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Assessment of Maize Yield Variations Due to Climatic Variables of Rainfall and Temperature

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Abstract

The purpose of this study was to provide a better understanding of the maize yield variations as a function of climate in selected districts in Zambia. The specific objectives were: (i) to explore geographical patterns of the maize yield variations (ii) to investigate the possible relation between maize yield and climatic variables of rainfall and temperature. Data on maize yield was collected from Central Statistical Office while that for rainfall and temperature was collected from Zambia Meteorological Department. A mapped distribution of maize yield was produced to visualize the spatial pattern of maize yield across the selected districts. The strength and direction of the relationship between maize yield and rainfall and temperature was determined using correlations implemented in SPSS. Multiple regressions with ordinary least squares regression was used to fit models of how much variation in maize yield was explained by climatic variables. Results indicated that for one district (Nyimba), a significant ($p = 0.05$) explanation of variations in maize yield was attributed to levels of minimum and maximum temperature and amount of seasonal rainfall with 51.9% of the variation explained. However, the variation in maize yield that was explained by rainfall and temperature was not significant for the rest of the districts considered in the study.

Keywords: maize yield variation, rainfall, temperature

1. Introduction

Climate change is a topical issue of our times. Many documented studies indicate that climate variability is evident in many places (Lobell et al., 2011; Wheeler & Braun, 2013; IPCC, 2007). For instance, Hansen et al (2006) reported that global surface temperature has increased by ≈ 0.2 °C per decade in the last 30 years. Other studies have used climate models to predict future climate scenarios so as to inform policy of what to expect and possibly put in place measures to respond to the expected changes (Urban et al., 2012). Africa is predicted as a high risk continent to climate change, yet its coping mechanisms in terms of adaptation and mitigation is inadequate (Odingo, 2008).

Since climate is a fundamental component of agriculture production, recent studies have focused on how climate variability affects crop production. These studies indicate that changes in climatic variables have a major impact on crop yield (Akpalu, Hassan, & Ringler, 2008; Schlenker & Roberts, 2009). In this regard, Rwanyiziri and Rugema (2013) established that yields of rice were distorted by changes in precipitation, temperature as well as soil moisture. Another study demonstrated how maize was locally adapted to hot temperatures across US counties using spatial adaptation as a surrogate, and found that losses from a warming of 2 °C would be reduced from 14% to 6% with net production loss wholly averted (Butler & Huybers, 2013). It was thus recommended that correct estimates regarding the relationship between crop yield and climatic variables is a critical first step before more elaborate models are implemented to examine how crop-planting choices and food prices will shift in response to climate change (Schlenker & Roberts, 2009). Another study using the ARCH model estimates showed that a variation in rainfall and temperature from the long-term mean had significant effect on crop output, while exponential increase in rainfall had detrimental effect on crop output in Uganda (Mwaura & Okoboi, 2014). Further, a study in Kenya confirmed that the arid and semi arid counties suffer from significant climate variability which has huge implications on maize yields and food security (Omoyo et al., 2015). In Zambia, a study based on four years of data revealed that the largest factor contributing to yield growth was weather which explained 61% of the yield growth followed by increased fertilizer use which explained 32% of the yield increase (Burke et al., 2010). Another study by Ibitoye and Shaibu (2014) based on a 10 year data period for Kogi state, Nigeria yielded somewhat different results. That study showed that variations in both rainfall and temperature were found not to directly relate to the variations noticed in the output and yield of maize (Ibitoye & Shaibu, 2014).

Published studies indicate that climate change will have a definite impact on agriculture production. These studies confirm that there are a wide range of scenarios with regard to climatic variability across Africa. In countries with a staple food crop, it becomes pertinent to relate the climatic variations to output so as to put in place measures that will assure food security. However, in Zambia's case, studies at national level are limited. One study reported a generally high variability in rainfall and increasing temperatures across Zambia Agroecological Zones (Chabala et al., 2014). The study alluded to earlier by Burke et al. (2010) was based on national crop forecast survey data and qualitative data elucidated during interviews to explain the yield variations in maize. However, these studies have not highlighted the direct relationship of the staple food crop maize with climatic variables. This study builds on this earlier work by using empirical data collected by the Zambia Meteorological Department and yield data from the Central Statistical Office. In this regard, the study discussed in this article addresses the direct relationship between climatic variables and maize yield in the context of six districts representative of Zambia Agro-ecological Zones (AEZ).

Since the impact of climate change may not be homogeneous across Agro-ecological zones, it is imperative that assessments of the relationship between maize yield and climatic variables take this into account. Zambia is basically divided into three agro-ecological regions with rainfall as the dominant distinguishing climatic variable (MTENR, 2002; Perret, 2006). The agro-ecological regions or zones I, II and III receive annual rainfall of less than 800 mm, 800-1000 mm and more than 1000 mm respectively. It was against this background that this study was carried out. Two districts were selected per AEZ. These were Serenje and Mpika located in AEZ III, Choma and Petauke located in AEZ II and Sinazongwe and Nyimba representing AEZ I. The purpose of this study was to provide a better understanding of the crop yield variations as a function of climate in six selected districts in Zambia representative of Zambia's AEZ. The specific objectives were: (i) to explore geographical patterns of the maize yield variations (ii) to investigate the possible relation between maize yield and climatic variables of rainfall and temperature.

2. Methodology

2.1 Study Sites

The selected study districts were Serenje, Mpika, Choma, Petauke, Nyimba and Sinazongwe. The selected study sites represented the three Agroecological Zones of Zambia as shown in Figure 1. Serenje and Mpika are both in AEZ III and are located north of Zambia. They belong to the high rainfall areas with annual rainfall of more than 1000 mm. Generally, the soils of Serenje and Mpika are acidic with pH ranges of 3.8 to 4.4. The soils are strongly weathered with low base saturation. Choma and Petauke are in AEZ II of Zambia with rainfall amounts ranging from 800 to 1000 mm per annum. Choma is on the southern part of the country while Petauke is in the Eastern part. In Choma soils are moderate to slightly acidic with pH ranges of 4.4 to 6.4 while those in Petauke are more varied with pH ranges of 3.8 to 6.4. The soils in Choma have a high base saturation and a high content in the subsoil. In Petauke, the soils are fertile fine loamy clays.

The soils of Sinazongwe are medium to shallow in depth often occurring over rock with pH range of 6.4–7.1. The soil texture is sandy clay loam and gravelly when it occurs over stone in strongly dissected topography. On the other hand, the soils in Nyimba are varied, but generally of higher clay content in the subsoil than in top soil with high base saturation while others are coarse loamy to sandy clay loam where they occur over strongly dissected topography. The soil pH range is 4.8 to 6.4. The six districts were selected principally to represent the AEZ while taking into account variations that may exist in soil characteristics as well as availability of maize yield data for the period under consideration.

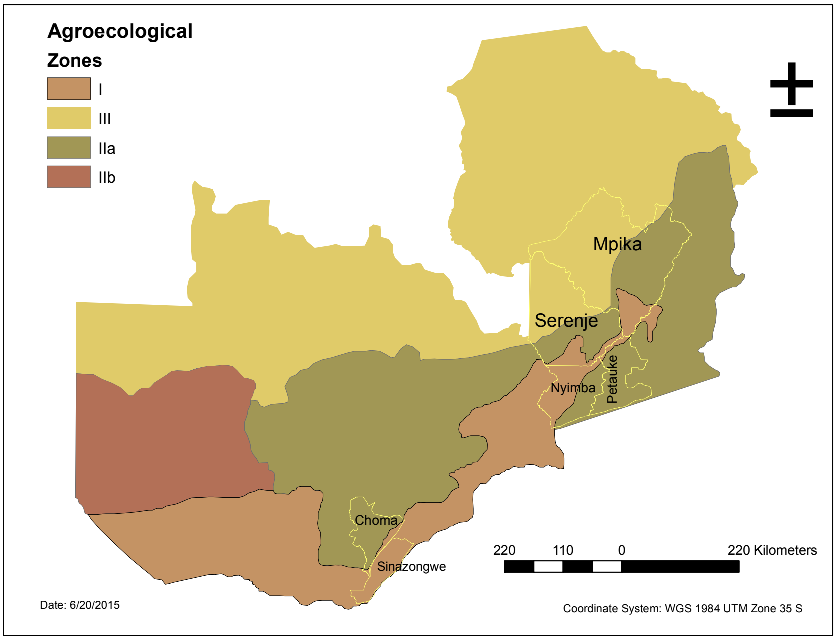

Figure 1. Location of study sites

2.2 Data Sources and Its Background

The data used in this study was obtained from Central Statistical Office (CSO) and the Meteorological Department of Zambia. The maize yield data was collected from Zambian crop forecast survey records maintained by the CSO and it covered a period of 14 years from the 1996/1997 farming season to the 2011/2012 farming season. The data for the 1997/1998 farming season was not available hence the 14 year data period. In the case of Choma additional maize yield data for agricultural blocks was collected from the District Agricultural Office. The data on rainfall and minimum and maximum temperature was collected from the Meteorological Department. Other data included shape files that were extracted from the districts map of Zambia obtained from the Department of Geography at the University of Zambia. Furthermore, shapefiles for agricultural blocks and associated maize yield data in Choma district were obtained from the Ministry of Agriculture and Livestock.

2.3 Data Processing and Analysis

As a first step, data pre-processing was done. For rainfall data, pre-processing involved calculating the seasonal totals for each of the years for which maize yield data was available. For temperature data, the yearly average minimum and maximum temperatures were calculated. Further data checks were done to determine the length of the data period which covered both crop yield and climatic variables. Missing data of crop yield was excluded from further analysis. Further, if the years had more than seven months of missing data for temperature whether minimum or maximum as was the case for Choma district, those data years were also excluded from the analysis.

Thus, at the end of this preliminary data processing, Petauke had 13 years of consistent data while Nyimba had 12 years of consistent data for both maize yield and climatic variables. For Serenje, the consistent data period was 10 years for both crop yield and climatic variables while that for Mpika was 11 years. In the case of Choma, the consistent data period for maize yield and rainfall was 13 years, while only 6 years was consistent for both average yearly minimum and maximum temperatures. The additional data on maize yield from the 2013/2014 farming season was taken as standalone data set that was used to map the geographical distribution of maize yield according to the agricultural blocks in Choma. In the case of Sinazongwe, the consistent data period for maize yield and rainfall was 10 years while only 7 years was consistent for both average yearly minimum and maximum temperatures.

The excel files of cleaned data on maize yield and climatic variables were then exported and joined to the shape file of districts in ArcGIS 10.1. A mapped distribution of maize yield was produced to visualize the spatial pattern of maize yield across districts in the Northern section of the country, namely Nyimba, Petauke, Serenje and Mpika as well as the two southern districts. Further, a mapped distribution was generated for Agricultural blocks in Choma districts. The shapefiles for agricultural blocks and associated maize yield data were not available for Sinazongwe and the Northern districts, at the time of writing this paper and hence excluded. Nevertheless, options are currently being explored to acquire shapefiles representing agricultural camps and blocks and associated yield data in all the districts so as to map the variation with respect to agricultural camps which are much smaller than blocks.

To explore the strength and direction of the relationship between maize yield and climatic variables, correlations were implemented in SPSS. The first goal was to check whether maize yield was associated with rainfall and temperature, that is whether as one variable increases, the other tends to increase (or decrease). This test of association was summarized with the *P* value where a significant association means that different values of the independent variable cause different values of the dependent. Multiple regressions with ordinary least squares regression was then used to fit models of how much variation in maize yield was explained by the climatic variables of rainfall and temperature. The regression models took into account correlations between explanatory variables with the aim of coming up with simple parsimonious models while avoiding collinearity. In view of the foregoing, only one of the strongly correlated climatic variables was included in the final regression models so as to avoid data redundancy. As general criteria, a correlation coefficient of 0.8 was taken to indicate strong correlation. The coefficient of multiple determinations (R^2) was used to determine the percentage explanation achieved jointly by the rainfall and temperature. This method is preferred since it gives the best linear and unbiased estimates among other estimators and has been used by several authors to effectively study the impact of climate on crop yield (Adamgbe & Ujoh, 2013; Odekunle et al., 2007; Tyubee, 2006).

The general regression equation was:

$$Y = b_0 + b_1 X_1 + \ldots b_n X_n + \varepsilon \quad (1)$$

Where, Y is the outcome variable, in this case maize yield, b_0 is the constant, b_1, … b_n are the estimated parameters and X_1, … X_n are the explanatory variables (e.g. seasonal rainfall, average yearly minimum temperature, average yearly maximum temperature) and ε is the error term.

3. Results

3.1 Summary Statistics

The summary statistics for maize yield in all the districts are shown in Table 1. The mean district annual maize yield was 42,542 metric tonnes (MT) for Choma with a standard deviation of 22,733 MT indicating that there was a high amount of variation around the mean. The mean annual maize yield was 6,402.80 MT, 25,829 MT, 17078 MT, 14,805 MT and 61599 MT for Sinazongwe, Serenje, Mpika, Nyimba and Petauke respectively. The standard deviations of maize yield were 5,572, 24,675, 12824, 8,278 and 36,760 for Sinazongwe, Serenje, Mpika, Nyimba and Petauke respectively. This indicated that there was a high amount of variation around the mean of maize yield for all the districts.

Table 1. Summary statistics for yearly maize yield in metric tonnes (MT)

District	No.of observations	Minimum (MT)	Maximum (MT)	Mean (MT)	Standard deviation
Choma	13	12 678	100 268	42 542	22 733
Sinazongwe	12	321	14 426	6 402.80	5 572
Serenje	10	193	79 567	25 829	24 675
Mpika	11	62	42 259	17 078	12 824
Nyimba	12	133	29 295	14 805	8 278
Petauke	13	447	144 041	61 599	36 760

3.2 Pattern of Maize Yield Distribution across Districts

The geographical pattern of maize yield in the Northern districts (Mpika, Serenje, Petauke and Nyimba) and the southern districts (Choma and Sinazongwe) for the period under review are shown in Figures 2 and 3. A large disparity was observed in the geographical distribution of mean annual maize yield for the period under review both for the Southern and Northern districts as was noted with the a mean annual maize yield of each district. For instance Choma and Sinazongwe despite being in a generally southern section, had a mean annual yield difference of almost 36, 139 MT. This could be attributed to the differences in the agro-ecological zones within which Sinazongwe and Choma falls. Sinazongwe falls in AEZ I with different climatic and soil conditions from AEZ II where Choma is located.

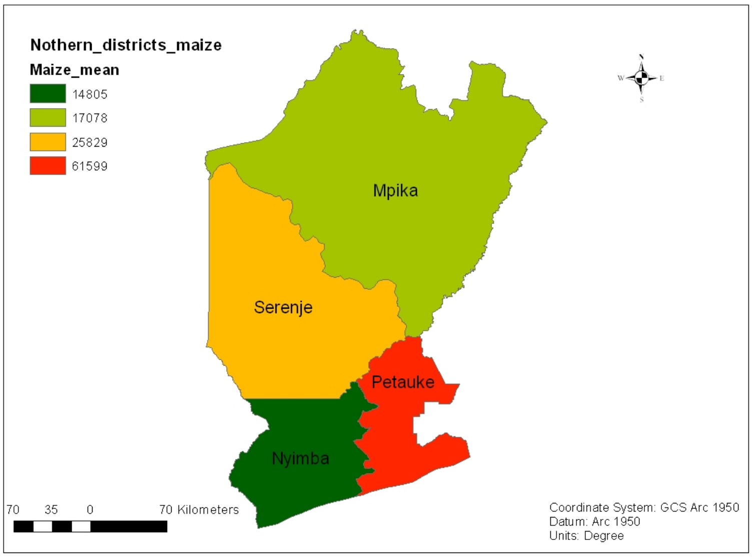

Figure 2. Geographical pattern of annual maize yield in the Northern districts

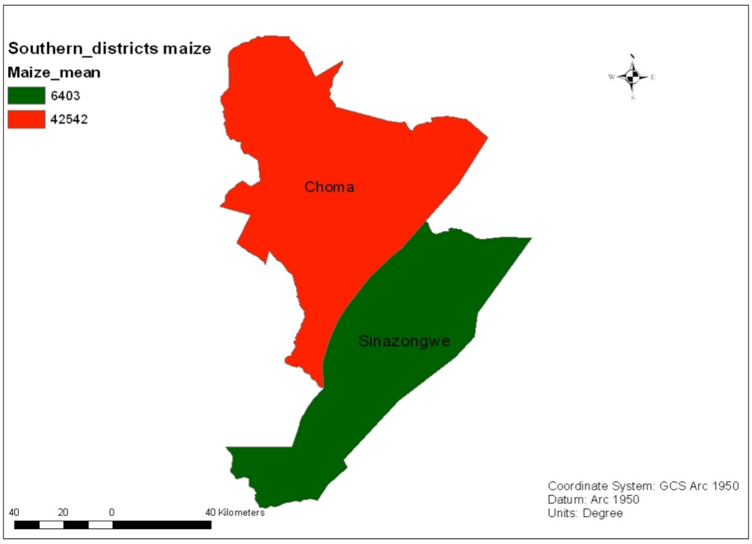

Figure 3. Geographical pattern of annual maize yield in the Southern districts

A mapped distribution of maize yield variation for the agricultural blocks in Choma district is presented in figure 4. It was noted that Singani and Mapanza Agricultural blocks despite being on opposite sides of each other had the highest yield at 28,000 and 29,000 metric tonnes respectively. Batoka despite being neighbours with the highest producing agricultural block had the lowest maize yield in the 2013/2014 farming season. This indicates factors influencing maize production vary even within the areas having similar climate, thus indicating that other factors other than climate should be taken into account in order to improve maize production.

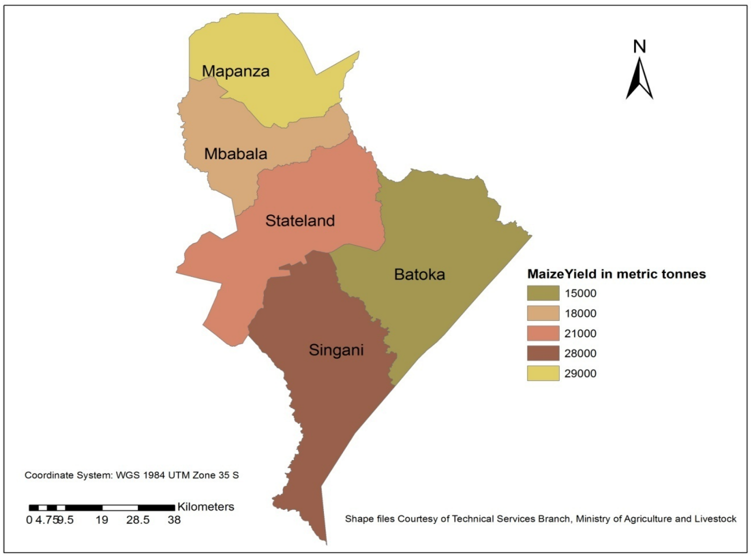

Figure 4. Geographical pattern of annual maize yield in Choma's Agricultural Blocks

3.3 Relationship between Maize Yield and Selected Climatic Variables

The correlation coefficients of maize yield and the climatic variables for each of the selected districts are shown in Table 2. Generally a weak to modest relationship was observed between the climatic variables and maize yield. For instance, Serenje had a modest yet non-significant positive correlation between seasonal rainfall and minimum temperature with correlation coefficients of 0.576 and 0.673 respectively. The correlation was non-significant, weak and negative at -0.237 for maximum temperature. Nyimba had a modest yet non-significant negative correlation between seasonal rainfall and maize yield at -0.469 indicating that areas of higher rainfall are likely to have lower maize yield. The correlation of maize yield with temperature was weak and positive although it was non-significant. Petauke also showed a weak negative correlation between maize yield and temperature at -0.027 which was not significant. Choma on the other hand showed a modest non significant positive correlation between seasonal rainfall, minimum temperature and maize yield at 0.600 and 0.429 respectively. However the correlation although modest was negative between maize yield and maximum temperature at -0.543. For Sinazongwe, a modest non-significant positive correlation was observed between seasonal rainfall and maize yield at 0.571.

Table 2. Correlations of maize yield and climatic variables

	Maize	Seasonal rainfall	Tmin	Tmax	Tmean
SERENJE					
Maize	1	0.576	0.673	-.237	-0.115
Seasonal rainfall	0.576	1	126	-.708*	-.572
Tmin	0.673	.126	1	.255	.547
Tmax	-0.237	-0.708*	0.255	1	.949**
Tmean	0.115	-.572	.547	.949**	1
MPIKA					
Maize	1	-0.091	-0.045	0.155	0.145
Seasonal rainfall	-0.091	1	0.189	-0.043	0.137
Tmin	-0.045	0.189	1	0.038	0.857**
Tmax	0.155	-.043	0.038	1	0.547
Tmean	0.145	0.137	0.857*	.547	1
NYIMBA					
Maize	1	-0.469	0.644	0.322	0.392
Seasonal rainfall	-0.469	1	.050	-.217	-.089
Tmin	0.644	.050	1	.768**	.940**
Tmax	0.322	-.217	.768**	1	.941**
Tmean	0.392	-.089	.940**	.941**	1
PETAUKE					
Maize	1	-0.027	0.518	0.300	0.278
Seasonal rainfall	-0.027	1	0.034	-0.219	-0.104
Tmin	0.0.518	0.034	1	0.779**	0.938
Tmax	0.300	-0.219	0.779**	1	0.948**
Tmean	0.278	-0.104	0.938*	0.948**	1
CHOMA					
Maize	1	0.600	0.429	-0.543	-0.429
Seasonal rainfall	0.600	1	-0.090	-0.448	-0.435
Tmin	0.429	-0.090	1	0.183	0.431
Tmax	-0.543	-0.448	0.183	1	0.966*
Tmean	-0.429	-0.435	.431	0.966**	1
SINAZONGWE					
Maize	1	0.571	-0.143	0.143	0.071
Seasonal rainfall	0.571	1	0.196	-0.110	0.069
Tmin	-0.143	0.196	1	-0.977**	-0.806
Tmax	0.143	-0.110	-0.977**	1	0.913**
Tmean	0.071	0.069	-0.806*	0.913**	1

3.4 Explanatory Models of Maize Yield Variations in Choma and Sinazongwe

The extent to which the amount of variation in maize yield was explained by rainfall for Choma and Sinazongwe districts is shown in Table 3. Results indicated that only a very low and non significant amount of variation in maize yield was being explained by rainfall. For Choma the amount of variation in maize yield was only 2.4% while that for Sinazongwe was 3.9% as indicated by the R squared. The beta coefficient for rainfall in both the short term and long term was positive suggesting that as the amount of rainfall increases so too does the maize yield.

Table 3. Model summary for Choma and Sinazongwe

Model	R	R Squared	Adjusted R Square	Std error of the estimate
Choma	0.156	0.024	-0.064	23 452.838
Sinazongwe	0.199	0.039	-0.500	5 728.412

3.5 Explanatory Models of Maize Yield Variations in Serenje, Mpika, Nyimba and Petauke

In the case of Serenje the first part in determining explanatory variables was to fit a regression model of maize yield with Tmean and seasonal rainfall. This model was not significant and revealed that only 16.1% of the variation in maize yield was explained by Tmean and seasonal rainfall which was noted from the adjusted R value shown in Table 4. It however indicated that as Tmean and seasonal rainfall increase, the levels of maize yield reduce. The beta coefficients which placed the two variables on the same scale showed that the influence of seasonal rainfall was higher compared to that of Tmean.

Later the Tmin was included in the model and it improved the explanation of the variation in maize yield to 25.5%. Since Tmean is a function of Tmax and Tmin, Tmean was removed and replaced with Tmax and this was taken as the final model (Appendix 1). The amount of variation in maize yield explained by the final model still remained at 25.5% as shown by the adjusted R which was not significant (Table 4). It however showed that as the minimum temperature increases in Serenje, so does the maize yield. The results further suggested that as the seasonal rainfall and maximum temperature increases, a corresponding yield reduction in maize was expected. The indication from the model was that maize yield decreases with increasing rainfall is contrary to the sign of the correlations (Appendix 2). Perhaps this is because after controlling for temperature, the rainfall did not exert that high an influence on maize yield in Serenje. The beta coefficients showed that the variable having the highest influence on maize yield was minimum temperature, followed by rainfall and lastly maximum temperature.

Table 4. Model summaries for Serenje district

Model	R	R Square	Adjusted R Square	Std Error of the estimate
1	0.312	0.097	-0.161	26581.780
2	0.710	0.504	0.255	21293.240

A similar approach to that used for Serenje was followed in fitting the regression model of explanatory variables for maize yield in Mpika. The first model having Tmean and seasonal rainfall was not significant but it showed that 20.2% of the variation in maize yield was explained by Tmean and seasonal rainfall as indicated by the adjusted R (Table 5, Appendix 3). The model coefficients indicated that Tmean had a higher influence on maize yield compared to seasonal rainfall.

The final model which included seasonal rainfall, Tmax and Tmin showed that 33.1% of the variations in maize yield in Mpika was explained by these climatic variables, although this model was not significant (Table 4). The model coefficients indicated that as the amount of rainfall and Tmax increase in Mpika, the maize yield reduces.

Table 5. Model summaries for Mpika

Model	R	R Square	Adjusted R Square	Std Error of the estimate
1	0.196	0.038	-0.202	14060.501
2	0.261	0.068	-0.331	21293.240

For Nyimba the first model was constructed by fitting a regression model of maize yield with Tmean and seasonal rainfall. This model was not significant as it indicated that only 35.5% of the variation in maize yield was explained by Tmean and seasonal rainfall which was noted from the adjusted R value shown in Table 6. It however indicated that as seasonal rainfall increase, the levels of maize yield reduce. The beta coefficients further showed that the influence of Tmean on maize yield was higher compared to that of seasonal rainfall Tmean.

Later the Tmean was removed from the model and replaced with Tmin and Tmax. This model was significant (p = 0.05) and it improved the explanation of variation in maize yield attributed to climatic variables to 51.9% as can be noted from the adjusted R (Table 6). This was therefore taken as the final model. It was shown that as the amount of rainfall and Tmax increase in Nyimba, maize yield reduces which was consistent with the correlation sign for seasonal rainfall. Further as Tmin increase, so too does maize yield (Appendix 3).The Beta coefficients showed that the variable having the highest influence on maize yield was minimum temperature, followed by maximum temperature and lastly seasonal rainfall.

Table 6. Model summaries for Nyimba district

Model	R	R Square	Adjusted R Square	Std Error of the estimate
1	0.687	0.472	0.355	6647.063
2	0.806	0.650	0.519*	5743.777

Note. * Significant at 0.05.

For Petauke the first model was similarly constructed by fitting a regression model of maize yield with Tmean and seasonal rainfall. This model was not significant as it indicated that only 6.2% of the variation in maize yield was explained by Tmean and seasonal rainfall which was noted from the adjusted R value shown in Table 7. It however indicated that as seasonal rainfall and Tmean increase, the levels of maize yield also rise. The Beta coefficients showed that influence of Tmean on maize yield was higher compared to that of seasonal rainfall Tmean.

Later the Tmean was removed from the model and replaced with Tmin and Tmax. This model was still not significant although it improved the explanation of variation in maize yield attributed to climatic variables to 10.3% as can be noted from the adjusted R (Table 7). This was taken as the final model. It was shown that as the amount of rainfall and Tmax increase in Nyimba, maize yield reduces. Further as Tmin increase, so too does maize yield (Appendix 4). The Beta coefficients showed that the variable having the highest influence on maize yield was minimum temperature, followed by seasonal rainfall and lastly maximum temperature.

Table 7. Model summaries for Petauke district

Model	R	R Square	Adjusted R Square	Std Error of the estimate
1	0.339	0.115	-0.062	37878.928
2	0.415	0.172	-0.103	38614.484

4. Discussion

4.1 Pattern of Maize Yield Distribution across Districts

Generally large disparity in the geographical distribution of mean annual maize yield in most Districts was observed. This variation is as expected since variations exhibited in climate, soils and other factors including management affect the output across districts. For instance, in Petauke District, the livelihood of the farmers is mainly farming hence the higher maize yield. Meanwhile, other areas such as Mpika and Serenje the livelihood of the people is mainly business with less emphasis on farming. While for Sinazongwe district, which lies in agro-ecological region I characterized by erratic rainfall and high temperature, the farmers focus mainly on growing drought tolerant crops such as sorghum and millet (MTENR, 2002; Perret, 2006). In addition the soils in Sinazongwe are generally different from those in Nyimba particularly with regard to pH.

4.2 Relationship between Maize Yield and Selected Climatic Variables

The results showed that in some districts where the correlation was positive and modest (Serenje, Choma, Sinazongwe), a rise in seasonal rainfall indicated a corresponding increase in maize yield. The opposite was true for the other districts which had negative correlation between maize yield and seasonal rainfall (Mpika, Petauke, Nyimba), that is a rise in seasonal rainfall indicted a corresponding decrease in maize yield. Similarly a decrease in maximum temperatures indicated a corresponding increase in maize yield in some districts (Serenje, Mpika, Choma) as shown by the negative correlation coefficients (Table 2). For all districts, the correlations between maize yield and climatic variables were not significant. The lack of significance indicated that, while noteworthy correlations were observed between climatic variables and maize yield, it cannot be stated with certainty that the differences are real. These results bring out a different dimension from what has been revealed by most studies of this nature. Nevertheless the results of this study are consistent with findings of Ibitoye and Shaibu (2014) whose results showed that variations in both rainfall and temperature were not to directly related to the variations noticed in the output and yield of maize in Kogi, Nigeria (Ibitoye & Shaibu, 2014). This suggests that in addition to climatic variables, there are several other factors including management that influence maize yield. In addition, the timing of the planting and dry spell occurrence may affect certain phenological stages of the crop (Chabala et al., 2013) that may not be captured in seasonal rainfall.

4.3 Explanatory Models of Maize Yield Variations in Districts

This study revealed the extent to which climatic variables of rainfall and temperature explained variations in maize yield. In Nyimba a significant explanation of variations in maize yield was attributed to levels of minimum and maximum temperature and amount of seasonal rainfall with 51.9% of the variation explained. Since climatic variables seemed to have an influence on maize yield in Nyimba, incorporation of agronomic practices aimed at mitigating climate could control some of the variations in maize yield. While the amount of variation attributed to maize yield was not significant in Mpika, the model coefficients for Mpika indicated that as the amount of rainfall and Tmax increase, the maize yield reduces. This trend was as expected since Mpika belongs to AEZ III which is already a high rainfall zone with seasonal rainfall being more than 1000mm per annum (Thurlow et al., 2008). This also suggests that with climate change, there is vulnerability in maize production that is entirely dependent on rainfall. This is in line with some studies which have revealed that changes in mean annual seasonal precipitation have a negative impact on maize production (Oseni & Masarirambi, 2011). It was further shown that as Tmin increased a corresponding rise in maize yield was expected. This is also in line with the correlations for Mpika. The beta coefficients showed that the variable with the most influence on maize yield was Tmin, followed by seasonal rainfall and lastly Tmax (Appendix 2). Since Mpika is already in a high rainfall area, it is to be expected that with higher rainfall, the possibility of crop failure is higher if rainfall increased just as would be the case for Serenje.

Generally the coefficients in Serenje, Mpika and Petauke were non-significant when rainfall and temperature are regressed with maize yield. The variations in maize yield in Serenje, Mpika and Petauke that was explained by the climatic variables of rainfall and temperature though not significant were 25.5%, 33.1% and 10.3% respectively. Meanwhile, despite Choma and Sinazongwe only having rainfall as the main explanatory variable, it was shown that a very small amount of the variation in maize yield was explained by rainfall at 2.4% and 3.9% respectively. The non-significance in these climatic variables is consistent with Kwesiga et al. (2009) who reported that variable maize yield was affected by several factors such as infertile soils, poor governance, poor management apart from rainfall and temperature. Further, these results are in agreement with Thurlow et al. (2008) who found normal weather pattern across all the agro-ecological regions of Zambia to be very a rare phenomenon every season thus accounting for yield variation. Based on this study, it can be deduced that rainfall alone is not grantee to obtaining optimal yields.

5. Conclusions

This paper has discussed the levels to which the climatic variables of rainfall and temperature explained variations in maize yield. It can be concluded that in Nyimba a significant explanation of variations in maize yield was attributed to levels of minimum and maximum temperature and amount of seasonal rainfall with 51.9% of the variation explained. For Serenje, Mpika and Petauke the variations in maize yield that was explained by the climatic variables of rainfall and temperature though not significant were 25.5%, 33.1% and 10.3% respectively. Choma and Sinazongwe which only had rainfall as the main explanatory variable showed that a very small amount of the variation in maize yield was explained by rainfall at 2.4% and 3.9% respectively. Since climatic variables seemed to have an influence on maize yield in certain districts, incorporation of agronomic practices aimed at mitigating climate could control some of the variations in maize yield.

However, a large amount of variations in maize yield remained unexplained, even in the significant model for Nyimba where 48.1% of the variation was not explained. It was therefore recommended that further work involving socio-economic and other variables be carried to identify the variables responsible for maize yield variations in the long term. Further work could also be carried out with field experiment and daily or decadal (10 day) climatic data while monitoring the agronomic performance of maize in a given location. This would help in targeting interventions that would have the desired effect on maize yield whether socio-economic, climatic or otherwise. It was further recommended that, similar studies should be extended to other major crops such as soyabeans, sunflower and cotton among others.

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Appendix

Appendix 1. Serenje model coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-272723.656	417818.377		-.653	.538
	Seasonal rainfall	-40.905	68.778	-.271	-.595	.574
	Tmin	59329.801	26576.321	.743	2.232	.067
	Tmax	-19601.988	14020.208	-.654	-1.398	.212

Note. Dependent Variable: Maize.

Appendix 2. Mpika model coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	64402.601	545993.965		.118	.909
	Seasonal rainfall	-14.053	26.191	-.200	-.537	.608
	Tmax	-4822.622	19912.479	-.089	-.242	.816
	Tmin	6511.456	12454.392	.195	.523	.617

Note. Dependent Variable: Maize.

Appendix 3. Nyimba model coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11550.680	107991.468		.107	.917
	Rainfall	-38.698	13.187	-.671	-2.934	.019
	Tmax	-6944.013	5545.376	-.447	-1.252	.246
	Tmin	14037.355	5442.102	.899	2.579	.033

Note. Dependent Variable: Maize.

Appendix 4. Petauke model coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-200813.747	637815.191		-.315	.760
	Seasonal rainfall	-26.380	88.095	-.099	-.299	.771
	Tmax	-13209.993	33821.334	-.205	-.391	.705
	Tmin	39063.096	35885.922	.558	1.089	.305

Note. Dependent Variable: Maize.