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Analysis of Rainfall and Temperature Variability in Kieni; Nyeri County

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Abstract:
Analysis of climate trend and projection is an important exercise because it can help in designing of climate change adaptation strategies and inform the options that are available for uptake by communities. This study considered the analysis of both precipitation and temperature in Kieni sub-county. The Mann-Kendall test was applied to test for significant trends. In this analysis the null hypothesis was tested at 95% confidence level. The datasets used were obtained from Kenya Meteorological Department (KMD) recognized weather stations - Sasini Farm; Munyaka Met Station and Naromoru Park Gate Met Station. These datasets included precipitation (1985-2015) and temperature (1991-2015). The study shows rainfall variations between the weather stations. The long-term mean annual rainfall estimated during 1985-2015 was 870.29 mm for Sasini Farm (Mweiga); 644.56 mm for Munyaka and 1664 mm Naromuro Park gate weather station in Naromuro. Results revealed a more successful short rain season (OND) and decline in long rains (MAM) in the area. Temperature trend analysis revealed that both the maximum and minimum average temperature has been reducing since 1991 up to around post 2010 where it started rising slowly.

Keywords: *Datasets, rainfall, temperature, Mann-Kendall, Kieni*

1. Introduction

Analysis of climate trend and projection is an important exercise because it can help in designing of climate change adaptation strategies and inform the options that are available for uptake. It is indisputable today that Climate variability and change has occurred and is still occurring all over the world; the difference being the magnitude of its impacts on ecosystems. Studies conducted in the latest past shows that the mean temperature has risen with evidence showing that Africa will particularly warming with up to 2^{o}C (Seneviratne *et al*.,2012). Studies also show that the Eastern African region has been experiencing rise in seasonal mean temperature and at the same time there is high confidence that the extreme temperatures will increase (Funk *et al.,* 2012, Anyah and Qui, 2012; Moyo *et al*., 2012; Wagesho *et al*., 2013; Opiyo *et al*., 2014).

Research conducted in 2010 revealed that many parts of Kenya will experience more dry seasons and decline of more than 100 millimetres in rainfall by the year 2025(Funk *et al.,* 2010). The report also showed that the experienced decline in rainfall is matched with increases in air temperature. Overall, the study revealed that the frequency of dry seasons will increase in Kenya. Other studies have also revealed significant warming in East Africa (Christensen *et al*., 2007; Nyong and Niang-Diop, 2006; Williams and Funk, 2010).

Central Kenya, which is one of the country's food baskets, has been experiencing significant changes in temperature and precipitation trends. The region's minimum temperature has been increasing since 1960 with a magnitude of 0.8-2.0^{o}C while the trend of maximum temperature has been increasing with a magnitude of 0.1-0.7^{o}C (GoK, 2010). Research done in the recent past revealed that rainfall received in Nyeri county has been dropping every 3 to 4 years (Karienye *et al*., 2012).

This study was undertaken to assess and understand rainfall and temperature trends in Kieni sub-county for year 1985 - 2015 and 1991 - 2015 respectively. This analysis can be used as a base for long term prediction of climate pattern especially forecast on droughts and frostbites which always have serious implications for rural livelihoods in the study area. Understanding of climate trends and being able to predict incidences of extreme weather events is of particular importance especially in planning for adaptation.

2. Materials and Methods

2.1. Study area

The study was conducted using rainfall and temperature datasets from three weather stations in Kieni sub-county. Kieni is located at 1^0 16' 46.111" N 36^0 47' 25.665" E (fig.1) with altitudes ranging between 1950 and 2270. The study area has 42% of semi-arid land and a research conducted in 2007 revealed that destruction of natural assets (especially the indigenous trees) is a major driver to climate change in the area (Sijali *et al*., 2007 as cited in Macharia *et al*., 2009). The area is characterized by bimodal pattern of rainfall i.e. the long rains experienced between March and May and the short rains experienced in October through to December. Kieni has a population of 175,812 people (KBNS Census 2009). The individual farm holding is 0.4 ha to 120 ha with an average size of 2.4ha (Maina *et al.,* 2012).

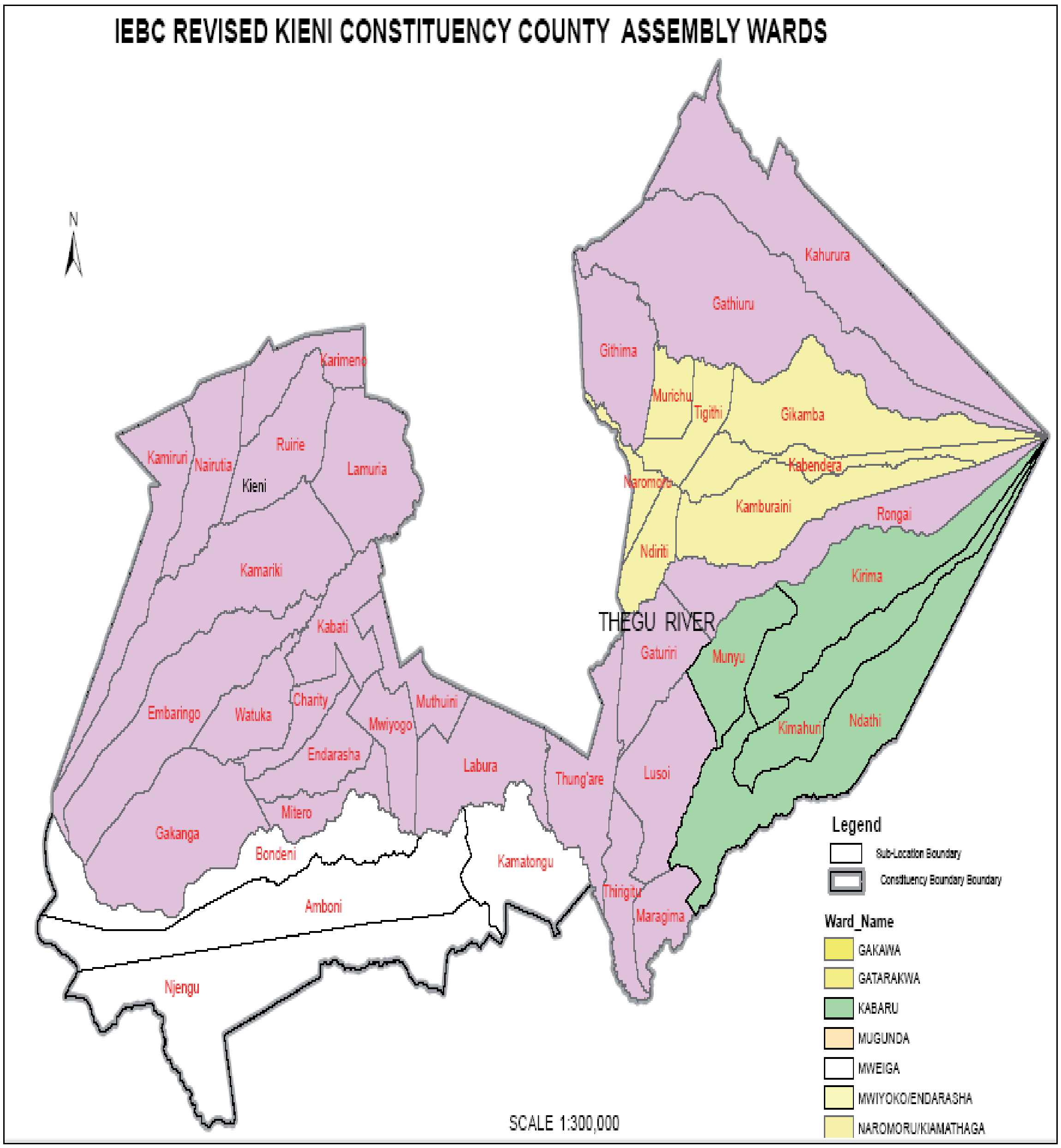

Figure 1: Map of the Study Area
Source: IEBC,2013

2.2. Rainfall and Temperature Data

The rainfall and temperature data was collected from KMD recognized weather stations in the study area. Naromuro Park Gate Met station with GPS coordinates of 0°10’27.99’’ S 37°08’53.95’’ E, Munyaka NRM Met station with GPS coordinates of 0°10’59.71’’ S 37°03’34.48’’ E and Sasini Farm with GPS coordinates of 0°19'0"S 36°54' 0"E. The data obtained included monthly average precipitation for year 1985 - 2015 as well as minimum and maximum temperature monthly recordings for year 1991 - 2015.

2.3. Analytical Methods

Statistical analytical approaches are used to detect temporal trends in climate. Coefficient of variation was used to calculate the degree of seasonal and inter-annual variation of climate data at the two sites of the study area using the formula below:

$$C.V = \frac{Standard\ deviation}{Mean} * 100\%$$

Comparative values of C. Vs between the two sites were conducted to determine the spatial differences in variability between sites of the study area. Mann-Kendall test was also applied to test for significant trends. This is a non-parametric test approach that is rank based used to test statistically significant trends (Kendall, 1975). Unlike parametric tests, the advantage of using Mann- Kendall approach is that it tolerates skewed distributions and outliers (Sneyers, 1990; Kendall,1975; Tabari *et al*.,2011; Onoz and Bayazit 2012; Karmeshu,2012). It is ideal to test inhomogeneous data because it has low sensitivity to abrupt breaks (Karmeshu, 2012). With Mann- Kendall, the null hypothesis (H_0) assumed that there is no trend while the alternative hypothesis H_1 assumed that there has been either an increasing or a decreasing trend in temperature and rainfall overtime.

In this analysis, the null hypothesis was tested at 95% confidence level. The trend is decreasing if Z is negative and the computed probability is greater than the level of significance. Similarly, the trend is increasing if the Z is positive and the computed probability is greater than the level of significance. Where the computed probability is less than the level of significance, there is no trend detected.

3. Results and Discussion

3.1. Trend Analysis of Rainfall

3.1.1. Analysis of Annual Rainfall

The study findings showed that long-term mean annual rainfall estimated during 1985 -2015 was 870.29 mm for Sasini Farm (Mweiga); 644.56 mm for Munyaka and 1664mm Naromuro Park gate weather station in Naromuro. The long term average monthly rainfall was reported as 72.5 mm for Sasini; 53.7 mm for Munyaka and 138.7 mm Naromuro Park Gate.

Figure 2 shows the total-annual rainfall variation for the three weather stations which represents the study sites. There was a sharp increase in the amount of rainfall received between 1997 and 1998; this finding correlates with the information obtained through FGD where participants reported enhanced rainfall during the same period. This observation agreed with other reports, which reported that between 1997 and 1998, Kenya as a country received El-Niño rains (Karienye *et al*., 2012; UNEP 2008; UNEP 2009; Takaoka 2005). These rains are highly influenced by the El Niño Southern Oscillation (ENSO).

The El Niño is normally associated with rainfall above normal which is normally followed by prolonged dry period known as La Niña (World Bank,2012). A study conducted in 2012 confirms that in Nyeri county droughts tend to take a decadal cycle though in the recent past it has become more frequent (Karienye *et al.*, 2012). Other studies done shows the decadal cycle of droughts in the East Africa which bring negative socio-economic impacts (Funk et al., 2005; Huho et al., 2011; Hillbruner and Moloney, 2012; Verdin *et al*., 2005; Williams and Funk, 2011; Lyon and DeWitt 2012; Yang et al., 2014). Major droughts that have been encountered in the country include the 1974, 1942-44, 1947, 1951-1955, 1957-1958, and 1984-1985 and the 1999-2000 (UNDP, WMO, GOK, IGAD and DNCN 2002). From the analysis done for Kieni, the dry spell of 2000 is also clearly visible in all the three weather stations as it is among the years with the lowest amount of rainfall. The 1983 - 1984 and 1999 - 2000 droughts are termed as the most severe in Kenyan history because it brought death to both human and animals and forced the government to spend much on response and rehabilitation (Ojwang’ *et al*., 2010).

The study also shows rainfall variations between the weather stations. The Naromuro Park Gate receives much rainfall as compared to Sasini and Munyaka weather stations. Various reasons could contribute to this on being that the location of the weather station is close to Mt. Kenya National Park which is forested and mountainous. As shown in figure 2, the rainfall pattern and variation for the three stations was similar up to around year 2000 when Naromuro Park Gate started receiving more rainfall. This can also be attributed to the efforts made in the 1980s and 1990s to conserve the major water towers in Kenya. In response to heavy commercial exploitation of Mt. Kenya Forest Reserve and other major water catchment areas in Kenya, the government revised the Forest Act back in 1982 and 1992 respectively (Emerton 1999). This saw coming into force of a number of prohibitions and bans against the use and exploitation of forest resources in Kenya.

The reintroduction of *shamba* system in forest management in 1990s has contributed to community forest conservation that has helped local communities plant trees and conserve the forest hence modifying the microclimate of the area (Ibid). Studies done show that planting of trees and reduction of deforestation by 50% by year 2050 has a potential of avoiding emissions equivalent to 50pg C (Bala *et al*., 2007).

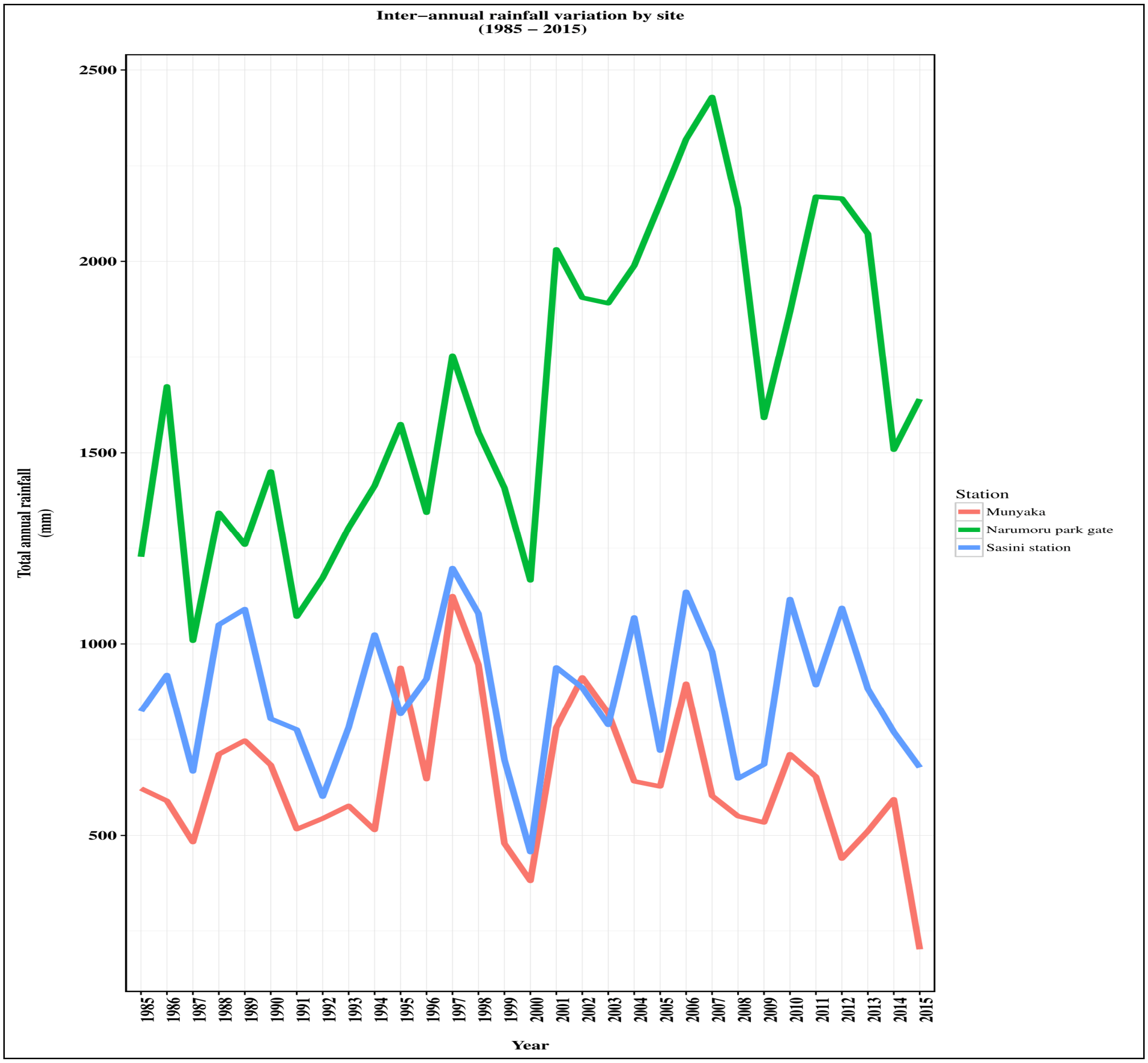

Figure 2: Inter-annual rainfall variation by weather station

Site	Weather Station	Average	SD	CV
Mweiga	Sasini Farm	870.29	182.67	0.21
Naromoru	Munyaka	644.56	188.76	0.293
Naromoru	Naromuro Park Gate	1664.31	397.27	0.239

Table 1: Long-term mean annual rainfall

3.1.2 Monthly and Seasonal Rainfall Trend Analysis

Rainfall in the three weather stations follows the same trend with high amounts of rainfall reported during the months of March – May and between October and December. During the two seasons, April and November reported the highest amount of rainfall respectively. February and September reported the lowest average monthly rainfall amounts in the two sites.

The average amount of rainfall during the long rains (MAM) was 106.7 mm for Sasini, 76.2 mm for Munyaka and 157.5mm for Naromuro Park Gate respectively. On average, Naromuro Park Gate reported higher amount of rain during the short rains season (OND) compared to the long rains season. The study shows that more successful short rains seasons were observed in Naromuro compared to the long rains season. In the East African region research done also predict that there will be an increase in rainfall over the region and particularly the short rains (OND) which is greatly influenced by El Nino like walker circulation response to global warming (Tierney et al., 2015; Wakachala *et al.,* 2015; Tierney et al., 2013; Omeny *et al.,* 2008). Other studies show that the precipitation pattern over East Africa will be enhanced with the warming climate implying that the long rains too will increase (IPCC 2007; Taylor *et al*, 2012; Held and Soden 2006; Seager *et al*., 2010; Laine *et al*., 2014).

From June – September, Naromuro Park Gate reported higher amounts of rain on average as compared to other sub-sites. In comparison, Sasini in Mweiga reported higher amount of rain on average compared to Munyaka in Naromuro.

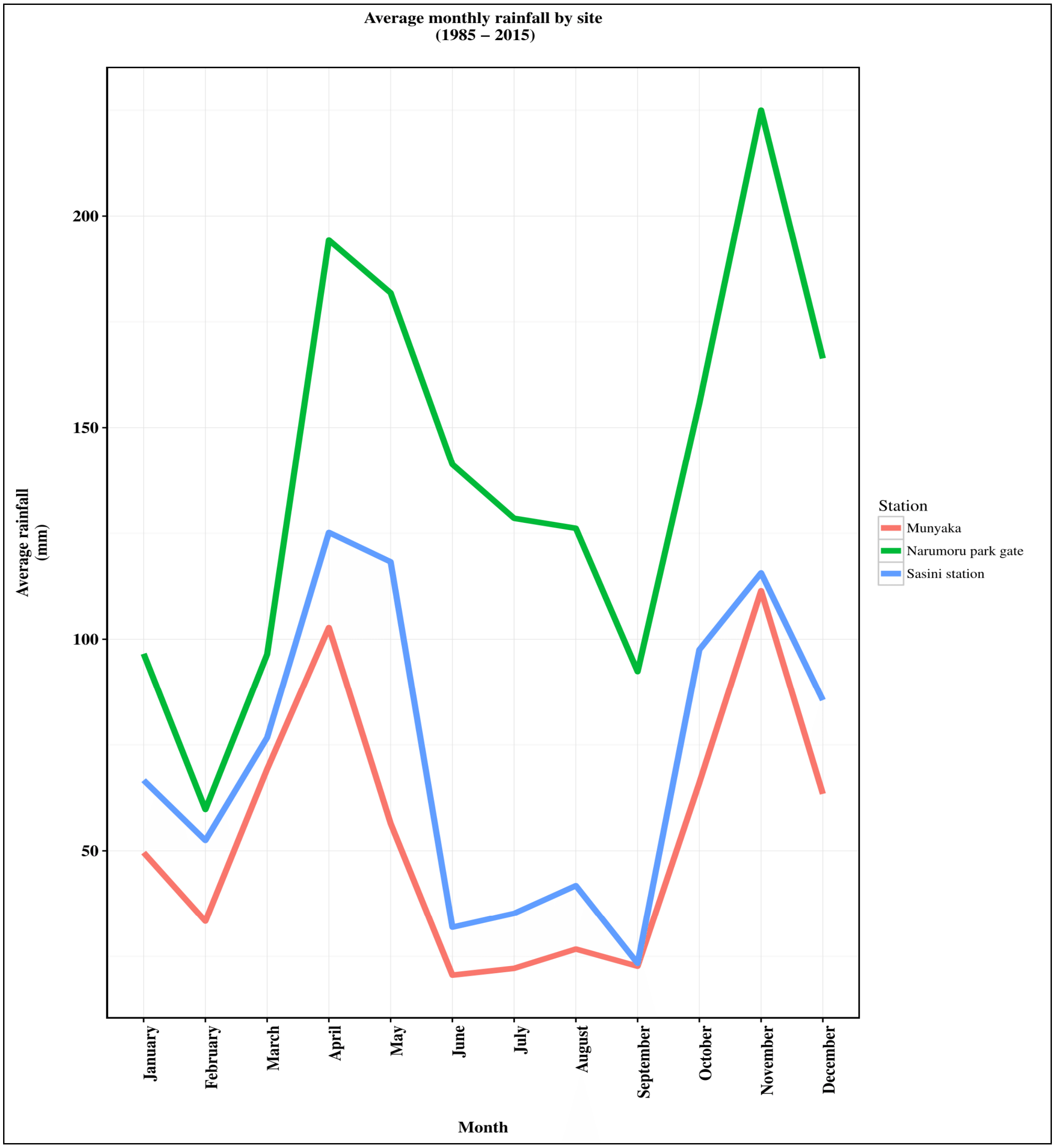

Figure 3: Season rainfall trends by site

3.2. Spatial and Seasonal Rainfall Variability

The coefficient of variation was used to study the variation in rainfall between seasons. During the short rains, Munyaka reported a C.V of 61.8%, Naromuro Park Gate reported 38.7% while Sasini reported 56.5%. In Munyaka, a higher variation was reported during long rains and short rains as compared to Naromuro Park Gate despite having the two sites located in same administrative ward. The differences in the degree of variation between long rains and short rains seasons in Naromuro could be a possible explanation for higher average rain reported during the short rains for the years under study.

	Munyaka		**Naromuro Park Gate**		**Sasini Farm**	
	Long rains	Short rains	Long rains	Short rains	Long rains	Short rains
Average	76.2	80.3	157.5	182.4	106.7	99.6
SD	47.5	49.6	83.2	70.5	59.9	56.3
CV	0.623	0.618	0.528	0.387	0.561	0.565

Table 2: Seasonal variability results

3.2.1. Mann-Kendall Test Results

The study revealed that for Sasini Farm and Munyaka, the months of March, April, May, June and July depicted a negative trend while the months of August, September, October and November revealed a positive increasing trend. Naromoru Park Gate however showed positive trend for the months of January to October and negative trend of -0.097 for November and -0.138 for December. This test showed a movement towards more successful short rains in the study area and declining long rains. These results coincide with the information shared during the FGDs and Key Informant interviews where it was reported that the short rains season has become more reliable for the communities in that area and the farmers are highly utilizing this season as opposed to long rains seasons.

	Station		
Month	Sasini Farm	Munyaka	Narumoru park gate
Jan	-0.11	-0.017	0.069
Feb	0.118	-0.022	0.385
Mar	-0.084	0.024	0.424
Apr	-0.17	-0.215	0.166
May	-0.116	-0.194	0.265
Jun	-0.058	-0.179	0.441
Jul	-0.071	-0.11	0.501
Aug	0.191	0.093	0.574
Sep	0.127	0.123	0.336
Oct	0.273	0.062	0.394
Nov	0.135	0.013	-0.097
Dec	-0.045	-0.168	-0.138
Ave. monthly rainfall	-0.015	-0.131	0.501
Period	1985 - 2015	1985 - 2015	1985 - 2015

Table 3: Mann-Kendall test results

3.3. Trend Analysis of Temperature

3.3.1. Monthly and Annual Temperature Trend Analysis

Monthly and annual temperature series for 1991-2015 were investigated. The time series was guided by the availability of observed data from the weather stations. The results showed a similar trend for both sub-sites though Naromuro Park Gate was a little warmer than Munyaka sub site. March and October were the warmest months in Naromuro Park Gate at 17.6^{o}C 17.5^{o}C respectively. In Munyaka, the warmest months are February at 16^{o}C, April at 16.4^{o}C, May at 16.3^{o}C and September at 16^{o}C. The study also observed that July is the coldest month on both sub sites with Munyaka experiencing average monthly temperature of 15.2^{o}C and Naromuro Park gate an average of 16.5^{o} C.

The study revealed a similar trend a decreasing trend for minimum and maximum temperature in both sub-sites from 1991 way up to post 2012 (see fig.4,5 and 6). The Mann-Kendall test results revealed a significant trend on average minimum temperature for Munyaka and average maximum temperature for both sites.

Station	**Average Minimum**	**Average Maximum**	**Average**
Munyaka	-0.192	-0.215	-0.290
Naromuro Park gate	0.085	-0.196	-0.101

Table 4: Temperature Mann-Kendall test results

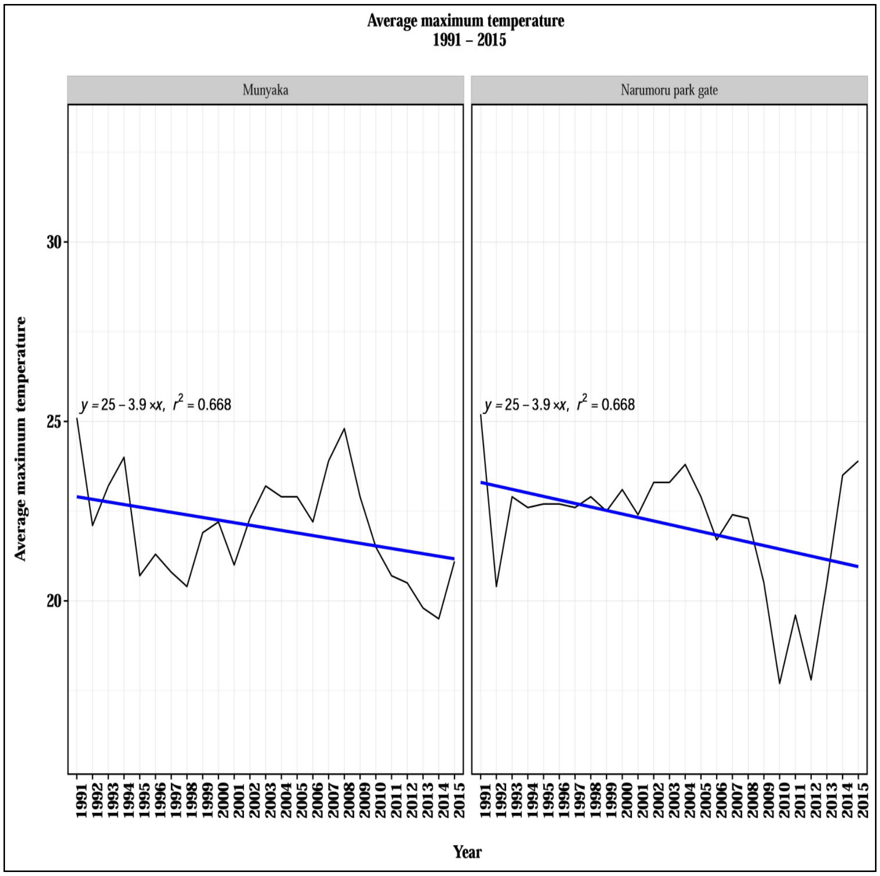

Figure 4: Average maximum temperature

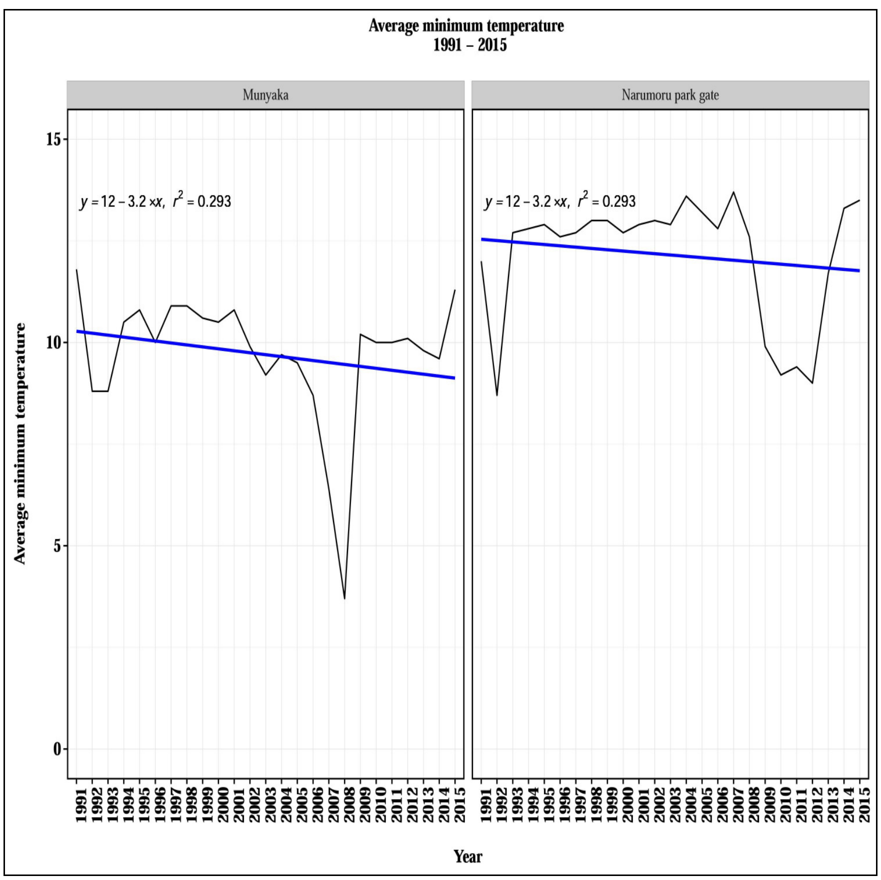

Figure 5: Average minimum temperature

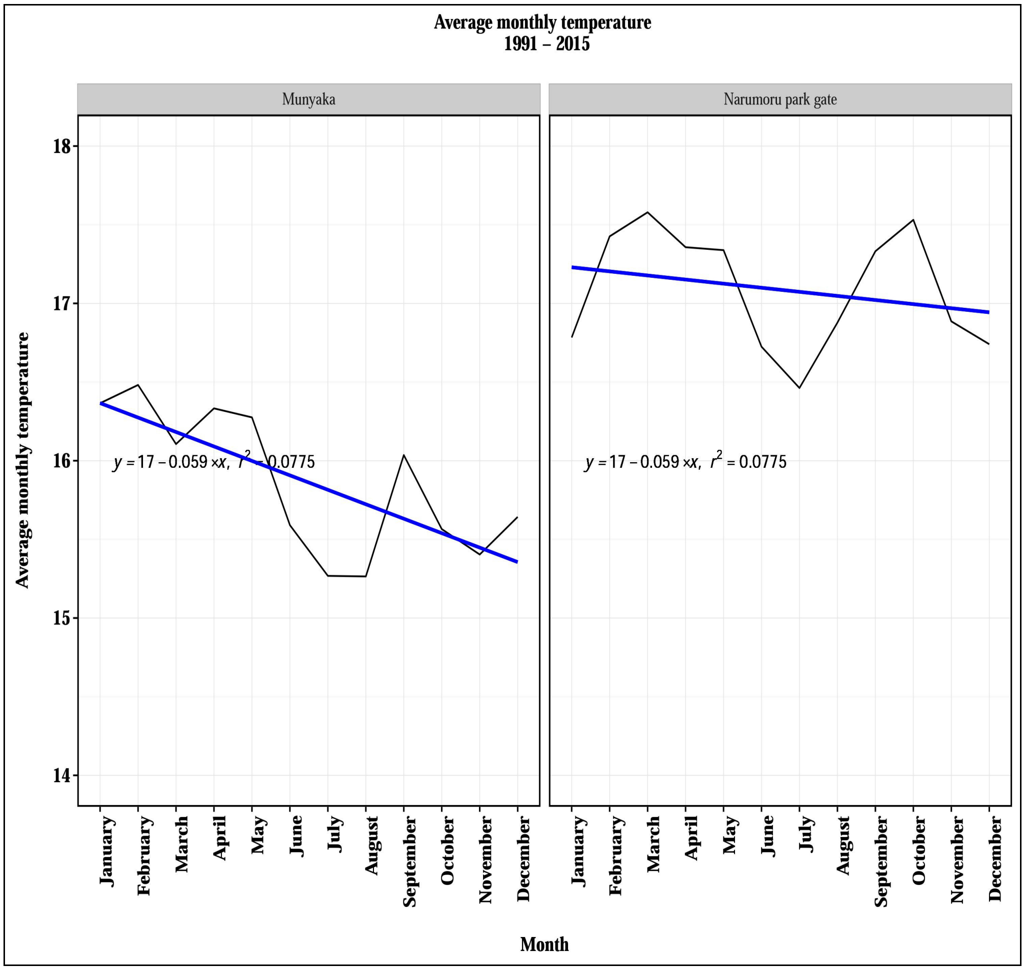

Figure 6: Average monthly temperature

4. Conclusions and Recommendations

The importance of studying climate variability and change at local level cannot be overstated. This has been revealed by the study where data from different weather stations in the same study area were used and showed varying results. For example, the long-term mean annual rainfall reported for 1985-2015 was 870.29 mm for Sasini Farm ;644.56 mm for Munyaka and 1664mm Naromuro Park gate. However, the study did not investigate the factors behind the difference in climate at micro level such as land use change and conservation measures being undertaken. The research therefore recommends further study to establish these factors. From the Mann-Kendall test, it was revealed that the area is receiving concentrated and more successful short rains. This is a very important finding that could help policy makers and the county government when planning for adaptation measures. This study also did not establish what is causing the increase in short rains in the area and would recommend further research on that.

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