Research Article

Analysis of Average Annual Rainfall and Average Maximum Annual Temperature for a Period of 30 years to Establish Trends in Kieni, Central Kenya

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ABSTRACT

The aim of the study was to analyze average annual rainfall and average maximum annual temperature records for 30 years in the study area to establish trends hence confirm the presence or absence of climate change. The analysis was accomplished with the use of MS Excel spreadsheets. The meteorological datasets were 1984-2013 records for rainfall and 1981-2012 for temperature. The rainfall climatological standard normal was computed for a 25-year period between 1989 and 2012 which was used to compute the average annual rainfall anomaly. The temperature provisional normal was computed for a period of 10 years due to lack of adequate data. The average annual rainfall anomaly for 1984-2013 periods was -8.8 mm an indication of a declining rainfall trend while the annual maximum temperature for 1981-2012 period was 0.5°C a positive trend showing that the annual maximum temperatures are rising in the study area. Therefore, the declining average annual rainfall accompanied with rising maximum temperatures were indicators of the presence of climate change.

Keywords: Average annual rainfall; Average maximum temperature; Trends; Climatological standard normal; Datasets; Climate change

INTRODUCTION

Establishment of rainfall and temperature trends of the agricultural area is important especially to the communities living in the area since they can be able to adapt by changing their farming practices and hence increasing their livelihoods from increased resilience in the face of climate change. The Intergovernmental Panel on Climate Change (IPCC) reported that most countries will experience increased average temperatures, more stressed water resources and unreliable precipitation [1,2].

Susceptibility of a country to climate change on the different sectors is related to the state of development, as indicated by the different impacts of climate change on the different sectors of a country's economy [3,4]. Agriculture is one of the key economic sectors that are highly venerable to the impacts of climate change [5]. The agricultural sector contributes approximately 32.6% of the country's GDP and employs more than 40% of the total population and more than 70% of the rural population in Kenya [6]. This means any major negative effect of climate change on agriculture would have serious consequences for the rural economy and the national economy as a whole.

Central Kenya, one of the country's food baskets has been experiencing significant changes in temperature and precipitation trends. Recent research in Nyeri County demonstrates that rainfall received has been decreasing every 3 to 4 years [7]. Since the 1960s, the region's minimum and maximum temperatures have been in the magnitude of 0.8-2.0 and 0.1-0.7°C respectively [8]. According to the Kenya Economic Survey Report Highlight, growth in Kenya's agricultural sector fell from 4.2% in 2012 to 2.9% in 2013 and this was attributed to inadequate rainfall received in some grain-growing areas. In Kieni, constituency, Nderitu et al., reported declining long rains that fall from March to May between 1985-2015.

The research sought to collect and analyse average annual rainfall and average maximum annual temperature data for a period of 30 years to establish the trends which would then show the presence or the absence of climate change in the area. This would be benefiting the community since the presence of climate change brings about ways of adapting their farming practices to increase livelihoods and become more resilient.

MATERIALS AND METHODS

Study area

The area of study is located in the greater Nyeri country. From the 2009 Kenya Housing and Population Census [9,10], Kieni had a population of 175,812 and covers an area of 1,378.10 Sq. Km. The amount of rainfall received in the area is affected by Mt. Kenya which is >4,000 m above sea level to the east and Aberdare Ranges to the west which is >3,000 m above sea level. The lowest area (1830 m above sea level) receives about 850 mm of rainfall per year and rises to 2300 mm near the slopes of Mt Kenya to 3100 mm in the Aberdare area. Kieni East District where the study was carried out receives annual precipitation of 500 mm and is therefore classified as a semi-arid region. These Arid and semi-arid lands where Kieni sub-county falls under are characterized generally by hot and dry climate, low and erratic rainfall that varies widely across space and time. The region experiences a bimodal pattern of rainfall with long rains falling around March/April and short rains falling in October/November.

Analytical methods

Rainfall trends: To establish rainfall trends in the study area, the annual monthly and the total annual average rainfall were computed for the years 1984-2013 using excel spreadsheets. The annual monthly average rainfall moving averages were computed and thereafter graphs drawn to show the overall trend over the 30-year period. According to the World Meteorological Organisation, in the absence of a climatological standard normal, a provisional normal can be computed from at least 10-12 years of the prior observations taken before the period under review.

In this case, average rainfall records used were from Nanyuki meteorological station which had observations from 1959 therefore the normal was computed for a 25-year period from 1959 to 1983 and was used as the baseline [11]. The computed normal was subtracted from 1984-2013 the total annual monthly average, as well as the average rainfall computed each month within the period to obtain the annual and monthly anomalies and graphs, are drawn of the same were drawn.

Temperature trends: Temperature data available from Nanyuki meteorological station was from 1997 to 2014 with many gaps in between. For this reason, it was decided to analyse the data from the Nyeri meteorological station which was available from 1976 therefore the data under review was for the 1981-2012 period. The same procedure as the rainfall data of determining the annual average and the monthly average maximum temperature for the period under review was followed. However, due to the lack of enough data, the provisional normal was computed from 1976 to 1985 a 10-year period. The annual monthly maximum temperature was plotted against the years between 1981 and 2012 to obtain the average maximum temperature trends within the period. The graphs were also plotted of the annual anomalies as well as the average monthly anomalies.

RESULTS AND DISCUSSION

Average annual rainfall trend analysis

Rainfall data records were analysed for 1984-2013, a 30-year period. The annual total and average rainfall were calculated for each year and the average rainfall plotted against its corresponding year as shown in Figure 1 below. The average annual rainfall for the 30-year period was 646.4 mm while the total monthly average was 53.9 mm per month. The highest total annual average was 967.8 mm in 1997 followed by 925.3 mm in 1988 and coming third with 924.7mm in 1998. Within the 30-year period the lowest average annual rainfall was in 2000 when only 287.1mm of rainfall fell, 1984 with 318.7 mm and 1993 with 370.0 mm.
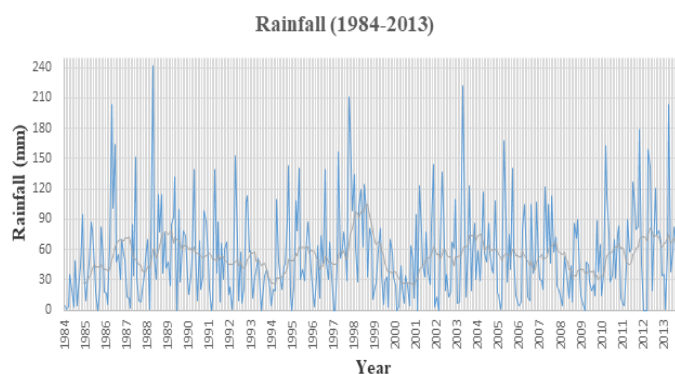
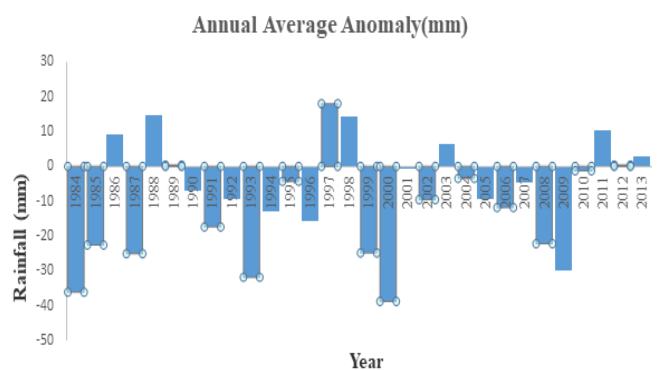

Figure 1: Annual average rainfall (1984-2013).

Figure 2: Annual average rainfall anomalies.

According to WMO (1989) provisional normal can be computed from at least 10-years of observations in the absence of a climatological standard. In this case, there were observations from 1959 and therefore the provisional normal was computed from a 25-year period from 1959 to 1983 which was. The computed normal was then used to compute the annual average rainfall which was the difference between the normal and the particular year's average as well as the total monthly anomalies. The highest negative anomaly was in 2000, 1984 and 1993 with -38.7 mm, -36.1 mm and -31.8 mm respectively an indication that in those years the average rainfall received was far below the reference normal [12]. 1997, 1988 and 1998, on the other hand, received the highest rainfall above the reference normal of 18 mm, 14.5 mm and 14.4 mm respectively as illustrated in Figure 2 above.
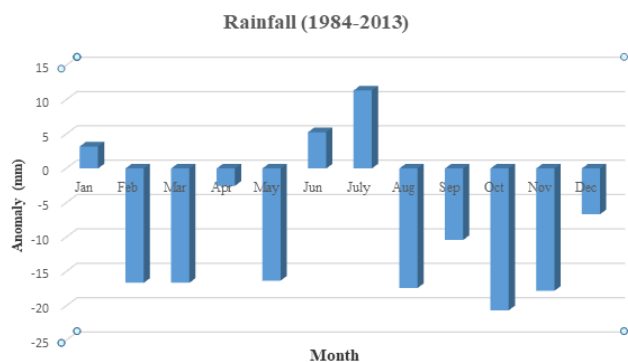
Figure 3: Monthly average anomalies.

The deviations from the 25-year normal as shown in Figure 3 showed that the months that returned positive values to be January, June, and July with records of 3.2 mm, 5.3 mm and 11.3 mm respectively. The positive sign was an implication that the monthly averages were higher than the 25-year normal therefore the annual monthly rainfall for January, June and July was higher. On the other hand, all the other nine months reported a negative anomaly in which case their monthly average rainfall records were lower than the 25-year average normal. The total average anomaly for the 30-year period was -8.8 mm which meant that it was lower than the computed reference normal.

DISCUSSION

The 25-year normal had an annual average of 751.6 mm while that of the 30-year period under review was 646.4 mm a 14% decrease in the average annual rains. The normal total monthly average rainfall for the 25-year period was 62.6 mm while that of the 1984-2013 periods was 53.9 mm which is also a 14% decline in the rainfall. According to WMO, if a climatological standard normal is not available for any reason, provisional normal should be calculated from observations extending over a period of at least ten years hence the 25-year period used above since the observations were available for that period. It had been stated in chapter three that the study area receives precipitation of about 500 mm which was close to our calculated value of 646.4 mm.

IPCC reported that most countries will experience more stressed water resources due to unreliable rainfall [1,2]. Recent research in Nyeri county demonstrated that rainfall had been decreasing every 3 to 4 years [7], while Nderitu et al., reported declining long rains in Kieni Constituency between 1985-2015. Erratic rainfall, couple with severe droughts was the biggest risk facing Kenya's agricultural sector with profound impacts on crop production.

The average anomaly was -8.8 mm which indicated a negative trend of the rainfall that the study area received over the period under review which was in line with the 14% general decline of the rainfall from the 25-year reference point. The above results, therefore, showed a decline in the average annual rainfall recorded in the study area covering the years ranging from 1984-2013 which was a 30 year period. Therefore, it can be concluded that there had been a negative change in the recorded average annual rainfall in the study area.

Average annual maximum temperature trend analysis

Maximum Monthly average temperature observations for 1981 to 2012 period were analysed and annual and monthly maximum temperatures computed for each year. Then a graph was drawn as shown in Figure 4 covering the period under review.
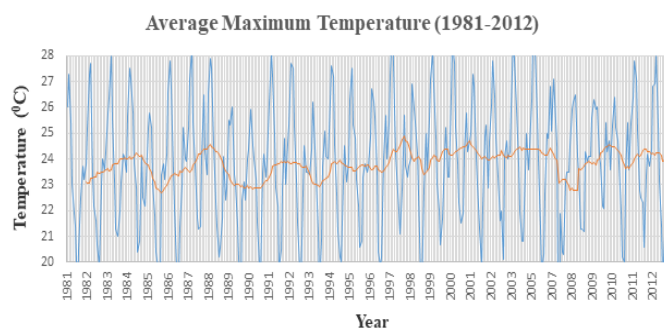

Figure 4: Average annual maximum temperature (1981-2012).

The average maximum temperature for the 1981-2012 period was 23.8°C while the three hottest years from the highest to the lowest were 2000 with 24.7°C, 1997 and 2009 both tying at 24.5°C. The lowest average annual maximum temperatures were recorded in 2007 with 22.8°C followed by 1985 and 1989 at 23.0°C. Monthly average maximum temperatures were highest in the months of February with 27.2°C, March with 26.7°C and 25.7°C in that order while July, August, and June recorded average monthly temperatures from the coldest of 20.4°C, 20.7°C and 21.7°C respectively.

According to, in the absence of a climatological normal, a provisional one could be computed from at least 10 years' observations. In this case, the average maximum temperature observations were available from 1976 which meant our reference provisional normal be computed from the monthly averages of 1976-1985 a 10-year period. This provisional reference normal computed was 23.3°C which was used to calculate the monthly and then annual average maximum temperature anomalies. The annual average maximum temperature anomalies were as shown in Figure 5 below.
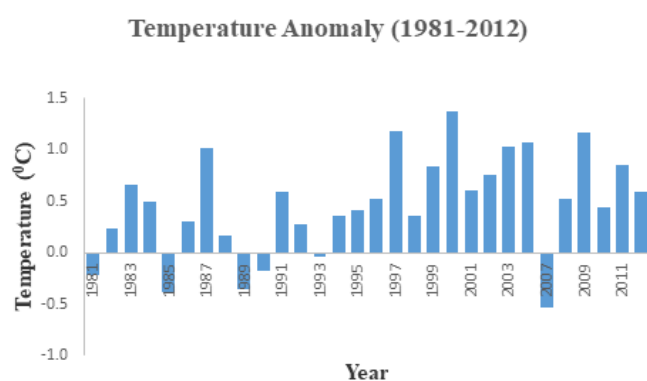

Figure 5: Annual average maximum temperature anomalies.

In Figure 5 above, the highest negative anomalies were -0.5°C in 2007 and -0.4°C in 1989 and 1985 while the highest positive anomalies were in 2000, 1997 and 2005 with 1.4°C, 1.2°C and 1.1°C respectively. The positive anomalies were indications of higher average maximum temperatures than the reference normal while the negative anomaly values indicated the average maximum temperatures were lower than the reference normal.
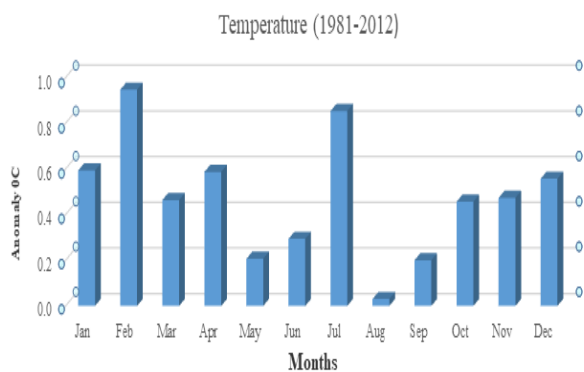
Figure 6: Average maximum temperature anomalies.

The monthly anomalies for the 1981-2012 period as shown in Figure 6 were all positive an indication that maximum temperature averages for the period were all above the normal calculated for the decade covering 1976-1984. However, there was no change in the averages of the months of August while months of May and September had an anomaly of 0.2°C. The highest anomalies were in the months of February and July with 0.9°C followed by January, April and December with 0.6°C. The total average anomaly for the 1981-2012 period was 0.5°C an indication of an upward trend.

Within the period of 1981-2012, the average annual maximum temperature recorded was 24.7°C in 2000 with the highest anomaly of 1.40C considering the reference normal of 23.3°C which was a 6% increase. While the lowest or coldest year had an average annual maximum temperature of 22.8°C an anomaly of -0.5°C a 2% decrease from the reference normal of 23.3°C. The hottest months for the 1981-2012 period were the months of February with an average maximum temperature of 27.2°C against the normal reference of 26.3°C an increase of 0.9°C while the coldest months were the months of July with a maximum average of 20.4°C against the normal reference of 19.5°C an increase of 0.9°C as well. The overall total average anomaly for the 1981-2012 periods was 0.5°C.

This increase in average maximum temperature of 0.5°C was an indication of the rise in temperatures in the study area just like it was reported by GoK that Central Kenya's maximum temperature had been in the range of 0.1-0.7°C since the 1960s. Also, IPCC reported that most countries would experience increased average temperature due to climate change. Zhao et al., reported that in the tropics agricultural activities occurring close to the limits of heat tolerance and moisture availability, implying the impact of climate change as most likely negative with profound impacts on crop production. The study area whose average maximum temperature increased by an average of 0.5°C was, therefore, showing a positive trend as far as temperatures were concerned due to climate change with even the coldest months of the year seeing a rise in maximum temperature.

CONCLUSION

The 1984-2013 periods under review had an average annual total rainfall of 646 mm of rainfall which compared to the 500 mm

annual rainfall for the general area reported in the literature review while the reference normal was about 751 mm a 14% decline. The total average anomaly for the 30-year period was -8.8 mm which showed a general decline and hence a negative trend an indication of an average decreasing average annual rainfall in the study area. The study did not investigate the seasonal annual average rainfall considering the area experiences a bimodal rainfall pattern therefore the research recommends further study.

The annual average maximum temperature analysed for the study area was for the period of 1981-2012 that had a total average of 23.8°C. The provisional reference average maximum temperature was 23.3°C, therefore, the overall average maximum temperature was 0.5°C which was a positive trend illustrating that the average maximum temperature in the study area has been rising a sign of climate change being experienced in the study area.

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