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MORALITY BEFORE KNOWLEDGE

Assessing the impacts of temperature and rainfall variation on rice yield at nkhate irrigation scheme in Chikwawa District

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ABSTRACT

Background: Most of African nations including Malawi rely on rain fed agriculture and Malawi's economy highly depends on agriculture, this makes Malawi to be severely affected by any slight variation in climate. This main objective was accompanied by the following specific objectives; (1) Assessing rainfall and temperature trends in Livunzu EPA, (2) Assessing the annual rice yield of Nkhate rice scheme, (3) correlating temperature and rainfall variations with the rice yield. **Methods:** A quantitative research design was adopted for this study. The study was conducted exclusively at Nkhate rice scheme located in Chikhwawa District. The study used historical data of temperature, rainfall, and rice yield. Statistical analysis, including regression and correlation, was conducted using R software to examine the relationship between climatic variables and rice yield. **Findings:** Results from the regression and correlation analysis showed that rainfall exhibited some degree of correlation with rice yield; however, the relationship was not statistically strong. In addition, no significant correlation was found between annual minimum and maximum temperatures and rice yield. These findings suggest that while rainfall does affect rice production, other factors may also play a role, and temperature variations alone do not significantly affect yields in this context. **Conclusion**: This study highlights important insights into rice production under climate variability. While rice cultivation generally requires ample water, excessive rainfall - especially during sensitive stages such as pollination - can negatively impact yields. The findings underscore the importance of understanding not only the quantity but also the timing of rainfall, as well as the need for adaptive agricultural strategies to cope with changing climate patterns in rainfed systems such as in Malawi.

KEYWORDS: climate change; rice yield; temperature and rainfall variation.

1. Introduction

Climate change has emerged as a pressing global issue, and Malawi is no exception in confronting its impacts (Joshua et al., 2016). The Nkhate irrigation scheme, located in the Livunzu Extension Planning Area (EPA) of the Chikhwawa district in southern Malawi, was constructed between 1979 and 1980 by the Chinese, covering 243 hectares. The scheme was designed to mitigate the effects of the region's high temperatures, which severely impacted agricultural productivity (Magreta, 2010). Before its construction, farmers in Nkhate faced significant challenges, particularly during the rainy season when the rains often ceased before rice crops matured, causing the plants to wilt under intense heat. This situation resulted in widespread food insecurity and hardship for many families.

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Initially, the scheme provided adequate water supply due to its limited membership, but as membership expanded to over a thousand families, water availability diminished, rendering parts of the scheme uncultivable. Despite its role in addressing climate challenges, the scheme now struggles with insufficient water supply, particularly during the dry season. The Chikhwawa district has experienced persistent dry spells, which led the Malawian government to establish irrigation schemes in the east bank area (Jens et al., 2014). These schemes utilize water from the Nkhate River to irrigate crops, addressing food shortages caused by recurrent droughts. However, high temperatures and limited rainfall in the district exacerbate water scarcity, reducing the cultivated area and rice yield. Although the scheme spans 243 hectares, only 183 hectares are cultivable during the dry season, affecting 915 of the 1,126 families dependent on it (Magreta, 2014).

The primary aim of this research is to evaluate the effects of temperature and rainfall variation on rice yield within the Nkhate irrigation scheme. The study examines rainfall and temperature patterns in the area, assesses annual rice yields, and analyzes the relationship between these climatic factors and agricultural productivity. Furthermore, this research emphasizes the importance of understanding how variations in temperature and rainfall influence rice yield. It aims to empower farmers with strategies to adapt to climate change, such as adopting early-maturing seeds, synchronizing planting with the onset of rainfall, and selecting higher-yielding crop varieties. These adaptive measures are critical for enhancing food security and ensuring sustainable livelihoods amid the challenges posed by climate change.

2. Methods

Nkhate irrigation scheme (1340 56’ E and latitude 160 9‘ S) is located in the EPA of Livunzu T/A Makhuwila in Chikhwawa district in southern region of Malawi. The scheme has an area coverage of 243 ha. This study followed quantitative research design.

Rainfall and temperature data for Livunzu EPA was collected for previous 11 years from 2009 to 2020 from the Department of Climate change and Meteorological Services (DCCMS). The annual rice yield for Nkhate irrigation scheme was also collected from Livunzu EPA for 11 growing seasons. This study has used temperature and rainfall data, rice yield data, and R. software

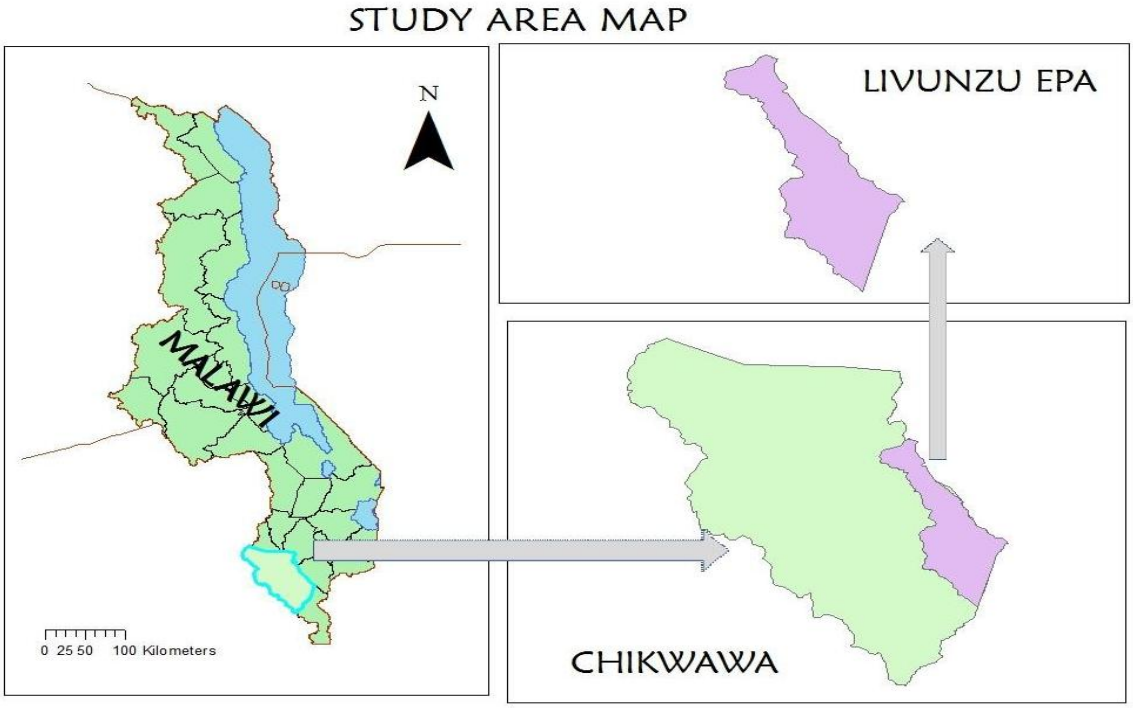

Fig 1. Study area

This project used quantitative secondary Data, data on temperature and rainfall variation was collected from the Meteorological department. Data on the annual rice yield was collected from Livunzu Extension Planning Area (EPA). The collected data was analyzed using R studio to relate the annual variation of temperature and rainfall with the annual rice yield. The data on the annual monthly mean minimum and maximum temperature and annual rainfall for the previous 11 years that was collected from Meteorological Department was analyzed using statistical software R to produce linear and bar graphs which show the trends of rainfall and temperature.

2.1 Assessing the annual rice yield of the scheme

The annual rice yield data that was collected from Livunzu EPA for the previous 11 years was also analyzed using the Statistical software R to produce linear graph in order to show yield production trend of the scheme. Correlation analysis was carried out to understand the relationship between temperature and rainfall with the rice yield at Nkhate irrigation scheme. Student t and tabulated values were used to test the significance of the correlation. The degree of relationship between temperature, rainfall and rice yield was analyzed using Pearson's correlation coefficient (r).

In the equation below, r is the product of moment correlation coefficient, x is either rainfall or temperature effective parameter (independent variable), while $\bar{x}$ is either the mean temperature or rainfall effectiveness parameter for Livunzu EPA, y is defined as total crop yields (dependent variable) for Nkhate irrigation scheme, $\bar{y}$ is the mean total yield for rice at the scheme.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad \text{(Eq. 1)}$$

3. Results and Discussion

3.1 Data quality

Data quality control was done to establish the homogeneity of the meteorological data and the rice yield before using them. Single mass curves for minimum and maximum temperature, rainfall and rice yield for annual cumulative against time were plotted. All the graphs almost showed straight lines.

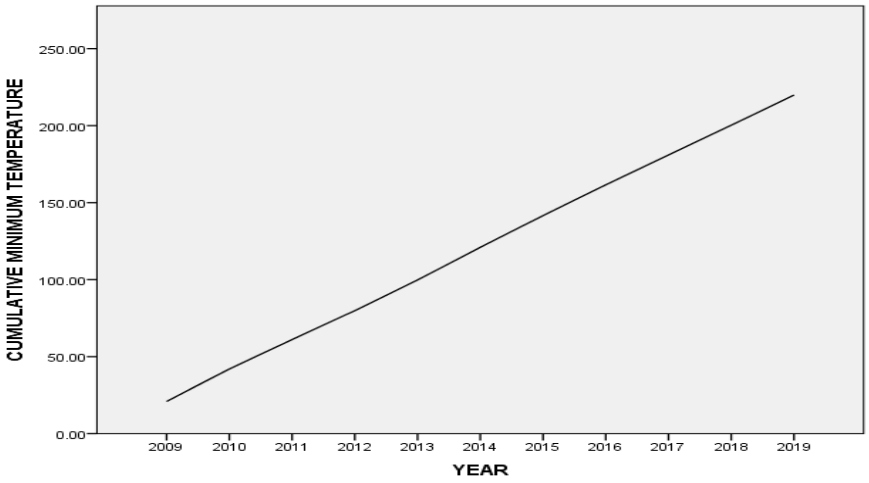

Fig 2. Single mass curve of minimum temperature

This single mass curve of minimum temperature is showing a straight line, this is a clear indication that the quality of data is ok. Recording data for temperature is very easy as exact daily leadings are directly taken from the Thermometer which increases the precision for the data.

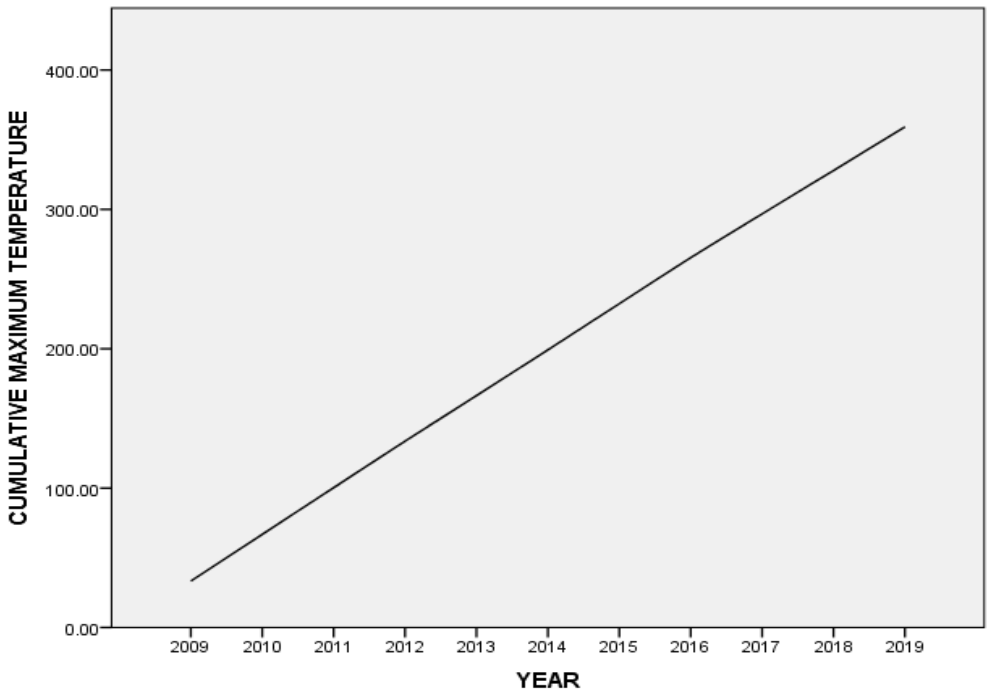

Fig 3. Single mass curve of maximum temperature

From the graph below we can see that the mass curve line is not completely straight, the reason behind this is that, rainfall data collection is subjected to a lot of errors. Some of the errors being failure to collect all raindrops in the rain gauge for measurement.

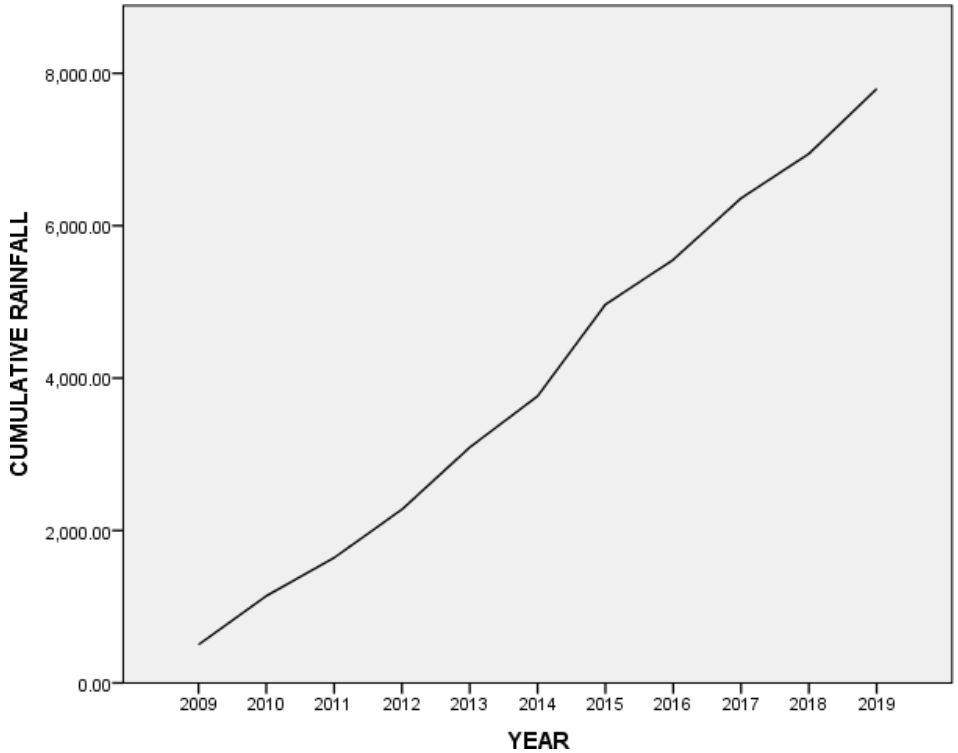

Fig 4. Single mass curve for rainfall

From the figure below, the single mass curve for rice yield is also not a perfect straight line. This shows that the rice yield data is of less quality. Quality is reduced through guesses of the annual rice yield that are made by the scheme extension workers. The challenge with extension workers of Malawi is that they do not lily go on ground to correct data. However, they depend on computer applications that make assumptions of the annual yields basing on the annual rainfall amount received that particular year.

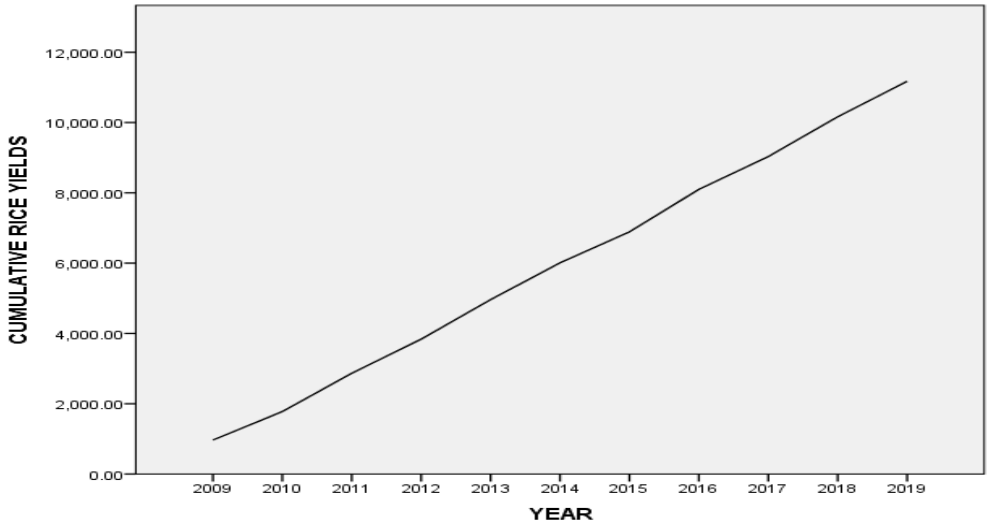

Fig 5. Single mass curve of rice yield

3.1.1 Trends analysis

The yield trend analysis shows variability in the yield for the previous 11 years with the hieghist yield recorded in 2016-2017 season. The season 2010-2011 recorded the least annual rice yield which is believed to have been caused by poor market fluctuations that occurred in 2009-2010 season. Farmers are discureged to plant more rice when the market prices of rice for the previous season were not good, as such farmers choose to grow other plants that are showing to have better prices on market.

Fig 6. Graphic of trends analysis for the previous 11 years

From the look of things in the figure below we can see that rainfall is correlating with the rice yield. As the annual rainfall increases the annual rice yield is decreasing. There are a number of factors that cause the increase in rainfall to lead in a decrease in the rice yield. Some of the factors are; heavy rainfall occurring in late growing season affects pollination process of rice hence resulting in a decrease in the yield. The other factor is poor drainage systems in the scheme make the scheme to be completely flooded in rainy season that bring some difficulties in planting the rice, thus why in 2015 the area received heavy rainfall but the yield decreased from 1050 Mt to 880 Mt.

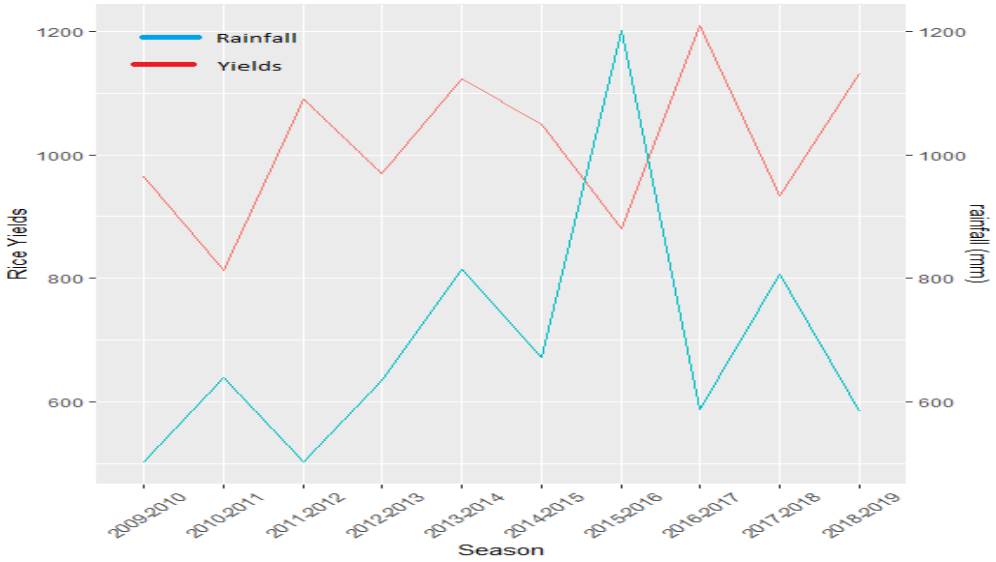

Fig 7. Graph of rice yeld and rainfall trend

3.1.2 Minimum and maximum temperature trends

Minimum temperature trends are showing variability in for the previous 11 years. However, trend analysis is showing a decrease in the annual minimum temperature. Some of the reasons for the decrease being the practice of developing community forests that is being adopted by more villages in Malawi (Norman & Kebe, 2004).

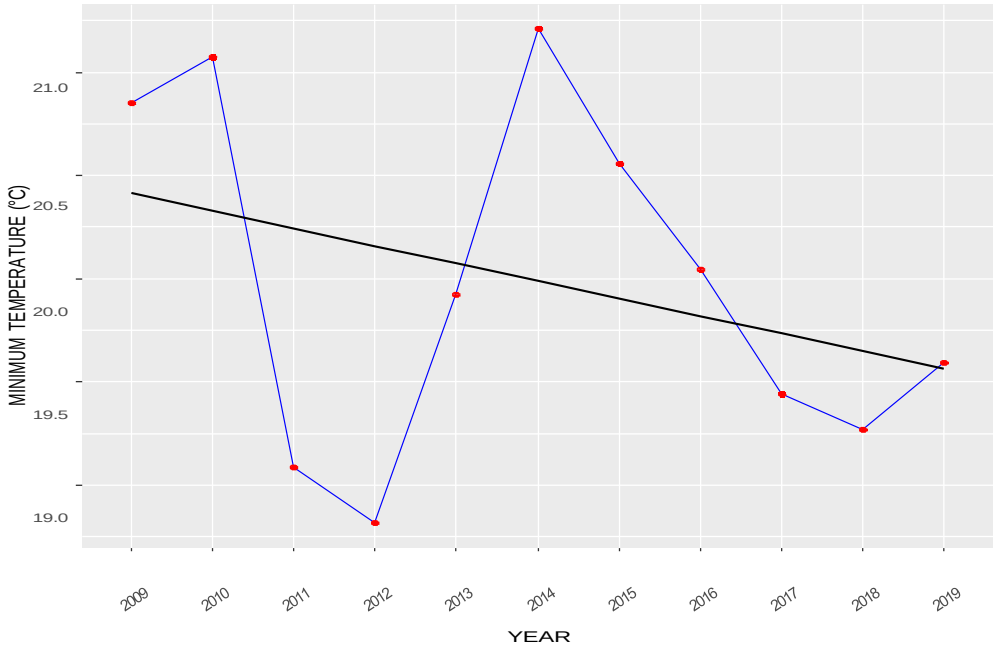

Fig 8. Minimum temperature trend

The annual maximum temperatures have been fluactuating within 31.50C to 33.50C, but trend analysis has shown that there is alittle decrease in the annual maximum temperature especially in the years 2017-2019. Some of the factors that cause the annual maximum temperatures to increase are land use and the emmission of gasses in the atmosphere. There are only two emitting industries in Chikwawa that is Nchalo sugar estate that processes sugar and Press Cane Limited that processes ethanol that are close to

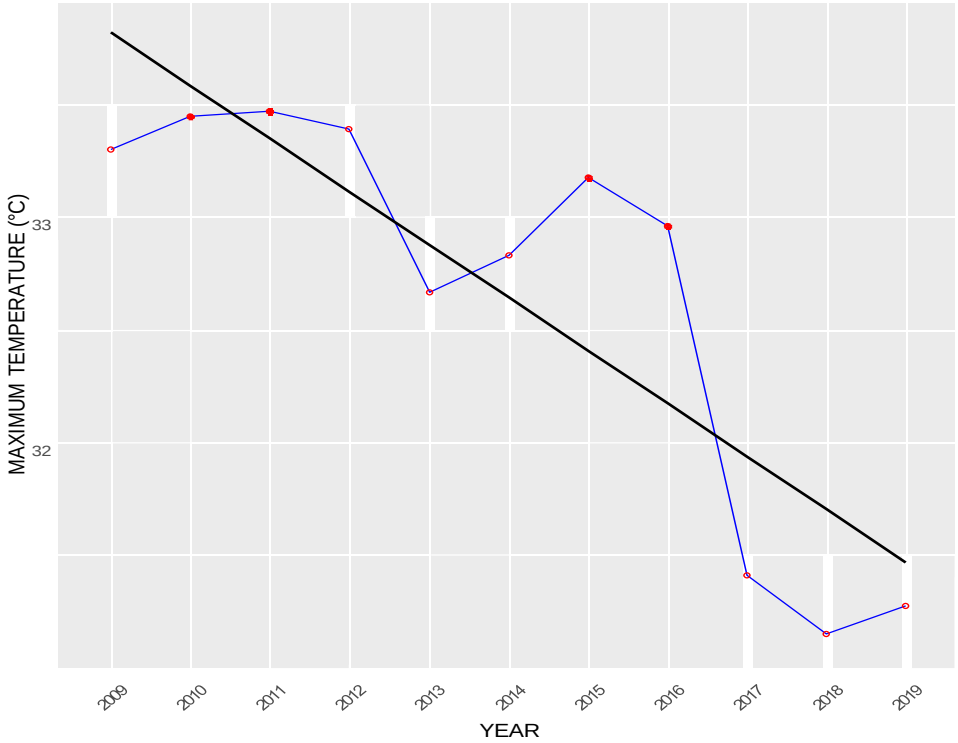

Fig 9. Maximum temperature trend

Ngabu weather station that might be the causing factor for the increase in the annual maximum temperature. Nevertheless, these industries do not produce a lot of emmissions that can increase the annual maximum temperatures. However, the practise of developing community farests and planting trees around residential areas is helping to cover most of the bare land in Chikwawa there by contributing in the lowering of the annual maximum and minimum temperatures.

Table 1. Regression and correlation analysis

	Rice yields		Std error	T value	Remarks
	r	p			
Rainfall	0.64659	0.04335	0.3768	2.397	Significant
Max temp	-0.07144	0.8445	0.0019847	-0.203	No significant
Min temp	0.0448	0.9021	0.0002	0.127	No significant

In this analysis, the significance level is set at $\alpha=0.05$. The p-value (P) is used to determine whether the relationship between variables is statistically significant. The Pearson correlation coefficient (r) is employed to measure the strength and direction of the relationship between the variables. If the p-value is less than the significance level ($P<\alpha$), it indicates a significant correlation. Conversely, if the p-value is greater than the significance level ($P>\alpha$), it suggests that there is no significant correlation between the variables.

As we have seen from the Table above when the P-Value is smaller than the value of Alpha we conclude to say there is significant correlation, while when the P-Value is greater than the value of Alpha we conclude to say there is no significant correlation. When correlation Analysis was done using R. studio the P-value for rainfall was found to be 0.043

which is smaller than the value of alpha and it shows to be correlating with the rice yield, but 0.043 is just so close to 0.05, that means there exists correlation between the two variables but it is not that much significant. While the P-values for both maximum and minimum temperatures are above the value of alpha, that means there is no any significant correlation between the variables.

From the correlation table above, we can also see that the r values of maximum and minimum tempereture are -0.07144 and 0.0448 respectively. When the r value is close to +1 we conclude to say there is strong positive relationship between the variables while when r value is close to -1 we conclude to say there is strong negative relationship. From the look of things, we can see that there is a very weak relationship between the rice yeild with either the annual maximum temperature or annual minimum tempereture because their r values are so close to zero.

3.2 Relationship between and minimum and maximum temperature

Looking at the correlation and regression analysis the study has found that there is no any relationship between minimum and maximum temperature with the rice yield. But rice yield is greatly increased when it is subjected to its optimum temperature which ranges between 250C to 350C. There are times when Chikwawa district records higher temperatures beyond 350C especially in the months of October-March. When the scheme continually records higher temperatures especially in the months of December to March which is the growing season of rice, stem elongation is compromised hence leading to a reduction of yield production.

3.3 Relationship between rice yield and rainfall

Looking at the nature of rice, it lily needs a lot of water for it to grow and produce more yield. Enough water is highly needed during tiering and stems elongation. Even though rainfall significantly affects rice yield, it also has negative impacts when it rains during heading and flowering stages of rice because it disrupts pollination process.

4. Conclusions

The results of this study clearly demonstrate that, while it is widely believed that rice production requires a significant amount of water, heavy precipitation during the pollination stage can have a negative impact on yield production. Moreover, although annual minimum and maximum temperatures have a minimal effect on rice yield, daily temperature fluctuations significantly influence production. The optimal temperature range for rice growth is between 25°C to 35°C, yet Chikwawa sometimes records temperatures exceeding 40°C, which further increases yield variability. The study faced several limitations, with the most significant challenge being the lack of historical data. The research intended to analyze rice yield data from the previous 30 years (1990-2020), but only 10 years of data (2009-2019) were available from the Extension Planning Area (EPA). Additionally, the scarcity of meteorological weather stations in Malawi resulted in the need to extrapolate data, as researchers often had to rely on meteorological information collected from locations far from the study area, thereby reducing the precision of their results. Despite these challenges, the study highlights the importance of the farm input subsidy program implemented by the government, which enables poor local rice farmers to access hybrid seeds and fertilizers regardless of their socioeconomic status. This program is instrumental in boosting rice yield at the scheme. Additionally, the availability of good markets enhances farmers' interest in cultivating more rice, further contributing to yield improvement.

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Author contributed fully to the writing of this article.

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The author declare no conflict of interest.

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References
Department of Climate change and Meteorological Services. (2009). *Environmental And Social Management And Monitoring Plan For Nkhate Irrigation Scheme–Chikhwawa*. Ministry of Agriculture and Food Security.

Joshua, M., Ngongonda, C., Manjerezi, M., & Liwenga, E (2016). Climate Change in Sem– arid Malawi: perception, Adaptation Strategies and water governance. *Jàmbá: Journal of Disaster Risk Studies, 8*(3), 255. https://doi.org/10.4102/jamba.v8i3.255

Magreta, R., Edriss, A. K,. Zingore, S. (2014). Economic Efficiency of Rice Production in Smallholder Irrigation Schemes: A Case of Nkhate Irrigation Scheme in Southern Malawi. *African Association of Agricultural Economists (AAAE). http://dx.doi.org/10.22004/ag.econ.161636*

Magreta, R., Zingore, S., Magombo, T.(2010) *Analysis of Effective Market linkage in Promoting Investments in natural resources management in the rice- based farming system in Malawi: a case of Nkhate irrigation scheme.* Inovation and Sustainable Development in Agriculture and Food 2010

Jens, B., Nagothu, U. S., Kjell, E., & Mahreteab, T. (2014). *Opportunities for support system of rice intensification in Tanzania, Zambia and Malawi* (Noragric Report No. 71). Noragric,

Department of International Environment and Development Studies, Norwegian University of Life Sciences (NMBU).

Norman, J. C., & Kebe, B. (2004). *African smallholder farmers: Rice production and sustainable livelihoods*. Food and Agriculture Organization of the United Nations (FAO).

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