ANALYSIS OF HISTORICAL MONTHLY AND ANNUAL RAINFALL AND TEMPERATURE VARIABILITY (1980–2020) IN BARINGO COUNY COUNTY, KENYA

ABSTRACT.

Climate variability entails the mean fluctuations in climatic elements and other observable characteristics on temporal or spatial scales. Assessing climate variability is a frequent practice in climatology based on its impact on social - economic aspects. Climate is subject to variations in many parts of world, exhibited mainly by rainfall and temperature fluctuations. The variability in Africa has resulted in the spread of desert conditions in the Sahel. Kenya experiences great variations of climate annually and considerable uncertainty when rains are expected, impacting negatively on farming activities. The study objective was to; establish the historical trends of variability patterns in rainfall and temperature in Baringo County between 1980 – 2020. The study adopted a longitudinal study design as it involved a time series analysis of the trends and variability patterns of rainfall and temperature. Secondary data on rainfall and temperature was collected from Kenya Meteorological Services headquarters in Nairobi. Rainfall variability was determined and measured using the following techniques; Mean ($\bar{X}$), Standard deviation (SD), Precipitation concentration index (PCI), Relative variability (RV) Drought Intensity (DI) and Coefficient of variability (CV).Temperature variability was determined and measured by analyzing the County temperature distribution tables. Results indicated Baringo South to have a higher variability than Baringo North, marked with its higher CV, DI, RV and PCI. Pre-drought planning to cope up or overcome the droughts were highly recommended and measures provided. The study findings are expected to help farmers, the government, and economic planners to focus on effective mitigation areas, formulate alternative policies on mitigating the effect of rainfall and temperature variability on activities of farming in Baringo County.

Key words;

Variability, climate, trends, drought intensity, coefficient of variability, precipitation concentration index, relative variability, Mean and standard deviation,

Acronyms and abbreviations

1. LTM …….. Long Term Mean 2. UNEP…… United Nations Environmental Program

3. IPCC ………Inter governmental panel on climate change 4. IIED….International institution for environment and Development.

UNDER PEER REVIEW

INTRODUCTION

1.1 Background to the Study

1.1.1 Intrduction

According to UNFCC (2019) climate variability entails the fluctuations or divergence from the state of the mean and other characteristics of the elements of climate including precipitation, temperature, humidity, and atmospheric pressure in terms of standard deviation, streams occurrence, on spatial and temporal scales far from those of individual events. Shisanya et al., (2014) asserts that, changes in climate refers to any climatic changes caused by either natural or anthropogenic forces over time. These changes are long term when compared to climate variability, typically over a decade or more.

Precipitation, particularly rainfall and temperature are in most occasions the major determinant input factors of climatology (Wenner, 2012). These inputs are subjected to undue pressure of uncertainty resulting from fluctuations (variability), errors of measurement and systems in the interpolation techniques, as a result of rainfall and temperatures' random nature (Barrow, 2003). Variability in climate elements and in particular, temperature and rainfall impact negatively on crop and livestock production. This problem is more serious in marginal and ASAL areas. The ASALs of Kenya such as, Lodwar, Garisa, kajiado, Samburu, Machakos and Baringo are the most affected with continued effects on vegetation and consequently crop production.

1.1.2 The Occurance and effects of Global Climate Variability and Uncertainty

Variability and uncertainty in rainfall has been evidenced in many areas of the globe, as a result of fluctuations and changing weather patterns (Medung, 2009). Variability of rainfall and temperature is a global problem disrupting farming activities in most parts of the world. In Australia, climate variability has had adverse effects on the eastern region of the country resulting in expansion of the country's arid or desert conditions (Nicholls et al., 1977). The semi-desert regions of Brazil currently suffering from drought, previously experienced rain between October and July annually. Today, this region experiences unpredictable rainfall with disappearing streams and drastically reduced water available for agricultural activities (Ribot et. al, 2006). Average daily maximum temperatures vary from season to season and have shown a rising trend over the past three decades (Bevan, 2002). Jose (2007) posits that weather and climate variability has caused irregular and uncertainty patterns of rainfall in many parts of the world.

The extreme variations in rainfall patterns and amounts have been witnessed in many parts of Africa (Ojany and Ogendo, 1993). Several studies have been conducted on the African climate, and in particular, rainfall and temperature variability. The results of studies such as Ouachani et al., (2013), Fonseca et al., (2015 and Owusu (2017) on African climate, agree on the fact that, African climate is characterized by considerable variability patterns in both precipitation and temperature. This is evidenced by decreased annual average rainfall since 1968 and extremely severe droughts occurring in the Sahel regions across West Africa. Climate variability in many parts of Africa, has been characterized with unpredictable onsets and cessations of rainfall, accompanied by prolonged droughts that have contributed to extension of Sahara desert conditions, encroachment by humans and destruction of the extensive savannah grasslands in recent times (Ngaira 1999).

UNDER PEER REVIEW

The effects of climate variability in Kenya, have attracted a number of studies. A study by Gichuki (1991) found that, the ASALs in Kenya experience a major prolonged drought after every five-year period escalating wide spread poverty, food insecurity, and intensive irreversible reduced crop yields and sizes of herds. The adverse effects brought about by variability in rainfall and changes in climate impacting negatively on farming activities, range from pronounced unpredictable patterns and fluctuations in rainfall and temperatures to severe and recurrent prolonged droughts. Ngaira (1999) posits that the 1991 – 1992, prolonged droughts had serious negative effects on social and economic aspects in many parts of Kenya.

1.1.3 The Historical Time Series Climate Variability Patterns and Trends

A number of studies have been conducted on the historical time series data to determine variability patterns and trends at global, regional/continental, national and local levels. World Meteorology Organization (2000) reports that between 1912 – 2000, there was a decline in global annual rainfall and extreme drought occurrence cycle between 1940 – 1960 in Argentina. An increase of 5% in annual rainfall with concentrations over the oceans and a decline in the dry lands was reported in the tropics by a NASA Space Flight Centre (2007). In Japan, a study by Yeu and Hashino (2003) analyzed the monthly and annual long term rainfall trends. Results indicated high monthly and annual rainfall variability in rainfall totals with a big decline in December by 6.7%. In India, changes in rainfall intensity was reported in a study conducted by Raisanen (2005).

In Africa a study conducted by Zinyowera and Unganai (2003), posited that SADC countries witnessed the worst prolonged droughts in recent times with a seasonal deficit of 80% between 1980 and 1992. Nicholson (2000) established a general annual rainfall reduction trend throughout Africa between 1950's and 1980's. Jose (2007) posits that changing climate has triggered off irregular and unreliable rainfall and temperature patterns in the African tropical regions. Ngongondo (2005) examined long term rainfall variability trends in Malawi and established significant rainfall departures from the annual mean of rainfall between 1960 and 2002 recording a C.V of 0.3.(30%)

The above studies have highlighted climate variability trends and its impact on the environment in general, in selected regions of the globe. There is need to focus on a smaller geographical area for more accurate results. The current study focusses on a smaller area, Baringo County in Kenya. This brings out more accurate results as compared to generalized information that may not be quite representative for some parts within the wider region. The study focusses on historical analysis of rainfall and temperature patterns and trends as they are the main elements of climate that determine crop and livestock productivity.

Both analysis of rainfall trends and variability in Kenya have been documented. Ngaira (1999) used a time series technique of data analysis to assess the trends, patterns and variability of rainfall in the then Baringo District between 1968 and 1996, which is currently Baringo County and the current study area. The results revealed a declining rainfall trend of 20% - 24% characterized by acute long term fluctuations, indicating high variability of rainfall in Baringo. The study did not incorporate the temperature element which is an important climate element. This provided a gap that the current study sought to address.

UNDER PEER REVIEW

Muriithi, et. al., (2017) also carried out a time series study of Baringo to determine the trend and variability of rainfall between 1974 and 2003. The study recorded an areal precipitation maximum of 1150 mm in 1978 and a minimum of 340 mm in 1984. The study also indicated a reducing precipitation amounts throughout the period time. Standard deviation (SD) analysis was used to determine and quantify the dispersion amounts or variations in the mean of the data set and the areal amounts of precipitation. They showed 763 mm - 178 mm, n = 30. This implies that the Standard Deviation was extremely high, in relation to the mean rainfall amounts. This clearly indicates a high rainfall variability in the county over the period of study. A decreasing average rainfall trend of the annual total was experienced in the study area. The study indicated that Baringo has been experiencing an acute rainfall variability over the study period between 1974 and 2003. Like Ngaira, Murithi also failed to integrate temperature in his study, which the current study also sought to address.

Koskei et. al., (2017) assessed the actual trends of rainfall and spatial variability by ecological zones in Baringo between 1981 and 2009. The study results indicated rainfall trends in both lowland and highland areas of Baringo County that were highly variable. Nginyang station in the lowland areas of the County revealed that trends were increasing over the study period. The highest negative decreasing trends were 1983, 1984, 1991 and 1993. The highest positive increasing trends were in 1998, 2003, 2004, 2005 and 2006. The Relative Variability for Chemusus was recorded as 34.6% and the Coefficient of Variability was recorded as 36.2%. These trends and data depicted the lowlands to experience the highest variability in Baringo County. Chemusus

Station in the highlands depicted a decreased amount in rainfall over the study period. 2007 depicted the highest decreasing trend. A decreased amount in rainfall was observed. The latest study on trends in Baringo by Ezenwa falls between 1985 – 2015. This provided a gap of seven years that the current study intended to fill. Seven years is adequate enough to determine climate change.

1.2 Statement of the Problem

Baringo County receives erratic and unpredictable patterns of rainfall, below 500 mm annually. The rainfall is characterized and associated with uncertainty and acute fluctuating distributions spread from year to year. Studies conducted to determine climate variability trends in Baringo have not incorporated the temperature element. Most studies have dwelt on rainfall variability providing a gap that the current study sought to address. The current study focusses on both rainfall and temperature. The variability trends in existing studies go up to the year 2015. The current study covers the period 2018-2020. Analysis of rainfall data provided, reveal an occurrence of drought in 4 out of 10 years causing massive damage to farm crops and livestock. Droughts disrupt planned farming calendars and activities; and therefore lead to reduced crop and livestock productivity. Droughts are responsible for low harvests, failure of crops, and livestock deaths especially in arid and semi-arid areas like the Southern parts of Baringo County and many small holder farmers lack resources and the technical knowledge to counter these problems.

1.3 Justification of the Study

Farming activities rely on rainfall. Erratic, unreliable, and unpredictable rainfall will inhibit the development of these activities. A clear understanding of historical patterns and trends in the study will help farmers to plan for effective

UNDER PEER REVIEW

strategies and to make decisions on the best type of coping strategies to apply in various instances so as to improve on their productivity. The findings also aim at helping the farmers, government, policy decision makers, and economic strategic planners to focus and formulate alternative policies on ways of mitigating climate variability effects on farming practices in Baringo. The study also forms the basis for further research aimed at improvement of the living standards of the inhabitants of the ASALs of Kenya.

1.4 The objective of the study

The objective of the study was to establish the historical trends and variability patterns of rainfall and temperature in Baringo County between 1980 – 2020

1.5 The study Research Question

The current study was guided using the following Research Question**;** What trends and patterns have the monthly and annual historical rainfall and temperature taken between 1980 – 2020 in Baringo County?

1.7 The Significance of the Study

The effect of rainfall variability on crop and livestock farming have had major economic implications leading to food insecurity and increased poverty rate. The results of the current study are expected to contribute to initiatives aimed at enhancing food productivity. The initiatives will benefit both farmers, government and economic planners to focus on effective mitigation areas on the effects of climate variability on farming activities in Baringo County.

LITERATURE REVIEW

2.0 Climate Variability and Trends

2.1 The Concept and Factors influencing Climate Variability patterns and Trends

One of the main climate variability pattern is the El Niño Southern Oscillation (ENSO) in the Pacific Ocean. (Larkin and Harrison, 2002). It is characterized by periodic fluctuations in the sea surface temperature (SST) which trigger periodic spells of abnormal rainfall and floods and alternating droughts (Lanina) causing disasters (Vicente-Serrano et al., 2011). Pacific Decadal Oscillation (PDO) is another key driver of climate variability (Grimm et al., 2000). It is a pattern that is occasionally exhibited by the Pacific surface waters north of 20°N, that shifts at interval timescales between warm and cool phases triggering variability in rainfall and temperatures (Mantua et al., 1997; Hare et al., 2010). Its influence is increasingly evident in South America (Hare, 2010).

2.2 The effect of Climate Variability

The State of California in the USA, Middle East countries, Southern Brazil, and Australia are among many countries mainly affected by climate variability (Fraser et al.,1999). Climate variability has affected the region of Australia extending to the Australian desert (Nicholson, 2017). Ribot et al.,(2006) reports that the Brazilian semi-desert region which used to receive heavy equatorial rainfall from October to July annually, currently suffers from, unpredictable and erratic rainfall, droughts, disappearing streams and drastically reduced available water for agriculture.

PREVIEW

Rainfall variability has led to expansion of the Sahara desert and encroachment of savannah and steppes lands (Ngaira, 1999). Rainfall variability has been common in many regions of Africa including the Sahel South of Sahara, West, East and Central Africa. Many countries of the Sahelian region of Africa such as Burkina Faso, Mali and Sudan are today affected by prolonged droughts adversely affecting crop yields (Ominde and Juma,

Kenya's rainfall is characterized by variability in the annual total and considerable uncertainty in the time of the year the rains are expected (Ngaira,1999). This is mainly witnessed in marginal areas like Garisa, Mandera, Magadi, Kajiado, Samburu and Machakos which are semi arid (Ojany and Ogendo,1973). A study conducted by Ovuka (2016) analyzed rainfall trends of the Central highlands of Kenya.

2.3 Trends and Patterns of Rainfall and Temperature

Trends and patterns of rainfall and temperature have been documented in many parts of the world. According to Cruz et al,. (2007) decreasing and increasing annual rainfall and temperature trends and their fluctuations have been observed in many parts of the world and are key in examining rainfall variability. World Meteorology Organization (2000) reports that between 1921 – 2000, there was a decline in global annual rainfall and extreme drought occurrence cycle between 1940 – 1960 in Argentina. An increase of 5% in annual rainfall with concentrations over the oceans and a decline in the dry lands was reported in the tropics by a NASA Space Flight Centre (2007). A study by Brown (2005) reported very low rainfall throughout spring and summer in Europe in 2003. Analysis of rainfall trends in India between 1971 – 2003 by Dash et al., (2007) revealed a declining trend of rainfall in the summers of the monsoon and increased trends before and after monsoon months. A time series analysis of monthly rainfall totals by Domonkos (2003) was carried out in Hungary between 1971 – 1980. Findings revealed a decrease of 15% - 22% in annual total rainfall.

The African continent is highly vulnerable to variability in climate, and hence subject to frequent droughts and resultant famine (Ogalo, 2010). Nicholson (2000) established a general annual rainfall reduction trend throughout Africa between 1950's and 1980's. Jose (2007) posits that changing climate has triggered off irregular and unreliable rainfall and temperature patterns in the African tropical regions. Ngongondo (2005) examined long term rainfall variability trends in Malawi and established significant rainfall departures from the annual mean of rainfall between 1960 and 2002 recording a (CV) of 0.3. Gribbin (2011)'s study revealed persistent droughts in the Sahara's hot and dry region of Africa in the part of the early 1970's which caused declining harvests in agriculture in the neighboring Sahelian territorial lands. Wenner (2012) asserts that climate variability is a highly pressing challenge of the environment as most global regions are subjected to fluctuations in rainfall and temperature resulting in climate variability and uncertainty. This is brought about by the impact of man on the environment. The Sahara desert expansion and subsequent encroachment of the African savannahs and the Steppes lands of Russia in recent times have been attributed to rainfall and temperature variability patterns and trends (Schrek., and semazzi.,2004). Solomon (2015) observes that the entire African continent has experienced remarkable erratic Patterns and fluctuations of rainfall and temperature over several decades Like the global studies, these studies in Africa produce generalized results necessitating more specific and representative studies in smaller geographical areas.

UNDERTAKEN

Kenya's rainfall and temperatures are subject to variability in the annual totals and characterized by considerable fluctuations and significant uncertainties when onsets and offsets of rainfall are expected in the year (Ngaira, 1999). These variability patterns and uncertainty are dominant in the ASAL areas of the North, North Eastern, Southern, Eastern, South Eastern and North Rift areas of Kenya, comprising of Garisa, Mandera, Suguta plains, Magadi, Machakos, and Baringo among others (Frich et al., 2012). According to Baringo County integrated Development plan (2018 - 2022), the study area, Baringo County, is found in a semi-arid environment that receives 400 mm - 1000 mm of rainfall annually and experiences negative rainfall variability. Rainfall varies with altitude. The lower parts of the county comprising of Mogotio, Tiaty and Baringo South Sub-Counties receive relatively low amounts of less than 500mm per annum. The rains are erratic and unpredictable. Abnormal patterns are experienced with a fluctuating distribution of rainfall and temperature over the years. These rainfall totals vary from 1,000 mm to 1,500 mm in the highlands. The temperatures also vary ranging from 10°c to 35°c. As a result of varying altitudes, the Baringo sub-counties receive varying amounts of rainfall. Normally, the rainfall pattern assumes a double maximum with long rains from March to July and short rains from late September to early parts of November. Understanding the climate of the study area provides a basis for analyzing trends and patterns of rainfall and temperature in the area.

Using time series technique, Ngaira (1999) conducted a study to determine rainfall variability patterns and trends in the then Baringo District between 1968 and 1996. The results revealed a declining rainfall trend of 20% - 24% with fluctuations, indicating high variability of rainfall in Baringo. The element of temperature was not integrated in the study. Muriithi, et al., (2017) equally conducted a time series study of Baringo to determine the trends and variability of rainfall between 1974 and 2003. The results revealed a reducing amount of precipitation over the period. Like Ngaira, Murithi also failed to integrate temperature which the current study also sought to address. Koskei et al., (2017) carried out a survey on actual trends of rainfall and spatial variability by ecological zones in Baringo between 1981 and 2009. The study results indicated rainfall trends in both lowland and highland areas of Baringo County that were highly variable. Ezenwa et al., (2018)'s study entitled climate variability and its effect on gender and copying strategies was conducted in Baringo County. The study came up with a trend analysis of rainfall from 1985 – 2015. The trend reveals acute fluctuating patterns in the constant increase and decrease in annual rainfall. Changes in rainfall totals over time explained a variation in rainfall volume of 6.31% in the County. All the above studies were carried out to determine rainfall trends in Baringo County. As the current study focusses on climate variability, there was need to include the temperature element. Many studies have concentrated on rainfall variability. Very little has been done on temperature. This provided a conceptual gap to be addressed by the current study. Secondly, these studies examined rainfall trends in Baringo up to 2015. The latest study on trends in Baringo by Ezenwa falls between 1985 – 2015. Analysis of rainfall and temperature variability had not been adequately done by previous studies. This was one of the areas the current study focused on. The current study carries out a historical trend analysis for both rainfall and temperature in Baringo between 1980 – 2020. The study also incorporates more and detailed techniques of determining rainfall variability in Baringo.

UNDER PEER REVIEW

RESEARCH METHODOLOGY

3.1 Research Design

Longitudinal design was used for this study which is a time series data analysis technique on climate variability trends in the county between 1980 and 2020. The design, describes a given phenomenon and makes it possible to follow and understand a chronological pattern of events and activities (William, 2009).

3.2 Data Sources and Collection

Data on rainfall and temperature for the two rainfall stations in the three Sub Counties was collected from Kenya Meteorological Department headquarters in Nairobi.

3.3 Data Analysis and Interpretation

Data on rainfall and temperature for the two rainfall stations in the three Sub Counties was subjected to measurements of variability using the following techniques; Mean ($\bar{X}$) Standard deviation (SD) Precipitation Concentration Index (PCI) Coefficient of Variability (CV), Relative Variability (RV) and Drought Intensity (DI) to measure and determine variability levels. This helped to derive the historical rainfall and temperature variability trends, patterns and their degree of variability between 1980 – 2020.

3.3.1 The Mean

The mean is the average spread of a data set over a specified time period for example on monthly (mean monthly) or annually (Mean annual). It is used to determine the average amount of rainfall received in an area on monthly or annual basis. It can also be calculated for a given number of months or years. The mean is the basis on which different determinants of rainfall and temperature variability are built. It can be calculated basing the following formula;

$$\text{Mean} = \bar{X} = \Sigma x / n$$

Where $\bar{X}$ = the mean (average), Σx = the summation of X, n = the number of observations.

3.3.2 Standard Deviation

This technique computes or measures the degree to which the annual totals of rainfall and temperature tend to deviate from the average or mean. It can be determined using the formula below.

$$SD = \frac{\sqrt{\sum (x - \bar{X})}}{N}$$

For rainfall, deviation below the Mean is an indicator of drought years and above the Mean is an indicator of wet years.

3.3.3 Drought intensity

This is the rainfall deficit ratio in relation to the LTM (Pence et.al 2000). It is determined by the departure of the rainfall total from the LTM and expressed as a percentage. It is determined using the formulae below.

UNDER PEER REVIEW

Drought Intensity (D I) = $\frac{X - \bar{X}}{X}$ x 100

Where D1 = Drought intensity.

X = Annual rainfall for a given year.

$\bar{X}$ = Mean rainfall for a given period e g 1980 – 2020 (Long term mean).

For rainfall, the higher the deviation from the mean the higher the drought intensity implying high variability and the lower the deviation the lower drought intensity implying low variability.

3.3.4 Relative Variability

This is the total sum of all deviations from the rainfall mean without respect to sign. It is derived by establishing the number of observations expressed as a percentage of the rainfall mean (Ngaira, 1999). It is derived by the following formula.

$$R.V = \frac{\sum (X - \bar{X})}{N / \bar{X}} \times 100$$

Where $\sum (X - \bar{X})$ = Sum of all deviations from the mean.

N = Number of observations.

$\bar{X}$ = The mean

It is measured in Percentage. 1. < 15% Typical in high rainfall areas. 2. 20% - 25% Typical in Semi arid areas 3. > 40% Typical in Desert areas.

3.3.5 Coefficient of Variability

Coefficient of variation (CV) is calculated by the following formula;

Coefficient of variation (CV) = σ/υ x 100

Where = σ standard deviation and υ = mean

It is measured in Percentage. 1. < 20% Low variability (High rainfall areas) 2. > 20% - 25% High variability. (Semi arid areas) 3. > 40%. Extremely High Variability (Desert areas).

3.2. 6 Precipitation Concentration Index

The PCI is a climatological concept that indicates whether monthly rainfall is equally distributed in any given season or highly concentrated in one month. It is calculated using the formula;

$PCI = \frac{\sum X}{\sum X2}$ x 100 Where X = the monthly mean of rainfall for the year'

Oliver (1960) posits that the highest values of the PCI exist in areas where seasonal precipitation tends to concentrate in one month. PC1 of 8.3 - 0.9 indicates equal monthly distribution of rainfall. A PCI ≥ 20 indicates a marked concertation of seasonal rainfall. A PCI of 10 – 19 indicates an erratic distribution of seasonal rainfall.

3.2.7 Monthly Temperature Variation

UNDER PEER REVIEW

To determine the monthly Temperature variation. The variability of the monthly temperature anomalies within each year can be carried out by analyzing monthly and annual means and standard deviations from temperature graphs.

DATA ANALYSIS

4.1 Analysis of Monthly and Annual Rainfall totals and Means. 1981 – 2020 for Baringo South (Marigat)

Table 1 shows the monthly and annual rainfall totals and means for Perkera rainfall station for the 40 year study period (1981 – 2020). It indicates the monthly and annual distribution of rainfall totals and means.

The rainfall table reveals the erratic rainfall patterns in the lowland semi-arid areas of Marigat/Baringo South Sub County. The table shows both monthly and annual totals of rainfall and means in the lowlands of Baringo South. In this semi-arid lowland areas, the known dry seasons were between December to February and September to October when monthly rainfall was mostly below 50 mm. In some cases, these dry months were able to receive totals that were above the long term mean in their respective months. Examples can be seen in January 1990, 1993, 1998, 2000, 2002, 2004, 2005, 2006, 2007, 2008, 2013, 2016, 2017 and 2020. 14/40 years recorded totals above the long term mean of January over the entire study period (1981 – 2020). February 1983, 1985, 1987, 1989, 1990, 1996, 2005, 2006, 2007, 2017, and 2019. 11/40 years recorded totals above the long term mean for February over the entire study period (1981- 2020) and December 1981, 1984, 1989, 1993, 1995, 1997, 2002, 2003, 2006, 2013, 2015, 2018, 2019 and 2020. 14/40 years recorded totals above the long term mean of December over the study period. The designated wet months were April to August and November receiving a mean well above 80 mm per month. These rains were not experienced the time they were expected on many occasions, and only came when they were not expected. This is evidenced in 1993, 1998, 2007 and 2016. This kind of rainfall and its characteristics was considered as erratic and unpredictable. This created uncertainty and anxiety among the inhabitants of Baringo (Ngaira, 1999).

The variability in rainfall totals was evidenced in the monthly mean of rainfall in Perkera station of Baringo South Sub County. For example, the driest months in Baringo South were January with a mean of 21.73 mm and February with a mean of 19.81 mm. The wettest months were April with a mean of 102.95 mm and July with a mean of 97.64 mm. as shown on the table. Baringo South lies in the southern lowland areas and receives very low rainfall compared to the highland areas of Baringo North and Baringo Central. The designated wet months were April (102.95 mm) and July (97.64) but occasionally they received less than 40 mm such as in April 1984, 1995, 1998, 1999, 2000, 2011 and 2014; July 1982, 1987, 1995, 2002, 2009 and 2012. This kind of rainfall was erratic and unpredictable. A similar study was conducted by Alberto (2012) in Northern Tanzania's Kahangara Division. The study revealed that rainfall was unpredictable and highly variable. The results support those of the current study. Differences only appear when the wet and dry spells of the months occur in the two areas. In Kahangara Division, the known wet season was between October and May which was also the growing season and the dry season was between June and August. A study carried out by Ngaira (1999) examined the effects of rainfall variability on the semi-arid environment of the then larger Baringo District which is now Baringo County. Findings showed that rainfall variability especially droughts had a negative impact on the environment. The study focused on the environment in general while the current study specifically focuses on farming activities in Baringo County.

UNDER PEER REVIEW

The designated dry months in Baringo South Sub County were January with a LTM of 21.73 mm, February with a LTM of 19.81mm and September with a LTM of 30.89 mm. Occasionally some months received above a mean of 50mm. Examples include January 1993, 2006, 2007 February 1987, 1990 and 2010 and September 1988, 2005, 2007 and 2008.

TABLE 1 MONTHLY AND ANNUAL TOTALS OF RAINFALL FOR PERKERA STATION. MARIGAT: BARINGO SOUTH.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Mean
2020	24.6	7.4	24.9	98.1	64.3	28.2	55.1	81.7	46.5	102.3	222.3	101.0	856.4	71.37
2019	1.3	24.3	101.5	255.0	42.5	91.3	104.7	72.1	31.8	902.4	110.2	203	736.4	61.37
2018	8.7	8.5	114.5	144.7	75.4	85.8	84.4	42.3	15.7	17.6	122.4	49.2	669.1	55.76
2017	33.6	20.0	44.2	101.9	187.4	24.4	89.7	85.8	49.7	145.0	45.0	11.7	838.2	69.85
2016	34.5	3.2	40.2	81.9	113.8	123.8	112.3	43.2	44.5	33.3	23.7	0.4	654	54.5
2015	2.7	11.2	22.8	119.5	111.9	49.4	56.7	12.0	27.2	83.6	127.9	124.1	749.0	62.41
2014	6.6	3.0	40.4	23.6	36.3	54.4	76.1	75.2	43.1	88.9	73.4	8.3	529.3	44.10
2013	39.9	2.2	79.1	55.6	48.0	76.1	123.9	60.2	2.5	16.6	42.5	78.3	624.8	52.08
2012	1.3	0.4	15.6	169.2	35.6	72.4	9.8	64.6	20.8	21.8	10.5	33..0	455.0	37.92
2011	0.2	6.1	46.7	33.8	38.3	45.3	80.2	144.3	29.0	84.9	94.3	20.7	623.8	51.98
2010	6.2	127.6	130.7	122.9	115.6	48.9	96.5	102.1	22.8	57.0	21.4	0.8	852.6	71.05
2009	18.1	1.2	16.8	41.1	56.6	19.0	20.8	5.7	24.4	47.1	23.0	133.1	406.9	33.9
2008	45.9	4.7	41.3	50.0	28.1	26.8	161.4	82.7	93.0	93.3	70.8	1.4	699.2	58.26
2007	72.0	46.8	14.4	124.8	91.5	174.5	96.4	155.7	118.5	52.0	24.3	12.0	983.1	81.93
2006	57.6	22.2	46.7	74.5	29.9	57.0	55.0	79.4	7.8	83.6	243.6	90.4	847.8	70.65
2005	41.4	21.7	41.7	73.0	63.3	58.3	101.8	50.4	140.0	19.3	21.3	1.9	634.3	52.86
2004	40.5	7.0	56.9	115.8	36.1	40.9	95.9	39.6	21.3	39.5	98.8	13.4	605.7	50.47
2003	3.0	0.0	49.5	205.0	61.0	0.3	73.1	192.9	12.5	32.2	38.8	61.4	729.5	60.79
2002	42.8	0.2	106.9	78.9	23.2	72.2	17.4	25.1	0.6	22.1	39.0	106.0	534.4	44.53
2001	22.5	15.1	76.6	58.8	20.4	20.2	83.7	104.4	28.2	83.4	42.5	0.2	556.1	46.34
2000	8.5	1.6	3.6	16.5	41.5	66.6	85.2	88.5	9.7	49.7	63.0	17.9	452.2	37.68
1999	0.2	0.3	145.0	26.9	13.6	40.5	72.4	62.2	4.8	33.6	99.4	12.2	511.1	511.1
1998	121.8	10.8	3.2	30.0	77.1	52.8	682	116.1	10.9	39.5	22.3	1.2	553.8	46.15
1997	14.1	0.0	17.0	235.9	10.8	99.1	73.2	56.2	8.8	89.6	108.6	70.5	783.7	65.31
1996	18.8	35.5	44.8	31.6	50.5	150.5	85.5	64.7	10.9	22.9	8.2	4.7	478.0	39.83
1995	0.5	22.1	72.7	72.7	31.0	31.0	25.4	21.5	38.7	85.7	42.2	82.2	507.3	4228
1994	0.4	2.4	59.9	131.2	56.9	50.4	55.1	31.6	4.1	19.4	53.6	1.6	466.6	38.88
1993	96.6	44.2	2.7	59.7	69.5	72.5	46.1	13.4	10.9	13.6	19.8	43.8	492.8	41.06
1992	0.0	0.4	6.4	119.5	63.4	70.4	64.7	76.4	44.4	93.2	43.5	19.5	601.8	50.15
1991	35.9	3.6	47.8	40.3	61.9	115.9	66.0	134.4	11.1	41.0	30.7	13.0	601.4	50.12
1990	10.6	103.8	93.1	92.2	72.6	27.4	59.0	26.4	8.6	58.4	25.0	11.4	588.5	49.04
1989	8.3	45.6	90.7	136.0	64.5	40.4	221.8	30.7	32.7	69.5	76.8	41.4	858.4	46.53
1988	17.5	2.8	23.5	214.9	56.2	41.9	170.5	151.7	54.2	46.7	19.6	9.0	808.6	67.38
1987	2.3	54.2	17.8	83.4	118.6	116.6	12.3	30.6	4.2	7.5	77.2	0.8	525.3	4368
1986	0.1	0.0	15.6	150.0	55.7	94.1	40.8	40.1	47.8	6.4	2.8	9.5	482.9	40.24
1985	2.9	43.7	72.1	201.2	95.9	60.6	97.2	45.3	19.9	6.6	94.3	1.5	681.2	56.76
1984	1.0	0.2	1.1	32.0	10.1	22.2	42.3	16.4	12.7	20.6	43.0	27.7	229.3	19.11
1983	3.1	47.6	3.8	64.9	29.5	13.8	225.7	150.1	43.5	54.4	221.1	15.2	673.9	56.16
1982	1.2	11.8	20.5	175.5	96.5	20.5	30.3	115.4	8.4	52.2	132.2	24.2	688.9	57.41
1981	0.4	9.2	148.2	72.8	69.6	63.2	57.6	58.1	37.7	60.6	33.7	35.2	646.1	53.84
TO	847.6	772.6	2000.9	4015.3	2482	2445	3808	2861	1205	2116.	2643	1069	25218	
ME	21.73	19.81	51.31	102.95	63.63	62.69	97.64	73.36	30.89	54.26	67.76	27.41	646.6	
SD	27.11	31.52	38.82	44.74	224.9	243.6	264.3	24.5	213.8	202.6	241.6	24.8	151.3	

Source. K M D Nairobi, 2022).

UNDER PEER REVIEW

Some months did not receive any rainfall at all such as January 1992 and February 1986, 1997 and 2003 as can be seen in the table 1 The nature of erratic rainfall in Baringo County has a similarity to that one of the semi arid Machakos reported in Indiatsy (2015) study. Baringo recorded a total of seven years, when the expected rains were either too little or failed in the expected rainy season. This was compared to four years recorded in Machakos County.

The analysis of the annual rainfall distribution and trends for Perkera

The analysis of the annual rainfall distribution and trends for Perkera was equally done as indicated in figure 1 below.

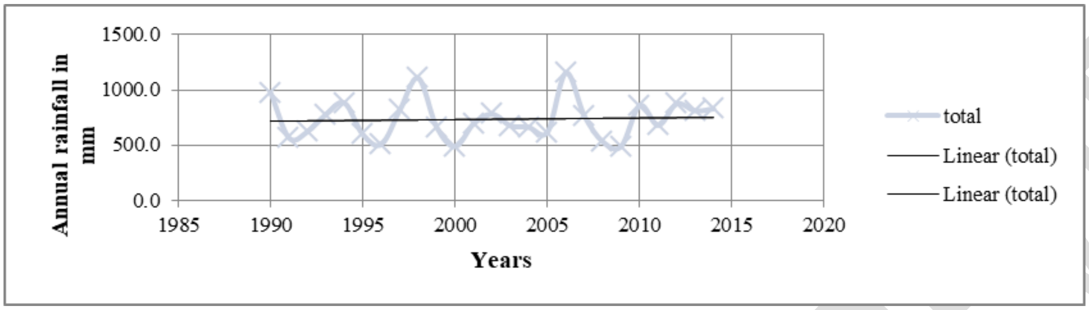

Figure 1 Total rainfall distribution and trends 1981 – 2020. Perkera station.

The analysis indicate a slight insignificant increase (r^2 = 0.043) in rainfall over the forty year study period. Figure 1 indicates fluctuations and trends over the 40 historical year period. The trend is interspersed by exceptionally acute or high values in 1998 and 2006. The lowest values recorded were in 1996, 2000 and 2009. Totals below the linear total indicate drought and those above the linear total indicate high rainfall.

4.2 Analysis of Monthly and Annual Temperature and Means. 1981 – 2020 for Baringo South (Marigat)

Table 2 shows the monthly and annual maximum temperatures and means for Perkera rainfall station for the 40 year period (1981 – 2020). It indicates the monthly and annual distribution of maximum temperature and means.

In this semi-arid lowland areas, the known hot seasons were between January to February and September to October when monthly temperatures were mostly above 35^0c. In some cases, these hot months experienced maximum temperatures below the long term mean of 33.9^0 c in their respective months. Examples can be seen in January 1990, 1993, 1998, 2014, 2010, and 1989 which recorded amounts below the LTM over the entire study period (1981 – 2020). February 1993, 1989, 2010 and 2020 recorded amounts below the LTM over the entire study period (1981- 2020). September 1983, 1986, 1996, 2007, 2011 and 2020 and October 2006, 2011, 2018, 2019 and 2020 recorded maximum temperatures below the LTM over the study period.

The hottest year was 2017 with an average temperature of 35.4 ^{0}c, followed by 2009 with an average of 35.2^0c and 1987 with an average 35^0c. These hot years happened to be very dry years. The coldest year was 2005 with an average temperature of 23.8^0 c, followed by 2018 with an average of 31.8 ^{0}c and 1985 with an average of 32.9^0c. The highest temperature recorded over the study period was 53.3^{0}c in October 1994 followed by 38.2 ^{0}c recorded in October 1987 and 37.3 ^{0}c recorded in July 2009.

In most cases the hottest months such as October 1994 (53.3^{0}c), 1987 (38,2 ^{0}c) and September 2009 (37.9^{0}c), happened to be dry months recording total rainfall amounts of 19.4mm, 7.5mm and 5.7 mm respectively. The months with the lowest temperatures such as March 1992 (23^{0}c) and November 2019 (20.8^{0}c) recorded rainfall amounts of 110.2 mm and 104.4 mm respectively.

TABLE 2 MONTHLY AND ANNUAL MAXIMUM TEMPERATURE FOR PERKERA WEATHER STATION. MARIGAT: BARINGO SOUTH.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVE.	Mean
2020	35.2	31.2	34.1	30.4	32.6	35.0	34.4	35.0	32.7	31.7	34.1	30.1	33.2	
2019	36.1	35.2	37.1	36.1	34.5	34.7	36.1	39.9	34.7	32.0	29.0	35.4	34.2	
2018	35.1	36.1	32.6	31.7	31.8	31.7	26.9	36.1	29.5	30.0	29.8	30.1	31.8	
2017	36.4	36.0	36.6	36.3	34.6	37.4	34.4	34.9	34.6	34.2	33.5	35.2	35.4	
2016	34.4	35.8	38.0	28.5	32.0	34.4	33.7	35.3	37.3	36.4	34.8	35.4	34.7	
2015	35.2	36.4	37.7	32.5	32.8	35.0	32.5	35.9	37.7	36.0	32.9	34.4	34.9	
2014	35.2	35.2	34.4	34.2	35.6	36.8	36.0	33.9	35.4	33.9	34.0	34.7	34.9	
2013	34.1	35.0	34.7	33.6	34.5	35.4	35.1	34.4	36.5	53.3	33.9	34.1	34.7	
2012	35.5	35.4	36.3	34.2	32.4	34.7	33.6	33.7	34.7	33.0	33.7	33.1	34.2	
2011	36.1	36.3	35.0	35.0	33.4	36.5	35.2	31.2	32.7	33.1	31.4	32.7	34.0	
2010	33.8	33.3	31.5	32.1	31.7	33.7	33.8	33.1	35.9	35.0	35.7	36.2	33.8	
2009	34.2	34.8	36.0	33.3	32.9	36.8	37.3	36.1	37.9	33.6	36.7	33.3	35.2	
2008	34.3	34.5	34.2	34.2	34.9	35.7	34.4	35.2	36.4	32.5	33.1	34.5	34.5	
2007	34.3	34.4	35.1	33.3	34.2	32.3	33.5	33.0	33.2	34.4	35.0	34.8	34.0	
2006	34.6	36.0	34.5	32.3	33.6	35.2	35.4	33.5	35.9	33.7	30.9	32.1	34.0	
2005	34.9	35.6	35.3	35.5	30.8	32.5	33.3	34.8	34.2	35.9	35.8	35.5	23.8	
2004	33.8	34.7	35.8	31.1	32.1	34.2	34.2	37.0	35.7	34.6	32.5	33.7	34.1	
2003	34.4	37.0	35.8	32.8	31.5	32.2	31.6	30.2	35.7	34.1	33.3	33.3	33.5	
2002	33.8	35.6	34.0	29.3	33.2	35.6	36.6	34.7	37.1	34.4	34.0	33.3	34.3	
2001	34.2	36.2	34.0	32.4	33.7	33.2	34.0	34.4	35.8	35.4	34.2	34.8	34.4	
2000	35.7	36.1	36.9	34.1	33.9	34.8	32.6	32.9	36.1	35.1	33.7	35.4	34.8	
1999	35.4	36.2	33.4	33.3	33.2	34.2	33.3	34.2	37.0	34.9	35.3	34.3	34.6	
1998	31.5	34.4	35.1	35.3	33.6	33.8	33.1	32.4	36.1	33.4	36.2	36.4	34.3	
1997	35.6	36.1	35.4	31.1	33.2	35.8	33.1	33.5	37.9	33.5	32.0	32.5	34.1	
1996	34.0	35.6	35.4	34.6	32.0	33.2	31.4	32.8	32.8	35.0	35.2	36.1	34.0	
1995	35.0	34.9	34.1	34.0	35.0	36.9	32.7	34.9	34.6	33.7	33.0	34.0	34.4	
1994	35.3	35.8	36.1	34.4	32.4	33.8	32.8	31.8	35.9	53.3	32.5	33.6	34.1	
1993	32.0	32.8	35.2	34.5	25.1	35.0	34.9	35.0	37.1	37.1	34.9	35.1	34.1	
1992	35.3	35.6	23.0	35.2	33.6	34.8	33.4	32.8	34.4	33.0	35.0	34.0	33.3	
1991	34.1	35.9	35.7	34.1	32.1	34.3	33.1	33.1	35.6	35.0	35.7	34.8	34.5	
1990	33.3	33.6	33.5	33.7	34.8	36.1	34.2	34.1	36.0	35.0	35.6	34.0	33.5	
1989	32.5	32.9	34.7	32.1	33.0	34.6	33.8	33.8	35.1	34.4	35.2	33.8	33.8	
1988	34.3	35.3	35.7	33.7	33.1	35.5	33.1	32.2	33.7	34.7	33.7	32.2	34.0	
1987	34.9	35.9	36.2	34.6	32.1	30.1	34.6	34.7	37.4	38.2	35.1	35.9	35.0	
1986	34.9	35.5	35.2	33.4	32.5	30.7	30.9	32.1	33.5	34.0	33.3	33.2	33.3	
1985	34.8	34.3	34.9	31.5	30.5	31.7	30.9	31.6	34.1	34.3	32.7	33.7	32.9	
1984	34.3	35.3	35.8	35.6	35.2	33.9	32.6	33.4	34.3	33.1	32.0	32.8	34.0	
1983	34.8	35.0	37.0	35.4	34.1	33.7	31.8	30.4	31.5	32.9	33.5	32.5	33.6	
1982	35.1	35.8	36.6	32.6	30.7	33.4	34..4	32.5	34.6	34.3	32.7	33.7	33.9	
1981	34.9	35.7	33.4	31.9	32.9	35.4	33.8	32.2	34.6	36.1	36.2	34.8	34.3	
MEAN	34.6	38.2	34.9	33.3	32.8	34.4	33.5	33.8	35.1	35.2	33.8	33.8	33.9	

Source. K M D Nairobi, 2022)

The designated cold months were April, May, August and November experiencing temperatures below the long term mean. These cold months in some years experienced temperatures above the LTM. Examples include April, 1984, 1987, 1992, 1998, 2005, 2011 and 2020. May 2014, 1995, 1984 and 1990. August 2005, 2008, 2009, 2018, 2019 and 2020. November 1991, 1992, 1998, 2005, 2007, 2009, and 2010. February was the hottest and the driest month. April was a cold and wet month over the study period.

4.3 Analysis of Monthly and Annual Rainfall totals and Means 1981 - 2020 in Chemusus, Baringo North

Table 3 indicates the monthly and annual rainfall totals and means for Chemusus rainfall station in Baringo North Sub County. The table also shows the Monthly and Annual rainfall Distribution for Chemusus rainfall station for the 40 years. It indicates the monthly and annual distribution of rainfall totals, trends, characteristics and variability patterns over the study period. This was the second weather station under the current study analysis to determine variability in the rainfall and temperature patterns in Baringo County.

Baringo North Sub County which is a highland area lying towards the west of Baringo County, has more months with no rainfall as compared to Baringo South, but it is still the wettest. January and February were the driest months as they received below a mean of 50 mm though there are cases where the designated dry months received a mean above 50mm. That was in January 1988, 1993, 1998, 2001, 2002, and 2017; February 1990, 1998, 2018, 2007, 2019 and 2019. April – August was the long rain period with almost all months receiving over a mean of 130 mm, with April (mean of 192.89 mm) being the wettest followed by May (137.19 mm), August (133.94 mm), June (133.22mm) and July (128.13 mm). Cases when a total of less than 50 mm were experienced, were in April 2000, May 1984, 1997, 1999, 2004 and 2002. June 2003 and July 2018 as seen in Table 3. In Baringo North the second rainy season with the shortest duration was between October (100.99 mm), November (94.16) and December (52.63 mm). These patterns differ with those recorded in Kahangara which revealed the wettest months to be May and October (Alberto, 2013). Variability in Baringo North is lower than that of Baringo South as the number of months that receive below 50mm total in April are less than those of Baringo South. Wet months recorded are more (nine years) compared to Baringo South which were recorded for five years. The month recorded as the wettest in Baringo North had a mean of 192.89 mm and for Baringo South it recorded a mean of 102.95 mm. The driest months in Baringo North were January (32.97mm) and February (32.8mm) as compared to Baringo South (January 21.73 mm) and February (19.81 mm). This implies that Baringo North is wetter with a lower variability as compared to Baringo South Sub County. Nicholson (2000)'s study of East Africa's climate variability between the 1950s - 1980s are also in support of the current study results. The results revealed high fluctuations in the trends of rainfall implying very high variability. Another study conducted in the semi-arid Laikipia District by Mburu (2013) to determine the effects of drought in the study area, also indicated high fluctuations and variability trends in totals of rainfall. Laikipa is found to the east of the highlands of Baringo North and Baringo North is found to the west and North West of the Baringo South lowlands. These unreliability and high variability patterns, disrupt farming calendars and activities. Persistent and prolonged droughts and generally recorded dry spells lead to crop failure and lowering crop yields in the county as compared to Baringo North which is wetter.

UNDER PEER REVIEW

TABLE 3 MONTHLY AND ANNUAL RAINFALL TOTALS FOR CHEMUSUS IN THE HIGHLANDS OF BARINGO

	Jan	Feb	Mar	Apr	M`ay	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Mean
2020	14.6	17.4	124.9	198.1	46.3	115.2	75.1	73.7	97.7	92.3	122.3	101	1267.2	105.6
2019	10.3	54.3	70.5	55	107.5	104.3	94.7	82.1	51.8	121.5	140.2	203	1129.6	94.13
2018	9.6	56.8	167.2	253.9	186	174	8.5	131.2	46.3	52.1	30.5	60.5	1253.4	1044.5
2017	62.2	45.4	4.7	204.4	416.6	66.1	176.5	192	81.4	822.7	96.5	34.8	2241.4	186.78
2016	45.7	35.2	56.4	173.2	170.1	93.4	90.3	88.2	32.3	28.1	40.1	7.9	861.5	71.79
2015	7.7	16	36.2	257	230.5	106.9	92.9	54.5	31.8	134.3	193.5	71.8	1233	102.75
2014	1.3	24.3	101.5	255	97.5	116.3	104.7	82.1	31.8	121.5	140.2	20.3	1096.5	91.375
2013	41.6	7.3	129	497.6	186	147.8	39.5	153.1	5.7	110	95.1	61.7	1475	122.9
2012	0.1	0.7	19.7	372.9	311.2	198.7	192.9	157.5	46.8	122.5	44.9	66.2	1434	119.5
2011	0.6	1.1	81	172.3	121	133.3	102	133.6	37.3	79.6	236.8	13	1111.7	92.64
2010	22.6	94.7	44.4	163	166.4	292	275.3	129.7	63.7	101	13.5	13.4	1379.6	114.96
2009	14.3	0.2	8.4	134.4	132.9	107.5	63.8	31.1	55.6	81.1	34.3	46.8	710.5	69.11
2008	3.8	0	94	65	65.2	851.5	165.9	141.7	99.2	81.4	27.7	0	829.3	69.11
2007	72.2	79.6	54.9	151.5	111.4	151	167.8	127.9	171.4	122.9	22.1	3.6	1236.3	103.02
2006	40	58	48.7	307.9	139.1	87.8	116.1	167.8	74.1	74	268.2	146.8	1507.4	125.61
2005	34.4	9	90.7	115.1	173.5	92.6	103.1	141.9	74.1	07	10.7	7.5	985.8	82.15
2004	33.9	2.2	78.3	174.1	40.9	65.9	100.1	140.6	14.7	87	115.5	39.1	892.3	74.36
2003	1.4	0	33.3	251.3	156.7	3.5	86.8	283.8	24.3	41.6	61.5	49.9	994.1	82.84
2002	83.8	2.7	103.2	133.3	147.8	62	41.8	141.9	11	47.5	77.3	206.1	1059	88.25
2001	103.2	35.3	105	182.3	107.2	132.8	127.1	107.4	50.5	67.7	159	14	1191.4	99.28
2000	8.8	0.2	07	40.7	67.7	108.4	203.3	88	34.8	114.1	86.4	17	776.3	64.69
1999	0.7	1.5	171.3	52.8	33	58.3	58.9	87.1	11.9	123.2	75	35.1	715	59.58
1998	115.4	118.5	14.4	123	114.7	63.4	140.7	187.6	46.9	78.2	52.6	2.3	1097.6	91.46
1997	7.7	0	57.7	352	20	111.3	135	109.2	13.8	122.6	238.5	58.2	1226.1	102.17
1996	30.1	44.8	147.6	51.8	109.9	139.9	203.6	241.9	67.4	16.7	125.6	4.4	1073.7	89.47
1995	0.3	40.9	151.9	127.7	55.8	119.4	112.9	121.8	71.4	71.4	46.3	43.6	978	81.5
1994	0.3	13.5	129.2	222.7	124.5	165.8	200.5	180	20.1	44.1	177.5	3.8	1282	106.83
1993	168.5	30	20.9	73.1	165.6	130.5	106.3	58.8	87.8	28.4	60.5	30.5	1060.9	88.41
1992	14.6	8.2	20.5	216	96.4	125.6	133.3	219.9	83.5	110.7	70.2	77.3	1176.2	98.02
1991	86	8.3	117.8	85.4	156.4	158.2	132.9	177.8	46.7	67.4	40.8	22.4	1100	91.66
1990	46.2	138.1	108.5	238.1	138.2	80	89.5	109.8	24.3	56.2	54.8	51.9	1135.9	94.65
1989	18.2	92.2	114.4	142.5	80.5	28.7	216.5	87.6	112.8	121.5	121.3	95.4	1231.7	102.64
1988	75.8	13.8	51.5	348	124.9	64.5	241.8	117.9	102.6	104	36.7	51.7	1333	111.08
1987	29.7	49.3	75.3	114.1	177.3	177.5	33.2	99.4	7.2	37.3	146.5	8.8	955.7	79.64
1986	6.6	19.5	31.8	188.7	113	167.5	112.1	81.9	65.1	19.6	65.4	21.6	892.7	74.39
1985	34.3	31.9	121.1	227.2	188.4	87.6	110.4	86.4	14.7	58.5	62.7	120.1	1144	95.33
1984	4.8	9.1	2.9	94	37.5	39.2	110.1	76.9	63.8	63.8	128.1	45.6	675.6	56.3
1983	10.4	36.2	8.6	182.6	105.9	103.3	104.9	232.3	122.4	182.2	69.4	60.6	1218.9	101.5
1982	24.1	47.7	38.2	313.6	195.1	80	107.2	129.3	68.1	63.8	63.8	98	1482.2	123.52
1981	0	35.3	167.6	211.4	131.9	84	219.2	168.3	147.6	59.4	20.4	36.5	1281.9	106.82
TOT	1285.8	1279.2	3010	7523	5351	5196	4997	5223.7	2314.4	3938.9	3672.4	052.2	57007	
MEA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SD	47.40	33.7	49.1	98.83	73.29	52.82	59.05	53.19	40.9	43.32	70.64	45.65	55.65	

Source. KMD. Nairobi (2022).

The analysis of the annual rainfall distribution and trends for Chemusus

The analysis of the annual rainfall distribution and trend for Chemusus was equally done as indicated in figure 2 below.

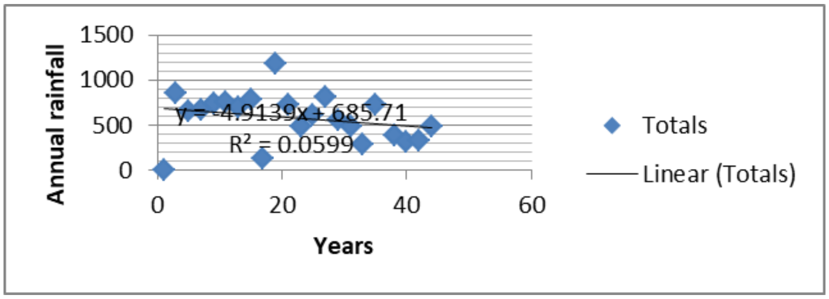

Figure 2: Total rainfall distribution and trends 1981 – 2020. Chemusus

The annual rainfall trend in figure 2 indicates a significantly decreasing rainfall over the forty year study period. Fluctuations of the rainfall patterns in figure 2 indicate evident variability over the 40 historical period with exceptionally high values in 2002, 1998 and 1990. Low extreme values were recorded in 2009, 2008, 2005 and 1997. The declining trend of rainfall is evidently significant as (r^2 = 0.298). This adversely affects farming activities like farming calendars, land preparation and yields in Baringo

4.4 Analysis of Monthly and Annual Temperatures and Means. 1981 – 2020 for Chemusus Baringo North) Sub County.

Table 4 shows the monthly and annual maximum temperature and means for Chemusus rainfall station for the 40 year study period (1981 – 2020). It indicates the monthly and annual distribution of maximum temperature and means. The table shows the distribution of monthly and annual distribution of maximum temperature patterns in the highland areas of Baringo North Sub County. In this highland areas, the known months with the highest temperatures were January, February and March when monthly long term average was above 25^0c and the known months with the lowest temperature record were June, July and August, when the monthly LTM temperatures were less than 23^0c. In some cases, these hot months experienced maximum temperatures below the LTM of 23.6^0 c in their respective months. Examples can be seen in January 1998, 1993, 2016, 2009, 2010, and 1989 which recorded amounts less than the January LTM over the entire study period (1981 – 2020). February 1993, 2020, 1989. 2019 and 2010 recorded amounts below the February LTM over the entire period of study period (1981- 2020). March 1981, 2010, 2019 and 2020 and October 2006, 2011, 2018, 2019 and 2020. These years recorded maximum temperatures below the March LTM over the study period.

TABLE 4 MONTHLY AND ANNUAL TEMPERATURES FOR CHEMUSUS WEATHER STATION. BARINGO NORTH.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AVE.	Mean
2020	26.3	21.0	20.0	34.2	26.0	22.7	27.0	23.2	20.8	23.4	21.2	23.6	34.2	
2019	27.2	25.2	21.0	23.7	24.0	23.8	24.0	24.1	22.1	24.9	24.5	22.9	24.2	
2018	25.5	27.6	23.9	22.9	23.0	22.0	21.9	20.0	24.9	24.7	24.2	23.4	23.7	
2017	26.7	27.0	27.3	26.2	24.4	23.8	22.4	22.8	22.9	23.9	22.7	24.3	24.5	
2016	24.8	26.4	28.6	19.8	23.5	22.8	24.2	23.6	24.6	24.8	23.2	24.4	24.2	
2015	25.6	27.5	25.2	23.7	23.3	22.7	22.2	23.6	24.9	24.8	22.7	23.6	24.2	
2014	25.5	25.8	25.6	24.6	24.2	23.0	22.8	22.0	23.3	23.6	22.5	23.6	23.9	
2013	34.0	26.1	25.7	23.6	23.4	22.5	22.5	22.1	23.7	24.0	22.2	22.9	23.6	
2012	25.6	26.7	27.4	24.2	22.9	22.1	21.4	22.3	22.9	23.0	22.7	22.4	23.6	
2011	26.2	27.3	25.9	25.3	24.0	23.8	22.8	21.3	22.5	23.4	21.8	22.6	23.0	
2010	24.5	24.9	23.5	23.6	23.1	22.5	22.0	22.4	23.6	24.0	23.5	24.8	23.5	
2009	24.9	26.3	27.2	24.6	23.8	24.3	24.0	24.0	25.2	23.5	24.5	23.5	24.6	
2008	24.8	25.9	25.4	24.1	24.0	22.5	21.7	22.7	24.0	22.6	22.6	24.2	23.7	
2007	24.0	25.1	26.0	24.0	23.9	21.4	20.3	23.0	22.8	23.0	22.8	23.9	23.2	
2006	25.2	27.0	25.3	23.1	23.5	22.5	22.1	22.5	23.5	24.0	21.4	21.8	23.5	
2005	25.4	26.6	26.1	24.9	22.0	21.5	21.4	22.6	22.9	24.1	23.4	24.4	23.8	
2004	24.1	25.6	26.2	22.7	23.3	22.1	22.2	23.5	23.7	23.9	23.1	23.2	23.6	
2003	24.7	27.5	26.7	23.8	22.8	21.7	21.2	21.1	23.5	23.7	22.9	23.0	23.5	
2002	23.9	26.3	25.4	21.0	23.6	23.0	23.7	22.8	24.7	23.8	22.9	22.6	23.7	
2001	23.7	26.3	25.0	23.3	23.7	21.7	21.8	22.9	23.7	24.	23.4	23.5	23.6	
2000	25.4	26.7	27.1	24.9	24.3	22.6	21.4	21.8	23.6	24.0	22.8	24.1	24.1	
1999	24.9	26.9	24.6	23.9	23.4	22.7	21.6	22.3	24.2	23.6	22.8	23.5	23.7	
1998	22.2	25.2	26.0	25.2	23.8	22.4	21.7	22.1	23.6	20	23.3	24.4	23.6	
1997	25.0	27.1	26.8	22.6	23.3	23.2	22.0	23.2	25.9	23.4	21.6	22.0	23.8	
1996	24.6	26.2	26.0	24.6	23.2	22.7	21.0	22.1	22.6	23.8	22.9	24.3	23.7	
1995	24.9	26.0	25.1	24.6	24.4	23.9	21.2	22.8	23.2	23.4	22.8	23.2	23.8	
1994	25.5	26.4	26.7	25.0	23.0	21.5	20.5	21.0	23.7	24.0	21.8	22.7	23.5	
1993	22.1	23.6	25.7	24.4	22.1	21.5	21.5	22.6	24.3	25.3	23.3	24.3	23.4	
1992	25.1	26.2	34.4	24.5	23.3	21.5	20.5	20.6	22.2	22.0	22.7	22.6	23.8	
1991	24.4	27.0	26.5	24.3	23.0	21.8	20.3	21.6	23.3	23.4	22.6	23.1	23.4	
1990	23.6	25.0	24.4	23.3	23.5	22.2	21.3	21.5	23.3	23.9	23.0	23.2	23.2	
1989	22.8	23.8	25.1	22.5	22.2	21.7	21.1	21.4	22.7	22.5	22.4	22.7	22.6	
1988	24.0	25.9	25.5	23.3	26.6	21.9	20.4	20.4	21.1	22.4	21.6	22.3	22.6	
1987	25.0	26.7	26.5	24.8	23.0	19.9	22.9	23.0	24.9	25.7	23.0	24.4	24.1	
1986	24.8	26.2	25.4	23.5	22.9	20.7	20.7	21.9	22.6	24.2	22.9	22.8	23.2	
1985	25.5	25.0	25.8	22.5	22.3	21.7	20.9	21.6	23.3	24.3	22.8	24.2	23.3	
1984	24.7	26.8	27.2	25.2	24.6	22.1	21.8	22.9	23.4	23.3	22.3	23.0	23.9	
1983	24.5	25.9	27.0	25.2	24.2	22.5	21.6	21.2	22.0	22.5	22.7	22.8	23.5	
1982	24.4	26.1	27.1	23.5	22.2	22.0	22.1	21.5	23.3	22.8	21.4	22.6	23.3	
1981	26.3	26.6	24.7	22.9	23.0	22.7	21.2	22.0	22.5	24.3	23.7	23.6	23.6	
MEAN	25.1	26.0	25.9	24.1	23.5	22.3	21.9	22.3	23.4	23.2	22.8	23.4	23.6	

Source. K M D Nairobi, 2022).

The designated cold months were June, July, August and November experiencing temperature below the long term mean. These cold months experienced temperatures above the LTM in some years. Examples include June, 1995, 1997, 2019, 2017, 2015, and 2002. July 2020, 2019, 2011, 2002, and 2009. August 2004, 2006, 2020, 2019 and 2016. November 2019, 2018, 2017, 2010, 2009 and 1999. February was the hottest and the driest month. April was a warm and wet month over the study period. The hottest year was 2020 with an average temperature of 34.2 ^{0}c, followed by 2017 with an average of 24.5^{0} and 2016 with an average 42.2 ^{0}c. These hot years happened to be very dry years. The coldest year was 1989 with an average temperature of 23.8^{0} c, followed by 1990 with an average of 31.8 ^{0}c and 1984 with an average of 232.9^{0}c. The highest temperature recorded over the study period was 34.2 ^{0}c in April 2020 followed by 34.0 ^{0}c recorded in January 2013 and 27.6 ^{0}c recorded in February 2017.

In most cases the hottest months such as January 2013 (34.0^{0}c) and February 2017(27.6 ^{0}c) happened to be very dry months. The months with the lowest temperatures such as October 1982 (20^{0}c) and June 1998 (22.0 ^{0}c) were wet months.

4.5 Annual Rainfall Totals, Means, Standard deviations, Anomalies and Coefficient of Variation

Table 5 shows the annual totals, means, coefficient of variation and anomalies for each year in the 40 year study period (1981 – 2020) in Perkera weather station, Baringo Sub County. Formulas to calculate each of these variables are clearly demonstrated in section 3.3 above.

Table 5 Annual Rainfall totals, Means, Standard deviations, Anomalies and Coefficient of variation of each year from 2018 – 2020. Perkera Station. Baringo South Sub County.

Year	Total rain fall (mm)	Mean	Std Deviation	Anom alies		Year	Total rainfall (mm)	Mean	Std Deviation	Anoma lies
2020	856.4	71.37	8.1	+24.5		2000	452.2	37.68	5.87	-42.9
2019	736.4	61.37	7.5	+12.2		1999	511.1	42.59	6.25	-26.5
2018	669.1	55.76	7.1	+3.4		1998	1154.6	553.8	9.63	+52
2017	838.2	69.85	8.00	+23		1997	783.7	65.31	7.73	+17.5
2016	654	54.5	7.1	+1.12		1996	478.0	39.83	6.04	-35.2
2015	749.0	62.41	7.6	+13.6		1995	507.3	42.28	6.23	-27.4
2014	529.3	44.10	6.4	-22.2		1994	466.6	38.88	5.97	-38.5
2013	624.8	52.08	6.9	-3.48		1993	492.8	41.06	61.3	--31.2
2012	455.0	37.92	5.8	-42.1		1992	601.8	50.15	6.78	-7.44
2011	623.8	51.98	6.9	-3.6		1991	601.4	50.12	6.77	-7.5
2010	852.6	71.05	8.07	+24		1990	588.5	49.04	6.70	-9.8
2009	406.9	33.9	5.57	-58.9		1989	858.4	46.53	8.23	+24.6
2008	699.2	58.26	7.31	+7.5		1988	808.6	67.38	7.85	+20
2007	983.1	81.93	8.66	+34.2		1987	525.3	43.68	6.33	-23.1
2006	847.8	70.65	8.04	+23.7		1986	482.9	40.24	6.07	-33.9
2005	634.3	52.86	6.96	-1.9		1985	681.2	56.76	7.22	+ 5.1
2004	605.7	50.47	6.80	-6.7		1984	229.3	19.11	4.18	+181
2003	729.5	60.79	7.46	+11.3		1983	673.9	56.16	7.17	+4.1
2002	534.4	44.53	6.38	-20.9		1982	688.9	57.41	7.25	+6.1
2001	556.1	46.34	6.51	-16.2		1981	646.1	53.84	7.02	-0.07
						TOTAL	25218	646.61		
						MEAN	646.61			
						SD	151.3			
						CV	0.23			

Source. KMD NAIROBI Perkera Weather Station (2022

Determination and Measurement of Rainfall Variability for Perkera Station Baring North

1. The Mean ($\overline{X}$) = Mean

Mean = $\overline{X} = \Sigma x / n$

UNDER PEER REVIEW

Mean for the year 1990 rainfall in Baringo South = 588.5/12 = 81.3 and Long Term Mean = 646.61

2. Standard Deviation (SD) for Perkera Stationn Baringo North

$$SD = \frac{\sqrt{\sum (x - \bar{X})}}{N} = 151.3$$

Deviations below the Mean is an indicator of drought years. Drought years over the 40 year study period in Baringo South Sub County were 2014, 2013, 2012, 2011, 2009, 2005, 2004, 2002, 2001, 2000, 1999, 1996, 1995, 1994, 1993, 1992, 1991,1990, 1987, 1986 and 1981

3. Drought Intensity (D I) for Perkera Stationn Baringo North

Drought Intensity (D I) $= \frac{X - \bar{X}}{X} \times 100$

$\bar{X}$ **= Mean rainfall for 1981 – 2020 (Long term mean).**

Dl for Perkera in 2006 $= \frac{847.8 - 646.61 \times 100}{847.8} = 23.73\%$

4. Relative Variability (RI) for Perkera Stationn Baringo North

$$R.V = \frac{\sum (X - \bar{X})}{N / \bar{X}} \times 100$$

For example the RV for 1995 for Perkera Stationn Baringo North

$$RV = \frac{\sum (534.4 - 44.53) \times 100}{12/44.53} = 25\%$$

5. Coefficient of Variability (CV) for Perkera Station in Baringo North

Coefficient of variation (CV) $= \sigma/\upsilon \times 100$

The CV for the 40 year period for Perkera is calculated as follows;

$$= 151.3/646.61 = 0.23 \times 100 = 23\%$$

6. Precipitation Concentration Index for Perkera Stationn Baringo North

$$PCI = \frac{\sum X}{\sum X2}$$

1. PCI for Perkera (Baringo South)

$$PCI = \frac{\sum X}{\sum X2} = \frac{746.8}{557.710.} \times 100 = 13.4(13)$$

UNDER PEER REVIEW

4.6 Monthly Rainfall totals, Annual Rainfall totals, Means, Standard deviations, Anomalies and Coefficient of Variation between 1981 – 2020. Chemusus. Baringo North.

Table 6 below shows the annual rainfall totals, means, standard deviation, anomalies of each year and coefficient of variation (CV) over the 40 year study period (1918 – 2020). Chemusus weather station, Baringo North Sub County. Formulas to calculate each variables are shown in section 3.3 above.

Table 6: Annual Rainfall totals, Means, Standard deviations, Anomalies of each year and Coefficient of variation (1981 – 2020). Chemusus. Baringo North Sub County.

Year	Total rain fall (mm)	Mean	Std Deviation	Anom alies		Year	Total rainfall (mm)	Mean	Std Deviatio	Anoma lies
2020	1267.2	105.6	9.84	9.2		2000	776.3	64.69	7.69	88.1
2019	1129.6	94.13	9.29	91.6		1999	715	59.55	7.39	91.6
2018	1253.4	1044.5	4.17	90.6		1998	1097	91.46	9.15	92.0
2017	2241.4	186.78	13.08	91.6		1997	1226.1	10.17	10.06	99.2
2016	361.5	71.79	4.92	80.1		1996	1073.7	89.47	9.05	91.6
2015	1233	102.75	9.70	91.6		1995	978	81.5	8.64	92.0
2014	1096.5	91.375	9.15	92.0		1994	1282	106.83	9.89	75.4
2013	1475	122.9	10.62	91.6		1993	1060.9	88.41	9.00	91.7
2012	1434	119.5	10.46	92.3		1992	1176.2	98.02	9.47	90.6
2011	1111.7	92.64	9.22	92.0		1991	1100	91.66	9.15	91.6
2010	1379.6	114.96	4.69	91.6		1990	1135.9	94.65	9.32	92.0
2009	710.5	69.11	7.31	90.2		1989	1231.7	102.64	9.69	91.0
2008	829.3	69.11	7.95	90,1		1988	1233	111.08	9.66	91.3
2007	1236.3	103.02	9.71	91.6		1987	955.7	79.64	8.54	89.2
2006	1507.4	125.61	10.73	92.0		1986	892.7	74.39	8.25	88.9
2005	985.8	82.84	8.67	92.0		1985	1144.5	95.33	9.35	91.7
2004	892.3	74.36	8.25	90.2		1984	675.6	56.3	7.18	92.0
2003	994.1	82.84	8.72	92.1		1983	1218.9	101.5	9.64	91.6
2002	1059	88.25	8.99	92.1		1982	1482.2	123.52	10.64	91.7
2001	1191.4	88.28	9.58	91.9		1981	1281.9	106.82	9.89	92.5
						TOTAL	57007	1461.7		
						MEAN	1461.7			
						SD	3.82			

UNDER PEER REVIEW

Source. Chemusus Weather Station (2022)

UNDER PEER REVIEW

1. **The Mean for Chemusus, Baringo North.**

Mean = $\bar{X}$ = Σx / n

Mean for the year 1990 rainfall in Baringo North = 1135.9/12 = 71.4 2) Long term Mean = 1461.7

2. **Standard deviation for Chemusus Baringo North**

$$SD = \frac{\sqrt{\Sigma(x - \bar{X})}}{N} = 3.82$$

Standard deviation technique is employed to compute the extent of deviations from the mean annual rainfall. Deviation that falls below the Mean indicates years of drought. Drought years in Baringo North Sub County were 2014, 2013, 2012, 2011, 2009, 2005, 2004, 2002, 2001, 2000, 1992, 1999, 1996, 1995. 1987, 1994, 1990, and 1993. A standard deviation of 3.8 (38%) indicates a high variability.

3. **Drought Intensity (D I) for Chemusus Baringo North**

Drought Intensity (D I) = $\frac{X - \bar{X}}{X} \times 100$

$\bar{X}$ **= Mean rainfall for 1981 – 2020 (Long term mean)**

Dl for Chemusus in 2006 = $\frac{1507.4 - 1461 \times 100}{1507}$ **= 14.1%**

4. Relative Variability (RI) for Chemusus Baringo North

$$R.V = \frac{\sum (X - \bar{X})}{N / \bar{X}} \times 100$$

The RV for 1995 Chemusus = $\frac{\sum (978 - 81.5) \times 100}{12/81.5}$ **= 15%**

5. Coefficient of Variability (CV) for Chemusus Stationn Baringo North

Coefficient of variation (CV) = σ/υ x 100

The CV for the 40 year period for Chemusus is calculated as follows;

= 3.82/146.7 = 0.26 x 100 = 26%

6. Precipitation Concentration Index for Perkera Stationn Baringo North

$$PCI = \frac{\sum X}{\sum X2}$$

PCI for Chemusus (Baringo North $PCI = \frac{\sum X}{\sum X2} = \frac{1174.73}{1,379,90.57} \times 100 = 8.512(9$

Out of 14 drought years in Laikipia's Central Division, dry months totaled to 11 for December (78.6%), 12 for January (85.7%) , 14 for February (100%) and 11 for march (78.6%). Out of the 17 drought years in Mukogodo Division in Laikipia, the total number of dry months were 12 for December (70.6%), 16 for January (94.1%), 15 for February (88.2%)

UNDER PEER REVIEW

and 12 for March (70.6%) (Mburu, 2005). This is a clear indicator of Laikipia District being drier compared to Machakos District.

In Chemusus weather station, acute negative deviations from the LTM (anomalies) were recorded in 2013 (-90%), 2008 (-100%) and 2005 (-110%). These became the severe periods of drought. The highest positive deviations from the LTM were experienced in 1997 (+50%), 1998 (50%) and 1990 (30%). Perkera recorded a higher drought intensity compared to Chemusus basing on the above analysis. The effect of drought on finger millet and goat farming was more severe in Baringo South as compared to Central Baringo North. Baringo South had lower yields and adverse crop failure as compared to Baringo North.

Mburu (2005) posit that Laikipia District recorded varied drought intensities from one year to another. Central Division recorded 52.8% with a LTM of 636.6mm where as Mukogodo Division recorded a DI of 40.5% and a LTM of 507.8mm. The DI was higher compared to that of Machakos District. The 1984 drought in Ethiopia, experienced rainfall totals less than the LTM by 22%, with other areas recording $\geq$ 50% below the LTM (Web et al. 1991).

Ngaira, (1999) posits that a **coefficient of variability** above 20% implies unreliable and a highly variable rainfall posing panic and uncertainty problems. Coefficient of variability between Baringo South and Baringo North reveals that though these two areas are categorized as semi-arid/desert, their degree of aridity varies. Baringo South is more arid than Baringo North. Baringo South shows a higher variability and uncertainty in its characteristics of rainfall. Coefficient of variability (CV) in the annual total rainfall of Chemusus, indicates a very unreliable and highly variable rainfall.

As suggested by Doorenbus (1976), rainfall data with a CV of 0.2 (20%) or above is highly variable. From the figures for Chemusus, coefficient of variability in all the years is 0.20 (20%) means very high variability throughout the 40 year period compared to Baringo South 0.23 (23%). Coefficient of variability between Baringo South and Baringo North Sub Counties reveals that though the two areas are categorized as semi-arid/desert, their degree of aridity varies. Frequent delays in rainfall causes panic and uncertainty on decisions as when to prepare land or plant. In extreme cases it causes low yields and crop failure. Kahangara Division recorded a coefficient of variability of 40% which is one of the highest rainfall variability in the region.

UNDER PEER REVIEW

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.2 Summary

Variability in climate, has become a global environmental problem and concern in the recent times. It entails the fluctuating mean in the elements of climate and its other observable typical characteristics on both temporal and spatial scales. The impacts and effects of variability in climate are mostly common and highly experienced in the ASALs that happen to be deficient in moisture. These arid and semi-arid lands with extreme inter annual rainfall and temperature variability inherently dominate many parts in the tropical regions of Africa, including Kenya and its neighbors. Characteristics of these climatic conditions include severe and prolonged droughts with devastating effects featuring very prominently.

Climatic elements and especially rainfall and temperature are subject to variations in many parts of the world, exhibited mainly by fluctuations in rainfall and temperature on both temporal and spatial scales. Africa happens to be one of the leading victims of the global variations in climate and eventually climate change. This situation has culminated in the spreading of desert conditions and characteristics in the Sahelian Africa and other areas in the neighborhood of the major continental deserts including Kalahari, Namib and Sahara. The most effective and efficient mitigation strategies should be brought on board to help cushion the residents of these areas from the adverse effects of these conditions.

Extremely high variations in both rainfall and temperature with considerable uncertainties when the rainfall onsets and are expected is becoming a global concern. This situation continuously impacts negatively on planned farming activities and calendars particularly in the ASALs of Africa such as Kenya including Baringo the study areas.

The objective of the study was to; Establish the historical trends and variability patterns of rainfall and temperature in Baringo County between 1980 – 2020. The methods of data collection included; a) Reviewing existing related literature from university and UNEP libraries, internet, journals and periodicals, newspapers and magazines. b) Collection of secondary documented data from meteorological department, County government departments such as Agriculture, livestock and statistics.

The data analysis methods included climatological techniques to determine and measure rainfall variability including; Mean Precipitation concentration index (PCI), Relative variability (RV), coefficient of variability (CV), Standard deviation (**σ),** Time series analysis, This study analyzed monthly and annual variability of rainfall and temperature in the semi-arid Baringo County over a 40 year period (1981 – 2020). The analysis identified various characteristics and patterns of rainfall, including anomalies, trends, coefficient of variability, onsets and off sets of rainfall and drought periods. Variability in rainfall and particularly droughts pose negative impacts on farming activities of the semi-arid Baringo County. The observed statistical analysis indicated varying rainfall patterns within the monthly and annual rainfall totals.

Analysis of rainfall in Baringo County reveals acute inter seasonal differences in rainfall distributions and totals. High levels of variability have been observed and recorded within the months, for example April and February have the highest variability compared to all the months. Increasing levels of dry spells were noted with less wet spells within the months

UNDER PEER REVIEW

during the rainy seasons over the study period 1981 – 2020. Rainfall on some occasions have come earlier than expected. For example, from rainfall table 1, it can be seen that, in 1993, 1998 and 2008, the onset of rains came in January when they were expected in march. The onset expected wet periods have been reported to be dry such as 1992, 2001, 2008 and 2012. March and April were dry when they were expected to be wet. Respondents equally reported delays of onsets in rainfall and sometimes receiving unexpected earlier rainfall. All these are indicators and determinants of rainfall variability characteristics in the study area.

5.3 Major findings

The study sought to establish the historical trends and variability of rainfall and temperature in Baringo County between 1980 – 2020. The summarized major findings include the following;

1. The study established extremely variable and unreliable, monthly rainfall distribution in Baringo County, making it somehow difficult to clearly define the dry and rainy seasons particularly in the lowland areas Baringo South and Tiaty. Variability of rainfall is shown on the table

1 Perkera station and 4.2 Chemusus weather station. From these two tables we can clearly see where the unexpected onset of the long rains came earlier in Baringo South for instance in January 1993, 1998, 2007, 2006 in February 2000, 1990, 1999 and 1987 or the expected onset failed completely such as in January 1981, 1986, 1994,1990 and 2011. In February 2003, 2002, 1992 and 1981. January and February are the driest months in Baringo County. April is normally the wettest month but in some years they were very dry eg 1984, 1999, 2011 and 2014,.

Variability in the county is shown through marked differences in rainfall amounts between Baringo South (Perkera station) and Baringo North (Chemususu staion). Baringo South is more moisture deficient with a coefficient variability of 0.23 (23%) which designates it a semi-arid area while Baringo North remains a bit wetter with a coefficient variability of 0.18.5 (18.5%). This demonstrates the fact that lowland areas in Baringo County are drier, coupled with a high rainfall and temperature variability. This is further shown by their differences in Drought intensity (DI) (Perkera 23.73 and Chemusus 13.03). Relative variability (RV) (Perkera 25% and Chemusus 15%) and Precipitation Concentration Index (PCI) Perkera 13.4% and Chemusus 8.5%).

2) There is evidence of frequent occurrence of droughts in Baringo County . Drought years in Baringo South were 1981, 1986, 1987, 1990, 1991, 1992, 1995, 1996, 1999, 2003, 2005, 2009. 2012 and 2014 which was an average interval of about 4-5years. In Baringo north the drought years were, 1987, 1990, 1993,1994, 1995, 1996, 1999, 2002, 2005, 2009, 2012, and 2014. Baringo South recorded a higher drought intensity compared to Baringo North.

3) There are indicators of drier conditions in future from the analysis of long term rainfall trends. Figure 1 shows total rainfall distribution and trends 1981 – 2020 for Baringo South. It shows a insignificant increasing trend (r^2 = 0.043) in Perkera. While the trend in figure 2 is significantly declining. (r^2 = - 0.298 for Chemusus. Prolonged drought especially in Baringo South is also an indicator of changing climate.

5.4 Conclusion.

UNDER PEER REVIEW

The study assesses and analyzes the rainfall characteristics within Baringo County. The analysis reveal a high temporal variability in the County. A comparison of the two Sub Counties clearly shows Baringo South to have more variable rainfall than Baringo North. The study assesses and analyzes the rainfall characteristics within Baringo County. The analysis reveal a high temporal variability in the County. A comparison of the two Sub Counties clearly shows Baringo South to have more variable rainfall than Baringo North.

5.5 Recommendations

Baringo residents need to understand and internalize the rainfall and temperature trends and patterns in order demonstrate the right perceptions of variability in climate if any meaningful solutions to the problems farmers encounter on the effects of rainfall variability on farming activities. Otherwise the continuity of the problems would subject subsistence farming to risks culminating into persistent food shortages, hunger and food insecurity.

REFERENCES

1. Bevan, R. (2002). Variability of Rainfall. Ottawa, Canada; Noble books Publishers.
2. Koskei, E. C, Kitetu, J.J, and Wambongo C. R (2018) Analysis of spatial variability in rainfall trends in Baringo County, Kenya.
3. Medung, F. (2009) Environmental Challenges. London, Uk; Oxford University press.
4. Ngaira, J.K (2004). Basic Facts in contemporary climatology. Kisumu, Kenya; Lake publishers.
5. Ngongondo C.S.(2005) Analysis of long term rainfall variability. Trend and water avilable in Mulunguzi river catchment, Malawi journal of science and Technology, 7: 34 - 44
6. Nicholson, T. (2017). Rainfall variability. Ibadan, Nigeria;Evans brothers.
7. Nicholson, S.E.,(2000). The nature of rainfall variability over Africa on time scales of decades to millennia. Department of Meteorology, Florida State University. Tallahasee, USA.
8. Ojwang, F. (2010). The effect of variability of rainfall. Nairobi, Kenya; Oxford University Press.
   i. Kenya. Longman Publishers.
9. Ominde, S. H and Juma, C. (1991). A change in weather systems. Org,wiki/Variability.
10. Ovuka, J. (2016). Rainfall variabilityin marginal lands Ibadan, Nigeria;Evans brothers.
11. Ribot, W., Brian, J., and Jean, S. (2006). Rainfall Variability in Africa. London, Britain; Arnold (publishers) LTD
12. Shisanya, C.A., Recha, C. and Anyamba, A. (2014): Rainfall variability and its impact on
13. U.N.H.C.R, (2010). Global environmental outlook 4. http/www.unep/org. London.
14. Wenner, R (2012). Wikipedia,Org/Wiki/Rainfall Variability.
15. World Meteorological Organization (2000). Impacts of present and future climate variability in the climate change on Agriculture and forest in the Arid and Semi Arid Tropics:
16. Zinyowera, M.C., and Unganai, S.L.,(1993) Adaptation and Vulnarability. The regional Impacts of climate: An Assessment of Vulnarability, IPPCC Special Report.

UNDER PEER REVIEW