Trends of Precipitation and Temperature in Morogoro Region in Tanzania

Dayoub, M.[1*], Thonglor, O.[2] and Korpela, T. [1]

[1]Department of Future Technologies, University of Turku, FI20014 Turun yliopisto, Finland; [2] Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Thailand.

Abstract Climate changes can seriously affect the environment and rural communities, water availability, health, food security, biodiversity, and agricultural production. Farmers in Africa who depend on rain to grow crops are already recognizing the effects of changing climate. Weather is essential to farmers' decision-making. The present study analysed spatial and temporal trends of precipitation and temperature over the Morogoro region by using available climate data from the local meteorological agencies. The data were analysed during the period of 1991–2015 for the mean monthly precipitation and temperature and predicted the monthly precipitation and temperature by using the time series analysis. The result showed that the climate is highly variable from arid to humid. At the same time, the trend line of mean monthly showed a slightly decreasing linear trend in precipitation and an increase in temperature. The forecast values of the rain and temperature until 2025 by the decomposition method with the multiplicative model showed that precipitation in May – October will be low. Moreover, the seasonal indices predicted that precipitation in those months will be lower than previously. The future trends should be carefully considered to help farmers in selecting proper cultivation strategies.

Keywords: Precipitation, Temperature, Time series analysis, Morogoro region, Tanzania

Introduction

Over the last few decades, most parts of Tanzania have experienced incidences of extreme climatic events, particularly floods and droughts that have been associated with severe socio-economic and ecological implications. The most recent severe floods include those of 2006, 2009, 2010, 2011, 2012, 2014, 2016 and 2017 that caused in many parts of the country loss of many lives and infrastructural destructions.(Kijazi and Reason, 2009) (Viste, Korecha and Sorteberg, 2013).

The climate in Africa is semi-desert (semi-arid), and the rainfalls vary over the area and time. Morogoro region lies between the seasonal rainfall patterns of Northern and Southern Tanzania. Northern Tanzania has bimodal rainfall. The short Vuli rains start between mid-September and mid-October and continue until December. The long Masika rains start in mid-March and last until late May. Southern Tanzania has unimodal Msimu rains, which start in November and end in April or May. (Paavola, 2008).

General climatic conditions and climate changes are well described by mean monthly values, while the extremes are better reflected by the daily data. During the last decades, daily temperature and precipitation observations have been used for computation of the indices. (Zhang *et al.*, 2011).

Annual rainfall in Morogoro region varies from 4000 mm in the high altitudes of the Eastern slopes of the Uluguru mountains to about 600 mm in the low altitude plains (Kangalawe *et al.*, 2014).Families live in farms which in many places are smaller than 2 hectares (Rapsomanikis, 2015). More than 95% of sub-Saharan African agriculture is rainfed, and rainfall changes are felt particularly by those who directly depend on reliable weather patterns. (Simelton *et al.*, 2013) (Mkonda and He, 1980). Weather is a multiple parameter made up of air temperature, atmospheric pressure, humidity, precipitation, solar radiation, and wind. In the dry and semi-dry areas climate naturally plays very crucial role in the agriculture and livelihood of the population. As a result of the climate change and variability, climate indicators have become unstable. The change in the quantity and distribution of rain has major long-term effects on the natural systems, such as surface waters and rivers and especially on those people who rely on agriculture. Rainfall fluctuations are the main cause of crop changes in many areas of Tanzania. (Dayoub *et al.*, 2018), although other factors such as soil type, temperature, and low agricultural inputs may play a role in the productivity. Therefore, the study of characteristics of mean monthly precipitation and temperature including monthly precipitation and temperature in Tanzania using time series analysis is of importance. (Hamisi, 2013).

* **Corresponding author:** Dayoub, M. **E-mail:** modayo@utu.fi

Materials and methods

Description of the study area

The United Republic of Tanzania locates to the South of the equator between 1 - 12˚S and 29 - 41˚E. The country has a total area of 945,087 km^2 of which 883,749 km^2 is covered by land area, and 59,050 km^2 is covered by inland waters and part of the Indian Ocean. The country is characterized by diverse and complex topographical features extending from a narrow coastal belt of the western Indian Ocean with sandy beaches to an extensive plateau with altitude ranging from 1000 to 2000 m above mean sea level. The plateau is fringed by narrow belts of highlands, including Mount Meru with an altitude of (4566 m), and the highest mountain in Africa and the second highest mountain in the world: Mount Kilimanjaro with an altitude of (5895 m). Tanzania has several fresh water bodies, including the largest lake in Africa; Lake Victoria, the longest and deepest lake in Africa; Lake Tanganyika and Lake Nyasa (Chang'a *et al.*, 2017) (Kijazi and Reason, 2009).

Morogoro is a town with a population of 315,866 (2012 census) in the Eastern part of Tanzania, 196 km west of Dar es Salaam, the country's largest city and commercial center, and 260 kilometres east of Dodoma, the country's capital city. Morogoro is the capital of the Morogoro region. It is also known informally as "Mji kasoro bahari". The annual temperature averages here 24.6 °C and rainfall 935 mm.

Data collection

Weather data for precipitation and temperature in Morogoro region, Tanzania were collected from WeatherOnline Ltd. - Meteorological Services. ('www.weatheronline.co.uk', 2018).
The precipitation data set was consecutive monthly from January of 1991 to December of 2015 and January of 2004 to August of 2019 for temperature data set.

Trend analysis

Trend analysis of mean monthly precipitation and temperature were analysed with Microsoft Excel 2013 to determine the trend line of mean monthly precipitation and temperature in Morogoro region. The model is Y = a + bt, where Y is precipitation /temperature, a is intercept, b is slope and t is time.

Time series analysis

The decomposition method was used with the multiplicative model to identified trend cycle, and the seasonal and irregular analysis for mean monthly precipitation and temperature.
Multiplicative model is $Y = T \times C \times S \times I$, where Y = precipitation/temperature, T = the trend component, C = the cycle component, S = the seasonal component and I = the irregular component. The analysis was carried out using Microsoft Excel 2013. Measures of forecast accuracy consist of Mean Absolute Deviation (MAD), Mean Squared Deviation (MSD) and Mean Absolute Percent Error (MAPE).

Results and Discussion

1. *Descriptive Statistics of mean monthly precipitation and temperature*

Temperature and precipitation are fundamental measures for describing the climate and can have wide-ranging effects on farming. Table 1 shows the average monthly rainfall from January to December (1-12) during the 25-year period. The standard deviation (SD) represents variation in the values for the temperature and precipitation, the highest relative SDs of rainfalls occurs during the dry season (6-8). The SDs of temperatures are annually rather small.

Table 1. Mean ± SD of mean monthly precipitation and temperature in Morogoro, Tanzania.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Precipitation	150.3± 41.8	129.9 ±36.4	174.5 ±36.3	147.8 ±29.5	56.8± 17.8	12.7± 6.1	5.3± 2.9	7.9± 3.7	17.8± 0.03	33.1± 0.5	89.4± 7.1	148.6 ±53.1
Temperature	27.29± 0.8	27.20 ±0.8	26.56 ±1.5	25.58 ±0.6	24.11 ±0.6	22.54 ±0.6	22.07 ±0.5	22.99 ±0.5	23.93 ±0.6	25.56 ±0.8	26.72 ±0.4	27.30 ±0.7

2. Trend Analysis of mean monthly precipitation and temperature

The trend line of mean monthly precipitation and temperature in Morogoro region were presented in figures 1 and 2, respectively. The trend lines showed slightly deceasing linear trend following the equation: $y = 83.5 - 0.015t$. It shows that every 83.5 months in Morogoro precipitation would decrease by 0.015 mm. Furthermore, it was observed that there was season component but there was no cycle and irregular component.

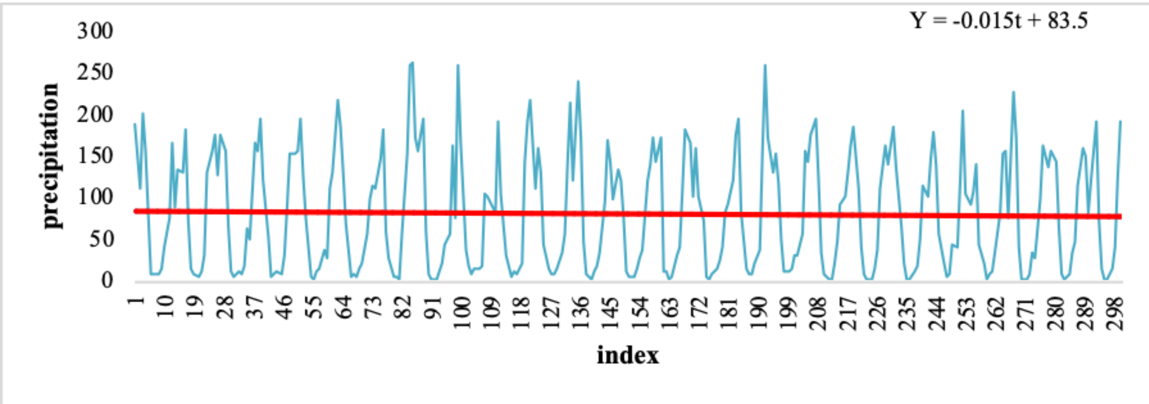

Figure1. Trend line of mean monthly precipitation in Morogoro, Tanzania (1991– 2015).

The trend line of mean monthly temperature (Fig.2), shows a slightly increasing linear trend described by equation: y =25.1 + 0.0002t. The linear equation shows that for every 25.1 months the temperature would increase by 0.0002 C.

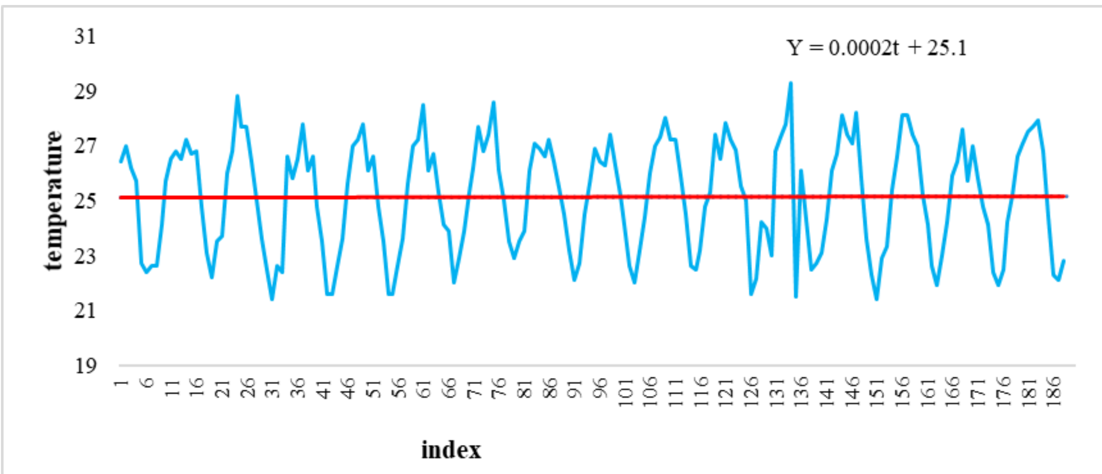

Figure 2. Trend line of mean monthly temperature in Morogoro, Tanzania (2004– 2019).

3. Time series Analysis of mean monthly precipitation

The result of time series analysis of mean monthly precipitation by using the decomposition method with multiplicative model indicated that the Mean Absolute Deviation (MAD) was 18.7. Mean Square Deviation (MSD) was 810.4. Mean Absolute Percentage Error (MAPE) was 38.4. Forecast values mean monthly precipitation in the future (2016 – 2025) was presented in Table 2 and Figure 3.

Table 2. Forecast values of monthly precipitation in the future (2016 – 2025).

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2016	149.4	129.9	174.2	143.8	60.6	12.7	4.7	7.78	16.9	31.7	93.3	152.2
2017	149.2	129.8	174.0	143.6	60.6	12.7	4.7	7.77	16.9	31.7	93.2	152.1
2018	149.1	129.7	173.8	143.5	60.5	12.7	4.7	7.76	16.9	31.6	93.1	151.9
2019	148.9	129.5	173.6	143.3	60.4	12.7	4.7	7.76	16.9	31.6	93.0	151.7
2020	148.7	129.4	173.4	143.2	60.4	12.7	4.7	7.75	16.8	31.6	92.9	151.6
2021	148.6	129.2	173.3	143.0	60.3	12.6	4.7	7.74	16.8	31.5	92.8	151.4
2022	148.5	129.1	173.1	142.9	60.3	12.6	4.6	7.73	16.8	31.5	92.7	151.3
2023	148.3	129.0	172.9	142.7	60.2	12.6	4.6	7.72	16.8	31.5	92.6	151.1
2024	148.2	128.9	172.7	142.6	60.1	12.6	4.6	7.72	16.8	31.4	92.5	151.0
2025	148.0	128.7	172.6	142.4	60.1	12.6	4.6	7.71	16.8	31.4	92.4	150.8

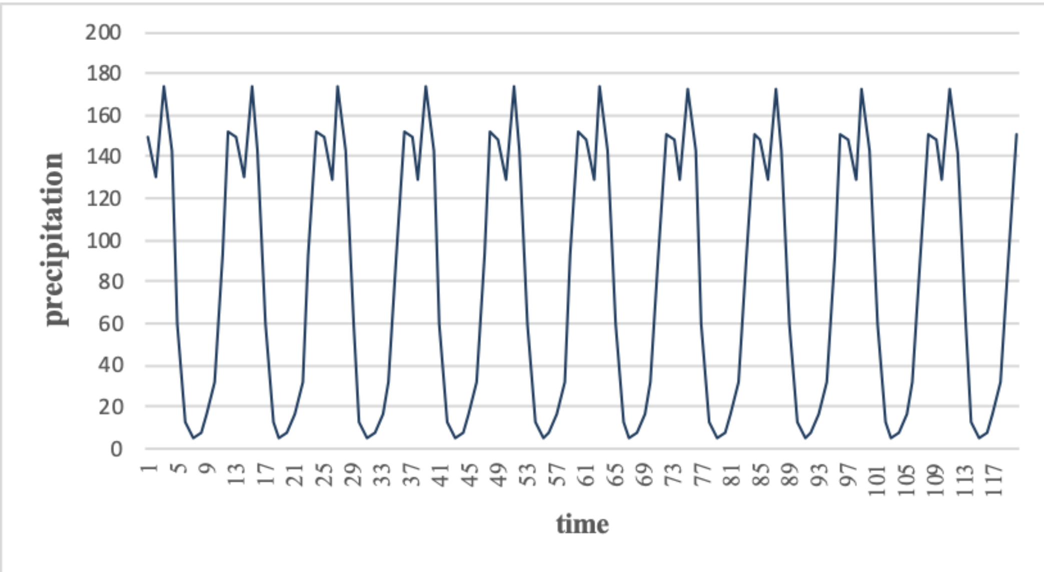

Figure 3. Forecast values of monthly precipitation in the future (2016– 2025).

The result of seasonal indices is presented in Table 3. It shows that precipitation in July is 94.3% lower than the normal level. Secondary was August (90.4%), June (84.4%), September (79.2%), October (61.1%) and May (25.6%), respectively. For the higher than normal level was March at 113.8%. Secondary was December (87%), January (83.4%), April (76.5%), February (59.5) and November (14.6 %), respectively.

Table 3. *Seasonal indices of precipitation*

	Seasonal Period (month: January-December)											
	1	2	3	4	5	6	7	8	9	10	11	12
Index	183.4	159.5	213.8	176.5	74.5	15.6	5.7	9.6	20.8	38.9	114.6	187

4. Time series analysis of mean monthly temperature

The result of time series analysis of mean monthly temperature by using the decomposition method with multiplicative model indicated that Mean Absolute Deviation (MAD) was 0.484. Mean Square Deviation (MSD) was 0.6. Mean Absolute Percentage Error (MAPE) was 1.9. Forecast values mean monthly temperature in the future (September of 2019 – December of 2025) were presented in Table 3 and Figure 4.

Table 3. Forecast values of monthly temperature in the future (2016 – 2025).

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
2019									24.2	25.8	26.7	27.4
2020	27.7	27.2	26.7	25.5	24.3	22.7	22.1	23.1	24.2	25.8	26.8	27.4
2021	27.7	27.2	26.7	25.5	24.3	22.7	22.1	23.0	24.2	25.8	26.8	27.4
2022	27.7	27.2	26.8	25.5	25	22.7	22.1	23.1	24.2	25.8	26.8	27.4
2023	27.7	27.2	26.8	25.5	24.3	22.7	22.1	23.1	24.2	25.9	26.8	27.4
2024	27.7	27.2	26.8	25.5	24.3	22.7	22.1	23.1	24.2	25.9	26.8	27.4
2025	27.7	27.2	26.8	25.5	24.3	22.7	22.2	23.1	24.2	25.9	26.8	27.5

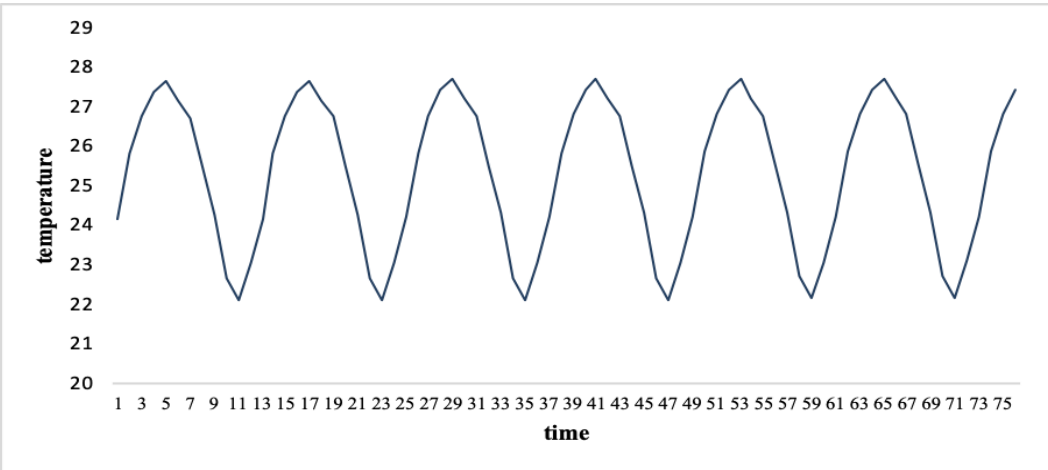

Figure 4. Forecast values of monthly temperature in the future (2019– 2025).

The result of seasonal indices is presented in Table 4. It shows that temperature in January was 9.6% higher than normal level. Secondary was December (8.4%), February (7.5%), November (5.9%, March (5.8

%), October (2.2%) and April (0.8%. For the lower than normal level was July (12.5%). Secondary was June (10.4%), August (8.9%), September (4.3%) and May (3.9%).

Table 4. *Seasonal indices.*

	Seasonal Period (month)											
	1	2	3	4	5	6	7	8	9	10	11	12
Index	109.5	107.5	105.8	100.8	96.1	89.6	87.5	91.1	95.7	102.2	105.9	108.4

Conclusions

The trend line of the mean monthly precipitation in the period of 1991– 2015 showed a slight decreasing linear trend. The forecast values in the future (2016 – 2025) by the decomposition method with the multiplicative model showed that precipitation in May – October is low (these months are very critical for crops). Moreover, the result of seasonal indices showed that precipitation in that month is lower than the normal level, as well. The present study suggests that Morogoro gets a higher rainfall in December. The study demonstrates the existence of trends in the yearly rainfall. However, in Morogoro, there is a decreasing trend.
Temperature showed no significant warming during the period of study even some very small linear warming component was noticed.

The strategy for farmers and policymakers may be advised to pay attention to improve new crop varieties which are more tolerant for drought and required less water. At the same time, there is a need for further studies with daily and monthly data for longer periods. To get more accurate data, more of the meteorological stations and their services would be needed available which data should be also available to farmers in village level.

References

Chang'a, L. B., Kijazi, A. L., Luhunga, P. M., Ng'ongolo, H. K. and Mtongori, H. I. (2017). Spatial and temporal analysis of rainfall and temperature extreme indices in Tanzania. pp. 525–539.

Dayoub, M., Helminen, J., Myllynpää, V., Pope, N., Apiola, M., Westerlund, T. and Sutinen, E. (2018, July). Prospects for Climate Services for Sustainable Agriculture in Tanzania. In International Conference on Applied Economics. pp. 523-532.

Hamisi, J. (2013) *study of rainfall trends and variability over tanzania a research project submitted in partial fulfilment of the requirements for the postgraduate diploma in meteorology university of nairobi*. (Ph.D. Thesis) University of Nairobi, Kenya.

Kangalawe, R. Y., Noe, C., Tungaraza, F. S., Naimani, G. and Mlele, M. (2014). Understanding of traditional knowledge and indigenous institutions on sustainable land management in Kilimanjaro Region, Tanzania. *Open Journal of Soil Science*, *4*:469.

Kijazi, A. L. and Reason, C. J. C. (2009) 'Analysis of the 2006 floods over northern Tanzania †', *INTERNATIONAL JOURNAL OF CLIMATOLOGY Int. J. Climatol*. Wiley InterScience, 29, pp. 955–970. doi: 10.1002/joc.1846.

Mkonda, M. and He, X. (2017). Are rainfall and temperature really changing? Farmer's perceptions, meteorological data, and policy implications in the Tanzanian semi-arid zone. *Sustainability*, *9*:1412.

Paavola, J. (2008) 'Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania', *Environmental Science & Policy*. Elsevier, 11:642–654.

Rapsomanikis, G. (2015) *Food and Agriculture Organization of the United Nations Rome*. Retrived from www.fao.org/publications.

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. and Stringer, L. C. (2013). Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. *Climate and development 5*:123-138.

Kijazi, A. L., and Reason, C. J. C. (2009). Analysis of the 1998 to 2005 drought over the northeastern highlands of Tanzania. *Climate Research*, *38*:209-223.

www.weatheronline.co.uk (no date). Retrived from https://www.weatheronline.co.uk/about/About.htm.

Zhang, X. B., and Yang, F. L. Alexander, GC Hegerl, P. Jones, AK Tank, TC Peterson, B. Trewin, and FW Zwiers, 2011: Indices for monitoring changes in extremes based on daily temperature and precipitation data. *Wiley Interdisciplinary Reviews: Climate Change*, *2*:851-870.