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RESEARCH ARTICLE

THE ANALYZING OF RAINFALL VARIABILITY ON AGRICULTURAL GROWING SEASON IN NAROK COUNTY, KENYA

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ABSTRACT

In recent decades, climate variability has been experienced globally. The rainfall patterns in Kenya are becoming unpredictable just like other regions in Sub-Saharan Africa. Rainfall variability affects crop yields by influencing growth and development rate, pests and diseases. Changes in rainfall patterns occur in the late onset of long rains and low average amount throughout the year. In Narok County, droughts often translate into food shortages and fluctuations in agricultural production. The current study examined the varying rainfall patterns during the wheat growing season of March-April-May. The study aimed at determining the inter-annual variability trends in onset, amount, cessation, and number of rainy days. In this research, Climate Research Unit (CRU) rainfall data set of 36 years (1981 to 2016) was obtained from Kenya Meteorological Department. Rainfall characteristics were analyzed using variability indices. The individual R^2 for onset, rain days, cessation and amount was 0.55, 0.5, 0.019 and 0.014 respectively. This showed that onset and number of rain days are the major rainfall characteristics likely to affect wheat yields. The results further showed that there was no significant impact of the rainfall characteristics on wheat. There is need for wheat farmers to adapt sustainable strategies in order to cope with seasonal rainfall variability associated risks.

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INTRODUCTION

Among the climatic elements, rainfall has the highest spatial and temporal variability in the tropical countries including East Africa (Basalirwa, 1991 and Ogola, 2011). From a farm's point of view, the seasonality of rainfall is very important as it directly impacts the crop yields. Hence the onset, duration, frequency and cessation of rainfall within the seasons are very relevant rather than average and amount. The occurrence of 7-14 non-rainy days within a growing season has demonstrated a major effect on final yields in semi-arid Kenya (Barron, 2003). The drought cycles that are becoming shorter are affecting rain-fed agriculture. For instance, Kenya has been experiencing a major droughts after every ten years and minor droughts every three or four years. More so, in recent years, critical drought periods in the country were experienced in 1984, 1995, 2000, and 2005/2006 (UNEP, 2009). In 2009, Kenya experienced a severe drought leading to hunger and starvation of an approximate 10 million people nationally. This resulted from poor yields, crop failure and rising cost of living (Kenya Red Cross, 2009). In an agricultural system, which is rain-fed, rainfall is the major source of soil moisture with such a system being very sensitive to rainfall variability particularly when rain is unpredictable, limited and varies over time and space.

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Moisture is the single largest factor that limits crop yields (Stewart, 1982). According to (Simane, 1993) rainfall amount and its distribution in the growing season is very critical as it affects both growth and yields. When there is uneven rainfall distribution within the growing season, crops are exposed to varying dry spell degrees without necessary reduction in total amount of rain received (Barron, 2003). Low and varying rainfall impose a very delicate balance between onset, frequency and rainfall amount on one hand and the timing of farming activities on the other. In the last ten years crop failures that have a relationship with climate variability in the sub-Saharan Africa have increased. Among the many manifestation of variability are floods, late onset during the start of the rainfall season and recurring droughts (Sivakumar, 1988 and Lobell, 2007). According to (Lobell, 2007) rainfall variation is increasing in different parts of the world. This has resulted in a decrease in crop yields. According to (10), In Portugal, variation in annual rainfall was recorded at 340 mm to 1180 mm. This has a huge impact on the rain-fed agricultural sector. According to (Kavikumar, 2010) agriculture is the most vulnerable field in regard to climate variability and change. Most wheat growing regions in the world experience two rainy seasons with slight rainy days between the two major seasons. However, in the last few years, changes have occurred in the normal rainfall patterns (Lobell, 2007). Rainfall characteristics such as onset and cessation are important characteristics in control of agricultural

activities and production in many tropical countries (Mage, 2015). There has been a delay in the onset of effective rainy seasons with the duration of rainy seasons being short. On the other hand, the cessation period of rains has experienced no delays. According to (Omotosho, 2000) abnormal onset of rainy season results in severe consequences, where abrupt floods destroy infrastructure, death to livestock, and increase of damage to crop fields. However, when the growing season is shortened by late onset, soil preparation is affected. This exposes the crops to water stress during grain filling and which reduce the yields. More so, higher rainfall intensity may lead to soil erosion which causes nutrients loss. Onset dates are very critical for agricultural production. By predicting onset dates more reliably, timely land preparation and seed mobilization will shield the farmers from planting too early or late thus reducing the chances of crop failure. Further, even with the right timing, these crops will need adequate rainfall conditions in the early stages of development (Phiri, 2005). With reasonable information on the likely rainfall cessation date the farmer can predict the length of the growing season hence choosing the type of crop to grow (Kowal, 1972).

Rainfall onset and cessation vary from place to place within a growing season where the onset has more impact on the growing season as it is varying more than cessation. An early onset close to the mean onset usually results in a longer growing season. The rainy season is hence an important factor, which determines crop production (Kowal, 1972). Due to this high rainfall variability, early/late onset and cessation of rainfall is not uncommon. Large deviations of the onset and cessation of rainfall from the mean may sometimes lead to poor crop yields even when the rainfall amount was above normal (Mugo, 2016). Both the frequency and intensity of severe weather conditions such as droughts have increased with receding water levels in the rivers. For instance in 2013, Narok County was adversely affected by floods where 15 people died and many more got displaced. These floods affected the constituencies where wheat is grown. Both the frequency and intensity of severe weather conditions such as droughts have increased with receding water levels in the rivers. For instance in 2013, Narok County was adversely affected by floods where 15 people died and many more got displaced. These floods affected the constituencies where wheat is grown (Indigenous Information Network, 2015). The annual distribution of rainfall and the total number of rain days received annually in the country varies significantly from the past years (Carvalho 2015). According to (Huho, 2014), the frequency of occurrence and severity of floods and droughts have been increasing over time. The worst drought in last one hundred years occurred in 1999-2001 causing massive crop failure where maize yields dropped from 2.5 to 0.5tones/Ha in Narok County. In Kenya there are two rainy seasons March-April-May (long rains) and October -November - December (short rains). This rainfall is very erratic in nature reaching 1250 mm (in about 3% of the country) with the highlands getting up to 1800 mm and the semi-arid areas getting as low as 200 mm (UNEP/GoK, 2000). There are increased high probabilities for severe weather events. For example in 2009 there was a severe drought country wide due to failure of March to May rains. This drought caused both food and water shortage to about ten million people in Kenya who needed food aid leading to increased food imports (Easterling 2000). There is an increase in frequency of severe weather event such as floods, droughts and heat waves with dire consequences in agriculture activities (Bilham 2011). Stress due to drought is a critical factor in yield reduction with its severity and timing during plant growth being very important (Nicholson, 1985). Kenya had severe droughts in 1971-1973, 1983-1984 and 1991-1992. In 2004-2006 droughts affected 2.5 million people while that of 2008-2010 affected about ten million people (Rerieya, 2009). The impacts of temperature changes on crop yields are considered important area for future research (Lobell, 2008). Currently, about 57% of the Kenyan population lives in poverty since they largely rely on climate sensitive agriculture which is mostly rain-fed and small scale. Hence, when there is an abnormal onset of a rainfall season, there are often severe floods which destroy infrastructure. This abnormal rainfall leads to damage of crops and cause outbreak of diseases (FAO, 2010). In the past few decades, recurrent patterns between floods and droughts have become more pronounced, with their intensity and distribution spatially changing too. The effect of this cyclic pattern has also become more intense (IPCC 2007). There is evidence which strongly suggest that the repeated droughts and increase in floods may raise the levels of poverty leading to most small scale famers getting trapped in poverty circles (27). Dependence on uncertain rainfall and exposure to unmitigated climate risk are major obstacles in efforts to sustainably intensify agricultural production and enhance rural livelihoods (28).

According to (Hansen, 2004), variations in the annual rain days as well as the rainfall received play a key role in the amount of maize yields. From the research, the number of rain days annually are decreasing as the onset of rainy seasons are delaying and the cessation period does not delay. According to (Adamgbe, 2013) rainfall in the tropics varies greatly which makes it an important variable affecting crop yield. The variability of rainfall seasonally has a great effect on soil water that is available for plants and with serious consequences. At times the rainfall received is extremely heavy resulting in floods even in the arid and small arid areas. Improved agronomic management is important to reduce yield gaps and enhance food security in Sub Saharan Africa. Optimizing plant density in farmer fields, higher frequency of manure application and choice of crop varieties are important to reducing yield gaps. More so, timing of planting is one of the important factors that affect crop growth and development and eventually crop yield (HarvestChoice, 2010).

MATERIALS AND METHODS

Location of the study Area: Narok County lies in the Southern part of the Rift Valley in Kenya. It borders six counties: Nakuru, Bomet, Kisii, Kajiado, Nyamira and Migori. It also borders Tanzania to the South. The county headquarters is in Narok town. The area of study was Narok County which comprises six sub-counties: Narok North, Emurua Dikirr, Narok East, Narok West, Kilgoris, and Narok South. Narok County is situated 0°,30'S and 2°,0'S latitudes, and between 34°,46'E and 36°,15' East longitudes.

Climate: The county lies along the Great Rift Valley and its altitude varies from 1630 meters to 2200 meters above sea level. The area experiences bimodal patterns of rainfall; the long rains are experienced in March, April and May (MAM) while the short rains are experienced between October, November and December (OND) (Narok County report, 2014).

Narok County receives moderate to high rainfall of between 700 mm and 1800 mm in upper zone annually while the lower zones are dry and receive between 400 mm and 700 mm annually. Temperatures in Narok County range from a low of 12°C to a high of 28°C with an average temperature of 22^0c (12) Narok District has soils developed from igneous rocks that are shallow to deep and excessively drained (32). According to (25), Narok County lies within two Agro-climatic zones; zone III (Semi-humid) and zone IV (semi-humid to semi-arid). Wheat in Narok County is an annual crop grown during the long rains in the two zones. Most farmers practice dry planting just before the onset of the growing season with wheat taking between 4-5 months to mature depending on the altitude.

Land use: Wheat farming is carried out by small and large scale farmers where land tenure is both lease and free hold. In Narok County, wheat farming is mainly carried out in Narok North, Narok East, Narok South and Narok West sub-counties. Other crops grown in Narok County include: barley, maize, Irish potatoes, horticultural crops and beans. The farmers in the area also practice livestock farming

MATERIALS AND METHODS

This study examined the seasonal rainfall variability in Narok County in the wheat growing season of March to May.

Data Collection: Rainfall data was obtained from Kenya Meteorological Department. Rainfall characteristics analyzed include; nature and time of onset, number of rainy days, amount and cessation.

Quality control of climatic data: Determining the quality of data is considered an important part of climatological studies. Checking the quality of data is important so as to remove outliers and smoothening the data series. Outliers are data points that depart significantly from the trend (22). Issues which were considered included; missing data, consistency and extrapolating data in ungauged sites and homogeneity of rainfall data.

Missing data: Although there were 20 stations in Narok County with rainfall data, most had big data gaps within the period. To overcome this challenge, daily Climate Research Unit (CRU) dataset was obtained from Kenya Meteorological Department from the gridded polygon. This data was analyzed for gaps where some gaps were detected. The missing data was below five percent and hence it was estimated using equation one. According to (Naoum, 2003) this equation is used to replace the missing data with the long term mean where the data is homogeneous.

$$X_m = \frac{1}{N}\sum_{i=1}^{n} X_i \qquad (3.1)$$

Where X_m is the missing data being estimated, $X_{i\ is}$ available data points, N is the total number of points.

Consistency of rainfall data: *In order to check the consistency of rainfall data in a scientific way, a computation of coefficient of variation (CV) was done using the following formula:*

$$CV = \left(\frac{S}{\bar{X}}\right) 100 \qquad (3.2)$$

Where CV is Coefficient of variation, s is the standard deviation and $\bar{x}$ is the mean for data. This was computed using INSTAT 3.37. The Computed CV was 27.6%. This implied that the rainfall data obtained was consistent.

Homogeneity test for rainfall data: In the current study, rainfall data was tested for homogeneity. From the homogeneity analyses, the data had no Nil values (values below threshold) but 100% non-Nil values (above threshold) showing high homogeneity. Standard deviations (SD) of the normalized means for rainfall was 196.368 while for wheat SD = 9.98 in Narok. High SD values indicated the restriction of variations (rescaled cumulative deviations, RCD) around mean rainfall amounts thus low homogeneity. *The Kolmogorov-Smirnov (K-S value) Test values, R- Square for the rainfall, and the values of the average rainfall means for rainfall months were summarized. A plot of homogeneity of the average annual rainfall and for all the years studied showed deviations from the zero mark of the RCDs not crossing probability lines; thus homogeneity was accepted at 99% probabilities. There was a normal distribution of the sampled-temporal rainfall data with high goodness-of-fit (R^2= 92% to 96%) of the selected distribution showing continuity of the data from mother primary data thus high homogeneity. Kolmogorov-Smirnov values (one-sided sample K-S test) showed K-S values (0.15 to 0.23) consistently lower.*

Data in ungauged sites: Rainfall data that was used in this research was the Climate Research Unit (CRU). The CRU data is a gridded climatology data for Narok County for the period 1981–2016. According to (35,13), the African rain-gauge data observed during the post-independence era of 1970's through to recent years have many spatial and temporal discontinuities over large sections of East Africa. Gridded rainfall data was derived from a polygon drawn from rainfall stations within the study area which was taken as the rainfall data for the whole study area.

Data Analysis: Climatic Research Unit (CRU) rainfall dataset from a gridded polygon drawn from rainfall stations in the study area was obtained from the Kenya Meteorological Department. Objective one was analyzed by calculating indices of variability together with rainfall and wheat yield trends of monthly, seasonal and annually. Pearson correlation test was used to test the significance of the trend. Deviation of actual onset and cessation dates from the normal average dates was computed. The average seasonal rainfall amount was worked out. Onset and cessation dates were calculated using the formula by

$$A(D) = \sum_{j=d_{s-50}}^{D} R_j - \bar{Q} \qquad (3.3)$$

Where; $R\,j$ is the rainfall on day j and j ranges from $ds - 50$ to the day being considered (D), A (D) is calculated for each day from $ds - 50$ to $de + 50$ for each year. The day after the minimum in A (D) is the onset, as after this the rainfall is persistent in occurrence, duration, and intensity (10), and the day of the maximum (after the minimum) is the cessation date.

RESULTS AND DISCUSSIONS

Variability of rainfall characteristics in the March - May wheat growing season: In this section, seasonal variability of various rain fall characteristic is analyzed.

Rainfall Onset and Cessation Dates: The onset and cessation dates of rain varied in the years as from 1981 to 2016. The normal average onset of rain in Narok is towards the end of the third week of March while cessation is the end of the first week of June. Studies that had been done by (Dunning, 2016) found that on average, *the onset and cessation dates for Kenya were 17th to 21st March and 5th to 9th June respectively. In this study, the average onset (17th and 21st March) and that of cessation (5th and 9th June) dates was used. Variation of the onset occurs when the rain fall before or after March 17th while on the other hand deviation in cessation occurs when it happens before or after 9thin the month of June. According to (Kihara, 2015) delays in onset* of rains during the month of March, alter planting dates at times to early April. As from the year 1981 to 1989, the rainfall in these years started in March of each year. In 1990, the rainfall was recorded to have started in February. This was slightly different in 1991 and 1992 when the rainfall started in March. In 1993 and 1994, the rainfall started earlier in February. In the following years from 1995, a part from the year 1998 and 2009 when it started to rain in the month of April, the rainfall stabilized and started in March of each year. The deviation of the onset was established by computing the difference in the rainfall onset with the normal onset of 19th day of March. The result showed that there was an increase in deviation of rainfall onset from the normal dates over the years following a trend depicted by the equation, y = 0.0263x + 9.4587, while there was a decrease in deviation of rainfall cessation from the normal dates as depicted by equation ; y = -0.0534x + 14.683 in Figure 1.

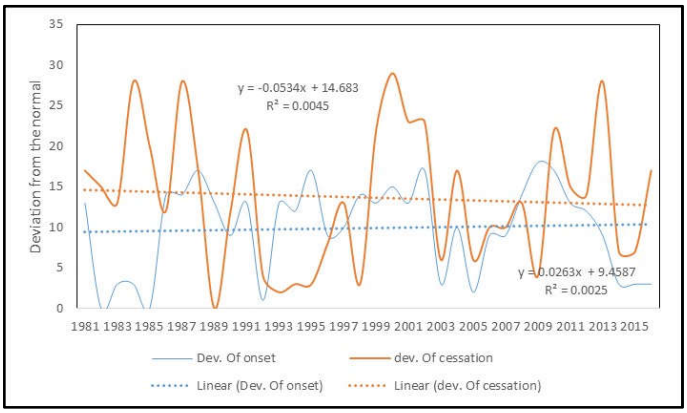

Figure 1. Onset and cessation of rainfall in March – May season

Seasonal rainfall amount: Narok region experiences largely bimodal rainfall distribution that comes in the months of March-ARIL-May (MAM, long rains) and September – October- December for short rains (Allusa, 1974). Farmers who participated in the research stated that they only grew wheat in the long rain season. Seasonal rainfall amount in the wheat growing season (MAM) therefore was computed by summation of the amount of rainfall for each season. The lowest amount was recorded in 1984 (447.9 mm of rainfall) while the highest amount was recorded in 1989 (1086.4mm of rainfall). This trend of seasonal rainfall amount, showed that there was a decrease in rainfall over the years = -0.1727x + 718.81; where Y = rainfall amount in the season and x is the year (Figure 2)

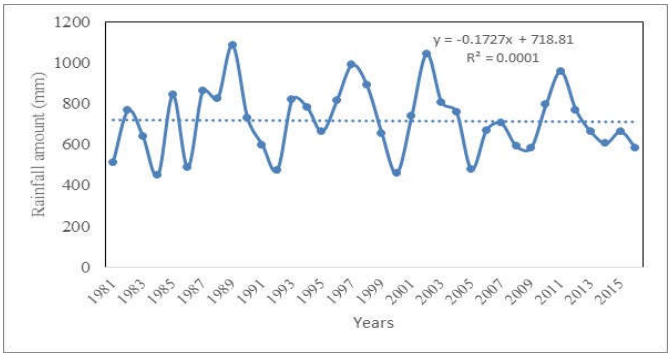

Figure 2. Rainfall amount in the season

Number of rain days in March to May season: Computation of the number of rain days in a wheat growing season was done for each year. The result showed that there was more number of rain days in the year 1994 (78.2 days). The lowest number of rain days was recorded in 2000 which had 37 rain days and 2004 which had 34 days. The number of rain days in a season declined over the years (1981 – 2016) as indicated in the trend line y = -0.595x + 92.924 (Figure 3).

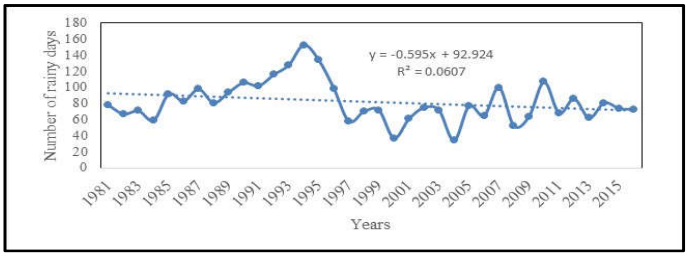

Figure 3. Number of rain days in the seasons

In establishing rainfall variability result, the findings indicated that there was a significant variation in the amount of rainfall (CV = 22.99%, R2 = 0.0001), onset (CV = 55.43%, R^2 = 0.0025), number of rain days (CV = 31.06%, R^2 = 0.0607) and cessation (CV = 61.07%, R^2 = 0.0045. The research established that there is seasonal variability in rainfall characteristics in Narok County.

Conclusions and Recommendations

This research sought to determine variability in the seasonal, onset, cessation, number of rainy days and amount of rainfall characteristics in Narok County from year 1981 to 2016. The study found out that there was variability of rainfall characteristics. For instance, the rainfall onset and cessation dates show variability during the study period where the normal average onset is expected in the third pentad of March while cessation is expected in early June. For instance, in the years 1990, 1993 and 1994 the big deviation in onset dates occurred in February while in 1998, there was a late onset in April. On the other hand there were early cessations in 1984 and 2000 and late cessation in 1991, 2007 and 2012. The result show an increase in deviation of rainfall onset from the normal dates over the years (y = 0.0263x + 9.4587) on one hand and a decrease in deviation of rainfall cessation from the normal dates (y = -0.0534x + 14.683) on the other.

Seasonal rainfall amount showed a decrease over the years with the highest peak in 1989 while the lowest dip in 1984. On the number of rain days in a wheat growing season, there was a slight decrease in the number of rain days from onset to cessation over the years. The analyzed seasonal and annual rainfall variability trends in Narok County indicated that there was a decrease in amount of rainfall, variation in the number of rain days over the years as well as deviating onset and cessation dates from the normal leading to an increase in risks associated with rain-fed crop wheat production in the study area. Delayed onset and early cessation leads to shortened wheat growing seasons thus exposing growing wheat to have moisture stress particularly at the grain filling stage. On the other hand, above normal and highly intense rainfall usually lead to both soil erosion and leaching denying wheat necessarily nutrients, this impacts the yields negatively. Rain-fed wheat farming in Narok County indicates a negative impact from rainfall variability and is likely to face further challenges as a result of future global climate changes. As a result, there is a need for wheat farmers to adapt sustainable strategies in order to cope with seasonal rainfall variability associated risks.

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