Vol. 14(8), pp. 214-221, August 2020
DOI: 10.5897/AJEST2020.2837
Article Number: B73437564637
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

Urban climate variability trend in the coastal region of Mombasa Kenya

Innocent Osoro Ngare[1*], James Kibii Koske[2], John Njagi Muriuki[2], Evelyn Wemali Chitechi[2] and George Njagi Gathuku[2]

[1]Department of Postgraduate and Research, Amoud University, Amoud Valley Borama, Somaliland.
[2]Department of Environmental Science and Education, Kenyatta University, P. O. Box 43844 -00100 Nairobi, Kenya.

Received 14 March, 2020; Accepted 28 July, 2020

The world population in global south countries is increasing. This fast growth has heightened urban ecological footprint that contributes to anthropogenic forcing triggering of the climate system. From this study, climate variability trend dynamics in Mombasa County, a coastal urban area in Kenya was examined. A retrospective study was done (1989-2019) to determine the changes in temperature and rainfall in the area of study. The results show that climate variability was experienced in Mombasa with a maximum temperature t=-5.628, df=23, *P*:0.000 and a minimum of t= -5.401, df=23, *P*:0.000, total rainfall t=2.025, df=23, *P*:0.275. The linear regression analysis shows rainfall variation y = -9.588x + 1217.1 and temperature y =0.0258x + 29.888 with an increase of +0.4°C. The annual maximum temperature averages show heterogeneous distribution from kurtosis coefficient with little observed skewness.

Key words: Rainfall, temperature, urbanization, retrospective.

INTRODUCTION

Proliferating climate change extremes globally are daunting, staging undeniable global debates that have exponentially increased in different international fora (Herman and Treverton, 2009; Hannigan, 2014; Abate, 2019). Studies (Innocent, 2017; IPCC, 2018) indicate that global surface temperature averagely has increased by 1°C or 33.8°F and could triple by the next century. As the human population surge in cities, it has heightened urban ecological footprint necessitating more mega tones emission of greenhouse gases. This anthropogenic forcing anchored on urban-human activities has mushroomed urban heat highlands contributing to climate change, thus a trigger to the climate system.

Temperature and rainfall variations serve as long-term determinants to predict the future climate projections and scenarios (Mellander et al., 2018; Barton et al., 2019). The study aimed to examine trend variations in rainfall and temperature in Mombasa County, a coastal region in Kenya to ascertain the degree and level these climate variability variables had changed overtime. A thirty-year observed variation threshold (1989-2019) rainfall and temperature data was obtained from the Kenya Meteorological Department to determine observed climate variability in Mombasa County.

*Corresponding author. E-mail: ngare.innocent@gmail.com.

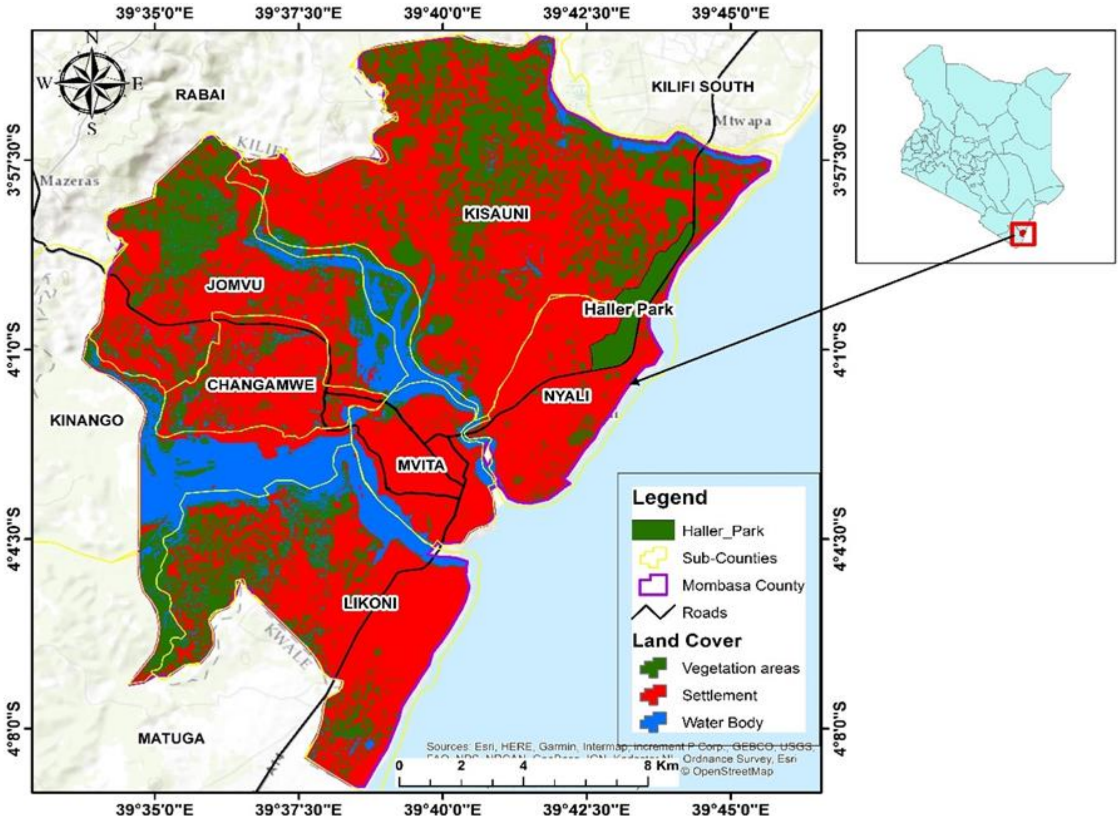

Figure 1. The map of Mombasa County, Kenya.

METHODOLOGY

A retrospective study between 1989 and 2019 on climate variability review was done at the coastal region of Kenya in Mombasa County. The county lies slightly below the equator on a latitude and longitude of -4°S, 39°E respectively (Figure 1).

Climate variability data was obtained from the Kenya Metrological Department. Both rainfall and temperature recordings for the region was run on times series to observe anomalies across the trend through simple regression analysis. One-Way-Anova was run to test the hypotheses under investigation. Kurtosis coefficient was used to determine the distribution patterns in temperature and temperature with simulated equation;

$$Kurtosis = \frac{\sum_{i=1}^{N} \frac{(X_i - \bar{X})}{N}}{s^4}$$

Where, $\bar{X}$ is the mean, s is the standard deviation and N is the sample size.

RESULTS AND DISCUSSION

Descriptive monthly average temperature

Temperature plays a crucial role when modelled for a more extended period to determine climate variation changes of the area (Graff Zivin et al., 2018; Turco et al., 2018; Grbec et al., 2019). The annual, monthly average, minimum and maximum annual average temperatures descriptively are shown in Tables 1 to 3, respectively. Descriptive statistics that include the mean, kurtosis, median, standard deviation and coefficient of variation are shown in the tables.

The coefficient of variance (CV) of average monthly temperature (Table 1) shows low and high ratios of standard deviation (SD) from the means. Averagely, March CV was the least with 1.56 (σ =0.44), where September averages had the highest with 2.65 with σ = 0.66. Comparing their dispersion from the mean, months with least CV had a low degree of variation from the mean, and those with higher CV ratio connotes that they had more degree of variation from the mean. From the distribution observation of the coefficient of kurtosis and skewness, the annual, monthly temperatures averages were evenly distributed with a coefficient kurtosis of -0.82 to 0.67, connoting heterogeneous distribution of average monthly temperature. However, even with the negative skewness observed, the measure of two-tailed thinness was neither highly concentrated to the left or right. The left highest (-ve) skewness was -0.82, where the right

Table 1. Average monthly temperature for the year 1989 to 2019.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Count	31	31	31	31	31	31	31	31	31	31	31	31
Mean	27.57	27.99	28.4	27.6	26.09	24.92	24.06	24.03	24.74	25.78	26.75	27.5
Std. E	0.1	0.09	0.08	0.126	0.14	0.09	0.11	0.11	0.12	0.1	0.1	0.1
Median	27.55	28	28.45	27.55	26.15	24.8	23.95	24.1	24.85	25.75	26.75	27.5
Mode	27.55	28	28.6	26.9	25.8	24.25	23.9	24.55	25.15	25.65	26.75	27.35
SD	0.54	0.51	0.44	0.7	0.76	0.1	0.62	0.63	0.66	0.54	0.56	0.57
SV	0.29	0.26	0.2	0.49	0.57	0.26	0.39	0.39	0.43	0.3	0.32	0.32
Kurtosis	-0.52	-0.82	-0.44	-0.4	0.44	-0.54	-0.29	-0.29	0.18	-0.45	0.67	0.55
Skewness	0.01	-0.05	-0.36	0.08	-0.67	0.58	0.24	-0.23	0.03	-0.25	-0.71	0.12
Range	2.1	1.9	1.8	2.8	3.35	1.75	2.65	2.6	2.9	1.95	2.25	2.6
Minimum	26.6	26.95	27.45	26.35	24.1	24.25	22.8	22.6	23.45	24.7	25.35	26.15
Maximum	28.7	28.85	29.25	29.15	27.45	26	25.45	25.2	26.35	26.65	27.6	28.75
CI (95%)	1.89	1.8	1.56	2.46	2.66	1.79	2.19	2.2	2.31	1.92	1.98	2
CV	1.95	1.83	1.56	2.54	2.9	2.04	2.59	2.6	2.65	2.11	2.11	2.06

SD: Standard deviation; Std E: Standard error; SV: Sample variance; CI: Coefficient of Interval; CV: Coefficient variance.

Table 2. Average minimum temperature for the year 1989 to 2019.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Count	31	31	31	31	31	31	31	31	31	31	31	31
Mean	22.94	23.2	23.95	23.85	22.5	21.27	20.32	20.23	20.88	22.02	22.92	23.23
StdE	0.13	0.15	0.13	0.16	0.17	0.15	0.16	0.16	0.16	0.17	0.13	0.13
Median	22.9	23.2	24.2	23.87	22.7	21.3	20.3	20.3	21	22.1	23	23.2
Mode	22.8	23.2	23.8	24.8	22.2	21.8	20.9	19.9	21.3	22	23	23.2
SD	0.74	0.82	0.71	0.91	0.94	0.81	0.88	0.89	0.89	0.92	0.75	0.75
SV	0.55	0.68	0.5	0.82	0.89	0.66	0.78	0.79	0.8	0.84	0.56	0.56
Kurtosis	0.71	-0.83	0.15	2.18	0.46	0.3	1.2	0.85	0.72	0.43	1.64	1.27
Skewness	-0.62	-0.1	-0.91	0.34	-1.14	-0.17	0.1	-0.55	-0.64	-0.37	-0.74	-0.63
Range	3.4	3	2.6	4.9	3.4	3.3	4.6	4.3	4.2	4	3.5	3.4
Minimum	21	21.6	22.3	21.7	20.2	19.5	18.1	17.7	18.6	20	20.8	21.3
Maximum	24.4	24.6	24.9	26.6	23.6	22.8	22.7	22	22.8	24	24.3	24.7
CI (95%)	0.255	0.294	0.255	0.314	0.333	0.294	0.314	0.314	0.314	0.333	0.255	0.255
CV	3.226	3.534	2.965	3.816	4.178	3.808	4.331	4.399	4.262	4.178	3.272	3.229

SD: Standard deviation; Std E: Standard error; SV: Sample variance; CI: Coefficient of Interval; CV: Coefficient variance.

skewness (+ve) was 0.67 across the trend in the past 30 years in Mombasa County (Table 1).

Descriptive minimum average temperature

Descriptive statistics of average minimum rainfall for Mombasa County for the years 1989 to 2019 is shown in Table 2. Statistical measures of central tendency and dispersion determine the spread, distribution, and trend of average minimum temperatures. Figure 2, the monotonic trend of the variables outlined by the linear. The standard deviation ratios from the mean show reliability variations. The month of March has the lowest CV of 2.965, thus less variation from the mean (μ =23.95). August had the highest reliability of variation from the mean with a CV of 4.399 and a SD of 0.89, unlike that of March (0.71). The average SD deviation difference across the trend is 0.1; therefore, a standard normal distribution for each annual minimum monthly temperature for Mombasa County.

Computed skewness shows a ranging scale of -0.91 to

Table 3. Average maximum temperature for the year 1989 to 2019.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Count	31	31	31	31	31	31	31	31	31	31	31	31
Mean	32.21	32.77	32.85	31.34	29.67	28.57	27.81	27.84	28.61	29.55	30.59	31.8
Std E	0.11	0.07	0.09	0.13	0.14	0.07	0.1	0.11	0.11	0.11	0.1	0.12
Median	32.2	32.8	32.8	31.5	29.7	28.5	27.8	28	28.6	29.5	30.7	31.8
Mode	32.1	32.8	32.7	31.7	30.1	28.3	27.5	27.5	28.6	29.5	30.9	31.4
SD	0.59	0.42	0.49	0.72	0.76	0.41	0.58	0.59	0.61	0.64	0.57	0.68
SV	0.35	0.17	0.24	0.52	0.58	0.17	0.33	0.35	0.38	0.41	0.33	0.46
Kurtosis	-0.19	0.26	-0.39	-0.57	0.65	-0.19	0.93	0.31	0.85	3.92	-0.13	0.84
Skewness	-0.24	-0.5	0.08	-0.32	0.25	0.56	0.13	-0.54	-0.04	-1.35	-0.52	0.64
Range	2.5	1.8	1.8	2.8	3.7	1.7	2.7	2.6	2.8	3.3	2.5	3.1
Minimum	31	31.7	32	29.8	28	27.9	26.6	26.3	27.1	27.3	29.2	30.6
Maximum	33.5	33.5	33.8	32.6	31.7	29.6	29.3	28.9	29.9	30.6	31.7	33.7
CI (95%)	0.21	0.15	0.17	0.25	0.27	0.14	0.2	0.21	0.22	0.22	0.2	0.24
CV	1.84	1.27	1.48	2.3	2.57	1.44	2.08	2.11	2.15	2.16	1.88	2.14

SD: Standard deviation; Std E: Standard error; SV: Sample variance; CI: Coefficient of Interval; CV: Coefficient variance.

0.1, evident that distribution was left tailed (negative). However, the observed coefficient of kurtosis (Ck) readings (Table 1) shows April with the highest Ck of 2.18 and February with a Ck of -0.83. Though, from the kurtosis scale, the highest reading was less than three (<3). Therefore, a platykurtic distribution was observed. This can be interpreted from that within the 30-year variability threshold in Mombasa, observed positive and negative extremes of minimum temperature annual averages were less of few. For observed linear regression (y=0.0283x + 21.823, R^2 = 0.1655), Figure 2 shows oscillated monotonic trend of minimum rainfall across the trend but with fewer extremes of between 22.5 and 20.5°C in minimum.

Across the trend (Figure 2), climate variability anomaly in minimum average temperature gained its highest lowest peak in the years 2003 and 2004 recording lowest temperature of 20.5°C compared to the noted anomaly in four years of 21.5°C in the year 2007. However, the minimum temperature had increased in the modelled 30-year period. The accumulated minimum annual average temperature increase was +0.8°C (Figure 2). Therefore, from the linear (R^2 =0.1655), the noted increase was approximately 16.55% across accumulated the trend.

Descriptive maximum average temperature

The descriptive statistics approach was applied to assess the trend and distribution of maximum temperature in Mombasa County urbanized area. Different forms of dispersion and measure of central tendency have been used to describe commutated data. Figure 3 shows the linear trend in the past 30 years in the area of study. The least observed coefficient of variance was 1.27, and the highest CV being 2.57. From the two monthly data findings (February and May) (Table 3), CV of 1.27 had low standard variation ratio from the mean (μ = 32.77) compared to CV 2.57 with (μ =29.67) that had higher reliability variation from the mean.

The kurtosis coefficients show ranged between -0.57 and 0.93. The skewed values (-0.5 to 0.64) indicate a normal distribution spread despite a high left tailed concentration trend. It can be observed, therefore, that despite left inclined skewness, the highest positive skew point was 0.64. The skew values indicate, therefore, that symmetry indicator was longer in the left (negative) compared to the right. The asymmetrical skewness is within the 1, -1 or 0.5, -0.5; thus, the temperature trend was moderately distributed.

The linear trend of temperature (Figure 3) show a monotonic character (y=0.0258x + 29.888). The upward and downward observed anomalies could cause extremes in maximum temperature. For instance, the highest maximum temperature peak was observed in 2011 with 31°C, where the temperature had increased in the past 30 years by +0.4°C. The finding supports the modelled past, present and future projections by the IPCC's AR5 that project temperature increase by 2100. Since the pre-industrial period, the earth's surface temperature has warmed by 1°C (Hansen et al., 2018; Feulner, 2019).

Since the pre-industrial period to date, the estimated anthropogenic warming range has surpassed the 1°C mark (Tokarska et al., 2019). A report by IPCC (2018) indicates that by 2050, earth's warming shall hit past 1.5°C, wherein the year 2100, the average temperature warming will averagely hit 2°C. From these observed

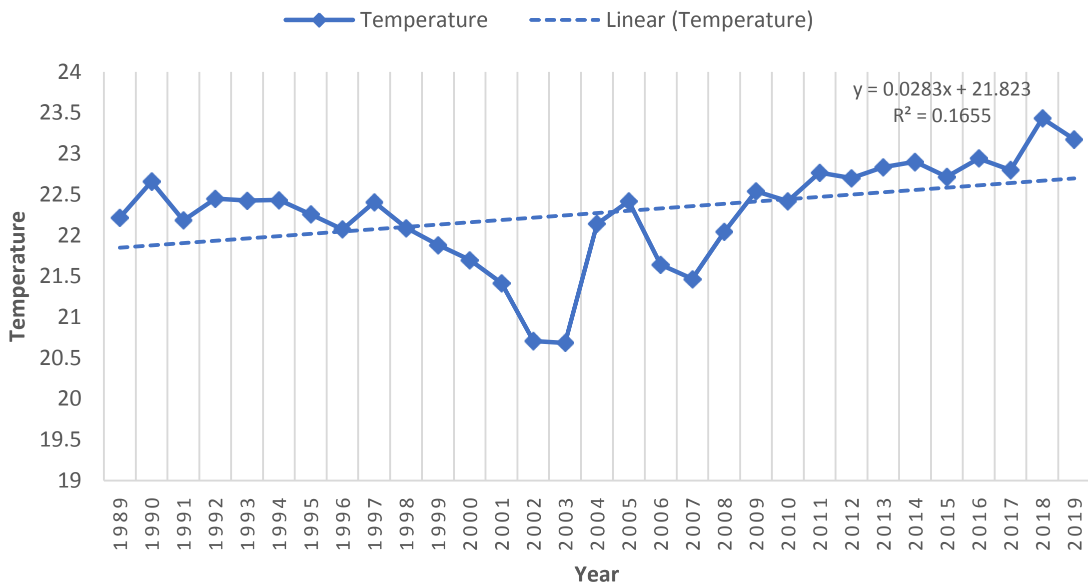

Figure 2. Minimum annual temperature for Mombasa Country (1989-2019).

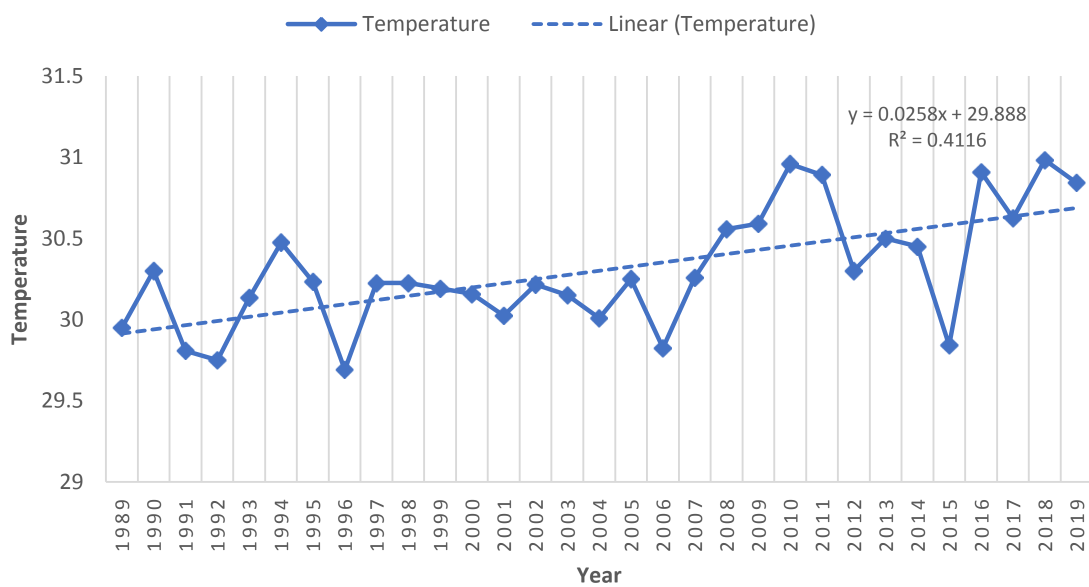

Figure 3. Maximum annual temperature for Mombasa Country (1989-2019).

projections, the observed average warming within Mombasa County of +0.4°C, adds to the global average warming index. Therefore, over the past 30 years, temperature variations in the Mombasa Country were positively contributing to warming.

Descriptive analysis of rainfall

Table 4 shows the descriptive rainfall data of Mombasa County in the past 30 years (1989-2019). Different descriptive statistics methods are indicated at the table, respectively. The coefficients of skewness (Cs), coefficient of variation (CV), sample variance (SV), coefficient of kurtosis (Ck) and Standard deviation (SD). A study by Hayelom et al. (2017) indicates that (CV) is important in the classification of the degree of variation. This classification is rated at a point scale as low (CV less than 20%), moderate (CV less than 30%), high (CV above 30%), very high (CV above 40%), and extremely

Table 4. Descriptive statistics of the rainfall data for the year 1989 to 2019.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Count	31	31	31	31	31	31	31	31	31	31	31	31
Mean	25.91	11.97	40.29	150.8	260.7	96.1	72.23	59.37	43.17	130.3	105.1	67.87
Std E	7.33	3.46	6.28	16.64	28.71	9.65	6.6	7.422	6.493	27.82	11.61	11.05
Median	16.2	3.3	34	137	229.7	97.3	64	45.1	38	68.2	89	52.2
Mode	25.9	0	#N/A	#N/A	#N/A	#N/A	#N/A	30.7	3.2	281.6	74.1	#N/A
SD	40.8	19.28	34.98	92.6	159.9	53.72	36.75	41.32	36.15	154.9	64.62	61.54
SV	1665	371.8	1224	8587	25558	2886	1350	1708	1307	23999	4176	3787
Kurtosis	15.08	3.27	3.78	-0.72	0.32	-0.47	-0.53	1.759	3.402	12.89	2.634	3.182
Skewness	3.53	2.06	1.69	0.68	0.78	0.26	0.495	1.477	1.804	3.154	1.386	1.7
Range	213.3	66.6	162	306.4	643.4	205.1	131.2	159.6	146.3	802.8	305	275
Minimum	0	0	0	26.8	21.4	4.1	20.2	14.5	3.2	16.9	11.5	0.5
Maximum	213.3	66.6	162	333.2	664.8	209.2	151.4	174.1	149.5	819.7	316.5	275.5
CI (95%)	14.36	6.79	12.32	32.62	56.28	18.91	12.94	14.55	12.73	54.53	22.75	21.66
CV	157.5	161.1	86.82	61.46	61.32	55.9	50.87	69.61	83.75	118.9	61.49	90.67

SD: Standard deviation; Std E: Standard error; SV: Sample variance; CI: Coefficient of Interval; CV: Coefficient variance.

high (CV above 70%). From Table 4, the total annual rainfall coefficient of variance and interval is above 5%, based on the kurtosis measure of distribution from the formula.

The computed data in Table 4 show 15.08 in January as the highest coefficient of kurtosis with -0.47 least kurtosis in June; thus, a platykurtic distribution (<3) was observed in June months. The platykurtic distribution of annual, monthly precipitation totals is also observed in April, May, June, July, August, and November. Other months recorded the kurtosis coefficient of (>3), thus an observed leptokurtic distribution. However, despite low values of skewness recorded, the distribution had a positive (+) skewness with normal distribution without negative (-) skewness observed across the distribution trend.

It is observed in the results (Table 4) that all the months had a high coefficient of variation (>30%); therefore, deploying a homogeneous character on their precipitation variations. From the mean annual precipitations (Figure 4), the range is observed to be low (1685 to 661 mm). The linear precipitation shows decline of rainfall of between 1989 and 2019 (y = -9.5882x +1217.1, R^2 =0.0712).

Across the linear trendline (Figure 4), precipitation anomalies were observed between the years 2004 and 2005 recording the highest rainfall 2157 mm, and the year 2012 to 2014 recording 1648 mm. Even with these peak precipitation anomalies, received precipitation in Mombasa County was decreasing across the trend. Evident that climate variability effect had been experienced in the county in between the years (1989 – 2019). The previous study by Sheriff (2019), shows variations in temperature and rainfall for 30 years (1986-2016) subjecting the area to climate variability effect.

To investigate if there is a significant variation in rainfall and temperature in Mombasa County, a paired t-test done on the meteorological data. The data was segmented into two data sets; the first data set consists of the measurements taken in the first two years that is 1989 and 1990 and the second data set consists of the measurements taken in the last two years that is 2018 and 2019. The first test was performed to test the difference between the mean rainfall between the first two years and the last two years. The assumptions were; that the level of rainfall in the last two years is significantly lower compared to the first two years of the collected data from Mombasa County.

H_0: The average rainfall of the last two years is equal to or higher than the first to years.

H_0: The average rainfall of the last two years is lower than the first to years.

The results (Table 5), shows that the mean rainfall for the last two years is significantly lower than that of the first two years [t (0.05, 23) = 2.025, P = 0.0275]. This implies that rainfall amount is decreasing significantly in the coastal region

Prior analysis indicated that the maximum temperature recorded in Mombasa County had increased over time. Using the paired t-test approach, the mean maximum temperature of the first and the last two years were compared and the results are as shown (Table 6).

Based on the findings above, it is evident that the maximum temperature of the last two years is

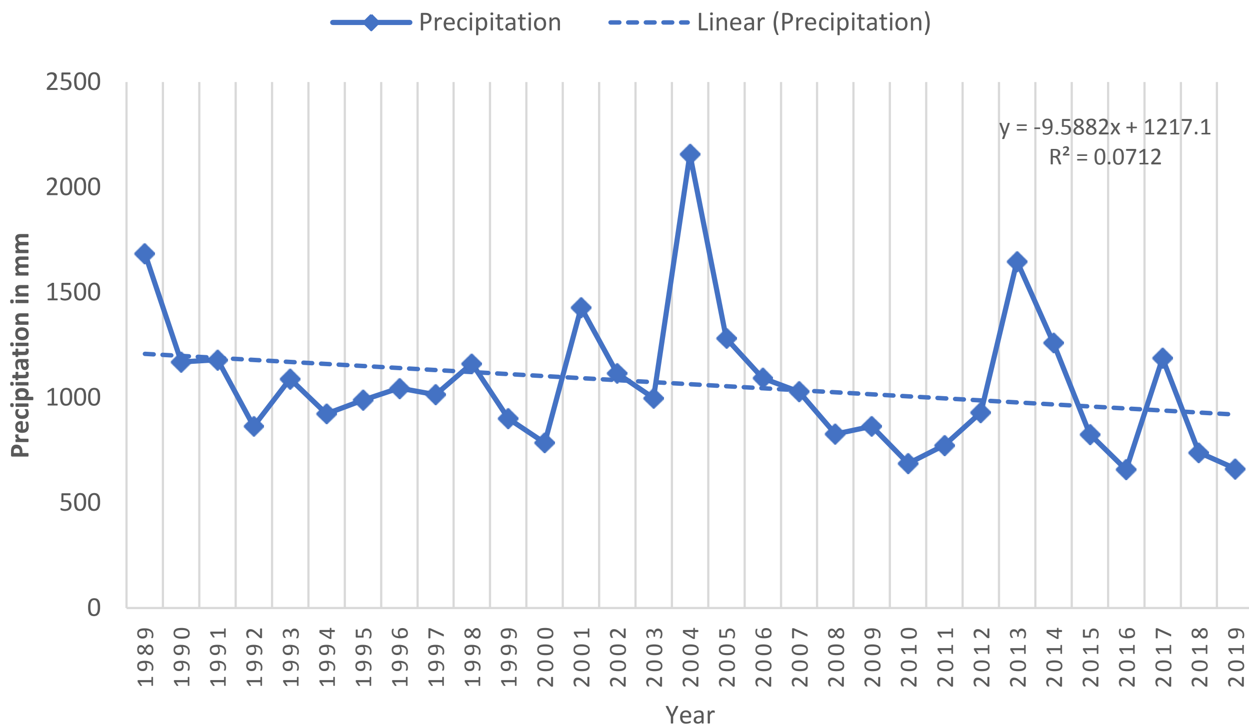

Figure 4. Total annual rainfall for Mombasa County (1989-2019).

Table 5. Rainfall variability t-test results.

	Paired differences					t	df	Sig. (1-tailed)
	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Year 1989-1990 - Year 2018-2019	60.6042	146.6121	29.9271	-1.3047	122.5130	2.025	23	0.0275

Table 6. Maximum temperature t-test results.

	Paired difference					t	df	Sig. (1-tailed)
	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Year 1989-1990 - Year 2018-2019	-0.7875	0.6854	0.1399	-1.0769	-0.4981	-5.628	23	0.000

significantly higher than the temperature of the first two years [t (0.05, 23) = -5.628, P=0.000]. Similarly, the minimum temperature of the regions was investigated to establish if a difference between the first and the last two years existed and the results are as shown (Table 7).

The results above show that the measured minimum temperature of the last two years is significantly higher than of the first two years [t (0.05, 23) = -5.401, p = 0.000]. Therefore, from the above t-test, the H_0: There is significant variations in temperature and rainfall in

Table 7. Minimum temperature t-test results.

	Paired differences					t	df	Sig. (1-tailed)
	Mean	Std. deviation	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Year 1989-1990 - Year 2018-2019	-0.8667	0.7861	0.1605	-1.1986	-0.5347	-5.401	23	0.000

Mombasa County was accepted.

Conclusion

The coastal urban setting of Mombasa County had experienced the effect of climate variability. The changes in rainfall and temperature had been experienced in the past 30 years as per the modelled retrospective study period. Temperatures had increased over time and decline of average rainfall even with trend line oscillations propagated climatic extremes.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENT

We thank researchers from Kenyatta University, Amoud University and the anonymous reviewers for their comments while developing early version of the manuscript.

REFERENCES

Abate RS (2019). Climate Change and the Voiceless: Protecting Future Generations, Wildlife, and Natural Resources. Cambridge University Press.

Barton MG, Terblanche JS, Sinclair BJ (2019). Incorporating temperature and precipitation extremes into process-based models of African lepidoptera changes the predicted distribution under climate change. Ecological Modelling 394:53-65.

Feulner G (2019). The Future of Earth's Climate after Paris. In International Climate Protection. Springer, Cham, pp. 5-11.

Graff Zivin J, Hsiang SM, Neidell M (2018). Temperature and human capital in the short and long run. Journal of the Association of Environmental and Resource Economists 5(1):77-105.

Grbec B, Matić F, Paklar GB, Morović M, Popović R, Vilibić I (2019). Long-term trends, variability and extremes of in situ sea surface temperature measured along the eastern Adriatic coast and its relationship to hemispheric processes. In: Meteorology and Climatology of the Mediterranean and Black Seas. Birkhäuser, Cham. pp. 311-326.

Hannigan J (2014). Environmental sociology. Routledge.

Hansen J, Satoa M, Ruedy R, Schmidtc GA, Lob K (2019). Global Temperature in 2018 and Beyond. Earth Institute, Columbia University: New York.

Hayelom B, Chen Y, Marsie Z, Negash M (2017). Temperature and precipitation trend analysis over the last 30 years in Southern Tigray Regional State, Ethiopia.

Herman Jr PF, Treverton GF (2009). The political consequences of climate change. Survival 51(2):137-148.

Innocent NO (2017). Farmers' perceptions On the Effects of Climate Variability on Dairy Farming in Masaba North, Nyamira County, Kenya. Masters dissertation, Kenyatta University.

IPCC (2018). Summary for Policymakers. In Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development. World Meteorological Organization, Geneva, Switzerland.

Mellander PE, Jordan P, Bechmann M, Fovet O, Shore MM, McDonald NT, Gascuel-Odoux C (2018). Integrated climate-chemical indicators of diffuse pollution from land to water. Scientific Reports 8(1):944.

Sheriff SS (2019). Role of Indigenous Knowledge in Mitigation and Adaptation to Climate Variability Impacts on Coastal Settlement Areas in Mombasa County, Kenya. Masters Dissertation, Kenyatta University).

Tokarska KB, Schleussner CF, Rogelj J, Stolpe MB, Matthews HD, Pfleiderer P, Gillett NP (2019). Recommended temperature metrics for carbon budget estimates, model evaluation and climate policy. Nature Geoscience 12(12):964-971.

Turco M, Jerez S, Doblas-Reyes FJ, AghaKouchak A, Llasat MC, Provenzale A (2018). Skilful forecasting of global fire activity using seasonal climate predictions. Nature Communications 9(1):271-278.