Analysis of 30 years' historical climate change trends and variability in Mt. Elgon, Kenya, Africa

Sindani Bon Bonzemo[1], Daniel Ochieng' Olago[1], Lydia Atieno Olaka[1], Dorothy Akinyi Amwata[3]

[1]*Department of Earth and Climate Sciences, University of Nairobi, Chiromo Campus P.O. Box 30197-00100, Nairobi Kenya*

[2]*Department of Agricultural Sciences, Southern Eastern Kenya University P.O. Box170 – 90200 Kitui – Kenya*

Corresponding author

Sindani Bon Bonzemo[1],* (Email: sindani.bonzemo@gmail.com)

Abstract

Mountain habitats are critical for identifying the effects of climate change on livelihoods. The study's main goal was the "analysis of 30 years' historical climate change trends and variability in Mt. Elgon, Kenya, Africa." The study employed primary data from KIIs, FGDs, and household questionnaire survey representing community views. The study also employed secondary data from the Kitale Meteorological Station (KMS) for rainfall and temperature from 1986 to 2015. Statistical and descriptive techniques were used to analyse both quantitative and qualitative data. The yearly rainfall trend has typically been growing increasing as evidenced by the positive slope of 9.96, but with a tiny coefficient of determination of 0.28, according to the study of rainfall data. Within time series, MAM trends have been dropping, whilst OND trends have been increasing. However, when these trends were tested for significance using linear regression, the p-values were found to be bigger than the level of confidence, indicating that the increases in trends are not significant (5 percent). According to the study's findings, temperature trends have risen significantly between 1986 and 2015. The temperature trend had a significance of 5%, which is comparable to climate change as a result of global warming. Over 90% of the farmers polled said they had noticed changes in climate patterns as far back as 30 years. As a result, the region's overlapping climate changes include altered precipitation regimes and higher surface temperatures. These findings are crucial for improving adaptive ability and increasing resilience, as well as making informed decisions and planning future livelihood management strategies. This data can also be used to develop appropriate response mechanisms to adapt and mitigate the effects of climate change and variability on livelihoods in the study area.

***Key words*:** Ecosystems, climate change, climate variability, response mechanisms.

1.0 Introduction

Climate change can have serious consequences for people's livelihoods and the natural environment, including ecosystem alterations. Climate change is undeniable, and it has accelerated to unprecedented levels in recent decades and millennia (IPCC, 2014). Any increase in global average temperature exceeding 1.5°C - 2.5°C is anticipated to cause significant changes in ecosystem structure, function, and geographic ranges, severely affecting species distribution and survival. This can have an influence on communities' socio-economic status, stymie progress toward development goals, and pose a general danger to sustainable development in emerging countries with a higher reliance on natural resource-based livelihoods (IPCC, 2007). Climate and non-climatic stresses may have a significant impact on ecosystem processes and ecosystem services when combined (Lovejoy *et al.,* 2005; Amwata *et al.,* 2015).

Mountains have a significant impact on global precipitation and temperature patterns. The increase and fall of rainfall across mountains on the windward and leeward sides creates humid and arid climate regimes, respectively. As a result, people's lifestyles on both sides of the border are very different. The richness of livelihoods on the windward slopes of mountains is owing to the high rainfall, which allows for more agricultural output than on the leeward sides. Such inconsistencies have been reported in Kenya's Mount Elgon region (Olago *et al.,* 2004). Some of the mountains in the world that experience this phenomenon include the Rwenzori Mountains in Uganda (Taylor *et al.,* 2009), the Himalayas (Negi *et al.,* 2009), the Aberdares highlands in Kenya (Kipkoech *et al.,* 2019), Mount Kilimanjaro in Tanzania (Kilungu *et al.,* 2019), the Rocky Mountains in the United States (Wallace *et al.,* 2021; Cuni-Sanchez *et al.,* 2019).

Small-holder subsistence farmers inhabiting mountain regions are among the worst hit by climate change and variability due to their low adaptive capacity and their dependence on rain-fed agriculture which is very sensitive to climate variability (Ifejika, 2010; Easterling, 2011). In Africa, precipitation amounts are likely to decrease for most parts of Sub-Saharan Africa (SSA) while rainfall variability is expected to increase (IPCC, 2014) Ifejika, (2010). Studies by the World Bank (2010) state that Africa is expected to experience mainly negative climate change impacts on livelihoods in terms of an increase in the already high temperatures and a decrease in the largely erratic rainfall in its context of widespread poverty and low development. The negative effects of climate change will be felt most intensely by smallholder farmers in poor countries, according to UNDP (2014), because they are largely reliant on natural systems for growing food and rearing livestock.

The climate in Kenya is already shifting (NCCAP, 2018). While total annual rainfall remains low, the long rains May-April-May (MAM) have gotten shorter and drier, and the short rains October-November-December (OND) have been longer and wetter (NCCAP, 2018). Long rains have been steadily falling in recent decades, and droughts have grown longer, more intense, and more likely to last through rainy seasons (Olago *et al.,* 2015). Floods have come from the increased frequency of rainfall events in East Africa, while severe rainfall and droughts have grown in size over the last three decades. The current trend of rising temperatures in Kenya is projected to continue throughout the year (Olago *et al.*, 2015). According to research, there will be an increase in the number and severity of weather-related disasters, which will exacerbate disputes over natural resources, food poverty, and threaten sustainable development and livelihoods (Olago *et al.*, 2015).

Climate change and unpredictability, including temperature and rainfall regime shifts, have had a negative influence on the Mt. Elgon environment (Rusell *et al.*, 2017). Environmental degradation causes social and economic suffering for those who rely on the environment, as well as increased competition and the risk of conflict over diminishing resources (Rusell *et al.*, 2017). Reduced agricultural production, changes in vegetation composition and structure, rapid deterioration of land cover, and depletion of water quality and quantity due to damage of catchments and subsurface aquifers are some of the impact indicators. Water scarcity will have an impact on agriculture and livestock rearing thus hurting livelihoods in the region. As a result of this reliance, any effects of climate change on the natural ecosystem endanger impoverished people's livelihoods (WRI *et al.*, 2008).

Communities throughout the world have been using genetic diversity and traditional knowledge about native species to adapt to climate variability for generations. This is proving increasingly valuable in the context of climate change adaptation (Hannah *et al.*, 2016). To achieve the study's aims, the following research three questions were formulated by the inter-disciplinary study team: a) What are the patterns in historical climate change data for the period 1986-2015 in Kapsokwony Division, Mt. Elgon Sub-County? b) "Have you ever experienced any change in threats over the last twenty years?" and c) "Have you ever experienced any change in threats over the last twenty years?" "If so, how does it affect your household?" and "If yes, how does it harm your household?" Rainfall and temperature data used in this research covered the period between 1986 and 2015. The study's main or prime goal was the analysis of 30 years of historical data on climate change and community views in Kapsokwony Division, Mt. Elgon Sub-County, Bungoma County, Kenya.

2.0 Materials and methods

2.1 Study site

The Mt. Elgon environment in Kenya is one of the country's major water reservoirs, with abundant land-based resources suitable for agricultural development. The research area is situated on fertile slopes that are directly impacted by human climate change. The research area is about between latitudes 0°47'3N and 0° 52'3N, and longitudes 34° 37'3E and 34° 43'E as indicated in (Figures 1 and 2). (ROK, 2009). The study was place in the twelve sub-locations that make up the Kapsokwony Division in Kenya's Mt. Elgon Sub-County. TThe research area is located on the south eastern slopes of Mt. Elgon and spans 58.4 km^2 with a Population Density of 624 persons (Sq, Km.) according to the population census of 2019 (GoK, 2019). Its isolation is defined by a lack of good roads, adequate schools, hospital, communication, and energy facilities, as well as piped water.. Domesticated animals (donkeys and oxen) are mostly employed for traction and transportation of farm products to market sites outside the region because to the region's weak infrastructure. In recent years, 'BODA BODA' (motor-bikes) have become the primary mode of transportation for people and farm goods.

The research was carried out in Kenya's Bungoma County, in the twelve sub-locations that make up Kapsokwony Division Mt. Elgon Sub-County as indicated on the map in (Figure 2). Chemwesuis, Bugaa, Komtiong', Kapsokwony, Kibuk, Kimobo, Nomorio, Kipyeto, Koshok, Saboncho, Sacha, and Kamuneru are among the twelve sub–locations studied (ROK 2009). To the north and west, the territory is bordered by Mt. Elgon Forest, and it stretches from upland to lowland. It shares borders with Kimilili Sub–County to the south and Kaptama Division to the east.

Agriculture is the primary source of income in the study area (FAO, 2013). The long rainy season, referred to as the MAM, and the short rainy season, referred to as the OND, are the two main growing seasons. Subsistence farming is supported by adequate rainfall during the extended rainy season. Because of its inadequacy, the current conditions during short rains do not sustain farming activities. Maize, beans, potatoes, onions, tomatoes, and green vegetables are the most common crops farmed, while cash crops like as coffee and tea are also grown for profit. Despite the fact that subsistence farming is the primary source of revenue, most households also plant economic trees for domestic use and social – economic profit. Due to uncharacteristically changing weather patterns, dwindling pastureland, and exponential population growth, crop production has decreased and animal productivity has declined in recent years (NCCAP, 2018).

Climate change is already putting a strain on the lives of the poor in the region, harming socio-economic growth and putting food security in jeopardy (FAO, 2013; World Bank, 2015). Data on rainfall and temperature were analysed to see whether there were any historical trends or fluctuation. Farm production is impacted by climate change and fluctuation patterns, resulting in low yields. Even though new seed varieties have recently been introduced, fluctuations in climate patterns have had an impact on food security as a result of low farming and livestock productivity (maize, beans, onions, green vegetables, and Irish potatoes). Poor farm production is characterized by unpredictable rainfall, long dry intervals, soil fertility loss, wind erosion, and a drop in pasture cover.

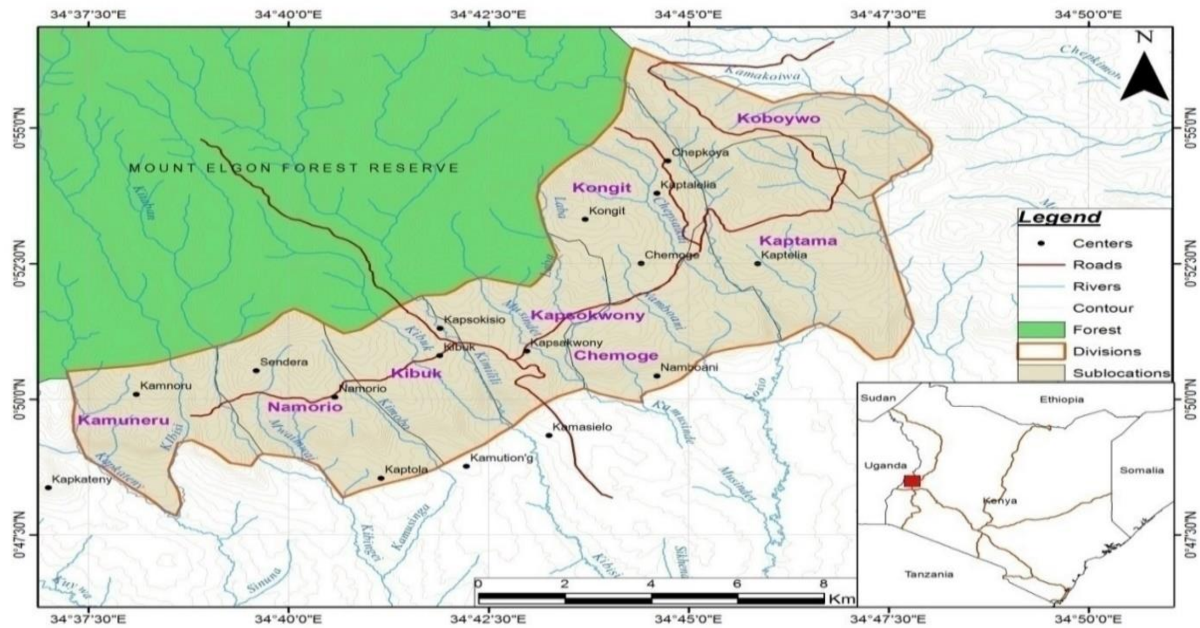

Figure 1: Map of Mt. Elgon region, Kenya showing the study areabetween latitudes (0°47’3N - 0º52’3N and longitudes 34°37’3E - 34º 43’E) (Source: Survey of Kenya)

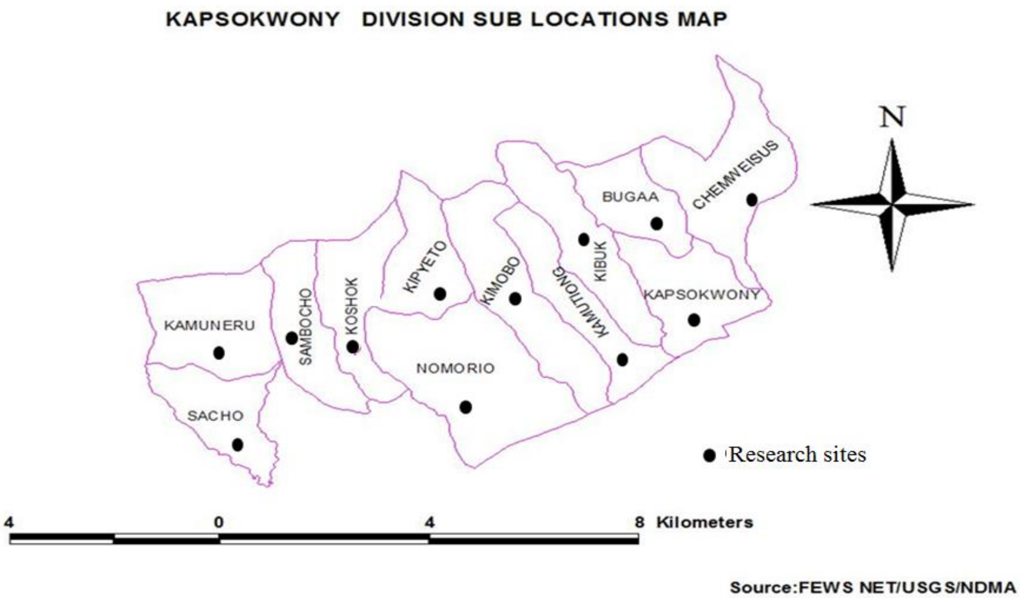

Figure 2: Map of study area showing sub-locations and research sites between latitudes (0°47’3N - 0º52’3N and longitudes 34°37’3E - 34º 43’E) (Source: Survey of Kenya)

3.0 Methodology

3.1 Introduction

During this investigation, both quantitative and qualitative data were gathered. Desk review, six (6) Key Informant and six (6) Key In-depth (KIIs) interviews, three (3) Focus Group Discussions (FGDs), and (398) household questionnaire administration (32) were used to obtain climatic data from each of the twelve (12) sub-locations. The meteorological data from KMS was collected and analysed to validate the changes in precipitation and temperature patterns.

3.2 Data collection

Kitale Meteorological Station provided daily rainfall and temperature data for the years 1986 to 2015. Data collection methods used included House Hold questionnaires (HHs), Focus Group Discussion (FGDs), Key Informant Interviews (KIIs) and farmers weather perceptions were all analysed by use of statistical and graphical methods. Sampling framework included (398) household questionnaires, six (6) Key In-depth Interviews, six (6) Key Informant Interviews, and (3) Focused Group Discussions. While being primarily quantitative in nature, it also included open-ended questions that supplied qualitative data. The goal was to gather information that couldn't be gleaned simply through focus groups or the household questionnaire. To gather information from persons with specific knowledge and experience of climate impacts, key informant interviews were done. Farmers' weather opinions were gathered through household questionnaires, focus group talks, and key informant and in-depth interviews. This data was utilized to supplement the results of the household survey (questionnaires). Participants' interactions sparked new ideas and views regarding climate hazards, such as the frequency and intensity of climate impacts changing over time.

3.3 Data analysis

Both the rainfall and temperature records for the study region from 1986 to 2015 were subjected to statistical and graphical analytical techniques. statistical and graphical analytical techniques The main statistical methods used in the present data analysis included descriptive statistics that was used to summarize data using indexes such as means, median and the inferential statistics that was used in drawing out conclusions from data by using statistical tests such linear regression, student's test and the F-test. The graphical methods applied in the that analysis to reduce random measurement errors included sample size determination, means, standard deviation and linear regression which were analysed using Excel data sheets and presented in histograms, line graphs, tables and charts. The idea was to establish if there was any significance in trends in time series or variability changes in the data settings. For statistical data analysis of climate patterns, the Excel program 2010 and the software version 2.1.0 were utilized. Rainfall and temperature data were analyses to determine historical patterns trends and variability. As a result of the respondents' direct observations and projections, the community's climate views were subjected to descriptive and thematic analysis. The data was then shown as means, frequencies, percentages, charts, and narratives.

4.0 Results

4.1 Rainfall results

4.1.1 Mean monthly rainfall

The station experiences three (3) peaks of rainfall, as seen in Figure 3 in three peaks (tri-modal). The month of April had the most rainfall, with a monthly average of 180 mm, followed by the month of August with 145 mm and the month of October with 130 mm.

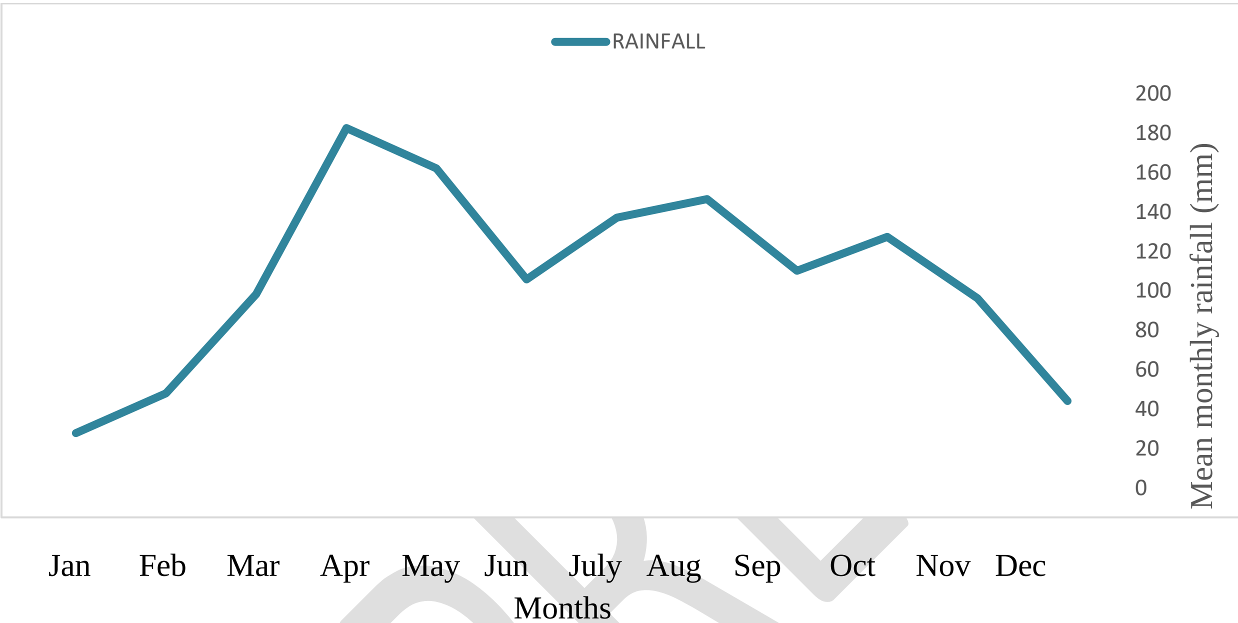

Figure 3: Trimodal rainfall distribution (Source: Figure generated by S. B. using 'Microsoft Excel').

4.1.2 Annual rainfall trends

Figure 4 depicts seasonal and annual rainfall trends. From 1986 to 2015, the rainfall trend has been increasing, but the trends have gotten more erratic. Between 1997 and 1998, there was an upward tendency that was attributed to the *El Nino* phenomenon. From the year 2005 to 2007, an upward trend in amount of mean annual rainfall was recorded while a slight fall was recorded in 2008. Another upward trend was experienced between 2009 and 2010 yet a constant amount of mean annual rainfall was experienced between 2011 and 2012. A drastic drop in rainfall amount was recorded between 2013 and 2015

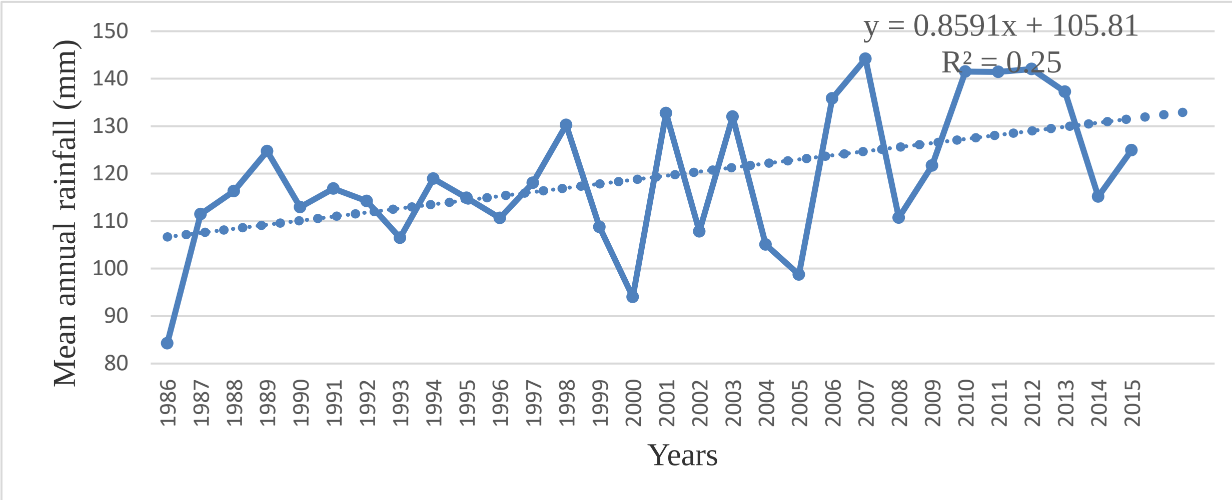

Figure 4: Annual rainfall trends from 1986 - 2015 (Source: Figure generated by S. B. using 'Microsoft Excel').

4.1.3 The MAM rainfall trend

MAM trends from 1986 to 2015 are depicted in Figure 5. The MAM trend displays the annual rainfall in millimeters. The MAM rainfall trend has been steadily increasing, with the highest amount of 750 mm being recorded in 2015. With a positive slope of 9.96 and a weak coefficient of determination (R2) of 0.28, the annual rainfall trend has been increasing. The MAM trend stayed unchanged, whereas the OND trended upward.

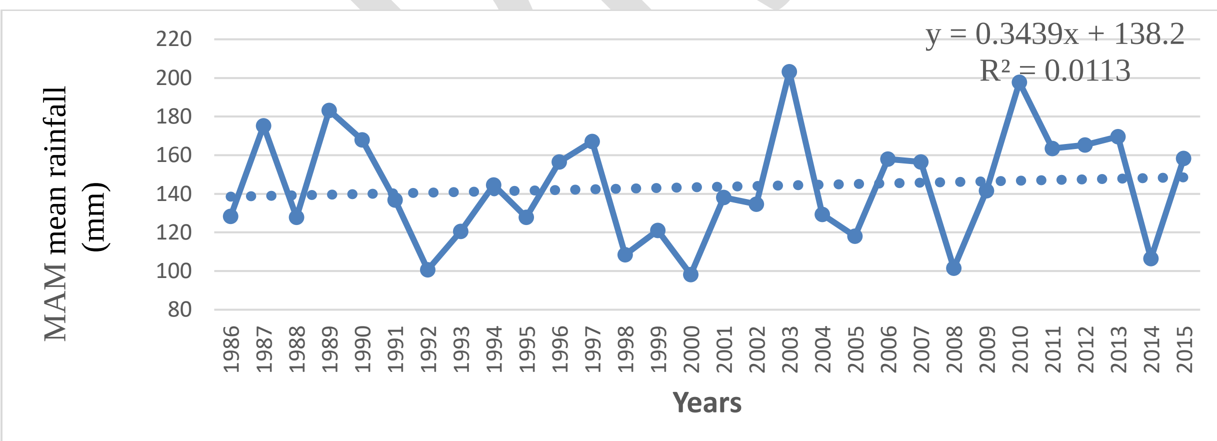

Figure 5: The MAM rainfall trend for 1986 to 2015 period (Source: Figure generated by S. B. using 'Microsoft Excel').

4.1.4 The OND rainfall trends

Figure 6 OND depicts the changing rainfall pattern, with the highest annual rainfall of 450 mm recorded in 2009. With the passage of time, the OND tendency has accelerated. The F-test, however, reveals that the increases in trends are not significant because the p-values were greater than the level of confidence (5%).

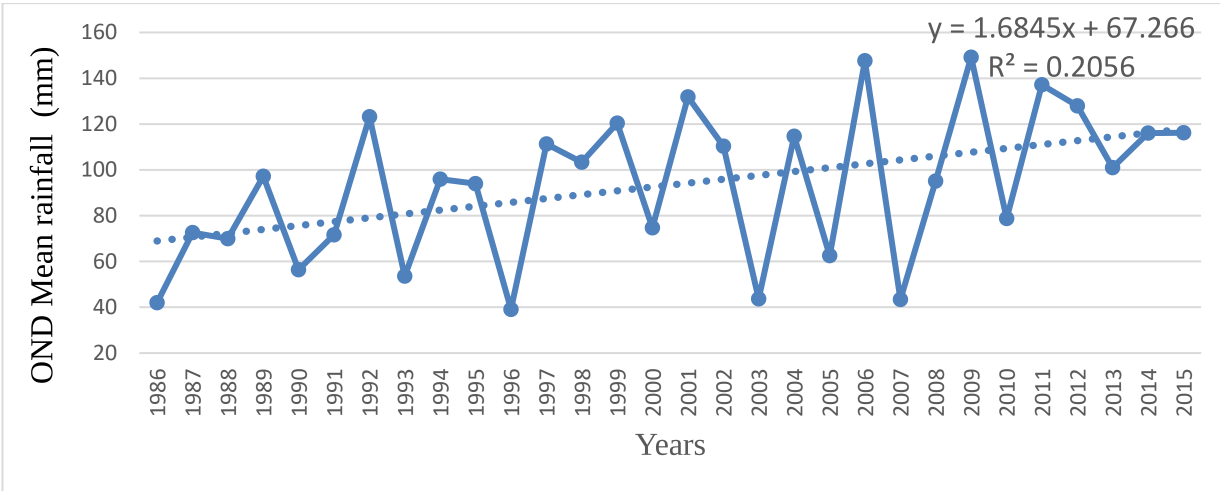

Figure 6: The OND rainfall trends for the 1986 to 2015 period (Source: Figure generated by S. B. using 'Microsoft Excel').

4.1.5 Rainfall variability

As shown by the two means 114.29mm and 101.24mm of the two rainfall data sets in Table 1, yearly mean rainfall fell for the first 15 years and final 15 years. The rainfall in the study area, on the other hand, is less variable, as seen by low standard deviations. The kurtosis and skewness scores are also modest, indicating that rainfall variation is close to average.

Table 1: Statistical analysis of two rainfall data sets of 15 years each for annual series

Variation 1	Annual	Variation 2	Annual
Mean	114.29	Mean	101.24
Standard Error	3.53	Standard Error	2.64
Median	121.25	Median	104.1
Mode	#N/A	Mode	#N/A
Standard Deviation	13.68	Standard Deviation	10.22
Sample Variance	187.08	Sample Variance	104.44
Kurtosis	-0.99	Kurtosis	3.82
Skewness	-0.61	Skewness	-0.99
Range	42.27	Range	47.59
Minimum	88.87	Minimum	73.6
Maximum	131.14	Maximum	121.19
Sum	1714.42	Sum	1518.58
Count	15	Count	15

4.2 *Temperature results*

4.2.1 Temperature trends

Annual temperature trends, MAM temperature trends, and OND temperature trends periodic changes over the 30 years from 1986 to 2015 are depicted in Figures 5 and 6. The highest observed surface temperature of 20°C was reported in 2015. The temperature increase was significant at 5%, which is an analogy for climate change. From 1985 to 2000, significant yearly temperature changes were also seen. Between the years 2000 and 2005, temperatures began to rise, followed by a declining trend. Between 2007 and 2014, both increasing and decreasing trends were observed, with an upward surge in 2015.

4.2.2 Annual mean temperature trends

From 1986 to 2015, yearly mean temperature trends have been increasing, as seen in Figure 7. The highest observed annual mean temperature of around 20°C was recorded in 2008, while the lowest temperature (18.5°C) was recorded in 2001.

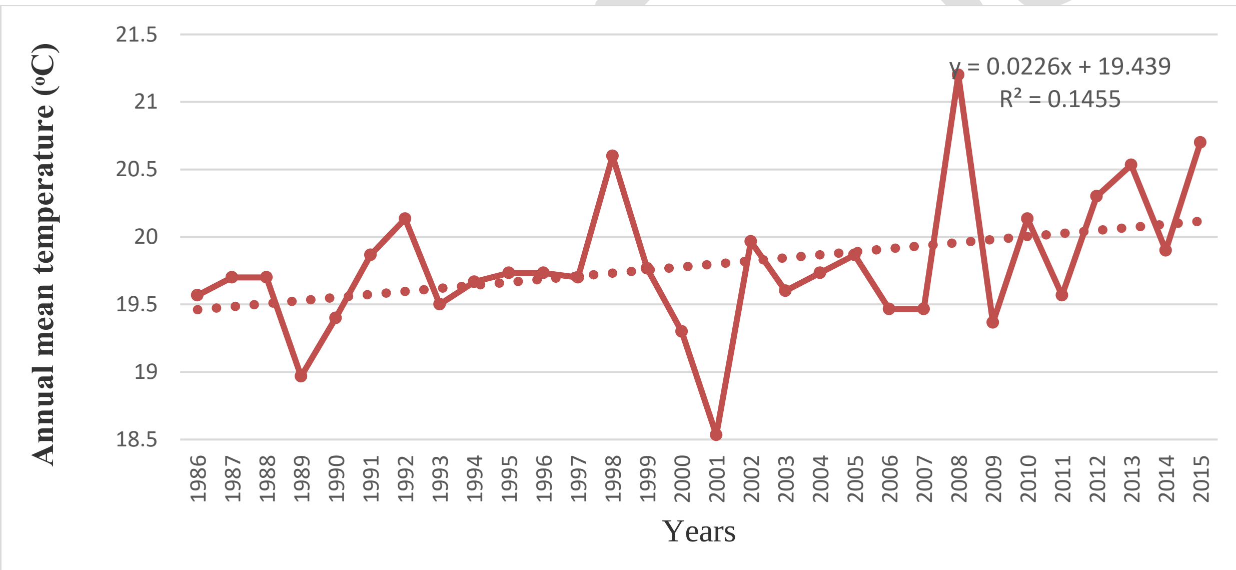

Figure 7: Annual mean temperature trends from 1986 to 2015 (Source: Figure generated by S. B. using 'Microsoft Excel')

4.2.3 MAM mean temperature trends

From 1986 to 2015, the MAM mean temperature (19.45 – 21.25°C) has been rising (19.45 – 21.25°C). The highest recorded mean temperature was (21.25°C) in 2008, and the lowest recorded mean temperature was (18.5°C) in 2001 as shown in Figure 8.

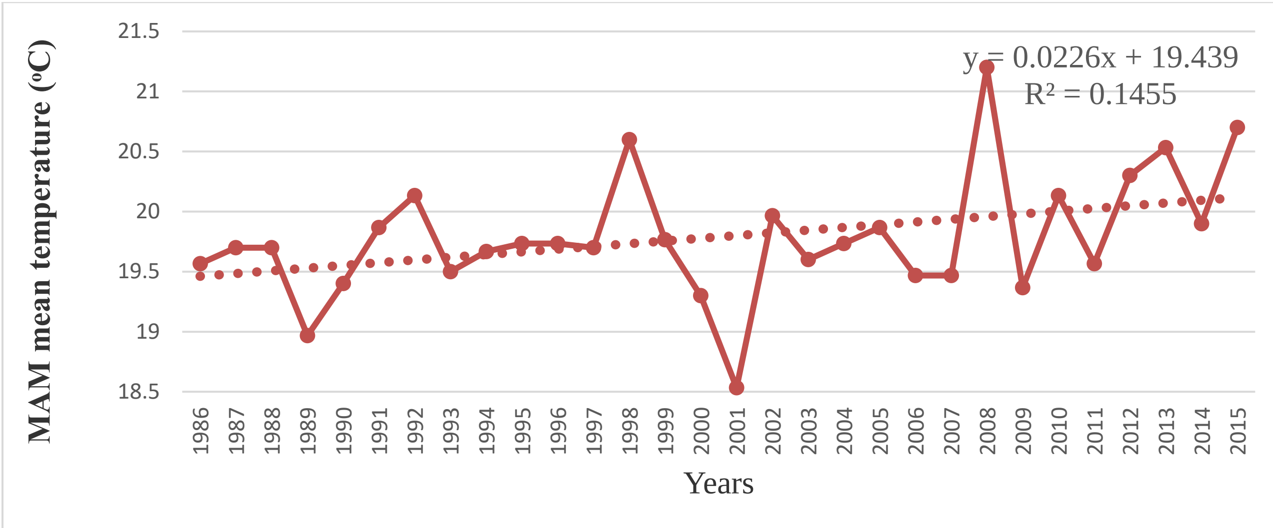

Figure 8: The MAM mean temperature trends from 1986 to 2015 (Source: Figure generated by S. B. using 'Microsoft Excel').

4.2.4 The OND mean temperature trends

Figure 9 depicts OND temperature trends over time (1986 - 2015). The data shows a sharp drop in temperature from 19.3°C to 18.2°C in 2012, before rising to 18.4°C in 2015. The OND mean temperature trend fell sharply to 12.5°C in 2006, most likely as a result of climate change. OND mean temperatures, on the other hand, have been continuously rising from 1985 to 2015.

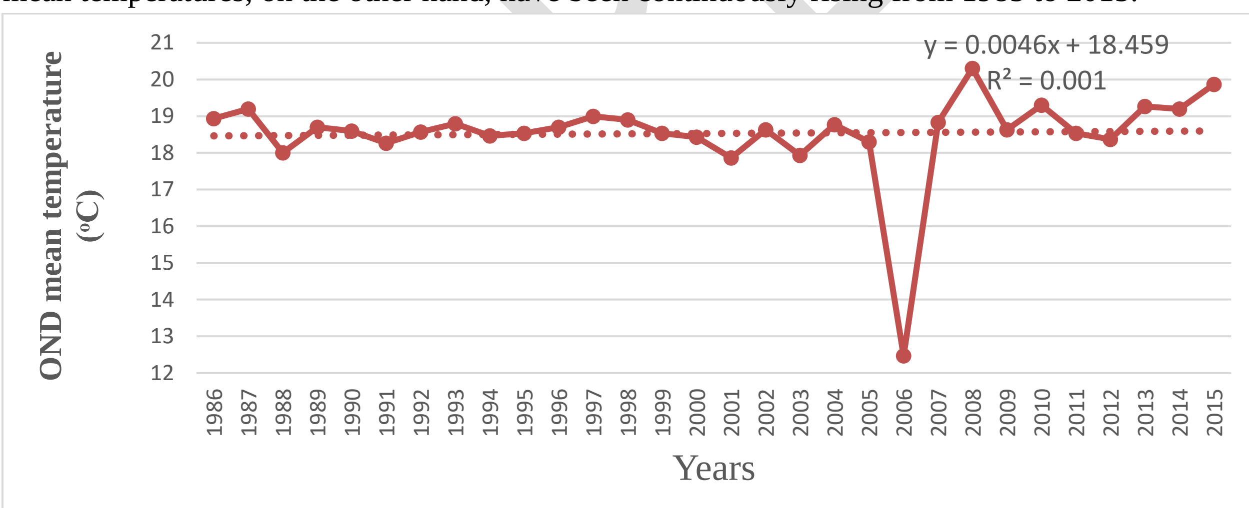

Figure 9: The OND mean temperature trends from 1986 to 2015 (Source: Figure generated by S. B. using 'Microsoft Excel').

4.2.5 Community perceptions of climate trends

Participants in the household questionnaire survey, key informant interviews, in-depth interviews, and focus groups all reported significant changes in the frequency and intensity of climate events. Perceptions of respondents were recorded in a variety of ways. a) "Have you noticed any changes in threats to family members during the previous thirty years?" b) "Have there been any changes in threats against members of your household in the last thirty years?" "How does it affect your household, if so?" "If so, how does it hurt your household?" and "If yes, how does it harm your household?"

According to focus group discussions (FGDs), over 90% of the farmers polled said they had noticed changes in rainfall patterns as far back as thirty years, based on weather records. Farmers often reported a late start to the rainy season, poor distribution throughout the season, and sometimes an early end. As a result, the planting season has moved from early March to late March and early April, with the season ending in June rather than May. Farmers have raised concerns about the fluctuation in the length, timing, and intensity of rains over the last ten years. For example, in the years 2005, 2007, and 2010, rainfall occurred at the beginning of the month of March. Farmers in various portions of the study region, particularly on the slopes, reported an increase in the number of cattle. Generally, participants in FGDs concurred that land surface temperatures had increased remarkably in the past thirty years as compared to past decades.

4.3 Respondents' perception of rainfall

In order to grasp the villagers' views on rainfall variability, a set of climate change questions were included in the household questionnaire. "Have you ever noticed changes in rainfall patterns?" for example, was one of the questions posed to respondents. The question required respondents to either answer 'yes' or 'no.' The majority of respondents (90%) saw changes in rainfall patterns, while 10% didn't (Table 2).

The total number of respondents interviewed ranged from 30 to 60 years old, with agricultural production and animal husbandry as their primary occupations. A total of 352 agricultural smallholder farmers (90%) reported changes in rainfall, while 46 (10%) reported no changes in rainfall. The majority of the respondents believed that changing weather patterns posed a threat to their livelihood activities.

4.4 Respondents' perceptions of temperature

The majority of farmers who filled out home questionnaires (80%) and participated in Focus Group Discussions (100%) believed that the region's temperature has increased significantly over the last three decades (1986–2015). This study looked at historical climate change data from Kenya's Mt. Elgon region to see if there were any trends, variability, or community perspectives. For the years 1986 to 2015, the Kitale Meteorological Station supplied data on rainfall and temperature (KMS). Quantitative and qualitative climatic data were evaluated using SPSS and descriptive techniques for trends and variability in order to develop climate change scenarios in the research area. The community's climate views were analyzed using descriptive and thematic analysis as a result of respondents' direct observations and projections.

5.0 Discussion

5.1 Climate trends

In the Mt. Elgon Region of Kenya, this study looked at historical climate change data for trends, variability, and community views. Kitale Meteorological Station provided rainfall and temperature data for the years 1986 to 2015 (KMS). To generate climate change scenarios in the research area, both quantitative and qualitative climate data were analysed using the Statistical Package for Social Scientists (SPSS) and descriptive techniques for trends and variability. As a result of the respondents' direct observations and projections, the community's climate views were subjected to descriptive and thematic analysis.

According to the results of a statistical analysis of rainfall data from 1986 to 2015, the research area has a tri-modal seasonal rainfall pattern, with long rains beginning in the month of March and ending in April or May. The brief rains peak in July and August, and then taper down in September. In November, the third high appears, followed by a decline in December (Figure 3). Surface air masses from the Equatorial Congo rain forest, Mt. Elgon Forest, and its vicinity to Lakes Victoria, Turkana, Albert, and Kyoga influence the research region, resulting in tri-modal rain patterns. Despite the fact that the research area receives sufficient and acceptable rainfall to support agriculture, the study discovered significant disparities in rainfall distribution on a yearly and seasonal scale (Kansiime, 2010).

The conclusions of climate data time series data analysis revealed an increase in annual and seasonal series rainfall. On a seasonal basis, the rainfall trend in May, April, and May (MAM) has been decreasing, whereas the rainfall trend in October, November, and December (OND) has been growing (Figures 4 and 5). The findings of this study show considerable increases in rainfall and tendencies that resemble climate change. However, because the p-value for the station was more than 0.05, any rise or decrease in rainfall trends was statistically insignificant. Seasonally and annually, rainfall distribution is uniform to moderate. The erratic distribution of rainfall throughout the OND season was highlighted by a number of years with percentages of 6.7 percent.

As indicated in Table 1, seasonal rainfall variability is greater than yearly rainfall variability. The annual rainfall mean was much higher in 1997/98, a finding ascribed to the *El Nino* event. The Government of Uganda (2007) validates these findings, exhibiting increasing inter-annual rainfall patterns, decreasing March-April-May (MAM) rainfall trends, and increasing October-November-December (OND) rainfall trends. Maximum, minimum, and mean seasonal and mean annual rainfall data were analyzed to determine skewness, kurtosis, coefficient of variation, and standard deviation as well as trend reliability. The study results also indicated that there was high rainfall variability within seasons and perceived rain patterns, as well as observed decreasing yearly rainfall. The research area's mountain slopes and diverse topography have a major and negative impact on the local climate. The observed rain data had a lot of variability within seasons, according to the data analysis.

This is consistent with certain studies on Kenya's increasing tendency in spatiotemporal rainfall distribution (Camberlin and Philipon, 2002; Funk *et al.,* 2010). A number of additional studies have found that the long rains (MAM) are decreasing, which may be due to land-use change in and surrounding East Africa (EA). Large land surface disturbances, such as replacing current land cover with an estimate of zero anthropogenic influence (Chase *et al.,* 2000) or replacing twenty-first-century expansions in crop or pasture land with an estimate of zero anthropogenic influence (Hagos *et al.,* 2014).

Several other similar studies (Camberlin and Philipon, 2002; Funk *et al.,* 2010) undertaken in mountain regions around the world concur with the findings of this study, indicating rising rainfall patterns and unpredictability. Long rains (MAM) have decreased in the East African region, but short rains (OND) have increased (Lyon and Debitt, 2012; Viste *et al.,* 2013; Liebmann *et al.,* 2014), according to other renowned experts (Lyon and Debitt, 2012; Viste *et al.,* 2013; Liebmann *et al.,* 2014). This has led in terrible drought effects, which have resulted in low agricultural productivity, starvation, and increased poverty for millions of people in the region. Arragaw *et al.*, (2017) did a recent study in Ethiopia's central highlands (which is quite similar to our study location) and found that yearly and June–September rainfall were statistically inconsequential.

The region has undergone significant temperature rise in the last three decades (1986 – 2015), according to a trend analysis of temperature data (Figure 7). Both the MAM and OND temperature trends have been increasing throughout the study period 1986 – 2015 (Figures 8 and 9). Evaporation increases when air temperatures rise, contributing to dry conditions, especially when precipitation falls. Drought is projected to become more prevalent in some areas in the study area, posing a threat to food and livestock production. By 2085, temperature forecasts suggest a significant increase in the mean annual temperature of 1.3^{o}C –4.5^{o}C warming in the cooler season (June–September) of 91.7^{o}C – 2.9^{o}C under RCP 4.5^{o}C and 4.9^{o}C under RCP 8.5^{o}C. This will most certainly have a detrimental influence on the water resource sector, resulting in food insecurity and, as a result, a loss of livelihood according to studies in the Lake Basin by Olaka *et al.*, 2019 on anticipated Climatic and Hydrologic Changes to Lake Victoria Basin Rivers under Three RCP Emission Scenarios for 2015-2100.

In Nepal's rural and inaccessible mountainous Jumla District, similar observations of rising temperature trends were made. Warming temperatures are already having an impact in the research area. These findings are in line with prior studies on temperature variability trend anomalies by King'uyu *et al.*, (2000), Anyah and Semazzi (2006). In the Horn of Africa, studies by Omondi *et al.*, (2013) found an overall increase in warm temperatures, particularly at night, while cold extremes are decreasing. Temperatures in the region have risen significantly in the last three decades, according to linear trend analysis. Confronted with urgent development needs, and in response to proximate risks associated with a variable and changing climate, decision-makers in Africa must be guided by currently available climate information to make informed choices, whilst acknowledging that information availability, relevance and usability will always evolve (Chandni *et al.*, 2018).

5.2 Community's climate perceptions

Over 90% of farmers between the ages of 45 and 65 had seen changes in rainfall patterns as early as 30 years ago. According to Rowel *et al.*, (2015), East Africa has lately undergone a succession of disastrous droughts, but models indicate higher rainfall in the next decades, posing questions about possible adaptation alternatives. They speculate that the expected trend is a result of both natural and manmade factors. Both hypotheses have had an impact on tropical Sea Surface Temperature (SST) trends, the Inter-Tropical Convergence Zone (ITCZ), *El Nino*, and Monsoon features, which are thought to be the cause of recent droughts. It is envisaged that research priorities will be more concentrated in order to give a process-based expert judgment of the climate reliability of East African forecasts, resulting in a better knowledge of projected variability. The community's view of rainfall sufficiency matched observational data, with respondents acknowledging late and early rainfall onset, mid-season droughts, and early cessations. Floods, droughts, and landslides are all reported to be on the rise as a result of climate change. Several other similar studies (Camberlin and Philipon, 2002; Funk *et al.*, 2010) undertaken in mountain regions around the world concur with the findings of this study, indicating rising rainfall patterns and unpredictability. According to trend research, the region has seen a considerable temperature rise of 1.0°C.

Farmers' perceptions of climate fluctuation are consistent with climatic data indicating season timing and distribution. This is a typical finding in other studies of resource users' perceptions of climate change, such as in Ethiopia's Nile basin (Deressa *et al.,* 2008), where farmers reported increasing variability in rainfall and shifts in growing seasons. The growing season is claimed to be shortening, and rainfall distribution has an impact on agricultural households' decisions about what crops to cultivate and how to manage their property (Komutunga and Musiitwa 2001).

However, farmers' perceptions of rainfall were not a good basis for making educated decisions about when to prepare fields and when to plant due to a lack of relevant information. Other notable scholars have predicted that an area's agricultural potential can be completely fulfilled by focusing on seasonal rainfall reliability rather than yearly rainfall reliability (King'uyu *et al.,* 2000; NMA 2007; Belay *et al.,* 2014). This shown that concentrating solely on yearly or seasonal trends might be misleading and should be accompanied by variability analysis and farmer perspective. Furthermore, combining a variety of methodologies rather than relying on a single method to detect variability and trend in meteorological variables allows us to get a clearer view of the situation. Incorporating farmer experience into trend analysis discourse could also provide crucial insights into the nature of meteorological processes that cannot be captured just through the examination of recorded data.

Appropriate, enabling frameworks, including proposed robust policies, integrated technology, and financial incentives, are required and can be implemented to improve people's adaptive ability and resilience in the research area. Adoption of climate change technologies will be aided by increased access to climate data and increased awareness. The promotion of climate awareness and the dissemination of climate information should be given high importance through effective demonstration projects conducted by experienced or knowledgeable individuals in diverse professions. As a result, additional adaption alternatives are still needed to supplement the present ones.

6.0 Conclusions

The current study looked at historical climate data for trends and variability, as well as villagers' perceptions, from 1986 to 2015. Significant differences in rainfall and temperature trends and variability were discovered, which were most likely due to an increase in annual rainfall extremes and a rise in surface mean temperatures, influencing climatic patterns. According to trend study, the region has experienced significant irregularity in rainfall patterns and a spike in temperature during the last three decades. From 1986 to 2015, the current study examined historical climate data for trends and variability, as well as villagers' impressions. The analysis indicated significant differences in rainfall and temperature trends and variability which was likely attributable to an increase in extremes of rainfall on the annual scale and an increase in surface mean temperatures therefore changing climate patterns. In the last three decades, the region has seen significant irregularity in rainfall patterns and a rise in temperature, according to trend research.

This study's findings have the following implications: Significant trends and variability in rainfall have an impact on crop production (maize, beans, potatoes, and onions), with total crop failure occurring in extreme circumstances due to extended droughts or when floods wash away the crops. Farmers' educated farming decisions are highly influenced by a rise in the magnitude of annual rainfall, a decrease in MAM rains, and an increase in the OND rainfall pattern. Because of diminishing pastureland, protracted drought, and increased cattle diseases, as well as human exponential population growth, livestock farming has a grim future. This could result in a large reduction in the economy in the region as a result of lost opportunities for farmers to earn a substantial income. If achieved, the wasted opportunity would inject cash into the veins of the rural economy, resulting in rural economic rebirth. Though livestock husbandry is a viable option for food security, it requires an economic recovery to alleviate poverty and enhance livelihoods in the region.

Planting fast-ripening crops and establishing early warning systems based on the combination of indigenous (experiential) knowledge and meteorological data should all be part of adapting to changing climate trends and variability. The way forward is for vulnerable populations in the region to improve household preparedness in order to plan and manage climate change trends and variability-induced hazards. Because high elevation experiences rarefied air, low or decreased pressure, decreased temperatures, and enhanced insolation, individuals who live in mountain regions should prepare for intensified consequences of climate change on livelihoods. Increased awareness will aid people in mountainous areas in mitigating and adapting to the effects of climate change, reducing the likelihood of more extreme weather. This can be accomplished by promoting conservation agriculture, implementing weather-indexed crop insurance schemes, supporting community-based adaptation, such as providing farmers with climate information, and providing more financial and technical assistance. Climate change impacts on livelihoods in the study region can be mitigated by raising animals that are tolerant of local climatic conditions, establishing fodder banks, providing water, and putting in place early warning systems.

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Data Availability Statement

"The datasets generated during and/or analysed during the current study are not publicly available due to *[because it could be compromised or replicated]* but are available from the corresponding author on reasonable request."

Conflict of interests

The authors have no relevant conflict of interests as regards to financial or non-financial interests to disclose in so far as the production of this manuscript is concerned. This is because the authors did not receive support from any organization for the submitted work. No funding was received to assist with the preparation of this manuscript. *The authors declare that no funds, grants, or other support were received during the preparation of this manuscript."*

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