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Original Article

Trends of Climate change: Examination of Trends and Perceived Impacts of Precipitation Variability in Mount Kenya East Region, Kenya

Nyaga David Mwenda[1, 2], Prof. Catherine Lukhoba, PhD[1] & Prof. Gilbert Ouma, PhD[1]*

[1] University of Nairobi, P.O Box 30197-00200, Nairobi, Kenya.
[2] Chuka University, PO Box 109-60400, Chuka, Kenya.
[*] Author for Correspondence ORCID ID: https://orcid.org/0000-0003-3752-5401; Email: dmwenda@chuka.ac.ke
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ABSTRACT

Changes in trends of precipitation is of significant influence on human-nature interaction globally. Therefore, understanding the patterns and distribution of precipitation is paramount to the success of many livelihood activities, especially in the rural areas of the global south where agriculture is climate dependent. This study aimed at investigating the trends and perceived impacts of precipitation variability in Mount Kenya East Region (MKER) between 1989 and 2019. The study analysed the historical precipitation data of MKER from Kenya meteorological stations and the IGAD Climate Predictions and Applications Centre (ICPAC) satellite data using Mann-Kendall test and Sen's slope estimator to determine the precipitation trend. Furthermore, perceptions of variabilities in precipitation characteristics and their impacts in availability of ecosystem services in the region were obtained by interviewing 54 local respondents. Major results indicated an insignificantly declining trend of the annual precipitation at $p < 0.05$, which was characterized by Sen's= 0.081 and Kendall's value of 0.76. This was corroborated by the respondents' analysis which reported a decline in precipitation characteristics like rainfall amount (70.37%), length of rainfall seasons (92.59%) and number of rainfall seasons per year (5.56%) respectively. Consequently, the respondents reported loss of crop yields, increased water and fodder scarcity among other ecosystem services. Thus there is a need to equip the residents with climate change adaptation and mitigation strategies. This will sustain their livelihoods activities which are currently threatened by precipitation variability.

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INTRODUCTION

Precipitation is one of the key influencers of the extent and success of human interactions with their physical environment. This is especially true in the rural areas of the globe where agriculture, ecotourism, mining and other raw material production activities are the major sources of livelihood (De Vasconcellos Pegas et al., 2016; Ramaano, 2021). In the agricultural sector, rainfall and ambient temperature are the most influencing climatic factors which significantly affects crop yield (Nema et al., 2016). Unfortunately, most of these developmental sectors have been affected by the unprecedented impacts of climate change, thereby triggering negative adjustments to human-nature interactions (Bedinger et al., 2019).

Impacts associated with occurrence of weather extremities have resulted in significant changes in human-nature interactions. Excessive or diminished rainfall (hydro-hazards and droughts) are occurring with higher frequency and greater impacts in many parts of the world (Fennell et al., 2020). In this accord, rainfall variability remains among the most widely studied weather parameter due to its impacts on agriculture, ecological management and sustainable water supply (Fennell et al., 2020). The impacts of climate change are disproportionate in nature, magnitude and distribution (Nyiwul, 2021; Solomon et al., 2007). Consequently, the developing countries especially in Africa and Asia are more impacted upon than their developed counterparts, while the coastal areas are more damaged than the hinterlands (Nyiwul, 2021).

Within Africa, rainfall hazards such as flash floods, droughts, tropical cyclones and thunderstorms among many other weather extremities are the most common direct impacts of climate change (Tiepolo et al., 2019). The subsequent outcomes of these hazards usually result in social, economic and ecological damage such as loss of lives and livelihoods, food insecurity due to crop failure, destruction of infrastructure, abrupt surges of pest and diseases and loss of various ecosystem goods and services among others (Gezie, 2019; Kangalawe, 2012). Further, it is projected that by the year 2050, agricultural production will decline by 8 - 22% across the African continent due to climate change (Mekuyie & Mulu, 2021). Correspondingly, in the East African highlands, the epidemiology of vector-borne diseases is influenced by the inter-annual and inter-decadal variability of climate where rainfall and temperature have been found to cause inter-annual and seasonal variability of malaria (Kipruto et al., 2017; Zhou et al., 2004). Congruently, institutional and policy weaknesses coupled with poor economic status do not allow funding, capacity building and technological innovations in Africa. This impedes her capacity to benefit from the synergies of sustainable development strategies for adaptation to the impacts of climate change (Nyiwul, 2021).

In tropical countries like Kenya, where livelihoods are based on rain- fed agriculture, understanding the trends and variability of climatic parameters such as rainfall amounts and distribution will present the basis for establishing a reliable early warning instrument for use in planning and improving the socio-economic welfare of the society (Kisaka et al., 2015). The lack of data is highlighted, in the arid and semi-arid zones of eastern Kenya, as well as in some parts of central Kenyan highlands, where the high rates of evapotranspiration combined with persistent droughts and unpredictable rainfall

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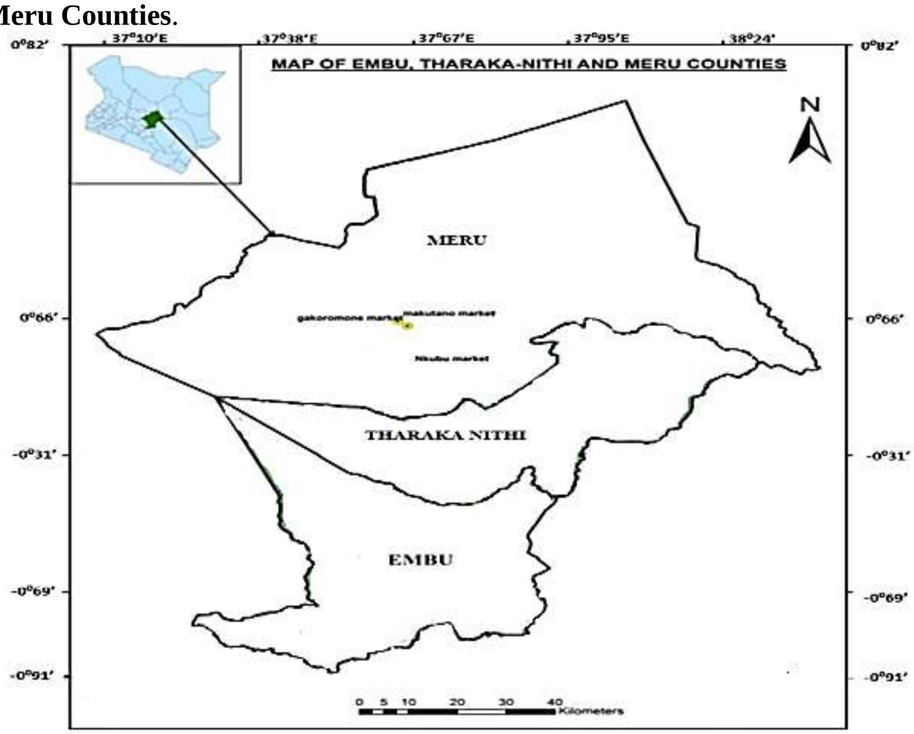
patterns have been experienced with a frequency higher than reported in the data reports (Kisaka et al., 2015). These areas, especially Mbeere and Tharaka districts, the rainfall is usually adequate, but poor in spatial–temporal distribution hence, resulting in reduced yields or complete crop failure in some seasons(Kisaka et al., 2015; Recha et al., 2012). During the 1997/1998 El-Niño event, some parts of this region reported rainfall amounts exceeding 2.4 times of the normal. Consequently, heavy crop yield losses, disruption in the transport sector due to landslides and various infrastructural damages associated with flash floods were experienced (Takaoka, 2005). Despite these plights, there is limited information published on the trends of climate change in this region. The aim of this study was to establish the trends, magnitudes and impacts of precipitation changes on the ecosystem services in Mount Kenya East Region.

METHODOLOGY

The study area

This study was carried out in Embu, Tharaka-Nithi and Meru Counties which occur in the Eastern slopes of Mt. Kenya. The region is lies between (37^{o} 10’E and 38^{o}24’E) and (0^{o}91’S and 0^{o}82’N) and an approximate elevation of between 600M above mean sea level (AMSL) in the dryland grasslands and 5199M (AMSL) at the mountaintop (Camberlin & Okoola, 2003). The study area occupies a total area of 12391 KM^{2}, in which 2564.4 Km^{2}, 2820.7 Km^{2} and 7006.3 Km^{2} are in Tharaka-Nithi, Embu and Meru Counties respectively (*Kenya Population and Housing Census*, 2019). Climatic conditions of the study area are characterized by a bi-modal rainfall pattern and temperature ranges of 13^{0}C to 28^{0}C in most of the months of the year (Kisaka et al., 2015; Mumo et al., 2018).

Figure 1: **Map of the study area showing the administrative boundaries of Embu, Tharaka-Nithi and Meru Counties**.



Data Sourcing

Both historical and current data of rainfall parameters in the region extending to a period of 30 years (January, 1989 to December, 2019) was obtained from two Kenya Meteorological Department (KMD) stations located in Embu and Meru for the two counties respectively.

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Additionally, rainfall satellite data for Tharaka-Nithi County was obtained from the IGAD Climate prediction & Application Centre (ICPAC) due to lack of a KMD ground station.

Before analysis, imputation of missing data was done using Kalman's filter approach (Durbin & Koopman, 2012; Gardner et al., 1980). The compiled data was then subjected to time series analysis using R language software version 4.1.1 which is freely available online (https://www.R-project.org/) for generation of statistical data such as mean annual precipitation per station from which the regional annual precipitation averages were obtained. Further trend analysis on the annual precipitation for each station as well as for the whole region was performed for the study period and presented using Mann-Kendall and Sen's slope estimator for inference on trend direction and magnitude (Atta-ur-Rahman & Dawood, 2017).

Rainfall Trend Analysis

In order to indicate the presence of upward or downward monotonic trend in the time series data in MKER during the study period, the following null hypothesis (H_0) which stated that there was non-existence of trend was tested. Basic statistic parameters such as mean, median, maximum and minimum values were performed by application of turkey's summary. Before using the Kendall's test, the annual and monthly time series data were plotted and fitted with a non-parametric locally estimated scatterplot smoothing (LOESS) curve to visualize the possible trends in the precipitation time series. The trend observed from the LOESS curve was further confirmed by performing non-parametric Mann-Kendall test and its magnitude and direction determined by use of Sen's slope estimator value. Serial and partial correlations in the data set was also conducted using acf () and pacf () functions in R-studio to determine the necessity for pre-whitening (Mumo et al., 2018) before Kendall's test. However, the results displayed by autocorrelation and partial autocorrelation plots for the time series were all non-significant hence, pre-whitening was not necessary (Mumo et al., 2018).

The rainfall time series were analyzed for linear trends using the Mann-Kendall test. The test is a non-parametric and first includes calculation of all the dissimilarities between the sets of its isolated observations as shown;

$$[xj - xk] \; for \; j > i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; equin\ 1$$

In each pair, a symbol for its change is computed as follows;

$$sign[xj - xk] = \begin{bmatrix} 1 & if\ xj - xk & > 0 \\ 0 & if\ xj - xk & = 0 \\ -1 & if\ xj - xk & < 0 \end{bmatrix} \ldots\ldots\ldots. \; equin\ 2$$

Where $x_1, x_2 \ldots\ldots\ldots x_n$ characterizes n data point while x_j represents data point at time j. Then S was calculated as follows;

$$S = \sum_{i-1}^{n-1} \sum_{j=k+1}^{n} sign(xj - xi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equin 3}$$

Where a rising trend is indicated by a +ve value of S value and vice versa (Diress & Bedada, 2021).

Perceived impacts of precipitation variability on Ecosystem Services

The approach for evaluation and scarcity rating was conducted as follows: - Decreased access to water was estimated as variations in waiting time at public water points or variations in distances walked to amass water for a daily domestic requirement for a 5 member family- atleast 100litres depending on regional water consumption behaviors (https://www.ndma.go.ke). Declining accessibility of fodder was appraised as variations in time for gathering adequate fodder for a daily need of single cow in a zero grazing unit while a variation in walking distances in search of pasture for free range animals was considered (Ndukuman et al., 2000; Huho et al., 2011). Soil fertility consistent with weakening of moisture content in the crop growing

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phase was appraised as perceived variations in the long-term number of 90kg bags of grain reaped per acre per season. Habitat loss on the other hand was estimated as frequencies of sighting or hearing noises made by climate sensitive creatures (eg chameleons, butterflies and certain bird species) in a season. Finally, declining accessibility of firewood (assessed as change in time for gathering sufficient firewood for a daily use in a family of atleast 5 members).

Where:

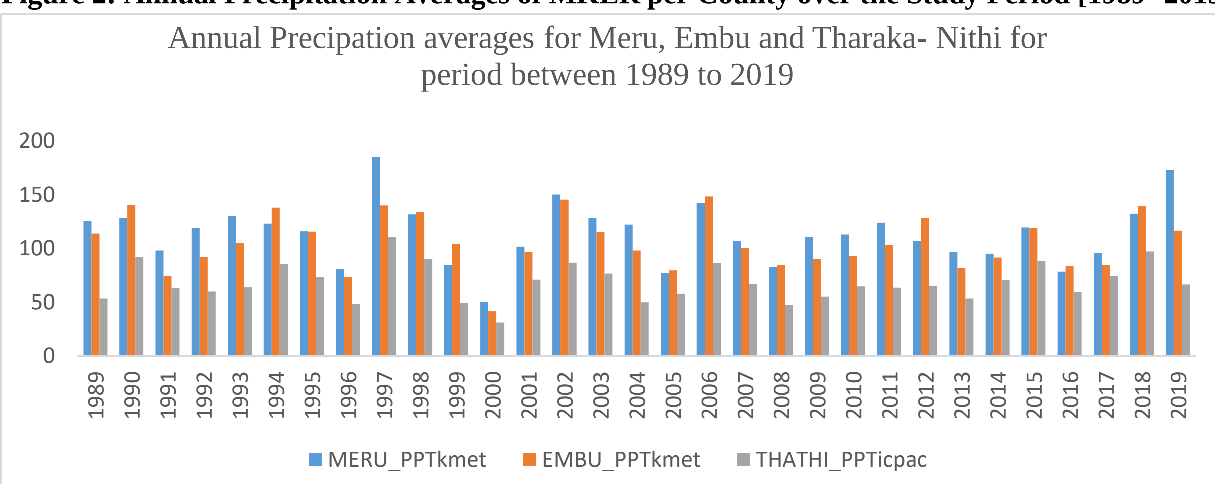
For water, fodder/pasture, and firewood, deviations in collection time or walking distances ranging between 0–15 minutes, 15–30 minutes, and over 30 minutes, or 0-0.5 km, 0.5–1.5 km, and over 1.5 km, were rated as low, moderate, and extreme correspondingly. Similar to this, accounts of sighting or hearing noises made by climate-sensitive faunae (such as chameleons, sparrows, and butterflies) in the ranges of; 0-10 times, 10-20 times, and 20-30 times were appraised as extreme, moderate, and low levels of habitat loss respectively. Correspondingly, variations in the grains yielded in the ranges of 0-2 bags, 2- 4 bags, and 4 beyond bags/acre/season, were appraised as low, moderate and extreme losses in the soil moisture respectively.

RESULTS AND DISCUSSION

MKER Precipitation Patterns

The twelve-monthly rainfall averages for the Counties of the study area are revealed in figure 2. Throughout the study period, Meru County had the peaking annual precipitation amounts except in 1990, 1994, 1998, 2006, 2012 and 2018. However, during these years Embu County was characterized by the highest annual precipitation of 140.28mm, 138.07mm, 133.98mm, 148.37mm, 128.28mm and 139.53mm respectively. The maximum annual average precipitations in the region were documented in 1997 (184.99mm and 110.81mm for Meru and Tharaka- Nithi) and 2006 (148.37 mm) in Embu County respectively. On the other hand, the minimum annual precipitation of the region was perceived in the 2000 when 50.05mm, 41.62mm and 31.08 mm were documented for Meru, Embu and Tharaka-Nithi Counties respectively) (see figure 2).

Figure 2: Annual Precipitation Averages of MKER per County over the Study Period [1989- 2019]



Source: Field work data (2021)

The minimum, maximum, mean, median, standard deviation for all the three stations of MKER are described in table 1. From the table, it is evident that the lowest and highest rainfall amounts were

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observed in Tharaka-Nithi ($\bar{X}$= 68.44mm; SD= 17.41mm and Meru stations $\bar{x}$= 113.84mm; SD= 28.02mm respectively over the study period, The results for Embu County remained at the middle but more skewed towards figures observed in the Meru station than those of Tharaka-Nithi. This finding contradicted the researchers' expectations since Tharaka-Nithi County is geographically located between the other two Counties of the study area (see fig.1), hence would have shown results similar to those of Embu County. The kurtosis showed a close to normal distribution of rainfall in all the counties of the study.

Table 1: Summary of Annual Rainfall in Meru, Embu and Tharaka-Nithi Counties and the Region (MKER).

Rainfall Parameters	MERU_ PPT kmet (mm)	EMBU PPT kmet (mm)	THATHI_PPT icpac (mm)	MKER_APP T (mm)
N	31.00	31.00	31.00	31.00
Min	50.05	41.62	31.08	40.92
Max	184.99	148.37	110.81	145.33
Mean	113.84	105.50	68.44	**95.93**
Median	115.92	103.28	65.44	91.30
Stds	28.02	25.58	17.41	21.89
Skew	0.31	-0.12	0.36	-0.01
Kurtosis	0.88	-0.23	0.06	0.30

Source: Field work data (2021)

Legend: N=Period of study (years), Min= Minimum mean precipitation received over the study period, Max=Maximum mean annual precipitation observed over the study period, stdp=Standard deviation, PPTKmet=Precipitation observed from Kenya Meteorological department station, PPTicpac= Precipitation data obtained from ICPAC satellites. NB: *we used ICPAC satellite data for Tharaka-Nithi County because there was no Kenya Meteorological Department station in the County.

For at least eight times during the research period, at roughly 4-year intervals, the mean annual precipitation, which peaked beyond the region's average of 95.93mm (see table 1), was recorded. Precipitation maxima that were lower than the average for the area were also discovered to indicate a repeat cycle that lasts roughly five years. Figure 3 shows that the precipitation peak patterns below and above average differed by at least one or two years, indicating that the entire region was experiencing an unexpected pattern of hydro-hazard occurrence linked to extreme weather conditions (droughts or floods). Such incidences are usually linked with in food insecurity that occurs in the region due to crop failure (Kisaka et al., 2015; Takaoka, 2005). Further the effects of hydro-hazards occurrence in this region have far-reaching impacts on the country's GDP as well as on the local economy since the study area together with Abadare ranges contributes upto 49% of the water used for electricity generation in the river Tana as well as supplying huge quantities of cash and subsistence crops to the local and export markets (*KPHC*, 2019; Njuguna et al., 2020).

Trends of Long-term Mean Annual Rainfall in MKER

Plotting the mean annual averages of MKER yearly rainfall trends across the research period shows clearly defined wave crests and troughs. Years throughout the research period with average annual precipitation exceeding the regional norm (>95.93mm) and vice versa are known as the crests. A recurrent cycle of roughly three to four years produced the above-average rainfall, which corresponded to the years 1990, 1994, 1997/98, 2002, 2006, 2011/2012, 2015, and 2019. The

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troughs, on the other hand, matched the years 1991/2, 1996, 2000, 2005, 2009, 2013, and 2017. Conversely, the precipitation below normal displayed a comparable pattern, albeit with a roughly 4-year repetition cycle. However, it is important to illustrate that all three stations/ counties showed similar patterns of rainfall trend with differences only being noted in the amounts of rainfall received in the specific locations/stations across the study area.

Visualization of the region's precipitation trend using linear trend line (Figure 3 (a)) revealed a slight downward trend in precipitation over the study period while visualization of the same using a LOWESS trend line (figure 3(b)) depicted a downward-upward trend. However further analysis of the statistics of MKER based on annual precipitation averages of the study period, produced a computed P-value of 0.7579 which is greater than α= 0.05. Hence the null hypothesis (Ho) which assumed that there was no trend in rainfall parameter in the region over the period of study (1989 to 2009) could not be rejected because the risk of rejecting a true null hypothesis was 75.79%. However, further analysis on Mann-Kendall and Sen's slope revealed that there was a non-significant drop of approximately 5mm in annual rainfall/precipitation at $p<0.05$ over the study period as characterized by the Sen's slope of -0.08143197.

The region's large-scale clearing of Trees outside the Forest (TOF) in the mid- and late-1990s and early 2001 to make way for agriculture and habitation may be the cause of the statistically insignificant decreasing trend of precipitation in the area, which is estimated to be 5 mm annually. Kariuki (2006) claims that this period corresponds with a period of politicization of the management of Kenya woods and other public lands, leading to the political allocation of the forests of Ngong, Karura, and Mount Kenya to certain individuals. Similar to this, the Kenyan government said in 2001 that it intended to clear 167,000 hectares of forest, of which 1825.12 ha were located in Mount Kenya Forest (Kariuki, 2006). Additionally, numerous scholarly studies have revealed the connection between forests/tree cover, regional precipitation, and climate as reason. For instance, according to (Andréassian, 2004), every time a fresh drought or flood occurs, the ghosts of deforestation inevitably reappear. Likewise, Bennett & Barton (2018) found that growing forest cover is critical to our ability to survive in a world with an abundance of water and to adapt more effectively to predicted climate change. Nonetheless, the region's proximate positioning towards the windward side of Mount Kenya and the Intertropical Convergence Zone (ICTZ) may also be linked to the statistical insignificance of the precipitation drop, as it benefits from both the orographic and relieve types of precipitation (Camberlin & Okoola, 2003).

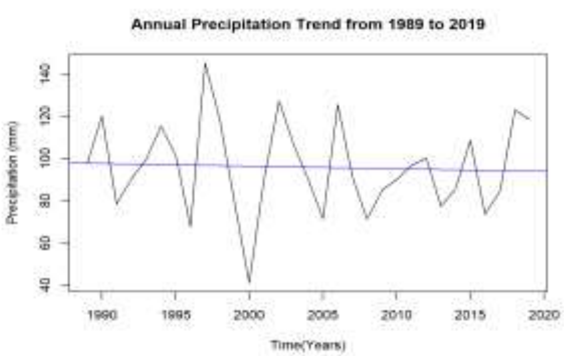

Fig 3(a)

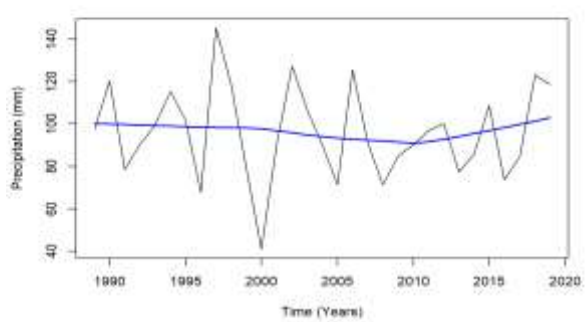

Fig 3(b)

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Figure 3: Long term Mean Annual Precipitation (1989 to 2019 (a): Mean annual precipitation trends of MKER with a linear trend line before performing the Mann-Kendall test. (b): MKER annual precipitation fitted with the non- parametric loess curve to better visualize the trend of the time series data before the performance of the Mann-Kendall test.

Trends of MKER annual rainfall based on monthly averages

The results of seasonal sub-series showed that July recorded a significant drop in precipitation as characterized by Sens's Slope value of -0.3509091 at a p-value of 0.05 (Table 2). However, insignificant drops in precipitation occurred in the months of January, February, March, August and December while insignificant rises were observed in April, May, June, September, October and November. These periods correspond to the long rain (MAM) and short rain (SOND) respectively. Thy reveal a likelihood of shortening length of the two rainfall seasons. Furthermore, the results of Mann-Kendall test also revealed that the short rains were shifting forwards while the long rains were shifting backwards as evidenced by the higher precipitation in June and September, months which normally correspond to the cessation and onset months of short and long rains in the region respectively (Kisaka et al., 2015; Recha et al., 2012).

Table 2: Monthly rainfall distribution and trend analysis results in Mt. Kenya East region for the period starting from 1989 to 2009.

Statistics_Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00
Z	3.50	3.06	3.25	2.18	2.70	2.21	3.42	3.81	2.62	3.43	4.40	3.37
S	207.00	181.00	192.00	129.00	160.00	131.00	202.00	225.00	155.00	203.00	260.00	199.00
VarS	3461.67	3459.67	3460.67	3461.67	3460.67	3461.67	3460.67	3459.67	3461.67	3461.67	3460.67	3461.67
Tau	0.45	0.39	0.41	0.28	0.34	0.28	0.43	0.48	0.33	0.44	0.56	0.43
Lower CI (95%)	0.02	0.01	0.01	0.00	0.01	0.00	0.02	0.03	0.01	0.01	0.03	0.02
Upper CI (95%)	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.06	0.04	0.04	0.05	0.05
Sen's Slope	0.03	0.03	0.03	0.03	**0.02**	0.02	0.04	**0.05**	**0.02**	**0.02**	0.04	0.03
P-Value	0.00	0.00	0.00	0.03	0.01	0.03	0.00	0.00	0.01	0.01	0.00	0.01

County-wise analysis for Mann-Kendall and Sen's slope testing

Meru station

From figure 4(a) below, there was a slight downward trend in the precipitation as shown by the trend line. However, the loess curve in figure 4(b) shows both upward and downward trends in the precipitation of the Meru station. Further analysis by the Mann-Kendall test and Sen's slope estimator revealed that the region experienced a statistically insignificant drop of approximately 5mm in annual precipitation as detailed by Sen's slope estimator value of Sen's slope=-0.383 and a 2-sided P-value of 0.455 which is greater than the significance level $p < 0.05$.

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Figure 4: long term Mean Annual Precipitation for Meru County (1989 to 2019 (a) plot of mean annual precipitation for Meru meteorological station fitted with a linear trend line before Mann-Kendall test. (b) Plot of mean annual precipitation for Meru meteorological station for period 1989 to 2019 with loess curve.

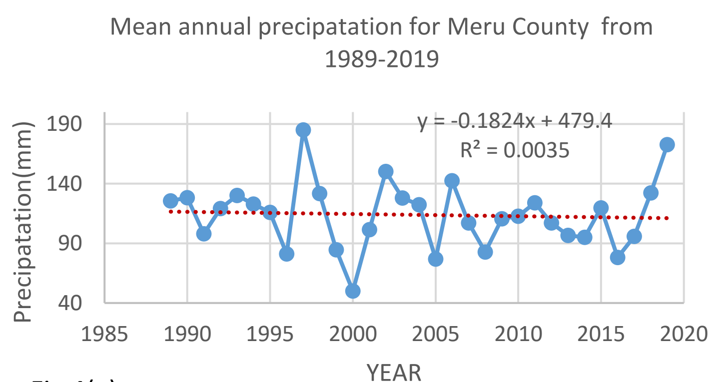
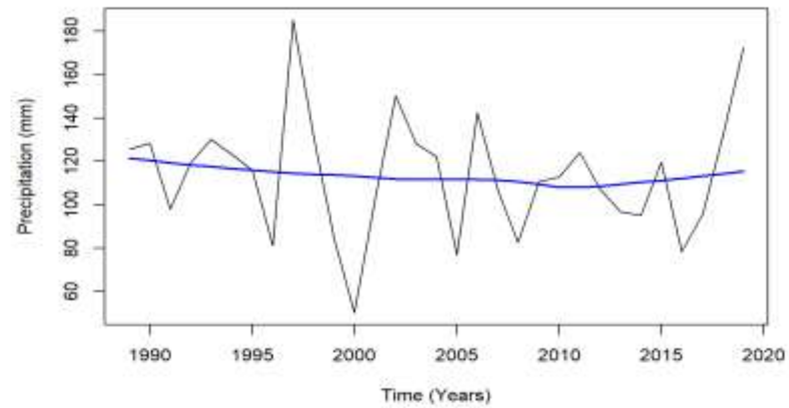


Fig 4(a)



Embu station

From the trend figures below, it was noticeable that the rainfall trend in Embu County depicted a downward trend. However, it was also worth noting that there was a level of consistency of less than approximately 12mm difference in the crests (the above-average figures) of the wave-like plot produced by the average annual rainfall over the study period. This corresponds to the years 1990(140.28mm), 1994(138.067mm), 1997(140.2), 1998(133.98mm), 2002(145.57mm) and 2018(139.53mm) respectively.

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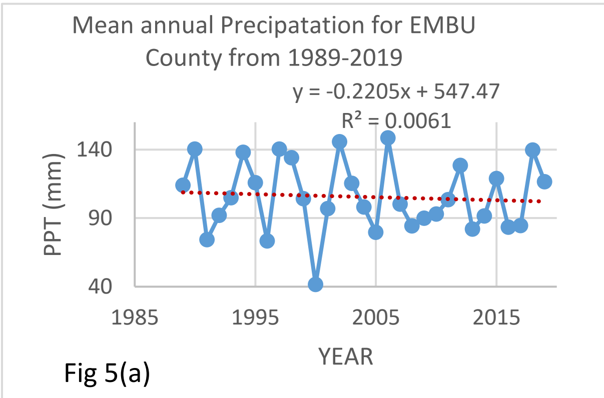
The Mann-Kendall test and Sen's slope estimator values confirmed the above observation by indicating that there was a non-significant monotonic downward trend of approximately 7 mm in the annual time series precipitation of Embu County as detailed by computed Kendall's 2-sided P-value of 0.6101 which is greater than the significance level of $P<0.05$ and Sen's slope estimator value of (Sen's slope=-0.3776042)



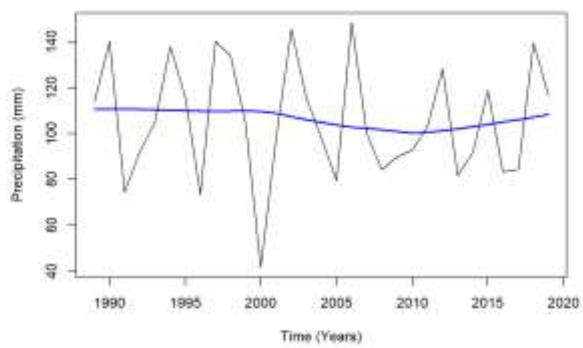
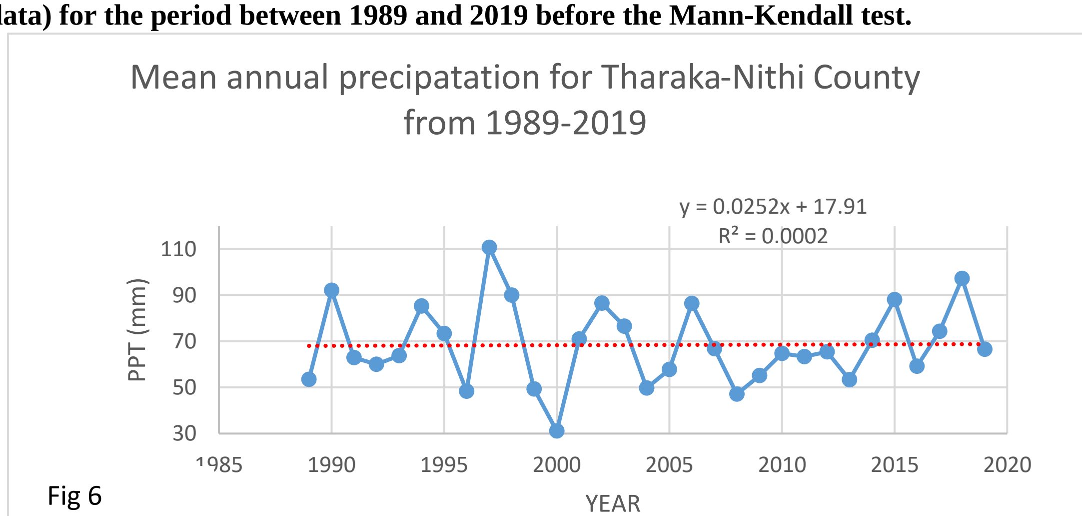


Figure 5: Long term mean annual precipitation for Embu County using Kenya Meteorological station data for January, 1989 to December, 2019. (a) Mean annual precipitation for Embu County fitted with a linear trend line for the period between 1989 and 2019 before the Mann-Kendall test. (b) Plot of mean annual precipitation for Embu meteorological station for period 1989 to 2019 with fitted loess curve before the Mann-Kendall test.

Tharaka-Nithi station

The linear trend line for the mean annual precipitation for Tharaka-Nithi County over the study period showed an insignificant descend in annual precipitation. This was confirmed by Kendall's two-sided p- value of 0.6054 and Sen's slope of – 0.00663 indicating a statistically insignificant decline.

Figurer 6: plot of mean annual precipitation for Tharaka-Nithi County based on ICPAC (satellite data) for the period between 1989 and 2019 before the Mann-Kendall test.



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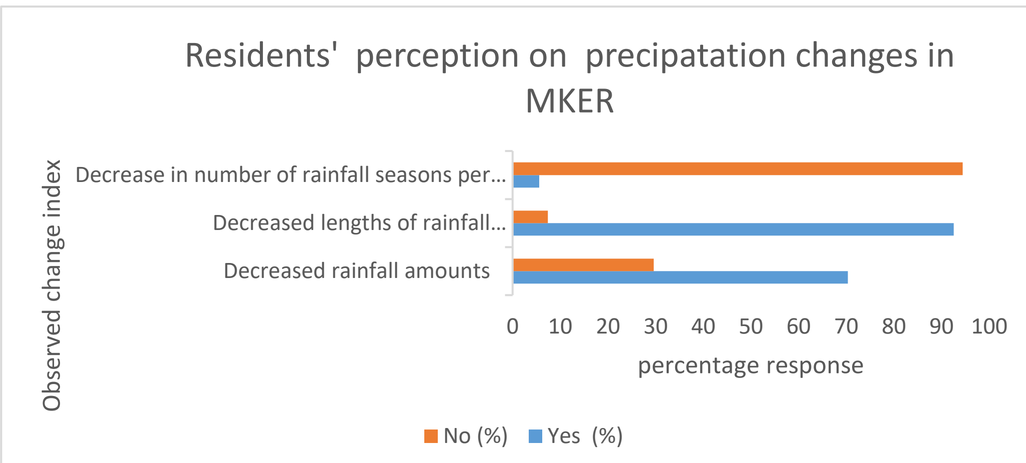
The station-wise analysis of precipitation trends showed a high level of consistency with the regional patterns except for Embu County whose highest precipitation peak years illustrated a high degree of uniformity in the annual averages with a maximum difference of approximately 12 mm. These results resonate well with conclusions other researchers who showed that there was a high level of homogeneity in precipitation data for Embu County based on average monthly rainfall (Kisaka et al (2015).

Perceived variability in the Characteristics of Precipitation in MKER

All the 54 interviewed respondents reported that they had noticed a change on some characteristics of precipitation in the region during the study period. Further results showed that 38(70.37%), 50 (92.59%) and 3(5.56%) of the total interviewed respondents had observed a decrease in the amount of rainfall received, decrease in the lengths of rainfall seasons and decrease in the number of rainfall events per year in the study area respectively during the study period. The shortened length of rainfall season was described with attributes such as delayed onset or early offsetting while decreased rainfall amounts was attributed to poor cloud formation, reduced frequency of hailstones and reduced incidences of thunder and lightning in the study.

Figure 7: Respondents Perception on Variability in Features of Precipitation



Perceived Impacts of Precipitation Variability on Availability of Common Ecosystem Services in MKER

Additionally, the perceived variability in the precipitation indices was associated with a wide range of changes in the availability of the five most commonly used ecosystem services in the study area. For instance, a high percentage of respondents- ranging from 65% to 76% among the 38 respondents who had witnessed a decrease in rainfall amount in the region, associated this phenomenon with a low impact of vulnerability rating on all the five evaluated ecosystem services. Conversely, high percentages of respondents ranging from between 36% and 68% of 50 respondents and between 66% and 100% of 3 respondents perceived an extreme impact of decreased length of rainfall season and decreased number of rainfall events on most of the evaluated ecosystem services respectively. However, 68% and 80% of 50 respondents reported low impact of decreased length of rainfall season on the availability of firewood and building materials respectively, while 100% of 3 respondent also reported that reduced number of rainfall events in the region had low impact on the availability of both firewood and building materials in each case respectively.

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Table 3: Respondents' Perception on the Effects of Climate Change on Loss of Ecosystem Services in MKER

Climate variability indicator	Impact on/Vulnerability of ecosystem services	Respondent's rating by perception (%)				
		N	**Extreme**	**Moderate**	**Low**	**Total %**
Decreased rainfall amounts	a. reduced access to water	38	5.26	28.95	65.79	100
	b. reduced availability of fodder	38	5.26	26.31	68.42	99.99
	c. loss of soil fertility (poor crop performance)	38	10.53	26.32	63.16	100.01
	d. loss of habitat (reduced incidence of seeing some animals)	38	7.89	18.42	73.68	99.99
	e. reduced availability of firewood	38	7.89	23.68	68.42	99.99
	f. reduced availability of building materials	38	5.26	18.42	76.32	100
Decreased length of rainfall season (droughts)	a. reduced access to water	50	36	44	20	100
	b. reduced availability of fodder	50	54	28	18	100
	c. loss of soil fertility (poor crop performance)	50	60	26	14	100
	d. loss of habitat (reduced incidence of seeing some animals)	50	**68**	22	10	100
	e. reduced availability of firewood	50	4	28	68	100
	f. reduced availability of building materials	50	4	16	80	100
Decreased number of rainy seasons per year	a. reduced access to water	3	66.67	33.33	0	100
	b. reduced availability of fodder (time to gather)	3	100	0	0	100
	c. loss of soil fertility (poor crop performance)	3	100	0	0	100
	d. loss of habitat (reduced incidence of seeing some animals)	3	66.67	33.33	0	100
	e. reduced availability of firewood	3	0	0	100	100
	f. reduced availability of building materials	3	0	0	100	100

The perceived changes in the precipitation features can be linked to a change in cropping practices and other ecosystem destructive activities like shamba system, Bhang (Marijuana) growing, illegal logging, forest fires and charcoal burning which have been reported in the region (Kariuki, 2006). Furthermore, such unsustainable activities have far reaching impacts on the stability of regional climatic variables and the ability of the study area ecosystem to sustain its supply for common ecosystem services. Hence, as a result the MKER residents reported a wide range of perceptions on the variability of precipitation characteristics in the region where, decrease in the length of rainfall seasons (droughts) was more perceived than both decrease in amount of rainfall received and decrease in the number(seasons) of rainfall events per year respectively. In addition, the variability of these characteristics of precipitation in the region, was also associated with changes in the supply of 6 most common ecosystem goods and services namely; water, fodder, soil fertility, wildlife habitat, firewood and construction materials. Most of these ecosystem goods and services were perceived to extremely vulnerable to reduced length of rainfall season (droughts), while reduced rainfall amount was perceived to have low impact on the availability of all them. For instance, some of the respondents said that crop failure occurred in the region when off set came earlier than expected. However, among all the evaluated ecosystem services, habitat for some climate sensitive organisms like butterflies, chameleons and African honey bee was perceived to be the most vulnerable to the occurrence of droughts in the region. During habitat loss evaluation, which took a period of 4 weeks, the respondents had encountered on 3 chameleon, one swarm of migrating honey bee and 0 butterfly.

Similarly, high rates of forest degradation have also been documented in Southeast Asia leading to heavy losses in the region's biodiversity (Koh & Wich, 2012; Sodhi et al. 2010). Likewise, there has also been a decline in vegetation cover all over the region due to changes in production system priorities by the farmers in the study area with a preference of annual over the perennial cropping system which characterized the region a few years ago (Kariuki, 2006). This complexity in the interactions shown by both biotic and abiotic factors in influencing the functioning this ecosystem have similarly been reported by Fath et al (2019) in marine ecosystems. Fath et al (2019) further recommends multiple dimensions and methods to evaluate and interpret the high number of interactions and feedbacks to ecosystem policy and decision makers.

Conclusion

Rainfall in the study area showed a generally decreasing trend. Further, during the study period precipitation decreased two-folds, thereby affecting residents' livelihoods through loss of crop yields, decline in fodder and water availability among other ecosystem services.

In this accord to sustain the livelihood activities of the residents we recommend for- initiatives to training the farmers on climate change adaptation and mitigation measures such as; climate smart agriculture, planting timing and crop diversification. Research for development of crop varieties with high water use efficiency by the certified seed producers. These can be planted during periods of expected droughts as per climate information revealed by this study. Lastly County and national governments through their respective ministries of agriculture should sensitize and advice the farmers on the need to adopt planting of drought tolerant crop species/ varieties like cassava, sorghum and millet together with on farm crop diversification for crop failure risk reduction.

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