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MORALITY BEFORE KNOWLEDGE

Impacts of precipitation and temperature variability on rice production in Mitole Epa Chikwawa

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ABSTRACT

Background: Rainfall and temperature variability are a threat to sustainable agricultural production in Malawi. Main crops which include rice are highly affected due to climate variability since this crop is grown during wet season. A study was therefore conducted in one EPA named Mitole in Chikwawa district in southern Malawi to determine the impacts of precipitation and temperature variability on rice production. **Method:** Secondary data of climate variables and rice data was used for a period of 16 years which was obtained from Department of Climate Change and Meteorological Services (DCCMS) in Blantyre and Mitole EPA in Chikwawa respectively. Before data analysis data quality control was done where outliers were manually corrected and also errors were corrected using homogeneity test in which single mass curve for each data were plotted. In data analyses; excel and R was used to do trend analysis. Mann Kendall test was used to test if there were significant trend of data or not. To determine the relationship between climate parameters and rice production correlation analysis tested. Regression analysis was also used to predict the results if the climate variables keep varying. **Findings:** The results showed that only minimum temperature had a negative significant trend and other variables had trends which were not significant. Correlation analysis showed non-significant relationship between climate parameters and rice production and also the results of regression analysis had non-significant relation therefore there was enough evidence to predict the results in future. **Conclusion:** Since the results did not provide enough evidence that climate variables specifically rainfall and temperature affect rice production in the area, it was recommended that more research must be done to discover the way farmers must follow to maximize the production. **Novelty/Originality of this study:** This study provides concrete data on the impacts of climate variability on rice production in southern Malawi, which farmers and policymakers can use to develop more effective agricultural adaptation strategies in the region.

KEYWORDS: agricultural sustainability; climate variability; Malawi; rice production.

1. Introduction

Climate change is one of the reason which has contributed to the vulnerability of livehood and poverty in Malawi. The frequence change of climate patterns including rainfall and temperature variation resulted to increase number of extreme weather events which cause mass damages in the country (PDNA, 2019). Temperature and precipitation pattern are changing as aresult of global warming which is resulting in having impact on crop yield. Agriculture in Malawi contribute one third of GDP and atleast 80 percent of employment. Rice is one of the crop grown by small scale farmers in many parts of the country and its productivity is highly affected by climate (Chen et al., 2017). Rice is the second main cereal

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food crop from maize which accounts for 60 percent of the cultivated land. Mainly, rice cultivation depend on season rainfall which is highly affected by severe weather.

Some studies showed that an increase in rainfall and temperature may decrease rice production (Tiamiyu et al., 2015). Considering previous studies relating to climate change impact on agriculture in Malawi, very little research work has been reported. Most of it focus on maize crop. Therefore, the study makes an attempt to reduce the gap through considering rice crop and impact of rainfall and temperature variability. As the population of Malawi keeps increasing, the demand of maize which is staple food to the country is high that the productivity of maize is not enough to satisfy the population. There is probability that demand to food will increase. The pressure increases to the country mostly when it is affected by severe weather like floods and drought. As second staple food rice reduce the demand of the country's population for food and income source. Although rice production plays major role to maintain food security, its productivity is highly affected by variation of rainfall and temperature. Therefore, it is important to analyze the impacts of precipitation and temperature on rice production in Mitole EPA, Chikwawa so that adaptation measure can be taken into account to maximize yield production.

Changes in rainfall frequency and intensity have been observed that rainfall is changing due to global warming on both global and regional scales. Global land precipitation has increased by about 2% in the twentieth century (Basis, 2001) and also, precipitation studies that were conducted in Bangladesh by Shahid (2012) that analyzed trends in annual and seasonal precipitation for the period of 1958 to 2007 demonstrated that the annual and pre-monsoon precipitation is increasing at the rate of 5.53 and 2.47 mm/year respectively. Canada precipitation has increased by about 10% annually during the 20th century. In addition, long term monthly precipitation studies in China from 1960 to 2008 has shown that precipitation is increasing in trend in summer and winter while there is a decrease in trend in spring and autumn.

On another hand, Global earth surface temperatures in 2018 were recorded to be the fourth warmest since 1880 and since 19th century global surface temperatures have risen by 0.6 degrees Celsius. Worldwide the number of cold days and nights are decreasing while increasing in heavy precipitation events and droughts since 1970 (Gedefaw et al., 2019). In many continents, globally in decades of (1950 to 1993), the daily minimum temperature rises fast as compared to the daily maximum temperature that is 0.2 degrees and 0.1 degrees Celsius per decade respectively (Maina, 2017).

Changes of these climatic parameters across the global are affecting the production of rice in all stages of cultivation. Increase in temperature result in decrease in rice yield as grain weight is reduced, flowering stage is disturbed and the formation of imperfect grains and the reduction in dry mass accumulation and translocation (Chen et al., 2017). The rice production and yield are highly related to fluctuations in annual rainfall. At the same time, he pointed out that the recurrent floods may also have a great influence on rice cultivation. Floods due to heavy rainfall can also affect rice production. Heavy rainfall in the transplanting period causes cultivated area loss, and deficiency of the growth period causes yield loss (Res et al., 2009). Increased temperature will be an important driver of future yields as it plays a crucial role in determining the growing season and yields of rice. Even in the most temperate of rice- producing areas, increased heat stress will lower production if nothing is done to counteract the effects of climate change (Wassmann et al., 2009). If all other climate variables were to remain constant, a temperature increase of 1, 2, and 3°C would reduce the grain yield of rice by 5.4%, 7.4%, and 25.1%, respectively.

Using the nonparametric Mann-Kendall (MK) test statistic, study conducted in 2014 using 26 stations countrywide find that there was a decrease in total annual rainfall, annual maximum 1 day and 5 day rainfall amount, number of heavy and extreme rainfall days. However, there was an increase in the consecutive number of wet and dry days (Ngongondo et al., 2014). On annual rainfall trend with same method to determine trend contrary to Ngongondo and his friends another study that focused in Lower Shire floodplain only find that the trend of annual rainfall was increasing and its results agree that monthly precipitation revealed an upward trend in wet seasons (November to April) and a downward trend in dry seasons (May to October). The monthly peak trend analysis has shown upward trend in rainy months at all stations (Rustum et al., 2017). According to a study conducted by Lucy Mtilatila and her friends find that that meteorological droughts are increasing due to a decrease in precipitation in Lake Malawi and Lower Shire basin which is exacerbated by an increase in temperature (potential evapotranspiration) (Mtilatila et al., 2020) which is in agreement with Ngongondo. According to these studies it proves that rainfall pattern in Malawi varies due this variations crops including rice respond differently in terms of it production. Study by Gaveta in 2017 find that monthly rainfall variations affect crop yields more than annual variations. The increasing temperature trend indicated the potential reduction of productive land over time (Gaveta, 2017).

In Malawi the maximum rice production can cause economic and social growth. It is estimated that if Malawi can manage to produce 500 000 metric tons of rice then the foreign exchange earned would out class the foreign exchange earned by tobacco. Although rice can contribute a lot on economic growth in Malawi less research has been conducted to analyze climate change and its impacts on rice production, therefore this study try to fill the gap by impacts of climate variables including precipitation and temperature on rice production in Chikwawa, Mitole EPA in Malawi.

2. Methods

Mitole EPA is in Chikwawa district located in Southern region of Malawi being bordered by Thyolo, Nsanje and Blantyre. It is situated at an altitude of 1039m above sea level. It is in Lower Shire and is located at latitude of -16º10'00"S and longitude of 34º 45'00"E south of equator. Malawi in general has a sub-tropical climate and relatively dry and strongly seasonal with the warm wet season stretching from November to April. The main rain-bearing systems that influence rainfall over Malawi include the Intertropical convergent zone (ITCZ), Congo air mass, Easterly waves and tropical cyclones. Chikwawa weather seasons are categorized as follows, rainy season from November to April, wet and cool season May to August and hot and dry season from September to October. The main factors influencing weather over Chikwawa district are Intertropical convergent zone (ITCZ), Congo air mass, easterly waves and tropical cyclones also local geographical features also affect Chikwawa weather patterns.

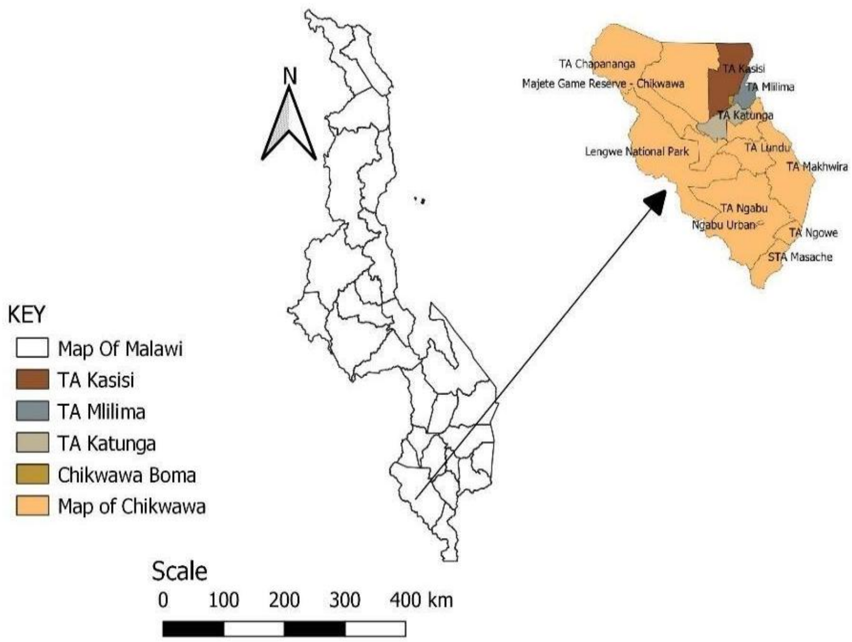


Fig. 1. Map of Chikwawa district showing Mitole area

Quantitative data was used in this study. Statistical methods and techniques were used to analyze the trends and relationships. R and excel software applications were used to analyze data. The data was presented in graphs, tables. In this research meteorological data from Nchalo station and rainfall data from Mitole rain gauge were obtained from Department of Meteorological and Climate Services (DCCMS) (Table 1). Its data is of monthly mean maximum temperatures, minimum temperatures and precipitation amount and data span from 2004 to 2019. The data of rainfall is in mm and temperature data in degrees Celsius for period of 30 years. The data of rice yield were obtained from Mitole agricultural extension planning area in Chikwawa, and the data span from 2004 to 2019.

Table 1. Data collection process

Variable	Data required	Source	Type of Data
Rainfall	Monthly rainfall in mm	Meteorological Department (Nchalo station)	Secondary
Temperatures	Monthly average temperatures in Degrees Celsius	Meteorological Department (Nchalo station)	Secondary
Rice Production	Yield of rice in kilograms per hectare	Mitole EPA Chikwawa District	Secondary

Approvals and guidance from relevant personnel of both the Meteorological Department and Mitole EPA management was attempted in accessing the relevant data. The research study was carried out in Chikwawa district specifically Mitole EPA as the study area. It focused on two climatic parameters namely; rainfall and temperatures. Mitole was chosen in this study because people depend on rice farming for their livelihood and the area is highly affected by climatic events. The findings were not taken as a representative to all rice producing areas across Malawi due to existence of different ecological systems in every part of the country. However areas with similar characteristics can have similar results. Other factors that can affect rice production such as fertilizer application, hybrid varieties and irrigation systems were not captured in this study.

3. Results and Discussion

3.1 Trend of annual rainfall

Trend analysis for rainfall and temperature was conducted using R and excel for testing if trends exists or not and for graphical presentation respectively. This helped to meet the purpose of first and second objectives. Mann Kendall test was used to test the existence of trends and if the trends were significant or not. The results in Figure 2. showed that the annual total rainfall trend was a increasing statistically non-significant (Z=0.29692, p-value=0.7665). The average annual rainfall data for period 2004 to 2019 (16 years) used in this study showed that the average annual rainfall of Mitole was 692.8mm per year.

The analysis showed that, the maximum occurrence of rainfall occurred in 2007 season and the minimum rainfall occurred in 2011 with total annual precipitation of 1281.9mm and 441.2mm respectively. There was increase in rainfall in 2006 and 2007 of 726.7mm and 1281.9mm respectively. In 2008 to 2014 the results shows decrease in rainfall, recording the lowest of 441.2mm in 2011. Then it rise to 1017.3mm in 2015 and steeply decreased to 445.6mm in 2016 and increased to938.6mm in2017. The rainfall decreased to 673.3mm in 2018 and rise to 921.4mm in 2019.

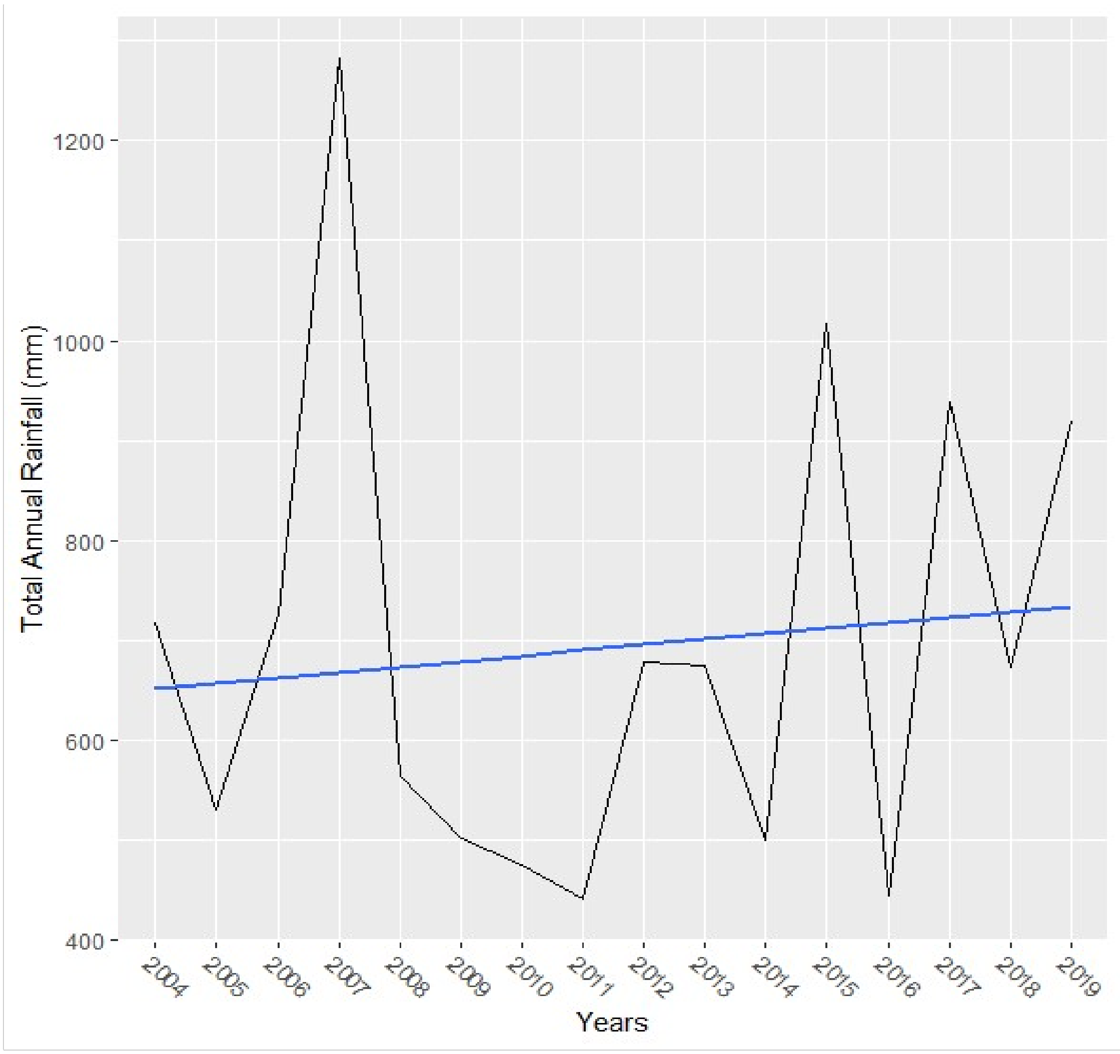
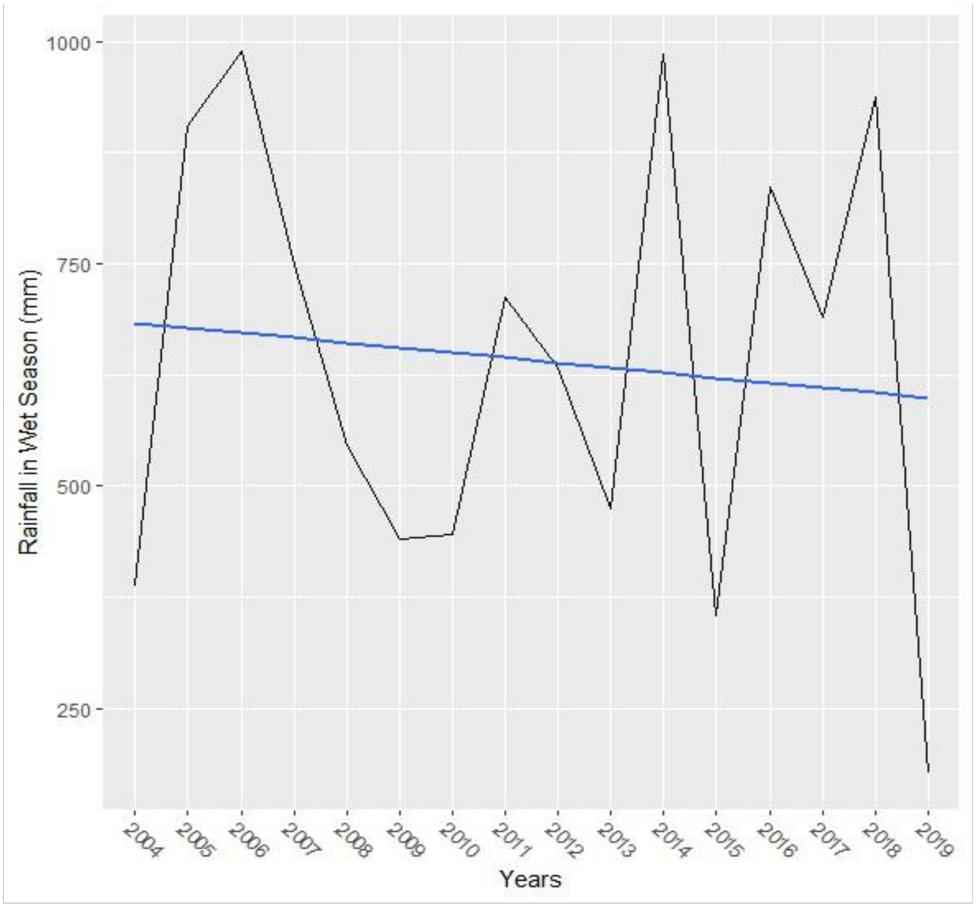


Fig. 2. Graph showing the trend of annual rainfall of Nchalo from 2004-2019

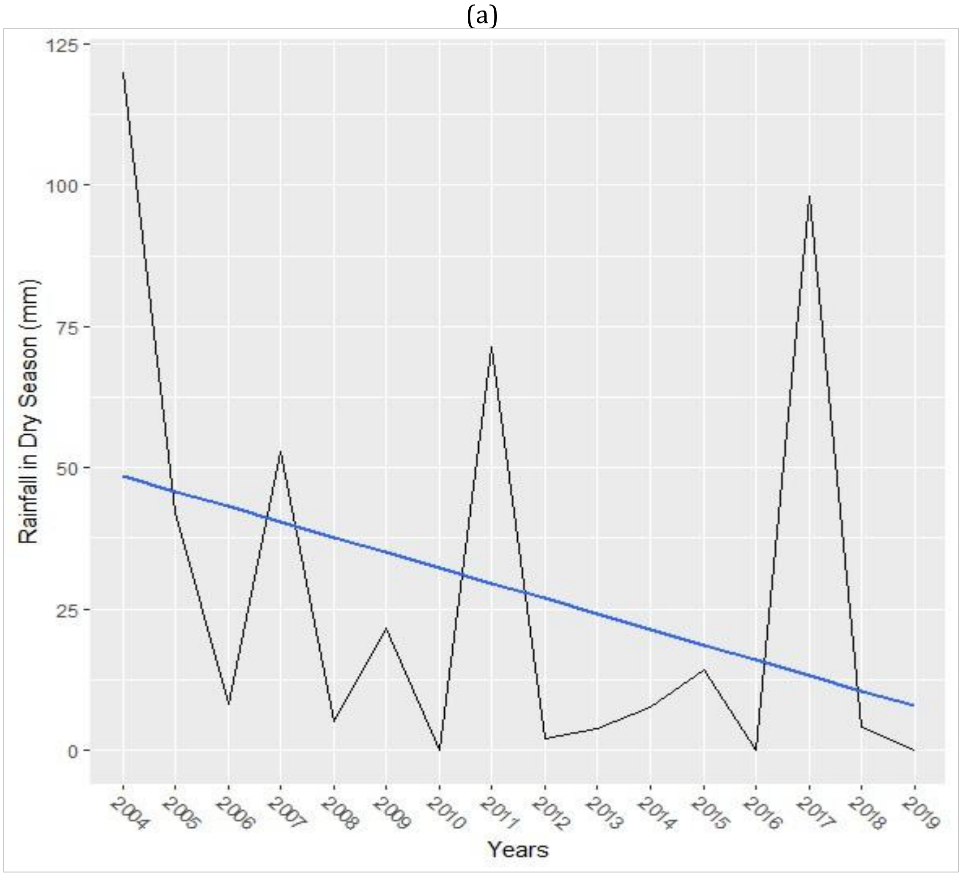
It was these years, 2006/7, when Malawi experienced La Nina across all regions of the country which is associated with more and heavy rainfall (DCCMS). Since 2008 to 2014 the results shows decrease in rainfall, recording the lowest of 441.2mm in 2011. The reason to this decrease may be due to extreme events which include severe drought, cyclone, floods, tropical storms. From 2015 to 2019 the rainfall varied due to the increase intensity of extreme events mostly heavy rain as result of cyclone and severe drought.

3.2 Seasonal rainfall trend

The trends of seasonal rainfall over study area for the period 2004•2019 represented in in Fig. 3 showed that In rain season an increasing trend of rainfall was found, which was not statistically significant (Z=-0.045023, p-value=0.9641). In Dry season a decreasing trend was found but it was not statistically significant (Z=-1.2387, p- value=0.2155). The amount of rainfall received seasonally varies each year. Since 2004 to 2019 the highest amount of rainfall was recorded in 2007 which was 1229mm during rainy season. Its lowest rainfall amount was 369.8mm in 2011. In cool and dry season and hot and dry season combined its maximum rainfall was 119.8mm in 2004 and its lowest was 0mm in 2010 and 2016.



(a)

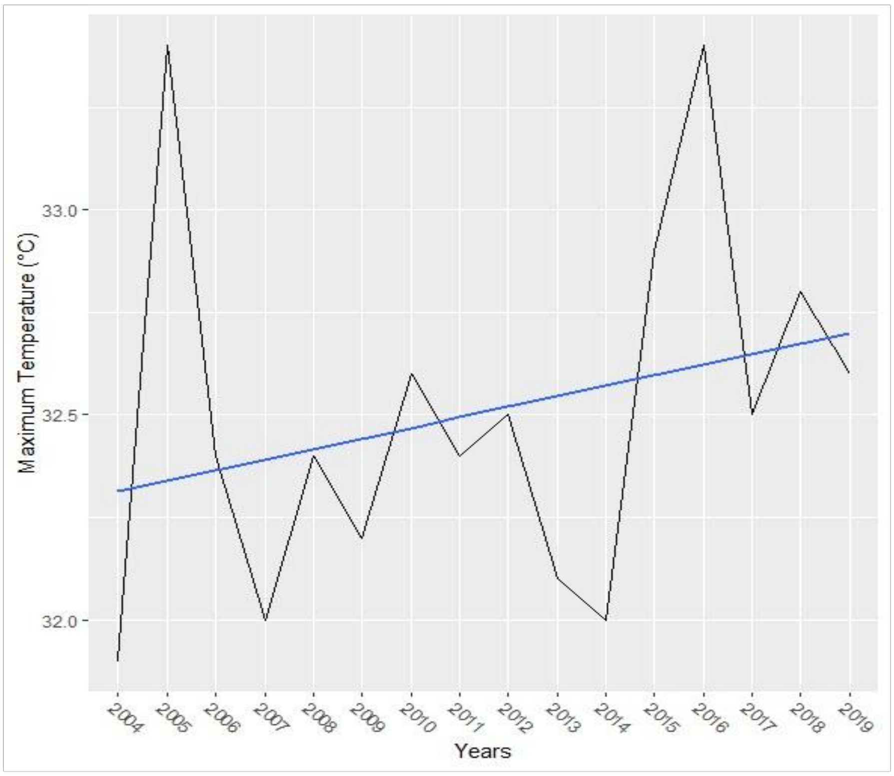


(b)

Fig. 3. Graph showing the trend of (a) rainfall in wet season and (b) rainfall in dry season of Nchalo from 2004-2019

3.3 Temperature trend

After the temperature trend was analyzed, time series graphs showed variation of maximum and minimum temperature year after year. From the finding as shown in Fig. 5 and 6 the annual maximum temperatures had an increasing trend which was statistically not-significant (Z=1.5428, p-value=0.1229). The annual minimum temperatures had a decreasing trend which was statistically significant (Z=-4.4663, p- value=7.959e-06).



(a)

(b)

Fig. 4. Graph showing the trend of (a) maximum and (b) minimum temperature for Nchalo from 2004-2019

The minimum temperature was ranging from 17.8℃ to 20.8℃ for the period starting from 2004 to 2019. The maximum temperature was ranging from 31.9℃ to 33.4℃ for same period. The highest annual maximum temperature was record in 2018 and it was 34.3℃ and the lowest maximum temperature was 31.9℃ in 2004. On other side the highest annual minimum temperature was recorded in 2005 and 2006 which was 20.8℃ and the lowest minimum temperature was 17.8℃ in 2018.

Table 2. Test statistics of climate variables with Mann Kendall test

Time series	z value	p-value	Kendall Tau	s	Alpha Value(α)	Results
Annual Rainfall	0.29692	0.7665	0.06666667	7	0.05	Non-significant
Rain season	-0.045023	0.9641	-0.01666667	-2	0.05	Non-significant
Dry season	-1.2387	0.2155	-0.2488067	-26	0.05	Non-significant
Mean annual Maximum temperature	1.5428	0.1229	0.3005649	35	0.05	Not-significant
Mean annual Minimum temperature	-4.4663	7.959e-0.6	-0.8403658	-100	0.05	Significant

3.4 Trend of rice yield

According to the results, as shown in Fig. 7 the trend of rice yield per hectare decreases. Between the years 2004 to 2008, the yield of rice increased from 1032 kg/Ha to 1426 kg/Ha. This figure then decreased to 956 kg/Ha in 2009 and continues decreasing up to 127 kg/Ha in 2010. In 2011 the yield increased to 1186 kg/Ha, it slightly decreased to 1031 kg/Ha in 2012 before it increased to 1402 kg/Ha in 2013. The yield decreased through 2014 to 2015 when it reaches 1205 and 83 respectively. In 2016 the yield increased to 1841 kg/Ha it continued increasing up to 357o kg/Ha in 2017. In 2018 and 2019 there was decrease in yield of 485 kg/Ha and 22 kg/Ha respectively.

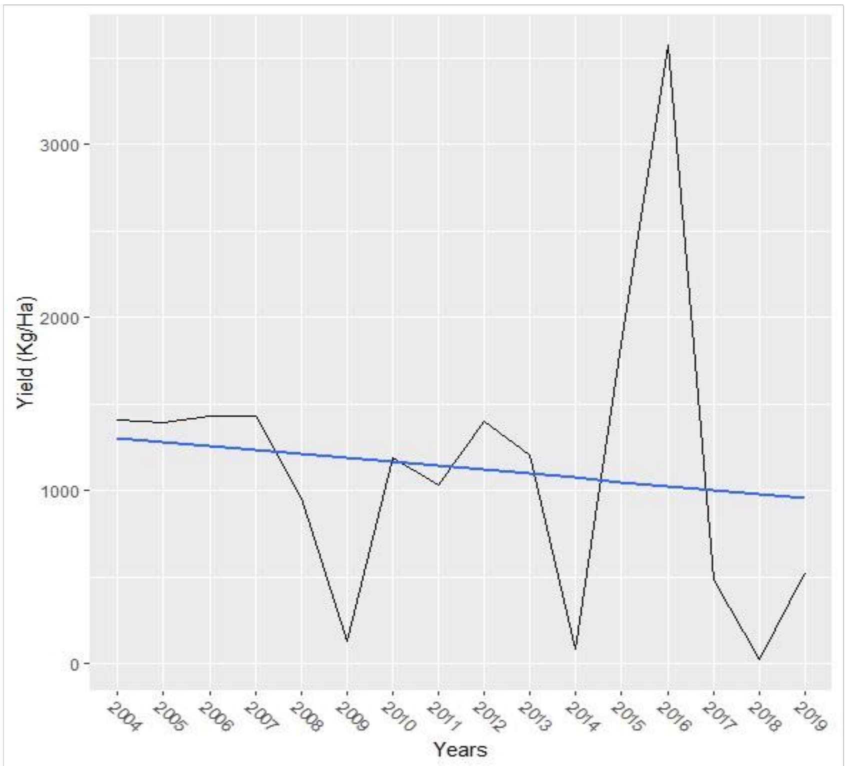


Fig. 5. Graph showing the trend of rice yield of Mitole from 2006-2019

3.5 Effects of rainfall and temperature variability on rice production

This study aims to assess the effects of rainfall and temperature variability on rice production in Mitole EPA in Chikwawa district. To determine the effect of climate variability on rice production and also to accomplish specific objective number 3, Pearson correlation coefficient and regression analysis were used.

3.5.1 Correlation of rice yield with rainfall variability

Rice production in response to seasonal rainfall especially rainy season when rice is grown as well as annual rainfall did not show any significant correlation. Although there was non-significant relationship, the trend of rice production in response to annual rainfall and dry season rainfall were increasing. The correlation coefficients of each season as well as annual rainfall. The decreasing of rice production can be due to flash floods due to heavy rain or overflow of Shire River. Also the trend of rice production in response to rain season showed that rice yield increases with increasing rainfall.

Table 3. Showing the correlation coefficient in Mitole EPA

	Rice Production	t-computed	t-tabulated
Annual Rainfall	0.047	0.176	2.056
Rain season	-0.246	-0.092	2.056
Dry season	-0.245	-0.245	2.056
Mean annual Maximum temperature	0.485	2.075	2.056
Mean annual Minimum temperature	0.121	0.454	2.056

3.5.2 Regression model test

Regression analysis was tested using R application to find the effect of each climate eleme nt on rice production and to develop the equation that can be used to predict future resu lts due to these elements. The results of showed that null hypothesis of all climate elemen ts were accepted as there p-value ($p<0.05$) were greater than 0.05. Therefore the results were not significant which tells that there was not enough evidence to predict using regression model. Therefore regression equation was not obtained as all variables were remov ed from regression analysis.

3.6 Discussion on trend analysis of rainfall and temperature and its variability

The results of rainfall showed that the annual total rainfall trend decreases non-significantly but rainfall season trend was increasing non-significantly. Trend of dry season analysis was decreasing. The results of rainfall explain that yearly the amount of rainfall received was decreasing but seasonally it is during rainfall season that register more rainfall, increasing trend than dry season decreasing trend. Although there exists trends but there trends are non- significant meaning that there is not much evidence that can support the existence of trends in the area.

The increase trend of annual rainfall may be due to presence of rainfall forcing in the southern hemisphere which include Inter-tropical convergence zone and Congo air masses. Decreasing trend in rain season (growing season) may be as a result of drought and consistence dry spells experienced in the area while there is less or no rain in dry season as the rainfall forces are far north of the hemisphere. The results of temperature trend showed that annual maximum temperatures had an increasing trend which was statistically not-significant while annual minimum temperatures had a decreasing trend which was statistically significant. The results explain that over the years the maximum temperature was increasing but is its trend does not have enough statistical evidence while minimum temperature is decreasing significantly over the years. The increase of maximum temperature can be due to its increase in sunlight radiation received per year. The results of rice yield trend showed the existence of decreasing trend. The decrease can be due to decrease uptake of water by crop which can reduce yield or shortening of crop growing season or due to extreme weather events like floods and drought that has been occurring within those years this agrees with study which find that floods due to heavy rainfall can also affect rice production. Heavy rainfall in the transplanting period causes cultivated area loss, and deficiency of the growth period causes yield loss (Res et al., 2009)

3.7 Discussion on the relationship between climate variables and rice production

It was noted that correlations between precipitations variability with rice yields were found for annual rainfall, rain season and dry season (cool dry season and hot dry season). As for an example, rice yield had positively correlated with rainfall annually which was non-significant. The result showed that the increase in annual precipitation had the some influence on rice yield. A positive correlation was observed between rice yields with precipitation in rain season. Even though the correlation was weak as it was not significant.

Even though the correlation of rice yield and rainfall are not significant the trend of rainfall and rice yield show that when the rainfall is too much and too low the rice yield is affected which agree with Mowla who showed that rice production and yield are highly related to fluctuations in annual rainfall. Since when there is too much rainfall floods are likely to occur which damage the crop resulting in less yield and also when there is less rainfall droughts are likely to occur which has effect on rice. For instance, in 2015 the area received maximum amount of rainfall of 1017.3mm and was hit by tropical storm Chedza which caused mixed extreme events like floods and drought (DCCMS) as result the area registered 83 kg/ha of rice yield. Also in 2019 when the area had rainfall of 921.4mm and rice yield produced was 22 kg/ha this was so because the area was hit by heavy rain and floods due to Cyclone Idai (DCCMS). Therefore the relationship of rice yield in response to rainfall can be weak since the area experience different extreme weather events each and every year which also affect rice yield. Some of these extreme events include floods due to overflow of Shire River and heavy rain, severe drought, strong storms.

In terms of Temperature, the correlation showed that the maximum and minimum temperature had positive correlation even though it was not significant. The trend of correlation shows that rice yield increases with increasing temperature. The results that was found after data analysis defied expectations as it does not provide significant relationship between climate parameters and rice yield, this can be due to the fact that data that was used was with the short period which was 16 years, also the geographical characteristics of the area, frequent occurrence of extreme weather events which include floods and drought as well as the methods practiced during rice growing seasons were not considered in this study but can greatly affect the rice yield.

Since the results of correlation analysis does not show any significant relationship between rainfall and temperature variability which is contradicting with past findings around the world that agree that rainfall variability as well as temperature affect rice yield significantly (reference). Therefore there is need to do more research and must consider factors like other climate factors, extreme weather events like floods, drought and cyclone, the geographical characteristics of the area, pests and diseases and also rice variety as well as methods in rice production. The results are very important as they will help small scale rice farmers in this area to understand how rainfall affect their crop even though more research is needed to improve production of rice regardless of climate variability.

4. Conclusions

From this study it is evident that rainfall and temperature play an important role in the growth and development of crops. These weather parameters were found to affect the crop differently on rice production but it was also observed that the results does not have statistical evidence to conclude that these climatic variable affect rice production in the area significantly. The results of this study will help farmers and other stakeholders to have an understanding on the relationship between rainfall and temperature variability and rice production so as to adjust their farm management practice hence increase in production and income.

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Author Contribution

C.P contributed fully to the conception, design, research, analysis, interpretation of data, drafting, and revising of this article. C.P approved the final version to be published and are accountable for all aspects of the work.

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Conflicts of Interest

The author declare no conflict of interest.

References

Basis, T. S. (2001). *Climate Change 2001: The Scientific Basis*. Cambridge University Press

Chen, J., Yan, H., Mu, Q., & Tian, X. (2017). Impacts of prolonged high temperature on heavy-panicle rice varieties in the field. *Chilean Journal of Agricultural Research, 77*(2), 102-110. https://doi.org/10.4067/S0718-58392017000200102

Gaveta, E. (2017). Crop Yield Responses to Temperature and Rainfall Variability in Bolero, Malawi. *The International Journal of Climate Change: Impacts and Responses, 9*(3), 43-54. https://doi.org/10.18848/1835-7156/CGP/v09i03/43-54.

Gedefaw, M., Yan, D., Wang, H., Qin, T., & Wang, K. (2019). Analysis of the recent trends of two climate parameters over two eco-regions of Ethiopia. *Water, 11*(1), 161. https://doi.org/10.3390/w11010161

Maina, M. (2017). Runoff response to climate variability: An analysis of Thika River Basin in Kenya using hydrological simulation model (HYSIM). *Journal of Environmental and Earth Science, 2*(1), 1-12. https://doi.org/10.18488/journal.108.2017.21.1.12

Ngongondo, C., Xu, C., & Gottschalk, L. (2011). Evaluation of spatial and temporal characteristics of rainfall in Malawi: A case of data scarce region. *Theoretical and Applied Climatology, 106*(3-4), 243-254. https://doi.org/10.1007/s00704-011-0413-0

Res, C., Asada, H., & Matsumoto, J. (2009). Effects of rainfall variation on rice production in the Ganges-Brahmaputra Basin. *Climate Research, 38*. https://doi.org/10.3354/cr00785

Rustum, R., Adeloye, A. J., & Mwale, F. (2017). Spatial and temporal trend analysis of long-term rainfall records in data-poor catchments with missing data: A case study of Lower Shire floodplain in Malawi for the period 1953–2010. *Hydrology and Earth System Sciences Discussions*. https://doi.org/10.5194/hess-2017-601

Shahid, S. (2012). Vulnerability of the power sector of Bangladesh to climate change and extreme weather events. *Regional Environmental Change, 12*(3), 595-606. https://doi.org/10.1007/s10113-011-0276-z

Tiamiyu, S. A., Eze, J. N., Yusuf, T. M., Maji, A. T., & Bakare, S. O. (2015). Rainfall variability and its effect on yield of rice in Nigeria. *International Letters of Natural Sciences, 49*(November), 63-74. https://doi.org/10.18052/www.scipress.com/ILNS.49.63

Wassmann, R., Jagadish, S. V. K., Heuer, S., Ismail, A., Redona, E., Serraj, R., & Sumfleth, K. (2009). Climate change affecting rice production: The physiological and agronomic basis for possible adaptation strategies. *Advances in Agronomy, 101*, 59-122. https://doi.org/10.1016/S0065-2113(08)00802-X

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