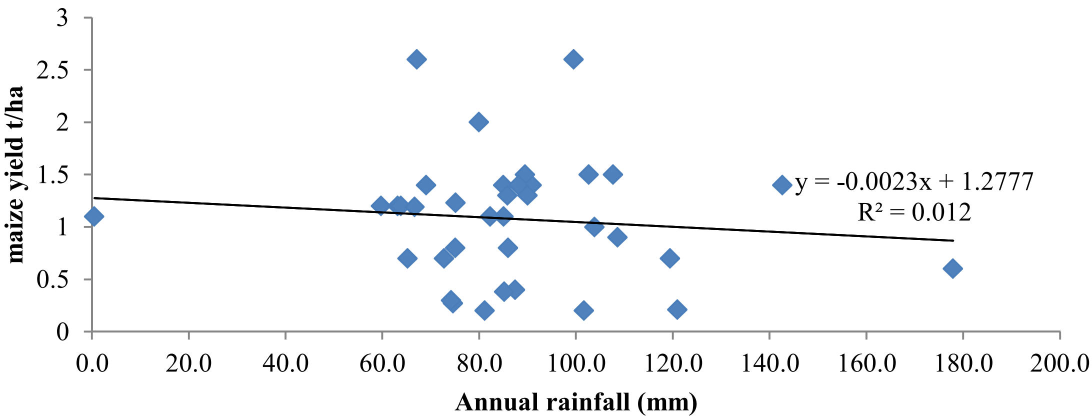

Figure 4. 15: Scatter plot of yield (t/ha) and mean annual rainfall (mm) for maize in Kilifi

Maize data was correlated with rainfall trends using R squared (R^2). The results demonstrated weak relationship ($R^2 = 0.012$) as demonstrated in Figure 3.15.

Decline in crop production yields were also attributable to crop decays, crop drying, loss of quality seeds and increased incidence of pests and diseases as shown in Figure 4.16.

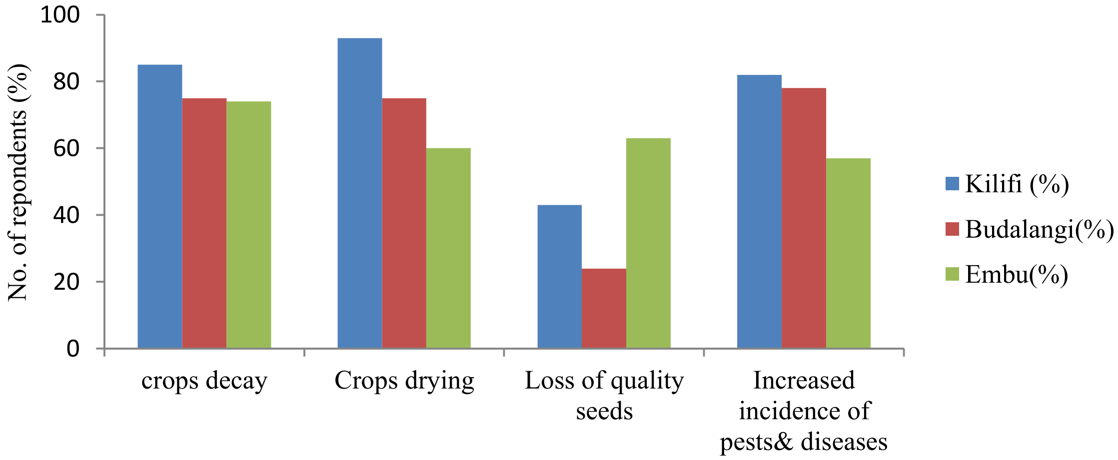

Figure 3. 16: Other effects associated with crop yields production

Crops decline were also as a result of crops decay in the farm, Kilifi (85%), Budalangi (75%) and Embu (74 %), (Figure 3.16) for example; maize and beans decay further demonstrated in plate 3.1.

Plate 3. 1: Maize decay in Kilifi *Beans decay in Embu*

The results (Figure 3.16) also showed that crops decline could be contributed by utmost incidence of pests and disease invasion in Embu, by 87.1 % of respondents, in Kilifi (59.8%) and Budalangi (52.6%). Examples of pests and disease invasions are demonstrated in plate 3.2.

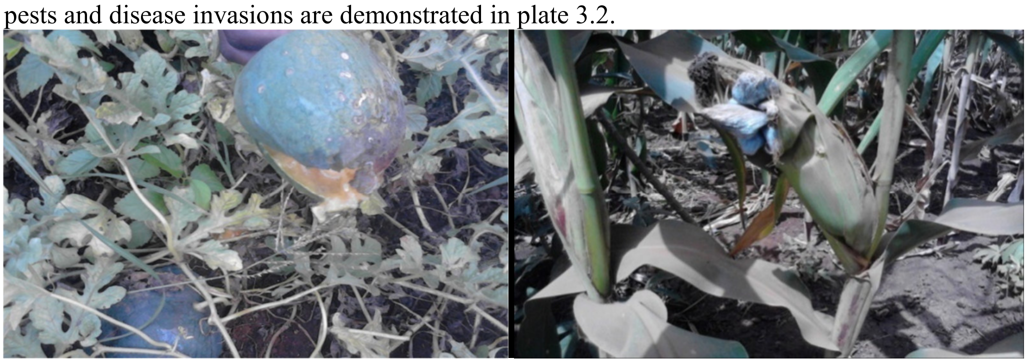

Plate 3. 2: Water melon disease in Embu *Maize disease in Embu*

To large extent, respondents ascertained that crops drying in the farms before reaching maturity were common, Kilifi at (93%), Budalangi (75%) and Embu (60%) as shown in Figure 3.16.

3.3 Effects of climate change on livestock production

This section answers objective two of this study. The effects of climate change on livestock farming considered in this study were limited to two climate change impacts; droughts and resource sharing conflicts (Table 3.7).

Table 3. 7: Effects of climate change on livestock production

Climate Change Impacts	Effects	(Total no. of farmers)affected		
		Embu (%)	Budalangi (%)	Kilifi (%)
Drought	Loss of pasture	68	72	77
	Livestock loss	54	44	81
	Overgrazing	20	58	44
	Drying of water sources	0	78	35
	Pests and diseases	63	81	75
Resource sharing conflicts	Increase in livestock induced-human &wildlife conflicts	30	29	47
	Water scarcity conflicts	0	26	54

Note: Respondents were allowed to provide more than one response to the climate change impact, thus the total exceed 100%

Loss of pasture was experienced by 68% of farmers in Embu, 72% in Budalangi and 77% in Kilifi especially during onset of droughts as portrayed in Table 3.7 and pictured in plate 3.3.

Plate 3. 3: Drought conditions in Kilifi; livestock feeding on grass in the farm

Undoubtedly, livestock loss was experienced by all regions sampled; Kilifi 81%, Embu 54% and Budalangi 44% (Table 3.7). A significant aspect of livestock loss would be caused by increase of pests and diseases infestations in the study sites as follows (Table 3.7); Budalangi (81%), Kilifi (75%) and Embu (63%).

Following Table 3.7, drying of water resources in Budalangi (78%) and Kilifi (35%) would have resulted to livestock loss due to inadequate water supply for livestock and died of dehydration, but was not a problem to Embu farmers. Notably, drying of water resources seems to be accelerating water scarcity and drought related problems in Budalangi (26%) and Kilifi (47%). However, incidences of conflicts due to resources sharing are on rise, eminent in Kilifi (54%) than Embu (30%) and Budalangi (29%). In the long run, afore mentioned impacts increased the farmers' risks to overgrazing in Budalangi (58%), Kilifi (44%) and Embu (20%), (Table 3.7).

3.4 Adaptation strategies to mitigate effects of climate change on crops and livestock production

This section answers objective three of this study. The adaptation strategies applied by the smallholder farmers in response to minimizing risks in crop yields and livestock were classified into three groups.

i. Adaptation strategies to reduce effects of climate change on crop production
ii. Adaptation strategies to conserve soil and water to reduce risks of climate change in crop farming
iii. Adaptation strategies to improve livestock productions

3.4.1 Adaptation strategies to reduce effects of climate change on crop production

Various methods of coping up with the effects of climate change on crop growth and development are summarized and presented in Figure 3.17

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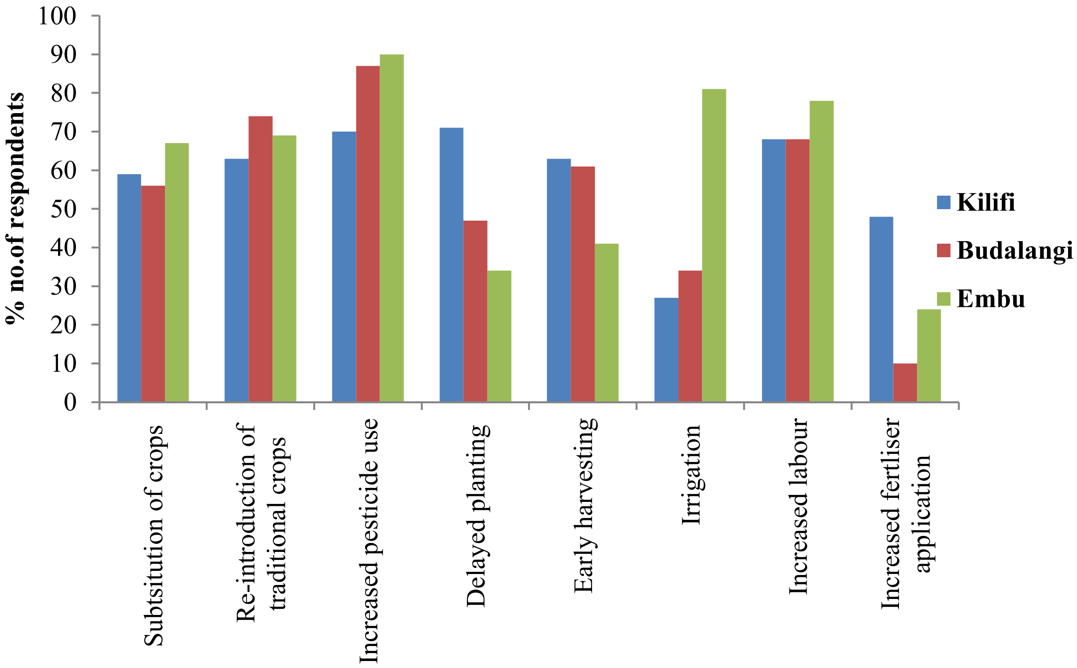

Figure 3. 17: Adaptation strategies to reduce effects of climate change on crop production in smallholder systems

From the Figure 3.17, in response to crops decline, most outstanding responses to effects of climate change included substitution of crops (never farmed before) into their farms such as horticultural crops, Embu (67%) Kilifi (59%) and Budalangi (56%). Additionally, households of Budalangi (74%), Embu (69%) and Kilifi (63%) have also increased production of traditional crops such as sorghum, millet, traditional vegetables and cassava, example demonstrated in plate 3.4.

Plate 3. 4*: Traditional crops (cassava) in Kilifi and smallholder irrigation in Embu farm under harsh drought conditions*

Moreover, 90 % of farmers in Embu have increased the amount of pesticide application to control pests and weeds in Embu, Budalangi (87 %) and Kilifi (70%) according to Figure 3.17. Statistics obtained (Figure 3.17) also shows that 34% and 47% farmers in Kilifi and Budalangi respectively delayed planting activities until the onset of the rains. Despite the fact that 81% of households in Embu (Figure 3.17) have access to water for irrigation; example in plate 4.4 but 34% (Figure 3.17) of the households delayed planting. Few farmers in Budalangi (34%) and Kilifi (27%) could get water for irrigation. Other measures included early harvesting in Kilifi (63%), Budalangi (61%) and least in Embu (41%). Increasing application use was the least common in all sampled sites at 48% in Budalangi, Embu (24%) and Kilifi (10%), as seen in Figure 3.17.

3.4.2 Adaptation strategies to soil and water conservation in reducing risks of climate change in crop farming

Soils and water availability plays a major role in agricultural production. Farmers responded differently to various adaptation measures and some measures aimed at conserving soils and water as presented in Figure 3.18 to reduce effects of climate change in crops production.

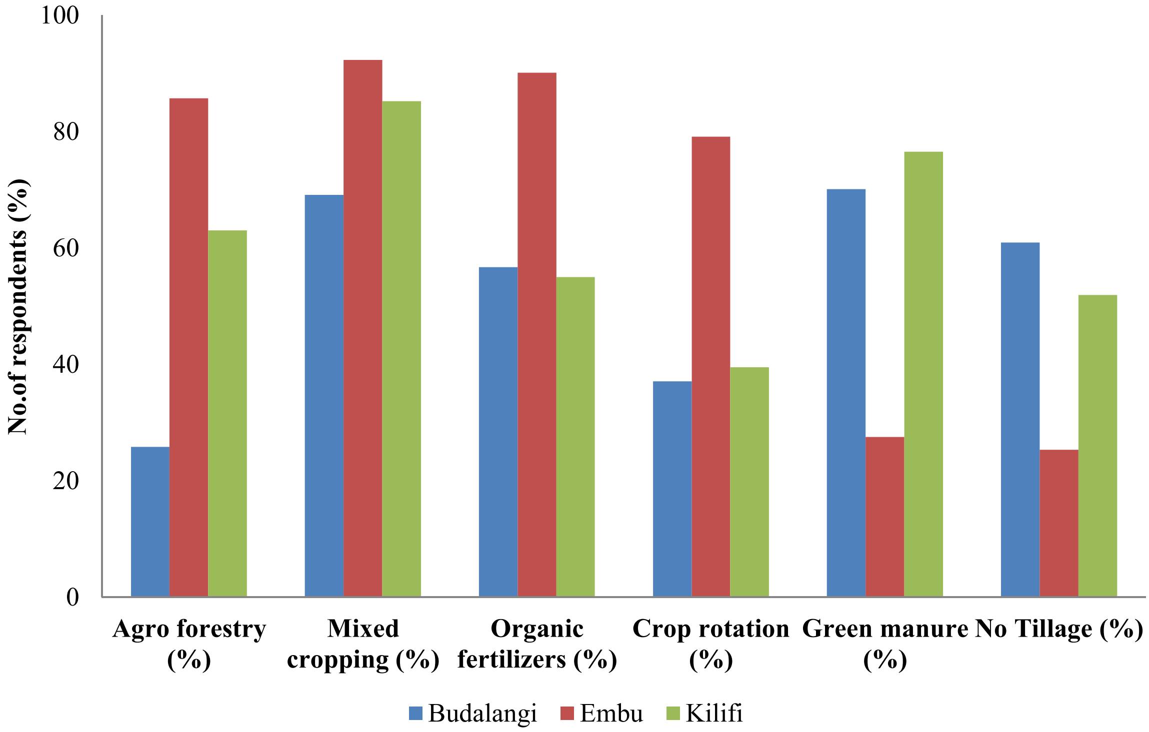

Figure 3. 18*: Adaptation strategies to conserve soil and water to reduce risks of climate change in crop production*

Evidently, most popular techniques in all three study areas as identified in Figure 3.18 were mixed cropping and increased use of organic fertilisers (farm manure from livestock). Mixed cropping was practiced by 92.3% from Embu, 85.2% from Kilifi and 69.1% of farmers from Budalangi. Other adaptation measures were localized such as increasing application of organic fertilizers in the farms especially in Embu applied by (90.1%) of farmers, then Budalangi (56.7%) and Kilifi (55%). Although green manure was not popular in Embu (27.5%), it was widely used by farmers in Kilifi (76.5%) and Budalangi (70.1%). Thus, crop rotation was suitable alternative for farmers particularly in Embu (79.1 %), least option in Budalangi (39.5%) and Kilifi (37.1 %), (Figure 3.18). Whilst practices of agro forestry were high among farmers in Embu (85.7 %,) and Budalangi (63%), such measures were low amongst the farmers interviewed in Kilifi (25.8%), Figure 3.18. Noting that drought was main threat to farming in Kilifi and Budalangi, the farmers practiced no tillage of land during onset of drought season, 60.9 % and 51.9 % of farmers in Budalangi and Kilifi in that order. However, in Embu drought was not a major problem, only 25.3 % of farmers would practice no tillage of land during dry season (Figure 3.18). In response to reducing effects of soil acidity, some farmers in Budalangi were educated on how to minimize effects of soil acidity through liming of the soils (plate 3.5).

Plate 3. 5 : Farmers and researcher adding lime to the soil in Budalangi under supervision of climate change expert,Budalangi

3.4.3 Adaptation strategies to climate change on livestock production

The study also assessed the adaptation strategies taken by livestock farmers to adapt to climate change and the coping mechanisms as tabulated in Table 3.8. Again, the coping strategies focused on two climate change impacts, drought and resource sharing conflicts.

Table 3. 8: Adaptation strategies to reduce effects of climate change on livestock production

Climate change impact	Effects	Coping mechanism	Coping mechanism (Total no. of farmers) (%)		
			Embu	Buda	Kil
Drought	Pasture loss	Fodder from the farm	91	89	44
		Buying fodder	12	14	25
		Long stroll grazing	*	23	30
		Buying feeds from shop	68	40	35
		Storage of hay	58	4	26
	Livestock loss	Promoting local breeds	70	82	60
		Selling during onset of drought	25	23	58
		Substituting livestock	52	27	28
		Insurance of livestock	4	0	0
	Overgrazing	Destocking to a manageable number	69	51	58
		Zero grazing	86	22	12
	Drying of water sources	Searching for pasture and water	*	64	58
		Drought resistant livestock	*	28	55
Resource sharing conflicts	Increase in livestock induced-human and wildlife conflicts	Livestock mobility restriction to neighborhood	21	22	13
		Reporting to relevant institutions	25	14	18
	Water scarcity conflicts	Long stroll in search for water and pasture	*	53	45

**effects not noted*

Note: Respondents were allowed to provide more than one response to the climate change impact, thus the total exceed 100%

Drought response mechanisms

In response to pasture loss (Table 3.8), 91% of farmers in Embu, 89% in Budalangi and 44% of Kilifi farmers opted for farm fodder (crop remains) as way of substituting low pasture availability. Other means included substitution of fodder with supplemental feeds bought from agro-vet shops, Embu (68%), B udalangi (40%) and Kilifi (35%). Farmers also searched for pasture and water from the neighborhoods in Embu (62%).Other ways included buying of fodder for their livestock, Embu (12%), Budalangi (14%) and Kilifi (25%); long stroll grazing , Budalangi (23%) and Kilifi (30%) while 58% (Table 3.6) of farmers interviewed in Embu stored hay for livestock feeding (plate 3.6) during drought season.

Plate 3. 6: Livestock feeding on hay under zero grazing in Embu

In order to minimize cases of livestock loss, the smallholder farmers reported to have increasingly promoted breeding of local breeds, which are drought resistant, Kilifi (55%), Budalangi (28%) presented in Table 3.8. Other ways adopted included selling of livestock during onset of droughts in Embu (25%), Budalangi, (28%) and Kilifi (58%); substitution of livestock by Embu famers (52%), Budalangi (27%) and (28%) in Kilifi. The result (Table 3.8) also showed that 69% of farmers in Embu, Budalangi (51%) and Kilifi (58%) destocked their livestock herds to manageable numbers while least common method was insurance, by three farmers (4%) in Embu (Table 3.8).

Farmers in Budalangi (53%) and Kilifi (45%) also searched pasture and water from different sources to compensate for unavailability of water. However, smaller percentage of farmers introduced drought resistant livestock that can cope up with the droughts as illustrated in Table 4.8, at (42%) and (28%) in Kilifi and Budalangi respectively.

Treatment measures

Other measure taken in reducing livestock mortality caused by increased incidences of pests and disease in livestock involved use of treatment and control measures such as vaccination, spraying and de-worming as illustrated in Figure 3.19.

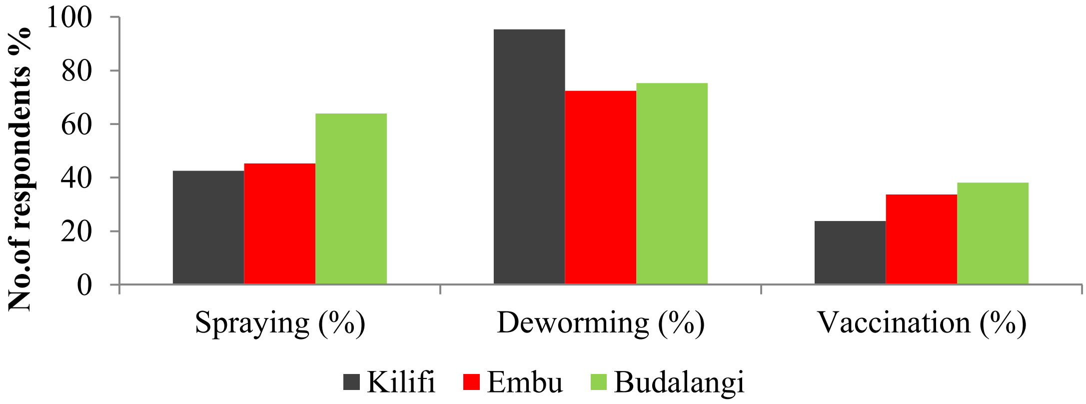

Figure 3. 19: Livestock treatment practices

Noting from Figure 3.19, deworming was the most common and available treatment practices, carried out by Kilifi (95.4%), Embu (72.4%) and Budalangi (75.3%) of farmers sampled. Spraying was done by most farmers in Budalangi (63.9%) as compared to Kilifi (42.5%) and Embu (45.3%). Lastly, vaccination was poorly adopted in comparison to other treatment practices, Kilifi (23.8%), Embu (33.7%) and Budalangi (38.1%), Figure 3.19.

Measures to reduce resource-sharing conflicts

To cope up with resource conflicts, 21% of farmers in Embu, 22% of respondents from Budalangi and 13% from Kilifi said they restricted their livestock mobility. However, 20 % (Embu), Budalangi (12%) and Kilifi (14%) reported the incidences to the relevant institutions (Table 3.8).

Incidences of conflicts associated with water shortage and scarcity were on rise in Kilifi (54%) and low in

Budalangi (26%). Meanwhile, livestock farmers in Budalangi (53%) and Kilifi (45%) respectively searched for water and pasture from the surrounding areas, as others covered long distance strolls in search of these commodities, Kilifi (40%) and Budalangi (43%), noted in Table 3.8.

3.5 Challenges of adaptation to climate change in smallholder farming systems

This section answers objective four of this study.

The Table 3.9 summarizes frequencies and percentages of the key challenges affecting farmers in effort to adapt to climate change.

Table 3. 9: Challenges faced by farmers in effort to adapt to climate change

S/no	Challenges	Frequency	Percent
Budalangi			
1.	Finance	75	77.3
2.	Policy	7	7.2
3.	Infrastructure	4	4.1
4.	Information	6	6.2
5.	Social crimes	5	5.2
Kilifi			
1.	Finance	52	63.4
2.	Policy	7	8.5
3.	Infrastructure	5	6.2
4.	Information	5	6.2
5.	Education	3	3.7
6.	Government help	3	3.7
7.	Land ownership	3	3.7
8.	Market	2	2.4
9.	Agricultural inputs	1	1.1
10.	Environmental challenges	1	1.1
Embu			
1.	Finance	40	43.0
2.	Policy	6	6.5
3.	Infrastructure	15	16.1
4.	Information	2	2.2
5.	Education	1	1.0
6.	Market	12	12.9
7.	Government help	9	9.7
8.	Social crimes	8	8.6

There were quite many challenges that were given by the farmers sampled. The challenges were recorded and categorized as in Table 3.9. The smallholder farmers complained of array of constrains affecting their ability to adapt such as insufficient finances (Table 3.9). Moreover, other issues such as poor infrastructure, lack of essential education, information and policy, coupled up with poor market access and other problems (Table 3.9) limited their potential to adapt to climate change.

In ascertaining the biggest challenge faced by smallholder farmers in effort to adapt to climate change, the challenges were further ranked using mode frequency and presented in Table 3.10.

Table 3. 10: Ranking of the challenges

Study areas	Rank 1	Rank 2	Rank 3
Budalangi	Finance	Policy	Information
Kilifi	Finance	Policy	Infrastructure & Information
Embu	Finance	Infrastructure	Market

From the Table 3.10, finance was ranked as the biggest challenge identified in all sampled areas. Policy ranked as second in both Budalangi and Kilifi. Infrastructure was ranked second for Embu . Meanwhile, lack of information appeared as third challenge by Budalangi farmers, infrastructure and information in Kilifi and market ranked third in Embu. Finance stood out (Table 3.10) as the biggest challenges in the study areas.

4.0 DISCUSSIONS

This chapter is devoted to discussion of results and findings in chapter four, focusing on the objectives stated in chapter one.

4.1 Effects of climate change on crop production

Linear regression trend was used to observe the changes in rainfall and temperature variability of Embu, Budalangi and Kilifi. The trend analysis of annual temperatures (Figure 3.5) showed increasing trends meaning that the temperatures are increasing slowly over time. The mean annual maximum temperatures for all study areas were found to be rising at range of 0.01 ^{O}C (Kilifi) to 0.02^{O}C (Embu and Budalangi), (Figure 3.5). Similarly, mean annual minimum temperatures for all study areas were increasing at ranges of 0.01^{O}C (Budalangi), 0.02^{O}C (Kilifi) to 0.01^{O}C (Embu) (Figure 3.5). With given evidence that greenhouse gases are the major causes of warming of the temperatures (IPCC, 2007a), even slight increase of temperatures will have discernible effects to crop yields. Furthermore, mean annual minimum temperatures were noted to be increasing at higher rates than mean annual maximum temperatures (Figure 3.5). If the mean annual minimum temperatures are increasing at rates higher than mean annual maximum temperatures, it will result to narrowing down of the diurnal temperatures. The narrowing of diurnal temperatures affects thermal limits required for crops development. As result, alteration of biological processes such as photosynthesis, biomass productions, evapo-transpiration, proliferation of pests and disease may occur and pose greater threats to both crop and livestock productions (Yadav *et al*., 2011; Mahdi *et al.,* 2015). Ultimately, increase in mean temperatures threshold will amplify crop losses, if all other factors are kept constant. In seeking more details, studies by Easterling *et al.,* (2005) also supported findings of this research that narrowing of the diurnal temperatures affects crop adaptation and consequently lowers the yields (Easterling et al., 2005).

Another important point to note is the outcome of rainfall variations on crops production due to climate change. The effect of rainfall fluctuations were observed in both annual and seasonal rain seasons (Figure 3.10, 3.11, 3.12). However, seasonal rainfalls varied considerably whereby rainfalls in the long rains seasons (MAM) have reduced (Figure 3.10, 3.11 and 3.12), while for short rain season (OND), (Figure 3.10, 3.11, 3.12) have increased. This study agrees with other early studies (Kansiime *et al,*. 2013; Ongoma *et al*., 2015) that there is a shift in the rainfall patterns, where long rain seasons are receiving less rainfall while short rains seasons receiving more precipitation. Particularly noteworthy is that annual rainfalls for Embu (Figure 3.6) showed a marginal decrease of annual rainfalls as compared to Kilifi (Figure 3.7) and Budalangi (3.8). Embu is ranked as a high-medium agricultural production zone (Hadas, 1992). Reductions of rains in high-medium agricultural area will result to losses of crops and yields for example as presented in Embu.

The results of field study surveys in all study areas point to the fact that the smallholder farmers are directly affected by effects of climate change. The identified effects include crops decline, crops decaying before maturity, crops drying before maturity, increased incidences of pests and diseases and loss of quality seeds (Figure 3.6). Assessment of effects of climate change in smallholder farming showed a declining trend of maize yield in Kilifi of 0.032 t/ha (Figure 3.14). However, in correlating maize data with rainfall trends, correlation of determination (R^2) between maize yields and rainfall data demonstrated weak relationship ($R^2 = 0.012$) as shown in Figure 3.15. Reasons could be linked to variability in annual and seasonal rainfalls and other non-climatic stressors such as poor seeds performance, market access issues, invasion of pests and others. Another study by Rao *et al.,* (2011), revealed similar results (Rao *et al.,* 2011). Many farmers in all sampled areas recorded crop declines (Figure 3.13) due to their high dependence on rainfall events. For this reason, crop yield declines resulted to poor yields which threatened their financial resources and livelihoods. Poor yields experienced at farm levels do not satisfy the farmers' needs, especially when most of the produce falls below Ksh.20, 000 per harvest (Table 3.6), which means that their financial resources are strained and limited to afford progressive adaptation measures.

4.2 Effects of climate change on livestock production

A significant factor of climate change and rainfall variability is that, it directly affects all cropping and livestock management. This study narrowed down the climate change impacts to droughts and resource sharing conflicts (Table 3.7). From the study, climate uncertainty is prevalent. Alterations of the climatic conditions pose drought risks to the smallholder farmers, especially due to increasing temperature (Figure 3.5) that results to warming conditions than the normal conditions. Increase in temperatures will affect rainfall patterns. This may lead to more frequent dry seasons and reducing the amount of available surface water. In this case, more drought periods are expected to occur. Basing on evidence provided in Figure 4.9, possibility of late arrival of rains or early cessation of rainfalls is anticipated. Ultimately, this will result to prolonged drought conditions. The effect of drought affects both pasture availability and number of livestock (Table 3.7). In relation to study by Marriara and Karanja (2007), confirmed that drought exposes livestock to high temperatures which increases susceptibility of livestock pests and diseases (Marriara and Karanja, 2007). Decline in crop yields also affects pasture availability. In the study area, livestock loss was increasingly related to declining pasture availability and high temperatures. Livestock loss in Kilifi was significantly high (81%), 'from statistics (Table 3.7)' as compared to Embu (54%) and Budalangi (44%), fundamentally attributed to droughts and high temperatures. Increase in maximum temperatures also increase incidences of pests and diseases infestation which causes livestock mortality and loss. Nevertheless, drought induced livestock loss remains a global problem of climate change as identified in studies done (Desenker, 2002; Gbitibouo *et al.,* 2010 and Calzadilla *et al.,* 2013)

Again, conflicts in the study areas are on rise due to resource sharing. While farmers in Kilifi recorded highest incidence of livestock induced wildlife conflicts (47%), the situation in Embu (30%) and Budalangi (29%) was quite low as indicated in Table 3.7.

The human - wildlife conflicts arise because the farmers' access forest areas in search of pasture. For instance, Kilifi farmers complained of loss of poultry due to attacks by wild birds. While, in Embu, 30% (Table 3.7) of respondents said that the wild animals escaped the nearby forest area (Njukiri forest) and attacked their livestock. The farmers also entered protected forest areas and cleared up forest areas in search of fuel and land. The clearance of forest land results to conflicts with wild animals and authorities. Not to mention, conflicts with water resources also occur as they struggle to access the water points. Additionally, human wildlife conflicts have increased because the wild animals and humans are competing for the same water and food resources thus, raising the incidences of wildlife attack on humans and vice versa. Evidence in support of these conflicts that are rising up due to climate change, can be found in studies also done by (Okech, 2011) and (Otiang'i, 2011).

4.3 Adaptation strategies to climate change on crop production

The most outstanding adaptation strategies that stood out in all the tree study areas were as follows; substitution of crops, re-introduction and increased production of traditional crops and increased labour. Then other coping strategies were localized in different regions, such as delayed planting, early harvesting, irrigation and increased fertilizer application.

Re-introduction and increased production of indigenous crops such as sorghum, millet and traditional vegetables was common because traditional crops are able to do well under the unpredictable and harsh climatic conditions. In areas of Kilifi (63%), Budalangi (74%) and Embu 69% of respondents (Figure 3.17) have re-introduced or increased production of traditional crops. However, some farmers are still reluctant to reintroduce these crops in their farms, due to poor market preference. Even those that have introduced, have not fully implemented these crops in their farms, only smaller proportions of farming land is grown, yet the harvest is substantial. This sentiment expressed in the previous paragraphs, also embodies other studies done by Ndaki (Ndaki, 2011) and Altieri (Altieri & Koohafkan, 2008).

Substitution of new crops in the farms (never farmed before) by the farmers was also evident (Figure 3.17). Conversely, new crop alternatives have ability to survive under the changing climatic conditions, for example, horticultural crops which mature faster and are managed under controlled conditions such as greenhouse farms. However, more labour is needed in improving agricultural yields, especially due to increased weed growth and hardened soils that require more energy for land preparation. Consequently, farmers in Kilifi (68%), Budalangi (68%) and Embu (78%) have increased labor demands in their farms (Figure 3.1).

Other adaptation options were localized, such as delay in planting activities whereby a proportion of farmers would wait for the rains before undertaking any planting activities. For instance, quite common in Kilifi, 71% of the farmers delayed planting as they waited for rains. Unfortunately, most of the farmers do not have access to irrigation. Even so, 81 % (Figure 3.17) of farmers in Embu could access water for irrigation but still, 34% of the respondents delayed planting, considering that irrigation was a suitable alternative for failed rains in Embu due to availability of water for irrigation. Early harvesting of crops before reaching full maturity was also recorded especially in Kilifi and Budalangi. In Kilifi, early onset of short rainfalls would have resulted to harvesting of some crops before they dry completely. Also, in Budalangi, early arrival of floods made the farmers harvest early before reaching full potential maturity to avoid complete losses of crop yields.

In effort to reduce the effects of climate change on soil and water conservation, farmers diversified to several measures to conserve soils and moisture. Measures that were most used in all three study sites included mixed cropping and use of organic manure. These measures were localized to study areas such as agro-forestry, crop rotation, use of green manure and no tillage during drought season (Figure 3.18).

Agro forestry is gaining popularity in the sampled sites, especially in Embu where farmers are faced with direct effects of deforestation. As a result, most farmers in Embu have taken up agro-forestry and formed agro-forestry farming units so as to improve soil productivity and increase water shed. Agro-forestry has proved to be one of the best options for climate change adaptation. Research done my Sanchez *et al*., 2008 in Embu support this study that agro-forestry is one of the most successful means of adaptation to climate change, not just because it mitigates the effects of climate change, but also promotes sustainable livelihoods of smallholder farmers (Sanchez *et al*., 2008).

However, green manure was preferred in Kilifi (70.1%) and Budalangi (76.5 %), as compared to Embu (27.5%) illustrated in Figure 3.18. The difference was brought by the vital role of farm remains after the harvest. In Embu, farm remains are used as livestock fodder for zero grazing, while the other two regions, these farm remains are left to decay in the farm as an option to boost soil fertility.

4.4 Adaptation strategies to climate change on livestock production

Poor livestock yields in farming are heightened by low pasture availability. In the light of low pasture availability, farmers in Embu stocked hay in silos for use during the drought periods, while Budalangi and Kilifi, livestock searched for feed in the farms and nearby neighborhoods. Additionally, livestock feeds were bought from agrovets to supplement the nutritional dietary needs of the livestock (Table 4.8).

Other adaptations options preferred included promotion of local breeds. This is because local breeds are said to have high adaptability levels that can withstand both hot and wet climatic trends. Destocking of livestock to manageable numbers was noted in all study areas, whereby 69% (Embu), 51% (Budalangi) and 58% (Kilifi) of farmers reduced number of livestock to manageable numbers. Zero grazing was most promising among the respondents interviewed in Embu (86%) and poorly adopted in Kilifi (12%) and Budalangi (22%). Farmers in Embu have adopted to zero grazing because the livestock mobility and feeding is controlled. Also, they rely on the manure fertilizers for use on their crop farms, which is easily collected under this kind of management. Substitution of livestock as a measure to reduce labour cost was common in Embu by 52 % of respondents, 27% of Budalangi and 28% of Kilifi respondents where cattle breeds were replaced by goats and pigs which require less labour. However, not complete substitution was used because cattle are still required for manure productions (due to large quantity) needed in the farms, especially in Embu, due to their high dependence on organic manure (Table 3.4). The farmers were therefore clear about keeping small manageable numbers of cattle as compared to numbers of goats and poultry because they are most adaptable due to their low food quantity demands.

Selling of the livestock during onset of the drought was most preferred in Kilifi (58%) instead of starving the livestock to death during dry spells (Table 3.8). The income could also be used to buy feeds for the remaining livestock as well as meeting other family needs. Least popular coping mechanism was insurance of livestock, observed by farmers 4% of farmers (Table 4.8) of the interviewed livelihood households.

4.5 Challenges of adaptation to climate change in smallholder farming systems

As problem of climate change accelerates, challenges will deter agricultural adaptation. Main constrains faced by farmers are discussed as follows.

According to Table 3.10, shows ranking of the challenges. Financial constrain was seen as the biggest challenge of adaptation to climate change. If financial challenge is assumed to be a constant in this case, other challenges that stood out include lack of policy, poor infrastructure, inadequate provision of information and poor market access.

Smallholder farmers in Kilifi, Budalangi and Embu are limited by financial and capital resources, which explicitly affect their ability to invest efficiently to climate change. Coupled up with poor agricultural yields that cannot boost their farming livelihoods, thus, the little farm income obtained from farm remains unsustainable. From the research results, it was clear that the farm income in all study areas stood very low. Findings indicated that most of the farmers obtained less than Ksh 10,000 per harvest/season.

Results presented from the tables (Table 3.9 & 3.10), farmers sampled said that there was no policy to promote climate change initiative especially in agriculture. During the data collection period, there was a national plan for climate change in place, but the farmers had no idea of the existence climate change plan. Some farmers thought that there are no sufficient and functional policies particularly for climate change adaptation in Kenya. Actually, Kenya is the first country in Africa to put in place climate change act (The Climate Change Act, 2016). This policy is in existence but is less known and little information is provided to the farmers. Thus, government efforts in promoting climate change policy are diminishing. Bearing in mind, understanding of the policy possesses a major problem.

Infrastructure also plays a significant role in adaptation to climate change. In this research, infrastructures include access to good transport, telecommunication, irrigation infrastructure and market. Farmers in Embu identified poor infrastructural network as the second most notable challenge towards adaptation to climate change. Poor infrastructure affected access to good roads especially when it rained, roads becoming muddy and impassable, making it impossible to distribute and receive farm inputs. Poor tractor services were also noted where the tractor contractors provided poor services when hired to plough the farms. In the same manner, tractor services are sluggish and delays farmers' activities. By the same token, infrastructure also affects access to market. Poor market access includes availability of market infrastructure for procurement of fertilizers and other inputs at affordable prices. Purchase of good quality seeds is an expensive exercise, thus most farmers preferred storage of harvested seeds for the next season; which brought risk of spoilage and pests attack. Furthermore, poor infrastructure also limited the farmers to availability of extension services and knowledge sharing.

Lack of access to reliable information on climatic events and data makes it difficult in making farming decisions. To add a pinch to that, serious problems encountered when interpreting information such as poor skills of fertilizer application and management. There is also little information existing on climate data records and models, for example, getting all the data to compile this report wasn't easy, despite using all avenues to get comprehensive data. It is quite impossible for a smallholder farmer to access the records because there so many bureaucracies, obstacles and charges paid in accessing climate data in Kenya.

Also noted, government assistance is very little especially in providing timely information concerning adaptation to climate change practices vital in promoting agricultural adaptation. Not only the farmers but also the experts interviewed both believed that the government is not doing the best in ensuring adaptation measures are factored in effort to adapt to climate change. Government efforts should aim at helping poor farmers in facilitating services that will increase food production and reduce the cost of farming inputs. For example, looking at the 2014/2015 and 2015/2016 budget allocation, *appendix 6,* it is ironical that only 3% of the budget was allocated to Agricultural sector, while the main focus was directed towards big irrigation projects (KShs. 9.5Bn), farm inputs subsidy (KShs 3Bn), for strategic grain reserves (Ksh 2.7Bn) and (KShs. 1 Bn) for fisheries development), **(***PBB 2014/15 and 2015/16***)** (*appendix 6)*. There was no specific section of funds directed towards climate change adaptation in smallholder agriculture. However, the smallholder farmers gained a bit from the exempted tax on agricultural inputs especially the seeds.

Last but not least, high rate of social crimes involving agricultural production are on increase especially in the smallholder farming where security issues are involved. Farmers complained of stolen farm produce and livestock in the local context, for example, narration given by a farmer from Budalangi as follows.

"*It is so painful to work hard in the farms, and you lose half of the farm yields to nature's unavoidable circumstances, and a quarter of what you are supposed to harvest, to thieves. You only get a quarter of the yields, and putting in mind all the expenses used on that farming activities, you would rather stay at home and watch the seasons. You start rearing chicken, and they are stolen too, what will you eat?" (Source: narration by desperate farmer in Budalangi).*

The narration given by the farmer in Budalangi demonstrates that the farmers are already facing reality of climate change, but, their efforts are demoralized by other social crimes. The social crimes are on rise due to increased poverty levels that are brought about by climate injustices. So as to end social crimes, the farmers have reported the crimes/cases at the local chief's office but most reported cases are left unsolved by the security institutions. However, this has worsened the situations since the livestock raiding and crop theft cases are not brought to justice. The challenges of adaptation to climate change in agricultural productions are not only unique to the sampled farmers in this study, but in many other studies. These challenges faced by smallholder farmers in adaptation to climate change were also observed in other research findings (Ndaki, 2014) and (Sango, 2014).

5.0 SUMMARY, CONCLUSIONS & RECOMMENDATIONS

Summary

This thesis evaluated effects and adaptation measures that smallholder farmers in Embu, Kilifi and Budalangi adapt to curbing climate change. The first objective of the study was to assess the effect of climate change on crop production. The second objective was to evaluate the effects of climate change on livestock production. The third objective was to determine the adaptation strategies adopted by the smallholder farming systems and the final objective was to identify the challenges faced by smallholder farmers in adapting to the effects of climate change.

In order to achieve the stated objectives of this research, the study foremost used existing literature review on climate change impacts, adaptation at global, regional and local scale. The study also highlighted various aspects of meteorological changes over period of time (36 years), crop production trend for 35 years and how smallholder farmers responded to these changes. Survey design was the most appropriate whereby both qualitative and quantitative data collections were implemented in this research. Relevant ethical considerations were taken into account, such that, anonymity and confidentially were promoted in ensuring wiliness of participation and involvement of the survey by the smallholder farmers. It was noted that most of the data provided in this study was not sensitive, but confidentiality and anonymity was highly desirable to encourage farmers' participation.

A total of 272 households were sampled, due to financial and time limitation, the above sample size was estimated feasible for this study. '

Conclusion

The study revealed that there is a shift in the seasons. For instance, the rainfall amounts are reducing in the long rains and increasing in the short rains season as shown in Figures 3.7 & 3.8. Consequently, this variability could mean less precipitation in the long rains seasons and more precipitation in the short seasons over coming years. Modification of the climatic conditions will negatively affect both crop and livestock production. As a result, more crops decline as seen in Figure 3.14 and drop in livestock yields will continue to occur.

In response to climate change and variability, the farmers sampled practiced farm level adaptation, because it's affordable, accessible and requires little training or knowledge to practice it. In all three study areas, adaptation practices carried out at the farm levels aimed at reducing the short term effects rather than long term effects of climate change and variability.

The study also concluded that challenges limit farmers' capacity to adapt to climate change. Farmers are limited in adaptation options due to challenges experienced; or instance lack of financial stability, lack of supportive policy to support climate change adaptation, poor infrastructure and little information provided concerning climate change.

Recommendation

This study strongly recommends that measures for enhancing and empowering farmers' adaptation capacity to effects of climate change should focus on overcoming both short and long term challenges posed by climate change and variability. The farmers should be prepared for climatic variations, for example, changing to suitable crops and livestock varieties. Some measures could reduce the losses at low cost, such as agro-forestry, diversification and introduction of fast growing crops in the long rains, harvesting of rain water for use in the drought season.

Collective efforts should be encouraged in managing the risks under uncertainty of climate change, which smallholder farmers are exposed to, from weather variability to marketing related issues are required in climate change adaptation.

The smallholder farmers and stakeholder should be encouraged to practice community and institutional based adaptations to offer long-term adaptation mechanisms. Corporate agricultural production has failed in Kenya but corporate marketing societies are successful. Lessons learned from the marketing corporate could be replicated in the corporate agricultural production systems.

Further Research

This study has shown that climate change and variability is happening in Embu, Kilifi and Budalangi. The study also recognized that the farmers in different agro-ecological zones in Kenya are subjected to similar effects of climate change, however, faced with different intensities. New research should venture into innovation of potential of specific crops and livestock under changing climatic conditions. This research also generalized effects of the climate change on crop and livestock production, adaptation and the coping mechanisms carried out by the farmers. Further research should focus on recording of climate data and production data for each location in Kenya.

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