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Assessing 30 Years Historical Climate Data and Its Implication on Livelihoods in Kapsokwony Division, Mt. Elgon Sub -county, Bungoma County, Kenya

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Abstract
Mountain ecosystems represent unique areas for the detection of climate change and assessment related impacts. Highlands are warming faster than lowlands. People living on the margins of the forested part of the MEE are particularly vulnerable to extreme climate events in addition to widespread poverty and marginalization. The overlapping climate change impacts in the region include declining crop yields, increased surface temperatures, altered precipitation regimes, increased poverty levels, degradation and decimation, prolonged drought and increase in waterborne diseases Little has been done in tracking indigenous and new scientific technologies that can be used by farmers in the study area to address impacts of climate variability and climate change on food security, poverty levels and health of subsistence farmers. An interdisciplinary research team together with community actors will work together to achieve state of the art solutions to complex societal problems based on different scientific and non – scientific (epistemic) knowledge to improve livelihoods and sustain economic development in the region. The research findings will include new transformation knowledge, community empowerment, capacity building, new policy measures, and adaptive governance strategies which will be achieved through participatory and collaborative learning. The results obtained during this research to be used to enhance resilience, influence policy formulation, and institutionalize practice responses and sustainable adaptation to climate change adverse impacts.

1.0 Introduction

1.1 Background

Mt. Elgon forest has undergone dramatic changes in land use in recent decades, and there has been a reduction in forest cover due to clearing of forest land for agricultural production. This trend has been shown by satellite observations. The decrease in forest cover from 1973 to 2013 was a crucial input to the landslide and flooding risks. On Mt. Elgon, the climate models did not show significant changes in precipitation but they do predict a significant increase in temperature (Odada, and Olago, 2014). The means that a poor family that gains an income through exploitation of ecosystem natural resources including food, construction materials, medicine, wood fuels, fodder, water, pastureland and agricultural activities is badly affected. Therefore, poor people are severely affected when the environment on which they depend for their livelihoods is degraded. As a result of this dependency, any impacts of climate change have on a natural system threatened livelihoods of poor people (WRI *et al.,* 2008).

Many of the impacts of the observed changes are enhanced by anthropogenic activities that directly impact the landscape and play a role alongside natural climate feedback mechanisms in the modification of local to regional climates and environments. With great land - use pressure in the ecosystem, including deforestation and grazing combined with extreme rainfall, flashfloods and flooding will likely increase or too little water increases the vulnerability of mountain livelihoods (Kaltenborn *et al.,* 2010). It is for this reason that adaptation strategies that enhance the resilience of ecosystems, ensuring the continued provision of goods and services, can be particularly important for poor people (Adger *et al.,* 2005; Reid *et al.,* 2005). Poor people with low adaptive capacity are vulnerable to the impacts of climate change, which will contribute to the loss of their natural resource base.

Food production systems in Mt. Elgon are highly vulnerable due to an increase in climate variability. Agriculture activities are constrained by altered frequency, timing and magnitude of climate variables such as temperatures and precipitation. Systemic effects are needed to improve sustainability of the food production systems and ecosystem resilience under changing climatic conditions. Ecosystems such as that of Mt. Elgon particularly those that have already been degraded, are likely to be severely impacted by climate change (Fischlin *et al.,* 2007). Thus, the need to build resilience of ecosystems to maintain their productivity is often stressed in the development literature as a necessary part of adaptation strategies, particularly for vulnerable communities (Corfee-Morlot *et al.,* 2003; Tompkins *et al.,* 2004; Nkem *et al.,* 2007; Reid *et al.,* 2008; WRI *et al.,* 2008).

2. Objective of the Study

2.1 Main Objective

Assessing 30 years historical climate data and its implication on livelihoods in Kapsokwony Division, Mt. Elgon Sub-county, Bungoma County.

2.2 Specific Objectives

- Changes in rainfall variability is likely particularly in the long rains (MAM) and short rains (SON) in the forthcoming decades;
- Average annual temperatures and droughts are likely to increase in the future;
- Assess effects of climate change and its implications on livelihoods in the study area;
- Assess the impacts of climate change on the farmers' health and livestock keeping;
- Transform behavioral patterns towards climate adaptation strategies at all levels;
- Identify traditional and modern innovative technologies for climate change mitigation and adaptation;
- Determine long and short term adaptation policies and strategies by the different communities in the study area;
- Build capacity and access transformation knowledge of the communities in the study area to adapt to climate change impacts;
- Generate robust policy recommendations in order to build climate change resilience of the residents in the study area;

3. Literature review

3.1 Climate change according to the indigenous residents

The term climate change refers to the change in weather patterns such as temperature, precipitation and wind over a period of time, ranging from months to millions of years. The classical period often referred to in climate change studies is 30 years (Hannah *et al.,* 2005).

Climate change is largely attributed to both natural and anthropogenic factors (IPCC, 1996, 2007a). Natural factors such as solar variations and volcanic activities occur beyond human involvement. Anthropogenic factors are human (anthropogenic) activities are drivers that cause changes in earth's atmosphere. Climate change can also be attributed to alteration of the normal climatic patterns that occurs over a long period of time. It can also be defined to mean the change from one mode of climate to another mode which takes or may take hundreds or thousands years to occur (IPCC, 2007).

Climate change can have significant negative impacts on the natural environment including agricultural output and changes in ecosystem services. According to IPCC (2007a), any increase in global average temperature above the range of 1.5^0C - 2.5^0C is likely to result in significant alterations in the structure, function of ecosystems, thus negatively influencing livelihoods and human survival. In developing countries with a greater dependence on natural resource based livelihoods, this can impact the socio-economic status of communities, hamper progress towards development goals and present an overall threat to sustainable development (IPCC, 2007a). Together, climate and non-climatic stressors may have considerable impacts on the ecosystems functions and on ecosystem services (Lovejoy *et al.,* 2005).

Forests are highly sensitive to climate change. Kenya's forests cover is estimated to be 1.5%, which include both indigenous and plantation forests. Mt. Elgon water tower is one of the main water catchment areas in this country. Forest degradation has caused significant destruction, reducing forest canopy cover and increasing GHG emissions. Environmental degradation is caused by human activities, especially unregulated forest products removal by companies and communities. Changing climatic conditions have also affected the regeneration rate especially for natural forests. This affects the ecosystem services that forests provide, such as reducing soil erosion, natural pest control, preserving water availability, and maintaining water quantity and water quality (KFS, 2014).

Africa is the most vulnerable continent to climate variability and climate change (IPCC, 2007). Projected rainfall changes for period 2016-2035 can be up to 20% relative to reference period 1986-2005 whereas surface temperatures can be greater than 0.5^0C per decade for interior regions (Kirtman, *et al.,* 2013). Rainfall, temperature, humidity, and flooding are variables that most influence the transmission of malaria, cholera, diarrhoea, kala-azar, and dengue fever; climate change will affect all of these (IPCC, 2007). According to observations reported by the (IPCC 2007), future precipitation projections suggest a high likelihood of increases in the higher latitudes and decreases in sub-tropical regions. Overall, it is projected that the increasing concentration of greenhouse gases would result in several changes in the global climate system over the course of the 21st century that are expected to be larger than those observed over the 20th century (IPCC, 2007). This has significant implications for the survival of natural systems, many of which are already being affected by the temperature increases (IPCC, 2007).

3.2 Smallholder farmers need to choose, use, and capitalize on new adaptation technologies to improve their livelihoods and wellbeing.

Smallholder farmers need to choose, use, and capitalize on adaptation technologies to improve their livelihoods and well being, while enabling them to respond effectively to continuous and unpredictable climate change. To achieve food security and economic development, systems of food production and trade systems must be made more accessible for smallholder farmer. Funds from Green Climate Fund (GCF) as per the Paris Climate Change Conference of 2015 must be made available for the smallholder farmers so that they can achieve their food production targets.

Not all of this money will be invested in agriculture, but some will go into other sectors of investment to secure and improve livelihoods. Most of the financing will likely be offered as loans, not grants, to enable replenishment of the Fund.

Adaptive strategies devised by incorporating the scientific and the indigenous experiences are very important in the designing of adaptive policies that will help residents in the region to adapt to the vagaries of climate change. Knowledge of the indigenous community which is based on observations, perceptions and experiences over the years can effectively be blended with scientific knowledge to improve climate change mitigation and adaptation strategies. Other strategies that should be considered when designing adaptive technologies include cost efficiency, co-benefits, trade-offs and feasibility. Sometimes vulnerabilities of a community may result from differences in traditions, culture, socio-economy, lifestyles and gender differentiated responses. The technologies to be adapted must be beneficial under the current climate conditions and those that might be adaptive under the future climate conditions. Technologies are supposed to build resilience to climate shocks and support adaptation. Without adequate scientific knowledge of future conditions, technologies can be ineffective or even harmful.

Adaptation strategies should use both top-down and bottom-up approaches leading to higher effective, efficient, equal, sustainable, flexible, legitimate, robust and replicable. They need to be shaped in the context of available projected climate and impacts for the area under the study consideration. The way forward is to evaluate scenario methods and compare their strengths, weakness, and infrastructure and capacity requirements. I recommend the implementation of good, dynamic and robust adaptive technologies for the poor in the community to recover from climate shocks, achieve sustain economic development and improve livelihoods.

3.3 Indigenous technologies in mountain agro-ecological zone

Mountain ecosystems around the world are now affected by the combined impacts of climate factors and their interactions with other anthropogenic stressors such as encroachment, land fragmentation, degradation and destruction of natural resources. Climate change will affect human health through complex systems involving changes in temperature, exposure to extreme events, access to nutrition, air quality, and disease vectors (IPCC, 2007). For instance, losses in agricultural production in the Eastern Himalaya countries may lead to increased malnutrition and reduced opportunities for poverty reduction. Overall, climate change will lower incomes and reduce the opportunities for vulnerable populations. Mountain ecosystems around the world are now affected by the combined impacts of climate factors and their interactions with other anthropogenic stressors such as encroachment, land fragmentation, degradation and destruction of natural habitats (Mano and Nhemachena, 2007; Biggs *et al.,* 2008).

Studies on livelihoods in the Eastern Himalaya (EH) highlands reveal that subsistence farmers and pastoral people, who make up a large portion of the rural populations, could be negatively affected by climate changes. A major area of serious impacts is in the field of agricultural production. Agriculture is the direct or indirect source of livelihood for over 70% of the population in the EH and is a substantial contributor to national incomes (Fischer *et al.,* 2002a). Agriculture is highly sensitive to climate change and is expected to impact on the region differently, with some alteration in precipitation patterns. Impacts on livelihoods according IPCC projections in the EH show that there will very likely be decreases in precipitation in the future. Climate change impact and vulnerability (CCIV) in the EH is projected to experience a decline in potentially good agricultural land, while others will benefit from substantial increases in suitable areas and production potentials (Fischer *et al.,* 2002a).

Several studies in the past have shown that the production of rice, corn, and wheat has declined due to increasing water stress arising partly from increasing temperature, the increasing frequency of El Niño, and a reduction in the number of rainy days (Agarwal *et al.,* 2000; Jin *et al.,* 2001; Fischer *et al.,* 2002b; Tao *et al.,* 2004). Climatic changes are predicted to reduce the livelihood assets of poor people, alter the path and rate of national economic growth, and undermine regional food security. According to a World Bank report on climate change, upland areas are warming faster than lowland areas (World Bank, 2008).

3.4 The necessity of local climate change impact studies

Climate change has a profound influence on ecosystems. Climate change affects ecosystems in a variety of ways. For instance, this research will help the researchers develop a resilience framework for climate change adaptation in the study area. The case study will generate new knowledge which will be used to develop the state of the art solutions to societal problems and adaptive policies to demonstrate preparedness for a changing climate future in the region. Naturally, some regions and activities are more sensitive to climate change than others (Saarinen *et al.,* 2012). Secondly, regional climatic variations also mean that the impacts would be experienced differently in different regions. Climate change is likely to have major impacts on health systems through heat exposure, extreme weather events, water pollution, waterborne diseases and spread of disease vectors in any ecosystem (WHO, 2008). It has been reported that approximately one quarter of the global disease burden is due to modifiable environmental factors and that 42 per cent of incidences of malaria are associated with policies and practices related to land use and water resource management (WHO, 2008).

3.5 Climate change and sustainable development

The negative effects of climate change are threatening to reverse development gains in many parts of the world especially in Sub-Saharan Africa. It is now an accepted scientific phenomenon that the global climate is changing. Precipitation and temperature patterns are changing. In the Sub-Saharan region rainfall patterns have become less predictable, precipitation has decreased on average, and temperatures are rising. (Holmgren and Oberg, 2006). Evidence show that the upward trend of the already high temperatures and the reduction of precipitation levels will increasingly result in reduced agricultural production in Sub-Saharan Africa (Mano and Nhemachena, 2007; Biggs *et al.,* 2008). Agriculture is the mainstay of most rural economies in Africa. Negative developments in agriculture would adversely affect the rest of the livelihoods that depend on crop production. The Economist (2010) concludes that, ‘Global action is not going to stop climate change. The world needs to look harder at how to live with it’. The overall impact of climate change on countries in the Sub-Saharan region has been negative. Davidson *et al.,* 2003 argue that ‘…it is becoming increasingly clear that realization of the development goals can be seriously hampered by climate change.’ Simatele, Binns and Simatele (2012) notes that climate change is undermining efforts to protect livelihoods in Africa. Relevant development programming will need to increasingly incorporate climate change adaptation in order to holistically address development challenges pertaining to livelihoods in sub-Saharan Africa. Travers *et al.,* (2012) note that healthy ecosystems and their services provide opportunities for sustainable economic prosperity in conjunction with the provision of defense against the adverse impacts of climate change. The degradation of ecosystems results in increased climate vulnerability for communities that live in these ecosystems (Travers *et al.,* 2012).

4. Methodology

In this section of the research paper of the Case Study, we highlight the study area together with data collection methods which are also detailed. The data collection methods include desk review, in-formant and in-depth interviews, focus group discussions and household questionnaire administration with randomly selected households as respondents of the communities in the study area. This Case Study is the first to be carried out in the area.

4.1 Study area

Mt. Elgon Ecosystem is one of the very largest water towers in this country. The study area is found approximately on the Kenyan side between longitudes 0^0 47’30N - $0^0$52’30N and latitudes 34^0 37’30E - 34^0 43’0E. Extreme rainfall regimes and temperatures are part of the natural forcings that cause adverse impacts in the upper ecosystem thereby affecting livelihoods in the region. The research area is situated next to the natural forest ecosystem.

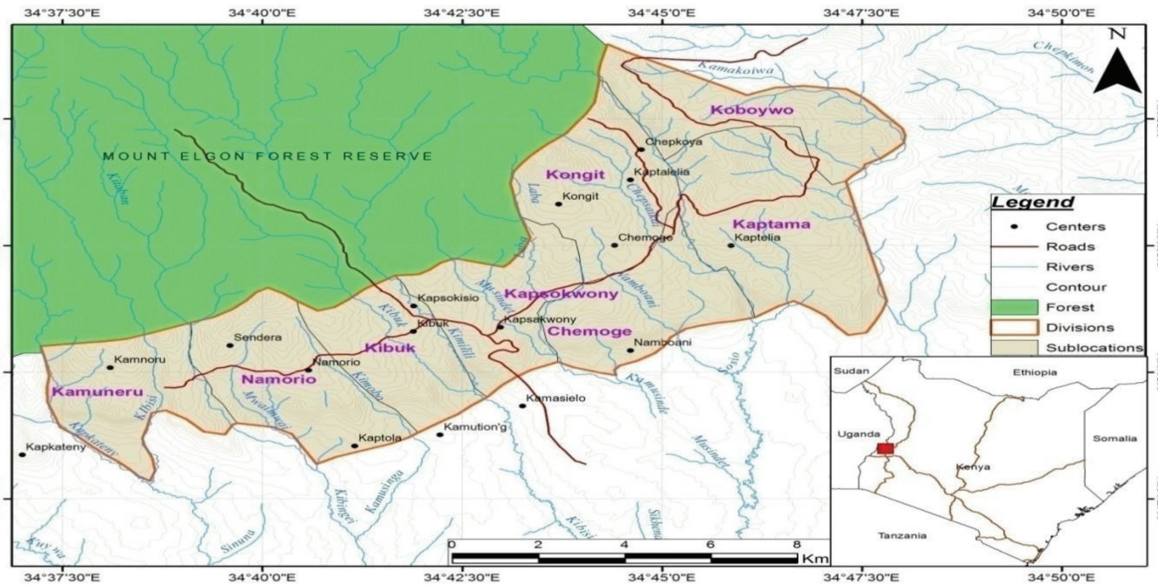


Figure 1: Topography map of Mt. Elgon region, Kenya showing the study area Coordinates: longitudes 0^0 47'30N - $0^0$52'30N and latitudes 34^0 37'30E - 34^0 43'0E.

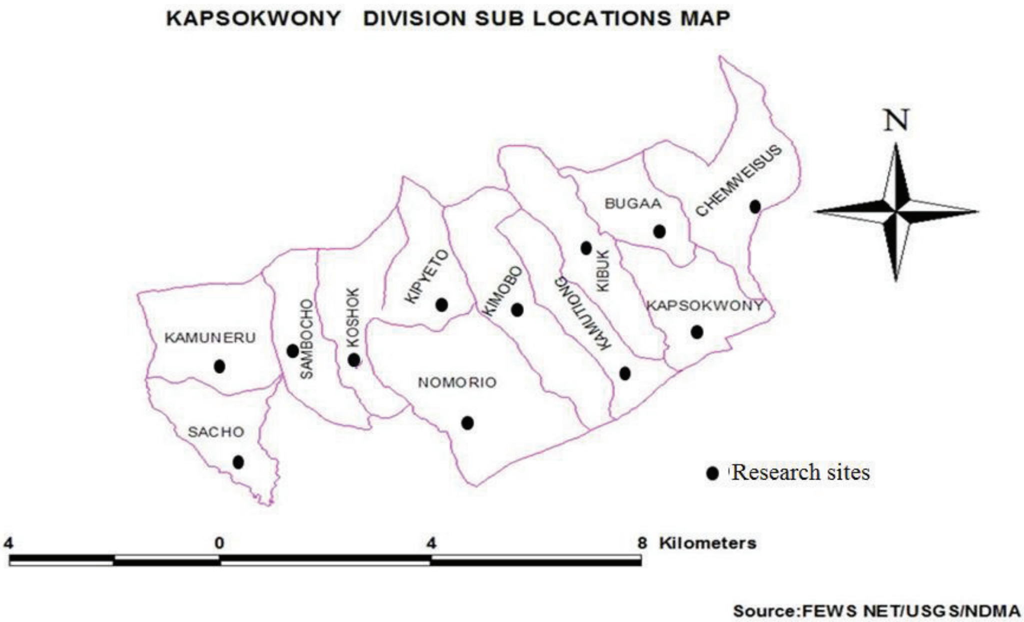


Figure 2: Map of study area showing sub-locations and research sites Coordinates: longitudes 0^0 47'30N - $0^0$52'30N and latitudes 34^0 37'30E - 34^0 43'0E.

The erratic weather changes due to climate change impacts in the region have greatly affected livelihoods of the people in the recent past. There is a big relationship between the mountain ecological zones and the people who reside near the forested part of the ecosystem. Thus, the degradation of the existing water supplies is directly linked to the degradation of the forest resources and this is due to impacts of climate change (WWAP, 2009).

Parts of the main physical features in the region are the protruding volcanic rocks which were formed millions of years ago by the process of volcanicity. The landforms and structures of Mt. Elgon landmass are changing due to landform evolution and the process of weathering. Landform and weathering processes are controlled by forces that include earth movements or plate tectonics and climate change. Continual fault movements and longtime effects of erosion have been responsible for the shaping of the landscape as seen today (Wesche, 2002). Mt Elgon landscape is also subject to climate change and different types of weathering. The annual alternating wet and dry climatic conditions are the main conditions that are responsible for shaping of the landscape. Water in rivers transport sediments, silt, sand and clay particles which are later deposited in the lowland areas. Most of the erosion takes place upstream and deposition takes place downstream on the floodplain (Wesche, 2002).

4.2 Data collection methods

Data was collected through an approach that combine a household questionnaire survey, three focus group discussions with a total of 80 women, men and youth, six key informant interviews with representatives of public and private organizations, and four in-depth interviews with some respondents who will participate in the household survey. Administration of the structured questionnaire involved a total of 384 heads of households 32 from each of the sub-locations.

4.2.1 Desk review

Desk review started by highlighting historical trends of climate change challenges as highlighted in the national climate policies through a review of different policies that addressed climate change issues in different national policies whether directly or indirectly. This took into consideration how smallholder farmers' traditional technologies and indigenous adaptation strategies to climate change impacts within the study area could be implemented. Desk review also mirrored the effective adaptation technologies which were used by farmers in the past to combat the vagaries of climate variability.

4.2.2 Quantitative data

The household questionnaire survey generated mostly quantitative data although it also contained open questions that provided qualitative information. The questionnaire had four sections. The first section dealt with general, socio-economic and demographic characteristics. This was followed by two sections on coping with extreme weather events and adaptation to gradual climatic changes to assess the impact of climate stressors on the households, and their strategies to cope with and adapt to the impacts of extreme weather-related events. The last section of the questionnaire uses open questions to examine local perceptions of vulnerability and the ideas of respondents about policy options to reduce climate risks. The questionnaire interviews took approximately 25 to 30 minutes each to complete.

4.2.3 Qualitative research tools

Qualitative information was obtained through focus group discussions, key informant interviews and in-depth interviews. This information was used to complement the household survey (questionnaire). A Focus Group Discussion (FGD) is a form of interview that involves addressing questions to a group of individuals who have been selected for this specific purpose. In this study, three FGDs were conducted to obtain the experiences of men, women and youth with impact, coping and adaptation to climate extreme impacts. In total there were about 80 participants. The participants were ordinary members of the community and other stakeholders. Interaction among them stimulated ideas and perceptions about climate risks, including perception of change in the frequency and severity of climate impacts over time, drivers of deforestation, impacts, responses, constraints (factors impeding effective coping and adaptation) and policy.

Key informant interviews were used to collect information from people with specific knowledge and experience of climate impacts. The aim is to obtain information that would not easily be obtained from focus group discussions and the questionnaire. The integration of both non-scientific (experiential) and scientific knowledge was of great importance because it had a prominent role in decision making. Observations were made overtime of projected weather patterns/climate change on livelihoods and alterations be recorded and analyzed. Secondary data from meteorological experts of the weather parameters in the region can be of importance in the prediction of climate change scenarios.

4.3 Data analysis

Seasonal rainfall and temperature data for Kitale Meteorological Station for the period 1986 to 2015 was used in the study. The data was obtained from Kenya Meteorological Department. Trend analysis was carried out by use of regression techniques whereas rainfall variability was done by use of Coefficient of Variation (CoV). The movements of rainfall patterns were investigated by use of graphical and statistical methods. Farmers' rainfall and temperature perceptions were run by use of the satisfaction index. Primary data analysis was carried out by the IBM Statistical Packages for Social Sciences (SPSS) version 23.0.

This section discusses the methods applied to achieve all the objectives under study where quality control results are discussed first. Completeness and consistency of data is important in any research works for determination of homogeneity over the study area. Single mass curve method was used to examine whether the historical data are samples from the same statistical distribution by checking the drifts in the data set which have taken place in the archived observations after a long period of recording or change in the site of the instrument or station. Data from different populations are considered inconsistent and therefore may not produce desired results in any meaningful research. The cumulative totals of rainfall and temperature were plotted in excel (graphical analysis) against the years to check for data (in) consistency.

Precipitation Concentration Index (PCI), Standardized Anomaly Index (SAI) and Coefficient of Variation (CoV) were used to study rainfall variability. Seasonal and annual precipitation concentration index were analyzed using De Lui's *et al*., (1999), which is the modified version of Oliver's (1980). It was computed as follows:

$PCI_{annual}=\frac{\sum_{i=1}^{12} p_i^2}{(\sum_{i=1}^{12} p_i)^2}*100$ …………………………………………………………………. [Equation 1]

$PCI_{seasonal}=\frac{\sum_{i=1}^{3} p_i^2}{(\sum_{i=1}^{3} p_i)^2}*25$ ……………………………..……………………………… …[Equation 2]

Where p=precipitation of i^{th} month and p=annual/seasonal precipitation.

PCI values

Range	**Indication**
<10	Uniform distribution
11-15	Moderate distribution
16-20	Irregular distribution
>21	Strongly irregular distribution

Coefficient of Variation (CoV) was calculated to evaluate the degree of seasonal and annual variability of rainfall and temperature. It was computed using equation 3 below.

CoV (%) $=\frac{\sigma}{\bar{x}}*100$……………………………………………………………………... [Equation 3]

According to Hare (1983), percentage Coefficient of Variation (CoV) values can be classified as shown in table below:

PCI values were determined and recorded as in the table below:

% CoV values	**Indication**
<20	Less variable
20-30	Moderate variable
>30	Highly variable

Standardized Anomaly Index (SAI) was used to determine dry and wet years in the study period. It is computed as shown in equation 4 below

$Z=\frac{x-\bar{x}}{\sigma}$ ………………………………………… …………………………………....[Equation 4]

Where Z is the standardized rainfall anomaly; x is the annual rainfall total of a particular year; $\bar{x}$ is the mean annual rainfall and σ is the annual standard deviation of annual rainfall over the period of observation.

Trend analysis was done by use of graphs depicting time series were drawn and analyzed in excel. Long term seasonal series of rainfall during the season of MAM and OND were drawn to depict the trends during these seasons. The trend of the rainfall and temperature was done using Mann-Kendall and the linear regression was used to confirm and visualize the results. The Mann-Kendal test is non-parametric and has been extensively used with environmental time series (Modarres and da Silva, 2007). It was used to test the significance of the trends at 95% level of confidence. The equation of a linear regression line is given as:

$y=a+bx$……………………………………………………………………………....[Equation 5]

The slope (b) is the most important parameter and it indicates the rate of change of the parameter over the years. Positive and negative values of the slope represent increasing and decreasing trends respectively. These were drawn and analyzed in excel software.

The student t-test was thereafter used to examine the difference between the means. The data was split into equal record period of 15 years to check if the trend has been increasing or decreasing for the two split periods. The student t-test is given by the following formula

$t=\frac{\bar{x}_1-\bar{x}_2}{\sigma_d^2}$ ……………...[Equation 6]

Where σ_d, the difference in variance given by

$\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}$ ……………………………………………………….. …………………[Equation 7]

Where $\bar{x}_1$and $\bar{x}_2$are the means of the two samples of sizes n_1 and n_2 with variances $\sigma 1\ and\ \sigma 2$ respectively. The computed t was checked against the tabulated t and null hypothesis accepted (rejected) if the computed t is smaller (larger) than the tabulated t.

Pearson's correlation formula was used to examine the association between rainfall and temperature over the study period. It is computed using the following formula

$$r_{xy} = \frac{\frac{1}{n}\sum_{i=1}^{n}\left[\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)\right]}{\left[\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 . \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2\right]^{\frac{1}{2}}}$$ ……………………………… [Equation 8]

r_{xy} is the correlation coefficient, $\boldsymbol{x}$ is rainfall and $\boldsymbol{y}$ is temperature.
The significance of the computed correlation coefficients were then accessed using the student t-test given by equation 9 below:

$$t=r\sqrt{\frac{N-2}{1-r^2}}$$ …………………………………………………...... [Equation 9]

t is the computed value of t, r is the correlation coefficient between the variables, n is the number of years used. These values were checked with the tabulated values of t and decision made. When the computed value of t is larger than the tabulated value, the correlation is significant and vice versa.

5. Results and discussions

5.1 Introduction

The major objective of the present chapter was to examine the significant trends in both mean annual rainfall and temperature trends over the study region. Both rainfall and temperature trend analysis are critical in this case study because humanity lives on and obtains sustenance on the surface of the Earth whereof these two variables are significant in this case study. The study investigated 30 years mean rainfall and temperature trends over the study area by use of both graphical and statistical techniques. Daily records (1986 – 2015) from Kitale Meteorological Station were used. In the past surface temperatures in the study area has not been a subject of rigorous climate analysis. The variations in rainfall and temperature patterns in the study area could be attributed to the general land use, landscape terrain and topography, nearness to the forest cover and wind resonance. The data from Kitale Meteorological Station represent the true reflections of the actual state of the environment in the study area. However, a small geographical variation in the weather variables is expected.

One major challenge in this study is the complete lack of homogenous and long term records of related studies because no such studies have been carried out in the region in the past. Therefore, this is the first case study to be carried out in the region to understand how climate change impacts livelihoods. It is expected that in spite of the fact that quality controlled meteorological and other data problems, the climate data derived from Kitale Meteorological Station was ascertained to reflect the actual state of the environment in the study area. This study is based on thirty year (30) climate variability mainly derived from rainfall and temperature trends. Precipitation and temperature information which were recorded on daily basis were collected and used to derive average/mean annual records which were used to draw climate trend analysis.

Another source of climate information was the interviews which were carried out with informant and in-depth interviewees, the debates during FGDs and the administration of the questionnaires to households. The respondents gave us the real live situations which are being experienced in the region daily, monthly and yearly basis on climate change. Most of the respondents concurred that significant trends in climate anomalies have been experienced in the region with rainfall becoming unpredictable, unreliable and erratic and that temperature trends were rising.

The chapter examines selected findings from the research study on tracking adaptation strategies on effects of climate variability in the study area on livelihoods smallholder farmers in Kapsokwony Division Mt. Elgon Sub-county, Kenya.

5.2 Results

In this section, the results obtained from each method in line with the objective one, are presented and discussions made. The rainfall data was computed based on observational rainfall data to obtain maximum, minimum, annual and seasonal rainfall as well as coefficient of variations and standard deviation. Other than the observed rainfall variable, subjective index was obtained by asking farmers in the study area questions related as to whether they had experienced a decrease or an increase in rainfall in the past decades.

5.2.1 Quality control results

The single mass curves for cumulative rainfall (mm) and cumulative mean annual temperature were drawn and the results represented test for homogeneity to check for consistency in the data. Figures 5.1 and 5.2 shows sample mass curves indicating good rainfall and temperature records.

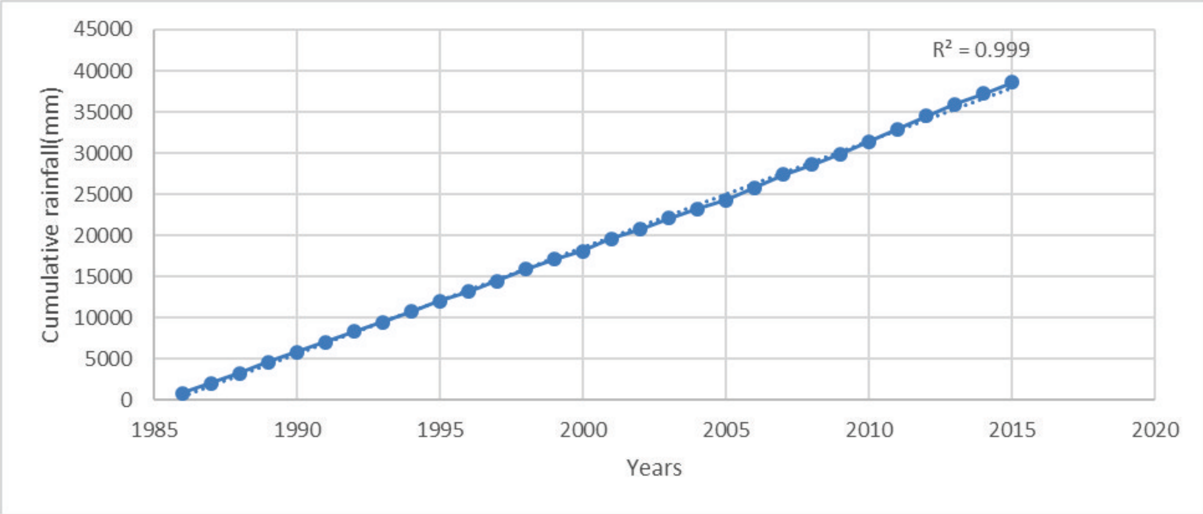


Figure 5.1: Single mass curve, cumulative annual rainfall for the study area.

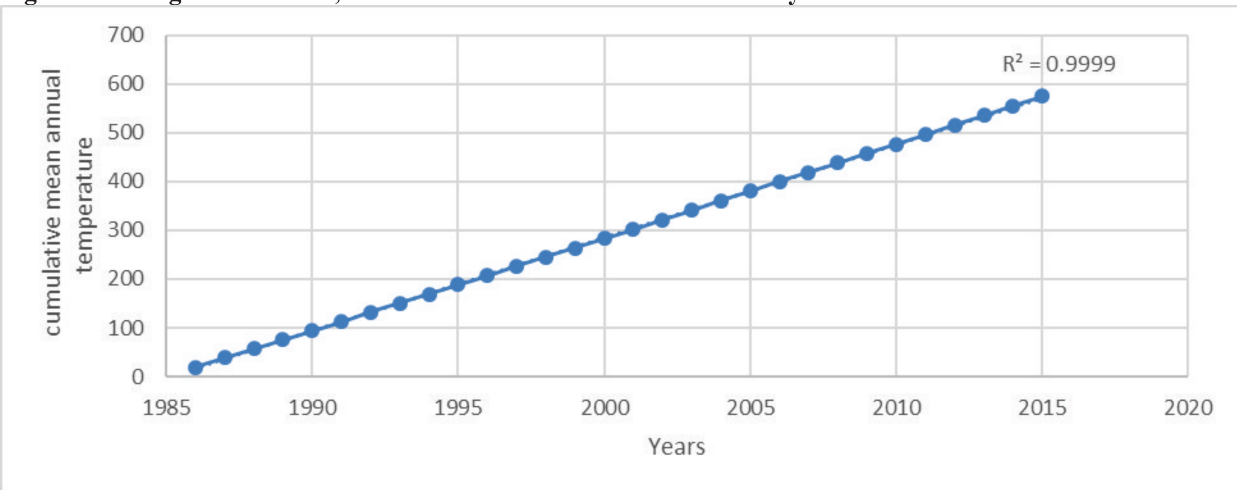


Figure 5.2: Single mass curve, cumulative annual temperature for the study area.

From figures 5.1 and 5.2 above, the graphs display straight line passing through the origin indicating no abrupt changes or breaks. These together with high values of coefficient of determination, R^2 (all above 0.99) indicate that the data is consistent and therefore good for use in the study.

5.2.2 Precipitation concentration index results

Seasonal and annual PCI values are shown in table below. The values indicate the number of years with PCI values less than 10, between 11 and 15, between 16 and 20 and the number of years having PCI values of greater than 21.

Table 5.1: Perception concentration index results

SEASON/ANNUAL	P C I V A L U E S			
	<10	**11-15**	**16-20**	**>21**
MAM	20	10	-	-
OND	11	17	2	-
ANNUAL	1	29	-	-

It can be noted from the table above that most of the years, study area rainfall distribution is uniform to moderate both seasonally and annually. However, 6.7% of the years indicated irregular distribution of rainfall during OND season. There was no period when the rainfall distribution was highly irregular over the study period.

5.2.3 Dry and wet years

The results for Standardized Anomaly Index (SAI) for the study area are tabulated below. The study revealed that the number of dry years were many as compared to the number of wet years. The number of dry years increased from 1986 to 1997 where the rainfall received at this station during the period was less than the climatologically average. Notably, in 1997/98, the annual rainfall mean was significantly higher than the climatologically average as a result of the El Nino rains experienced in 1998. Therefore, this was a significantly wet period. From 2009 to 2013, the station has been receiving above normal rainfall hence, this period can be classified as wet spell.

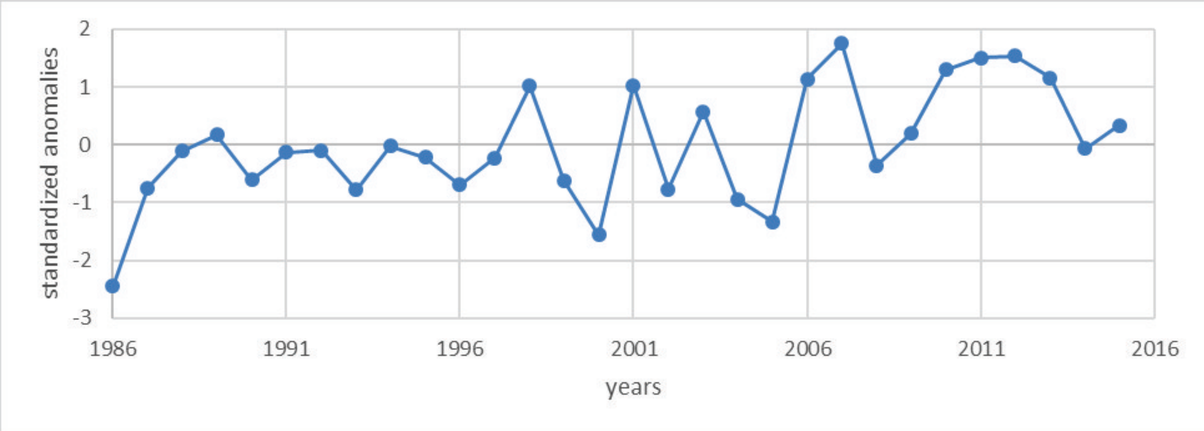


Figure 5.3: Dry and wet years over the study area.

5.2.4 Seasonal and annual rainfall variation

The following table shows the basic statistical analysis of rainfall for the first 15 years and the last 15 years for annual series.

Table 5.2: Coefficient of variability in percentage (%)

DATA SET		ANNUAL
Sub-set 1	Mean	1208.621
	Standard deviation	129.7871
	CoV	11%
	Skewness	-0.87916
	Kurtosis	2.460851
	Reliability	89%
Sub-set 2	Mean	1363.407
	Standard deviation	162.2889
	CoV	12%
	Skewness	-0.47626
	Kurtosis	-1.0299
	Reliability	88%
Whole Series	Mean	1286.014
	Standard deviation	164.4474
	CoV	13%
	Skewness	-0.14259
	Kurtosis	-0.10334
	Reliability	87%

From the table above, it is evident that there has been increases in rainfall as the annual rainfall mean changes from 1208mm to about 1363mm during the 1st and the last 15 years period respectively. The rainfall is less variable as shown by low percentages of coefficient of variation. This therefore means that the rainfall is highly reliable and the agricultural sector in the area can adequately rely on both the seasonal and annual rainfall before, during and post harvesting periods. Skewness and kurtosis values are relatively low indicating that all the data sets are nearly normally distributed.

Figure 5.4 below shows seasonal variation of rainfall for set one, set two and for the whole set.

Figure 5.4: Seasonal rainfall set one (blue), set two (red) and set three (brown)

From the graphical visualization of monthly mean is shown in figure 5.4 above, it is clear that there has been a shift in rainfall characteristics with the mean of set one generally lower than the mean of set two. The station receives a tri-modal rainfall with peaks in April, August and October. The results show statistically increasing trends ($P\leq 0.05$) in annual and seasonal. The study area generally receives rainfall throughout the year with low peaks of rainfall in the months of January and February.

Figure 5.5 below shows the seasonal variation of rainfall for set one, set two and for the whole set between 1986 – 2015.

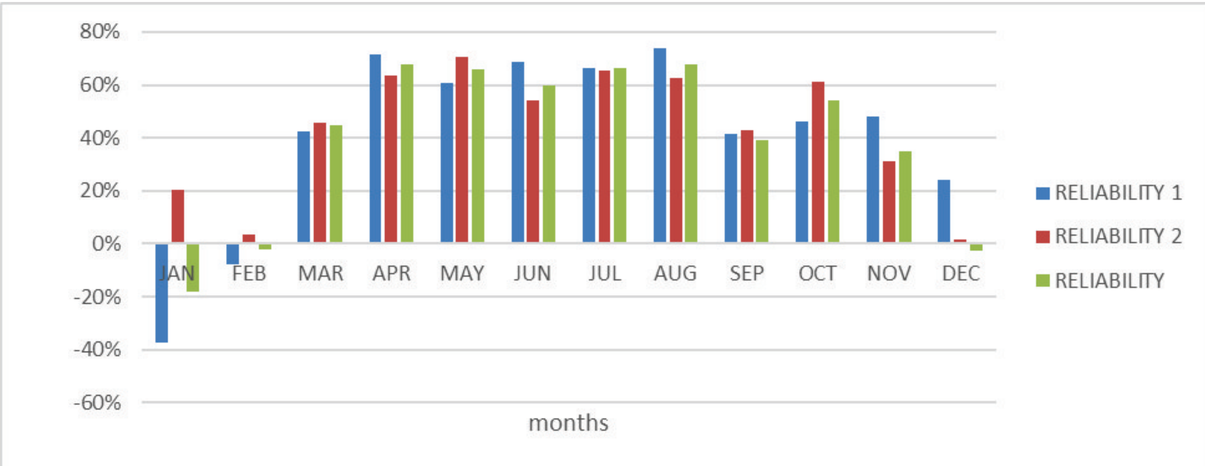


Figure 5.5: Seasonal rainfall set one (blue), set two (red) and set three (brown)

From the graphical visualization of monthly mean is shown in figure 5.5 above, it is clear that there has been a shift in rainfall characteristics with the mean of set one generally lower than the mean of set two. The station receives a tri-modal rainfall with peaks in April, August and October. The results show statistically increasing trends ($P\leq 0.05$) in annual and seasonal. The study area generally receives rainfall throughout the year with low peaks of rainfall in the months of December, January and February.

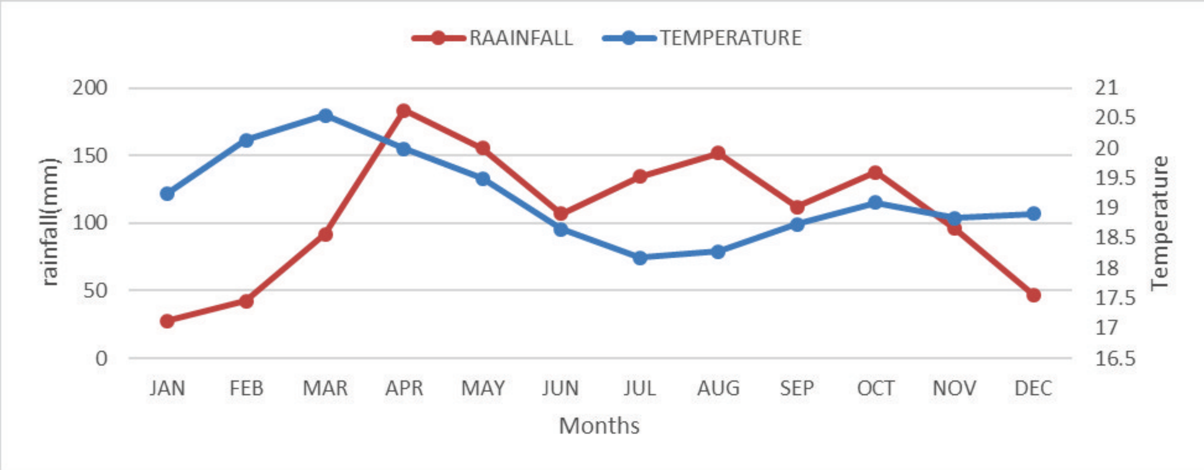


Figure 5.6: The reliability of rainfall for set one, set two and the whole set between 1986 and 2015

The figure indicates that the station receives three peaks of rainfall (tri-modal) and the highest rainfall is received in the month of April with an annual average of 180mm. The temperature range is small (about 3^0C) with highest temperature observed in the month of February, a month after maximum solar intensity and the lowest temperature is observed during JJA season.

4.2.5 Trends of rainfall and temperature

Seasonal and annual trends of rainfall are shown in the figure below.

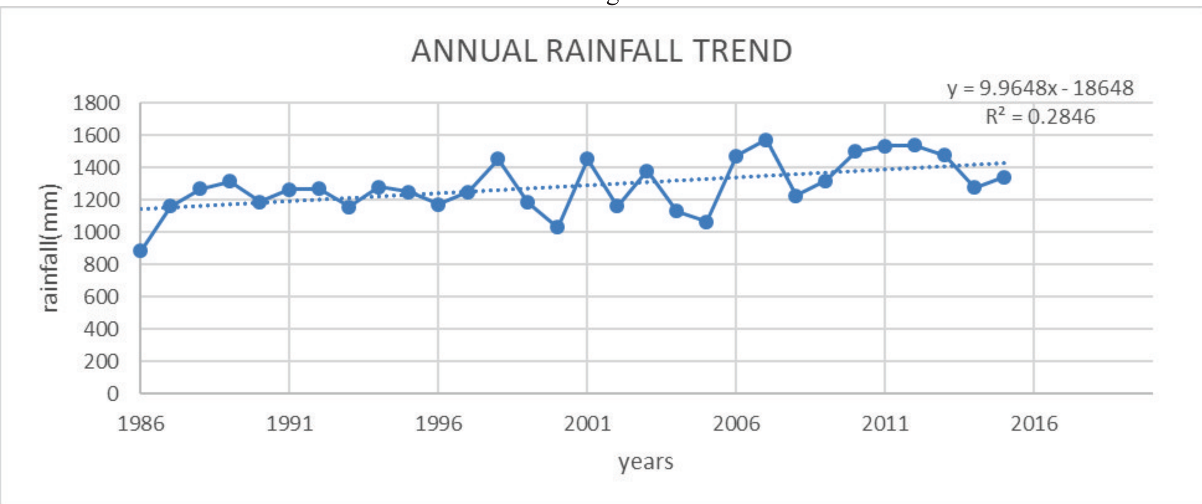


Figure 5.7: Annual rainfall trend from 1986 to 2015

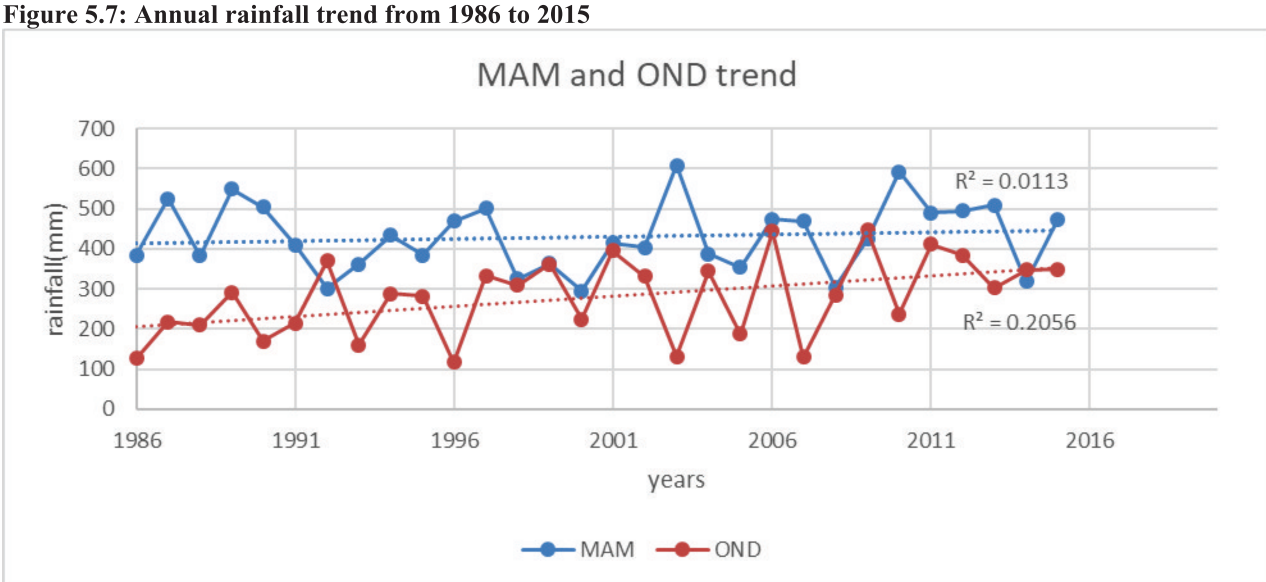


Figure 5.8: MAM and OND trends from 1986 to 2015

From figure 5.8 above, the trend of annual rainfall has been increasing generally indicated by a positive slope of 9.9648 but with a small coefficient of determination of 0.2846. MAM trend has been stationary while OND trend has been increasing over time. However, testing the significance of these trends (R^2) with the Mann-Kendall test reveal that the increase in trends are not significant as the p-values are larger than the level of confidence (5%).

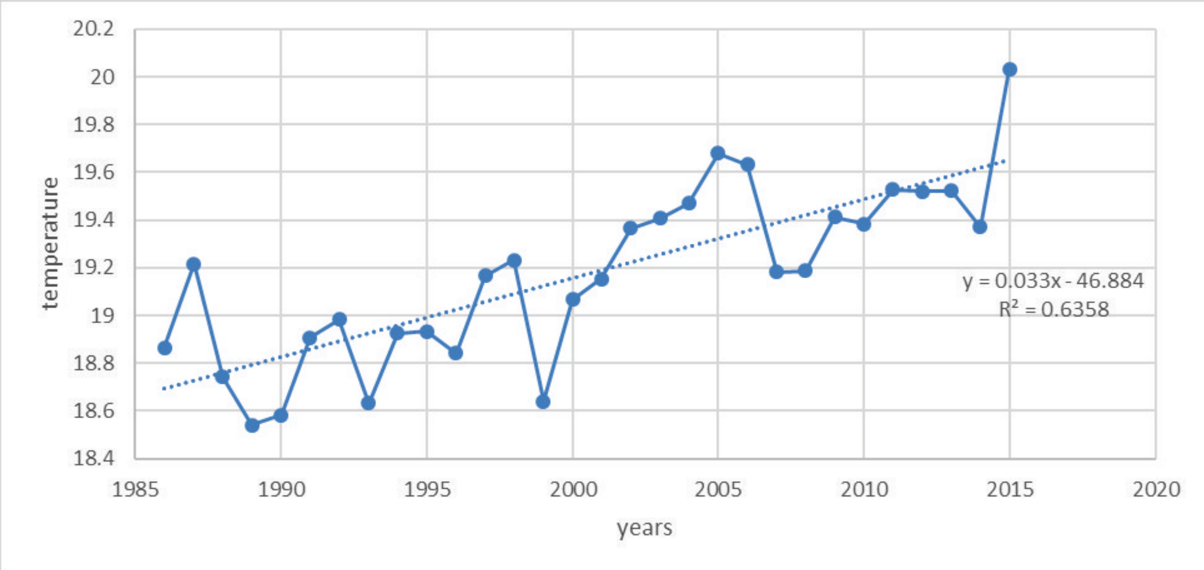


Figure 5.9: The trend of temperature from 1986 to 2015.

Figure 5.9 above indicates that the trend of temperature has been increasing from 1986 to 2015 with 2015 as the year with highest observed temperature of about 20^0C. This year is on record as one of the hottest year recorded. Upon checking the significance of the trend, it was noted that the increase is significant at 5% level of significance and therefore supports the analogy of climate change. It is believed that global warming may have resulted to an increase in temperatures leading to climate change.

5.2.6 Correlation analysis.

The results for annual correlation analysis indicate that temperature and rainfall are related with Pearson's correlation coefficient of -0.16. On checking the significance of the correlation coefficient using student t-test, the computed t(-0.8579) is smaller than the tabulated t(2.048) at 5% significance level. Therefore, the correlation is not stationary.

5.2.7 Characteristics of survey groups

The respondents to the household questionnaire were both men and women. Data analysis indicated that majority of the respondents were male making a total of 204 as opposed to females who were 180 both making 53.13 % and 46.88 % respectively. This clearly creates a range of about 6.25% as shown in table 5.1 and figure 5.1 respectively. Men are known to be absent because they are away fending for their families or being polygamous they may be in another household or are presumed to be dead. Table 5.2 shows that from the survey conducted it was realized that majority of the respondents were in a monogamous marriage set up 271(70.57%) followed by polygamous 59(15.36%) making a total of 330(85.94%). Those widowed also showed 33(8.59%) whereas the remaining forms constituted 21(5.47%). Those who had attained technical, secondary and tertiary constituted a total of 174(45.31%) but overall those with primary and secondary formed a huge majority constituting 191(49.74%) and 137(35.68%) respectively.

5.3 Farmers' rainfall perceptions

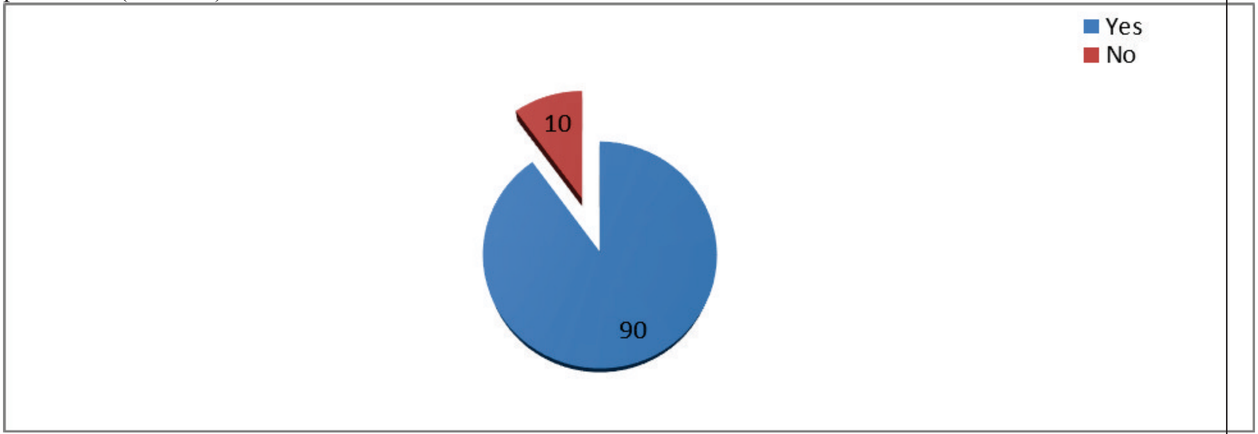
A number of questions relating to climate change were asked in the household questionnaire in order to understand villagers' views about the notion of rainfall variability. For example, respondents were asked the question: "Have you ever perceived changes in the rainfall patterns?" Respondents were required to answer 'yes' or 'no' to the question. The table below shows the distribution of responses and percentages of responses to the question.

	Respondents	**Percentage**
Yes	345	90
No	39	10

The pie chart below shows the distribution of responses to the question: "Have you ever perceived any changes in the rainfall patterns?"

The distribution of responses showed that the majority of respondents (90%) had perceived changes in the rainfall patterns while (10%) had not. This shows that the majority of the rural communities in Kapsokwony Division, Mt. Elgon Sub-county, Kenya are well informed about variation in rainfall patterns in the region. This is an important finding for climate change adaptation programming because responses cannot be effective without getting smallholder farmers to understand the notion of rainfall variability.

"The pie chart below shows responses to the question: "Have you ever perceived any changes in the rainfall patterns?" (N = 384)



However, it is important to quickly note that in spite of the fact that many farmers had perceived changes in the rainfall patterns, they did not have anything to do about it because this was a technical issue beyond their understanding. However, they knew and understood that there were major changes taking place in their environment. Another question was asked "Do changes in the weather patterns threaten your livelihood activities?" Respondents were quick to answer this particular question in the affirmative.

5.4 Farmers' temperature perception

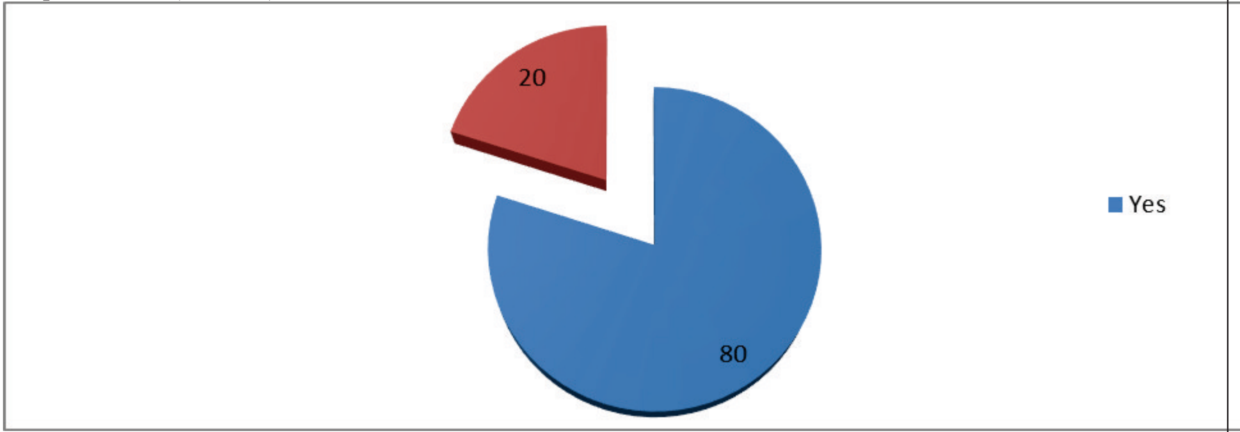
The temperature records for the study area were subjected to trend analysis. Graphical and statistical techniques/methods were used to determine the existence of any significant trends of temperatures changes over the years. Most farmers in the household questionnaires and in the Focus Group Discussions (FGDs) unanimously concurred that temperature in the region had significantly risen mainly due to deforestation and decimation of the ecosystem. In the view of Focus Group Discussions, participants from all the three groups' temperature levels had dramatically increased in recent years.

One woman noted in a Focus Group Discussion (FGD1) that: "Since I was born in 1950, I have never experienced such hot temperatures…. And concerning agriculture, I have a very fertile piece of wetland land which I plough year in year out, and I normally get good output but now it is drying up due to increasing temperatures…(FGD1)." Another participant in a focus group discussion (FGD2) commented: "It seems that the sun is moving closer towards the earth judging from the way it is hot." It was commonly reported by participants in the three focus group discussions that the sun had come closer to the earth leading to higher temperatures. Data gathered through household questionnaires was used to corroborate the views gathered from FGDs.

	Respondents	**Percentages**
Yes	307	80
No	77	20

Respondents in the household questionnaire were asked to select a response about temperature changes in the area by selecting from three possible answers, 'increasing', 'decreasing' and 'not changing'. As noted above, 80% of the respondents pointed out those temperatures were increasing, and only 20% said that temperatures were decreasing.

"The pie chart below shows responses to the question: "Have you ever perceived any changes in the temperatures?" (N = 384)



A large majority (80%) of household questionnaire respondents said that they felt that temperatures had been rising over the decades. The response is therefore statistically significant and in line with the trends as perceived by the IPCC, 2007.

5.5 Respondents' perception on climate variability

Participants in the household questionnaire survey, key informant, in-depth interviews and FGDs reported significant changes in the frequency and severity of climate events and impacts particularly on crop cultivation, livestock, food prices, and health. Different perceptions were recorded from the respondents' as below. It also depended on the type of questions which were asked during the interviews or discussions. The two questions that were commonly asked were: a) "Have you ever experienced any changes in the weather patterns over the years?" and b) "What have you done to cope with the changing climate?"

The general perception of increased flood frequency and intensity was confirmed during an in-depth interview with a traditional weather expert who stated:

"Rains have become unreliable and un-predictable and temperatures have increased over time. Farm productivity has greatly decreased as compared to the past decades. The water catchment has been tampered with in the study area resulting in threats to livelihoods. Further, this has been exacerbated by fragmentation of land as a result of exponential population increase and poor cereal storage. The level of poverty at household levels has increased and income generating activities are diminishing. In the river watersheds they have ignored the implementation of the rule of leaving 15 meters on either side in order to protect soils and riparian vegetation. The grains that are harvested at the end of the growing season are poorly stored for lack of knowledge and skills."

In-depth interview with Hesbon K. Naibei, a weather expert on 15th February, 2016

The general perception of increased flood frequency and intensity was confirmed during an informant interview with a traditional weather expert who stated:

"Climate change is taking place mainly as a result of human activities as perceived in the environment. These activities include encroachment on the forest ecosystem, overgrazing, poor agricultural practices, charcoal burning, fuel-wood collection, deforestation, water pollution and urbanization. This has resulted in altered rainfall patterns and increased temperatures. The rains either come too early or too late and therefore the farmers can not know when to plant. Heavy rains during harvesting periods destroy the crops due to either diseases or decomposition. Crops ripen earlier than expected because of increased temperatures. Starvation and malnutrition are common during certain months of the year in the region. Most farmers do not have a sound financial base to afford high quality yielding seed varieties and hence, they end up planting recycled seeds that are not disease and drought resistant. A paradigm shift is for the area residents to plant certified seeds and apply quality manure to improve farm output."

Informant interview with the Head of Biko Kapkoret radio station Mr. Zwingle Kibet on 16th February, 2016.

The deputy District Education Officer was interviewed and she had this to say about the changing scenario in climate change in the region on behalf of the education fraternity. She said:

"Families living adjacent to the forest ecosystem rely on its natural resources for their livelihoods. The region has become warmer than ever before and rainfall unreliable and unpredictable. Farm products have declined over time and food insecurity has become a major issue in the region. Lack of pastures in the villages has forced families to drive their livestock to graze in the forest. Some children have been forced to drop out of school because they have to take the animals to the forest for pasture and watering. Some schools in the region have been able to establish tree nurseries as an income generating activity."

Informant interview with Alice Sitawa, DEO Kapsokwony Sub – county on 20th, February 2016

"There has been a paradigm shift in the rainfall patterns in the region because of climate change. For instance, in 2014 the rains experienced during the long rain period were very heavy whereas those experienced during the short rain period were very low. In 2015, the rains experienced during the long rain period were low and those experienced during the short rain period were heavy. The dry spell experienced in 2015 caused the perennial tree crops that are tea and coffee to wither. The *El-nino* rains that set in at beginning of October 2015 to February 2016 complicated matters for farmers. Land for agriculture has been reduced due to exponential population growth and land fragmentation greatly reducing food productivity. Soil erosion and leaching have impacted soil fertility resulting in low farm output. Food crops such as the bananas, maize, beans, potatoes, cabbages and onions are grown for food while surplus are destined to local market. Deforestation and poor farming methods in the fragile ecosystem has increased its degradation."

Informant interview with Mr. Mark Otieno, District Agricultural Crop Officer Mt. Elgon District on 7th February 2016

Focus Group Discussions (FGDs) held with the youth representatives on 24th June 2016 stated that there is a change in weather patterns leading a decline in agricultural productivity and dwindling livestock production. They unanimously stated as follows:

"This is mainly due to altered rain patterns, increasing temperatures, diminishing water quantities and decline in pastureland. Impacts of climate change have greatly reduced income at household levels causing unemployment, rising poverty, insecurity, high food prices, waterborne diseases and under-nourishment among children. The movement of animals into the forest is an adaptive strategy to enable farmer's access pasture and water. The sale of animals at the end of the year is another adaptive strategy meant to earn the family some income and reduce the number of animals before the planting season. The shrinking land size has made the herders seriously reduce the numbers of animals reared at household levels. Exponential population increase has caused competition for land mainly between humans and at times among communities leading to real land conflicts at family levels. Furthermore, there is poor management of natural resources, rapid degradation of the ecosystem and reduced resources critical for livelihoods. These issues have been aggravated by climate change and anthropogenic activities which together act as drivers of environmental degradation. Generation of transformation knowledge will help them adapt and mitigate the vagaries of climate change over time. Some of the youth fall out of school because of poverty and engaging in early sexual activities."

FGDs conducted for all the youth representatives in the study area on 24th June, 2016.

5.6 Synthesis and discussions

Over 90% of the farmers interviewed had perceived change in the rainfall as far back as 15 to 20 years. Generally, farmers' reported late onset of rain, poor distribution within the season, and sometimes early cessation. In particular they reported that the planting season had shifted from early March to late March or to early April and now end in June rather than May. In the last 10 years farmers' highlighted specific problems of variability in the duration, timings, and intensity of the rains and heavy rains at the start of the seasons such as 2007, 2005 and 2010. In some part of the study area, farmers said that there was an increasing problem of flash floods as a result of increasing rainfall intensity which has also translated into increased ground water and water logging and landslides. Trend analysis found out that the region has experienced significant temperature rise in the past three decades.

Farmers' perceptions of climate variability are in line with actual climate data, noting variability in the duration, timing and distribution within seasons including strong winds and heavy rainfall at the start of the seasons. This is a common perception by farmers and other resource users of climate change such as in the Sahel (Mertz *et al.,* 2009) and Nile

basin of Ethiopia (Deressa *et al.,* 2008) where farmers perceive increased variability of rainfall and shifts in the growing seasons. Seasonal distribution of rainfall affects the decisions made by farming households on what types of crops to grow, when to plant and other farm management practices to adopt (Komutunga *et al.,* 2001). In addition, excessive rains both in intensity and duration lead to water logging conditions that negatively affect crops and pasture. Heavy rainfall experienced between 2006 and 2010 was responsible for the numerous landslides in the mountainous Eastern Uganda (Komutunga *et al.,* 2001).

In related studies in East Africa, Recha *et al.,* (2012) report that persistence of below rainfall is a great risk to people's livelihoods in Tharaka district in Kenya, where the majority of the people have been left vulnerable to hunger and famine. Similar observations have been reported by several scholars studying, for example intra seasonal factors, such as the timing of the onset of first rains affecting crop planting regimes (Tennant *et al.,* 2002), the distribution and length of period of rain during the growing season (Mortimore *et al.,* 2001) are the real criteria that affect the effectiveness of success of farming (IPPC, 2007).

The study shows significant increase in annual rainfall in the recent years mainly due to climate change. Farmers' perceptions of climate variability are in line with actual climate data, noting variability in the duration, timing and distribution within seasons including strong winds and heavy rainfall at the start of the seasons. This is a common perception by farmers and other resource users of climate change such as in the Sahel (Mertz *et al.,* 2009) and Nile basin of Ethiopia (Deressa *et al.,* 2008) where farmers perceive increased variability of rainfall and shifts in the growing seasons. Seasonal distribution of rainfall affects the decisions made by farming households on what types of crops to grow, when to plant and other farm management practices to adopt (Komutunga *et al.,* 2001). In addition, excessive rains both in intensity and duration lead to water logging conditions that negatively affect crops and pasture. Heavy rainfall experienced between 2006 and 2010 was responsible for the numerous landslides in the mountainous Eastern Uganda (GOU, 2007; Komutunga *et al.,* 2001).

6. Conclusions and recommendations

6.1 Conclusions

The main aim of this study was to evaluate sustainability of impacts of climate change on livelihoods among rural households in Kapsokwony Division. The communities living in the study area were investigated from the perspective of a people who experienced the livelihood threats due to climate impacts. The findings of this study will have several policy implications for politicians, planners as well as policy makers and rural dwellers who have different conflicting perceptions and concerns about a changing climate. Dialogue and inclusion of all stakeholders in development initiatives can mitigate this gap. The respondents in this study represent households that face increasingly frequent and severe livelihood impacts. These climate-related stressors come on top of a wide range of structural vulnerabilities, such as high poverty levels, rapid population growth, increased pressure on natural resources, limited livelihood opportunities, and low educational levels. The high incidence of poverty and low education level undermine households' ability to diversify livelihood sources in ways that could enhance their resilience to climate events. Participants in the household questionnaire survey, FGDs, key informant and in-depth interviews reported significant changes in the frequency and severity of climate events and impacts particularly on crop cultivation, livestock, food prices, and health

The study found significant variation in the amount and distribution of annual and seasonal rainfall. This is attributed to increase in extremes of rainfall on the annual scale such as high intensity rainfall and droughts thus affecting the variability. Significance in variations can be attributed to climate change, variations in altitude, cropping systems and land use intensity. Communities' perception of rainfall adequacy was in line with observational data, where respondents acknowledged late rainfall onset, mid-season droughts and early cessations. Climate related disasters such as floods, droughts and landslides are said to be on the increase. Several other similar studies conducted in mountain regions of the world are in agreement with results of this study confirming increasing rainfall trends and variability. Trend analysis found out that the region has experienced significant temperature rise in the past three decades.

The study revealed how sustainability of impacts of climate change affects livelihoods in the study area. There was evidence of traditional knowledge and adaptive decision making that were essential in the improvement of livelihoods. Further, there was also the evidence of the degradation of livelihoods, risk management systems and increased poverty due to recurrent shocks of climate change. Therefore, in the face of increasing threats to livelihoods brought about by climate change, there is a critical need to support and strengthen existing adaptive capacity, while importing scientific technologies, new transformation knowledge and innovative ideas and approaches to respond to the evolving scenario. Within communities that reside in the study area, variation in vulnerability and adaptive capacity exist, based on livelihood options available, access to resources and information and a range of other factors related to livelihood opportunities. Gender inequality means that women stand out as being disadvantaged due to restrictions by traditional practices and marginalization. The marginalization of women and other social groups reduces possibilities for household and community resilience that is equitable and sustainable over a long period of time. This study must therefore address gender inequality and social marginalization as important underlying causes of vulnerability to climate change.

The policy recommendations below provide actors and practitioners options of reflecting and responding to challenges in practise. These recommendations should be availed to all the stakeholders to improve livelihoods in the region. This is because climate change impacts have contributed to reduction of vulnerability of men, women and the youth. Emerging themes that will follow this particular study will continually be shared through dialogue and results be put to good practise to improve livelihoods and sustain social-economic development in the region.

Interventions by the government and NGOs are required to support households in preventing threat impacts that jeopardize lives and livelihoods. An important requisite for interventions to succeed is that the communities be consulted properly and given a voice in decision-making. This is especially true for interventions such as improvement in crop production, livestock rearing, and investments in infrastructure and ecosystem rehabilitation.

Some possible policy interventions listed are based on suggestions from questionnaire respondents (section 4 of the questionnaire), focus group participants, informant and in-depth interviews. As a disclaimer, it should be noted that policies to address loss and damage were not the main focus of this research, and the author recognizes that some of the interventions and policy reorientations suggested here, might be more complex to achieve than study participants imagine. It would be good to explore the possibilities of interventions that can help exploit the opportunities presented by threats for agricultural transformation to increase food production and incomes of rural households. The Mt. Elgon Environment Conservation Network has an important role to play here and should collaborate with other public and private agencies such as BIKO KAPKORRET Community radio. Although the use modern technology is highly recommended, households may also benefit from traditional early warning signs that are known to some 'local experts'. More research is needed to assess this indigenous knowledge and its applicability in the study area. Proper land use, good planning and efficient use of natural resources are must in order to sustain and improve livelihoods. Indeed, many of the questionnaire respondents, participants in focus group discussions and in-depth interviewees proposed similar interventions that they think could permanently solve the problem of livelihood threats. They proposed better adaptive strategies and robust policy recommendation to increase adaptive capacity and resilience under a changing climate.

6.2 Recommendations

- **Accessing a decent basic education to drive economic development**

Literacy level in the study area is wanting, worrying and low. A decent basic education is an important tool to promote transformation knowledge, drive socio-economic development and improves livelihoods. The major reason for low education is the lack of information and high levels of poverty. The socio-economic development potential and improvement and eradication of poverty in the region can be unlocked through the enhancement of literacy levels. For instance, education will help eliminate glaring gender disparities at household levels and at the same time inspire behavior change.

- **Accessing climate information is critical to adaptive decision making**

Accessing climate information and understanding impacts of climate change is critical to adaptive decision making in transforming livelihoods. In order for communities in the study area to effectively adapt to climate change, their wealth of indigenous knowledge must be integrated with scientific technical information that enables adaptive decision making. Communities living in the region should be sensitized on the value to use integrated traditional and scientific knowledge for decisions making on cropping systems and what quality of animals to rear.

- **Poor management of animal diseases significantly contribute to low productivity**

Disease management remains a pressing challenge among livestock keepers in the study area due to ignorance, animal movement and open grazing systems. Animal diseases and pests contribute significantly to low productivity and lead to low income for livestock keepers. Good management of livestock will enhance productivity and commercialize the livestock sector, ensuring livestock keepers earn handsomely for their efforts. New livestock management should be done through co-operatives which will provide access to credit at zero interest.

- **Diversification of livelihoods impacted by climate change**

Diversification of livelihoods impacted by climate change is a fundamental strategy in building adaptive capacity and resilience but it must be done in an informed and empowered way in order for it to be effective. The decision to diversify is always driven by recurrent climate shocks and stresses to existing livelihood strategies. Engaging in new activities requires new skills and knowledge that may not exist in the community, requiring capacity development and technical assistance from external actors.

- **Embrace potential for changes in gender roles and relations**

Climate change is a driver to gender roles and relations. As the impacts of climate change become more apparent, households in the study area are increasingly required to shift from traditional livelihood strategies and practices, and at the same time embrace potential for changes in gender roles and relations. Within households and communities, men and women have different roles and levels of adaptive capacity. It is imperative that vulnerability and adaptive capacity must uncover these differences and build an understanding of the specific roles, responsibilities and challenges faced by both men and women in securing their livelihoods.

- **Area residents to manage water resources effectively and efficiently**

One of the biggest threats facing livelihoods is the availability of the clean drinking water resource at household levels. Already residents in the study area are faced with water stress on the basis of water quantity and water quality. In future water scarcity will stress food production, trigger several new diseases, worsen fuel shortages which are already strained and retard economic development. Unreliable rainfall in the future will play a big role over water resources crisis. All residents must practice efficiency by managing water resources effectively.

- **Adapt new energy sources to improve socio-economic development and livelihoods**

Energy is a prerequisite to socio-economic development and securing livelihoods. However, the use of energy in the study area is both directly and indirectly associated with long term adverse environmental impacts which have significantly contributed to forest degradation due to cutting forest trees for biomass products. There is need to move away from traditional energy sources which are a pre-requisite to environmental degradation and embrace new energy sources in order to improve livelihoods.

- **Integrate traditional and scientific adaptive technologies to improve livelihoods**

Smallholder farmers need to choose, use, and capitalize on scientific adaptation technologies to improve their livelihoods and their well being under a changing climate. Adaptive strategies devised by incorporating the scientific and the indigenous experiences are very important in the designing of adaptive policies that will help residents in the region to adapt to the vagaries of climate change. Knowledge of the indigenous community based on observations, perceptions and experiences over the years can effectively be blended with scientific knowledge to improve climate change mitigation and adaptation strategies.

- **Adopt Climate Smart Agriculture (CSA) to achieve food security**

Due to high population density, most households own small parcels of land for crop subsistence farming crops and livestock in the region. Food security is a major issue in the area is becoming a problem. The adoption of Climate Smart Agriculture (CSA) would be a sure solution to achieving food security and economic development in the region under a changing climate to improve livelihoods. The smallholder farmers should feature CSA as a solution to resolving many livelihood challenges and make modern agriculture development a priority in achieving food security and earn higher incomes from the sale of surplus farm products.

- **Actions that develop agri-business to boost sale of agricultural outputs**

Most agricultural development plans always focus on supply side intervention, such as improved seed and fertilizers. Many people pay too little attention to the demand side, the place where the increased production will ultimately end or go. The increase will probably produce more farm products which can be sold for the expected economic gains once the subsistence requirements have been met by the local communities and the households. Improved seed, fertilizer and good weather can cause a surge in the production causing the farmers to be unable to sell the surplus.

- **Promote organic livestock farming to eradicate poverty and improve livelihoods**

Organic livestock farming refers to a system of production of livestock products that use biological and natural principles while observing animal welfare principles. Organic livestock farming follows strict certification measures to lock out unscrupulous farmers who may want to benefit from high prices charged for organic products. These measures are meant to ensure that bare minimum standards are met at every step of organic livestock production. The main products of organic livestock farming are eggs, milk and meat. Promote organic livestock farming to eradicate poverty and improve livelihoods.

- **Actions to reduce climate change threats to human health in the study area.**

Risks to human health in the study region will increase in the future due to climate change. Harmful health impacts of climate change are related to increasing heat stress, waterborne diseases, poor air quality, extreme weather events, and diseases transmitted by insects and rodents. Climate change variability influences the prevalence of communicable diseases such as highland malaria, fever, bubonic plague, cholera and tuberculosis. High incidences of malaria are caused by the spread of vectors into the Mt. Elgon region which is warmer than ever before due to climate change.

Acknowledgement: I take their opportunity to thank Professor Daniel Olago and Dr. Lydia Olaka of the Institute of Climate Change and Adaptation (ICCA), University of Nairobi for their invaluable and enormous contributions. I would also like to sincerely appreciate the entire research team which worked enormously hard towards the realization of this dream. Their input enabled me as the chief moderator/investigator to interrogate the history of impacts of climate change and climate variability on livelihoods during the study. Many thanks go to heads of households, heads of departments, the youth and all the stakeholders who made their input during the interviews, focused group discussions and administration of the questionnaires.

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