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Research Article

The Effect of Rainfall, Temperature, and Relative Humidity on the Yield of Cassava, Yam, and Maize in the Ashanti Region of Ghana

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This study examined the consequences of changes in minimum temperature, maximum temperature, relative humidity, and rainfall on the yields of maize, cassava, and yam per hectare of land in the Ashanti Region of Ghana. Correlation analysis of each climatic condition on the yield of each crop per hectare of land revealed that each of the climatic conditions was significant in predicting the crop yields. Separate multiple linear regression models were obtained for crop yield per hectare of land under all the climatic conditions. The regression models showed that an increase in maximum temperature reduces the yield of all the crops, whereas an increase in minimum temperature reduces only the yield of maize. Increases in relative humidity reduce the yield of maize alone, while increases in rainfall reduce the yield of only cassava. The significant multiple linear regression model for each crop yield indicated that 63.8% of the variations in the yield of maize per hectare of land, 74.3% of the variations in the yield of cassava per hectare of land, and 64.2% of the variations in the yield of yam per hectare of land are accounted for by minimum temperature, maximum temperature, relative humidity, and rainfall. We encourage the Government of Ghana, the Ministry of Food and Agriculture, and all stakeholders in the agriculture sector to increase their campaign on the consequences of climate change on the yield of these crops. They should educate farmers on the effects of overreliance on rainfed and traditional agricultural methods, introduce them to modern methods of agriculture, and provide them with varieties of these crops with higher-yielding capacities in higher temperatures.

1. Introduction

Throughout the last decade, the general size of the farming area in Ghana has more than split, adding up to 15.3% of ostensible Gross Domestic Product as of the second quarter of 2019, down from 31.8% in 2009. Regardless, agriculture holds its essential significance as a major employer, containing 44.7% of the workforce. Fluctuating appraisals put the number of families owning or working on a farm at somewhere in the range of 44.1% to 51.5%, adding up to around 7.3 million people. Given farming's pivotal role in giving positions to Ghana's developing populace, the public authority has set out on critical modernization endeavors since 2017; key among them is the Planting for Food and

Jobs drive. This was continued in 2018 by the umbrella program, Investing for Food and Jobs, which is centered on agriculture, food security, and rural development [1]. The main aim of these flagship programs introduced by the Government of Ghana through the Ministry of Food and Agriculture (MoFA) is to modernize the agriculture sector through improving food security, creating employment opportunities, and reducing poverty. All these are efforts geared towards achieving the Sustainable Development Goals (SDGs) 1 and 2 which aim at ending poverty and zeroing hunger, respectively [2].

The 2021 Ghana Population and Housing Census (PHC) estimated Ghana's current population at 30.8 million with the Ashanti Region being the second most populated region

[3]. The Statistics, Research and Information Directorate (SRID) of MoFA estimated that approximately 39% of women account for the labor force in agriculture. The mean size of a farm was estimated at 1.6 hectares with small-size and medium-size farms of up to 10.0 hectares accounting for 95% of the farms. Ghana's agriculture sector provides for 90% of the food needs of the entire population and is predominantly based on traditional methods and rainfed [4]. The farming systems in Ghana differ across agro-ecological zones. Notwithstanding, certain overall elements are perceptible all across the country. The main method employed by most farmers to recoup the fertility of the land is by the bush fallow system where the land is left to rest for one to three years. Mixed cropping is mostly employed in the cultivation of stable crops, while monocropping is used for cash crops [5].

Weather-related risks or drought cause great losses in crop cultivation resulting in negative growth in the sector. The overreliance on rainfed agriculture affected the production of cassava (*Manihot esculenta*), rice (*Oryza spp.*), yam (*Dioscorea spp.*), maize (*Zea mays*), and groundnut (*Arachis hypogaea*) even though the effects have not been statistically substantiated. Stakeholders are severely limited in terms of capacity to address the aftermath of these risks [6].

Climate variability and climate change seriously pose a threat to food production in Sub-Saharan Africa. Spatio-temporal patterns of temperature and rain likely affect the availability and growth of crops, yield formation, and water and nutrients. Climate change has resulted in a 20% average reduction in annual maize yield in Ghana [7]. Severe alteration in the pattern of rainfall due to global warming can disrupt crop production and may lead to poverty, food insecurity, and joblessness in Ghana. The yield of three crops (plantain, cocoyam, and cassava) in the Fanteakwa District of the Eastern Region of Ghana declined from 2003 to 2014 as a result of the variation in rainfall in the two major seasons over the period. Therefore, policies on adaptive agricultural production methods must be revised in the face of climate change [8]. Osabutey et al. [9] assessed the impact of rainfall and temperature changes to maize and cassava yields in the Kwahu South, Twifo Praso, and Offinso North Districts of Ghana. Their results showed that average rainfall and average temperatures have statistical significant relationship with the yield of these crops in the three districts. Cudjoe et al. [10] examined the consequences of variability in rainfall and temperature on the production of maize in the Ejura–Sekyedumase Municipality of the Ashanti Region of Ghana. They showed through regression analysis, chi-square test, and trend analysis that the duration of rainfall in the two seasons has shortened from previous trends and is less anticipated as compared to increased temperatures in the same period. Their findings revealed a general liaison between maize yield, temperatures, and rainfall. They showed that maize yield will generally increase with increased rainfall in the correct proportion and distribution. However, the yield of maize fell with a rise in temperature.

Emaziye [11] studied the influence of rainfall and temperature on the yields of maize, cassava, and yam in the Delta State of Nigeria. His results revealed that cassava, maize, and yam yields are negatively related to rainfall which is a hindrance to the optimal yields of these crops. Maize yields decreased over the period considered in the study. He further observed that mean annual temperatures were increasing while mean annual rainfall was decreasing during the same period, evidence of global warming. Akinwumiju et al. [12] were of the view that Nigeria will be able to double its current figures in the production of cassava if it adapts irrigation farming and soil fertilization techniques.

Adeleye et al. [13] used statistics to reveal that cassava gives the highest mean yield among cassava, maize, rice, melon, yam, cocoyam, potato, and cowpea under normal climatic conditions followed by maize. Olakojo and Onanuga [14] applied a long-run causality test, Markov-switching regression, and a structural vector autoregressive model to study the effect of climate change on cassava, yam, maize, okra, millet, groundnut, cowpea, sorghum, cocoyam, and rice. Geomultivariate analysis was employed to study crop yield and soil properties [15]. Geospatial analysis and analysis of variance have been applied to study the effect of soil properties and their consequences on the yield of maize and cassava [16].

The yield of cassava, maize, and yam have been adversely affected due to climate change and variability, structural adjustment programs, population growth and urbanization, new farming technologies, and economic development [17]. With the application of robust regression models and the GROWEST model, Kawaye and Hutchinson [17] revealed that a projected increase in temperature may not affect the yield of these crops.

Issahaku and Maharjan [18] envisaged that climate change will inform farmers to increase the production of cassava, maize, sorghum, rice, and yam in order to get the required yield. This is because of the negative impact climate change is expected to exert on the yield of these crops in the years ahead. They showed these with the application of the multivariate Tobit model.

Other studies on cassava have focused on trends of production and yield, effects of a single climatic condition on production, variety improvement, and technological improvement in yields [19–23]. Most studies on maize have dwelled on yield gabs, fertilizer application on yields, one or two climatic conditions effecting yields, and soil and crop management practices [24–30]. Additional studies on yam have concentrated on soil nutrient tolerance, mineral fertilizer response, stability and adaptability of species, production from tubers and minisetts, and potential returns on investment in research [31–34].

Clearly, we can observe that a lot of literature explored the influence of temperature and rainfall on the yield of maize, cassava, and yam neglecting the impact posed by relative humidity. There is also a mixed study on the impact of temperature and rainfall on these crops. Furthermore, most studies in Ghana on these crops are based on a single district or a few districts. In this paper, we investigated statistically the significant effects of temperature, rainfall, and relative humidity on the yields of cassava (*Manihot esculenta*), yam (*Dioscorea spp.*), and maize (*Zea mays*) in

the entire Ashanti Region of Ghana using correlation and regression analyses. The results will go a long way to assist the government, MoFA, and other stakeholders in the agriculture sector on policy direction on adaptive agriculture in order to achieve SDG 1 and 2.

2. Materials and Methods

2.1. Study Area. The study covered the entire Ashanti Region since it is one of the major producers of food crops in Ghana. The region is located between longitudes of 0 15–2 25 west and latitudes of 5 50–7 40 north. It covers a total land area of 24,389 square kilometers with about 60% of it being arable. MoFA estimates indicate that 81% of the arable is cultivated. Rainfall peaks in May/June and October every year with double maxima and mean annual values of between 1100 mm and 1800 mm. The region experiences a mean annual temperature of between 25.5°C in the southern districts and 32°C in the northern parts with high humidity averaging about 85% in the southern districts and 65% in the northern districts. The 2010 PHC estimates indicated that 706,888 out of the 1,612,467 people of the region's population engaged in agriculture. The southern districts are covered with moist semideciduous forest, Guinea savanna covers the northern part, and Riverine forests also occur along the Afram River and streams of the savanna zone. The region has forest ochrosols along the southern districts and savanna ochrosols along the northern part. Agriculture dominates the economic activities of the region. Yam, cassava, and maize are cultivated in all parts of the region [35]. Figure 1 shows a map of Ghana indicating the size of land for all administrative regions. The Ashanti Region is ranked third in terms of land size. Figure 2 displays the map of the study area showcasing various commodities produced in the various districts in the region.

2.2. Data. The data used in this study is made up of the yield of maize, yam, and cassava in tons per hectare of land alongside annual rainfall, annual average monthly minimum temperature, annual average monthly maximum temperature, and annual average monthly relative humidity from 1990 to 2020, provided by Ghana's Ministry of Food and Agriculture (MoFA). The crop yield from the MoFA is made up of all the yields in all the seasons in a calendar year.

Figure 3 shows the production of maize, yam, and cassava in the region. Figures 4 and 5 show the average annual rainfall and temperature, respectively.

2.3. Statistical Analysis. We employed a multiple linear regression model as proposed by [36–38].

Suppose $\mathbf{y} = \{y_1, \ldots, y_p\}'$ is an $n \times 1$ vector of the response variable (i.e., a particular crop yield, e.g., maize, cassava, or yam). Let $\mathbf{X} = \{x_1, \ldots, x_{p-1}\}'$ be $n \times p$ vector of explanatory variables (i.e., annual average monthly minimum temperature, annual average monthly maximum temperature, annual rainfall, and annual average monthly relative humidity) and $\beta = \{\beta_0, \beta_1, \ldots, \beta_{p-1}\}'$ be $p \times 1$ vector of regression parameter estimates with associated

$n \times 1$ vector of errors, $\varepsilon = \{\varepsilon_1, \ldots, \varepsilon_p\}'$. The multiple linear regression can be written as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \tag{1}$$

where $\varepsilon \sim N(0, \sigma^2)$ and $\mathbf{y} \sim N(\mathbf{X}\boldsymbol{\beta}, \sigma^2)$ with $\text{cov}(\varepsilon_i, \varepsilon_j) = 0$, for $i \neq j$.

We can therefore write the fitted values as follows:

$$\hat{\mathbf{y}} = \mathbf{X}\boldsymbol{\beta}. \tag{2}$$

Both methods of maximum likelihood and least squares estimation of the regression parameters yield the same results as

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y}, \tag{3}$$

with $E(\hat{\beta}) = \beta$, $\text{var}(\hat{\beta}) = \sigma^2(\mathbf{X}\mathbf{X}')^{-1}$, and $se(\hat{\beta}) = \sqrt{\hat{\sigma}^2(\mathbf{X}\mathbf{X}')^{-1}}$.

Also, the standardized "beta" coefficients indicate a change in standard deviation units in the average value of the response variable per one unit standard deviation change in the explanatory variable. These are the best for comparison of computed regression estimates [36]. The standardized "beta" coefficients are computed as

$$\beta_s = \beta_u \frac{\sigma_x}{\sigma_y}, \tag{4}$$

where β_s is the standardized coefficient estimate, β_u the unstandardized coefficient estimate, σ_x the standard deviation of a particular explanatory variable, and σ_y the standard deviation of the response variable.

Each response variable (respective crop yield) was fitted with all the explanatory variables (climatic conditions).

The coefficient of determination R^2, was used to measure the goodness-of-fit of the models [14]. The R^2 is given by the following expression:

$$R^2 = \frac{\text{model sum of squares}}{\text{total sum of squares}}, \tag{5}$$

where total sum of squares $= \sum_i (y_i - \overline{y})^2$, and model sum of squares $= \sum_i (\hat{y}_i - \overline{y})^2$. The R^2 measures the proportion of the variation in each annual crop yield explained by the meteorological conditions.

Correlations between the response and the explanatory variables were computed and their significance checked.

The Statistical Tool for Agricultural Research (STAR) version: 2.0.1 [39] and IBM SPSS Statistics for Windows, version 24.0 [40] were used for model fitting and estimations.

3. Results and Discussion

The correlation analysis is presented in Figures 6–8 as well as Table 1. Clearly, we can see that there is a significantly high negative correlation between maize yield per hectare of land and the annual average monthly minimum temperature ($r = -0.660$, $p - \text{value} < 0.001$) as well as the annual monthly maximum temperature ($r = -0.753$, $p - \text{value} < 0.001$). This result is similar to that of Maital et al. [29]. This means that
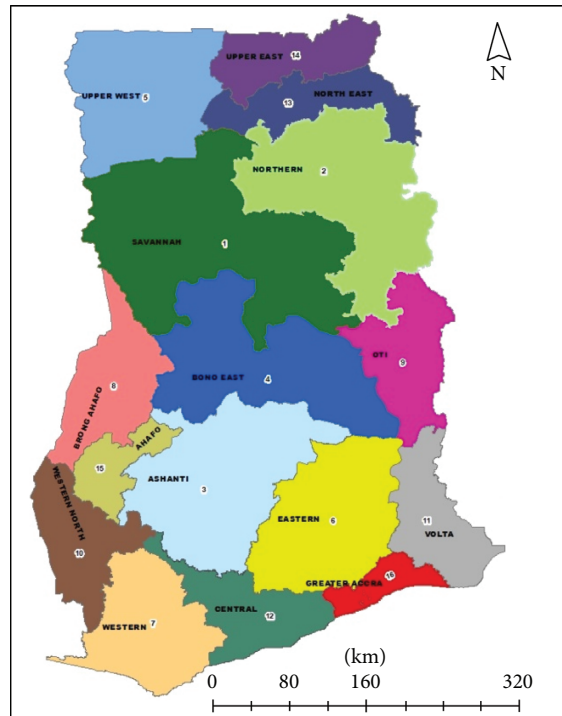
FIGURE 1: Map of Ghana showing all administrative regions ranked by size of land (the Ashanti Region ranked third in size of land) (source: https://upload.wikimedia.org/wikipedia/commons/e/e7/NEW_GHANA_REGIONS.jpg).
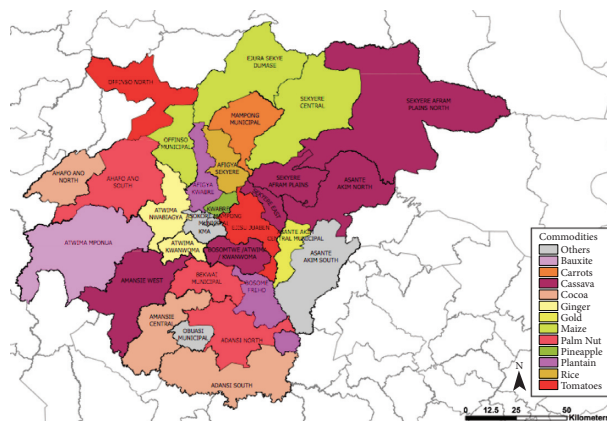

FIGURE 2: Map of the Ashanti Region indicating major commodities in the various districts (source: https://www.moti.gov.gh/1d1f/factories.php?region=ashanti).

an increase in the annual average monthly minimum and maximum temperatures, respectively, will adversely reduce maize yield per hectare of land. The R-square values for maize yield at minimum temperature and maize yield at maximum temperature were 0.436 and 0.567, respectively. This means that the annual average monthly minimum temperature accounts for 43.60% of the variations in maize yield per hectare of land, while the annual average monthly maximum temperature accounts for 56.70% of the variations in maize yield per hectare of land. On the other hand, maize yield per hectare of land had a significantly lower positive correlation with annual rainfall ($r = 0.098$, p – value $= 0.047$) and annual average monthly relative humidity ($r = 0.453$, p – value $= 0.012$), respectively. These results are similar to the results of Maital et al. [29], Cudjoe et al. [10], and Osabutey et al. [9]. This means that an increase in annual
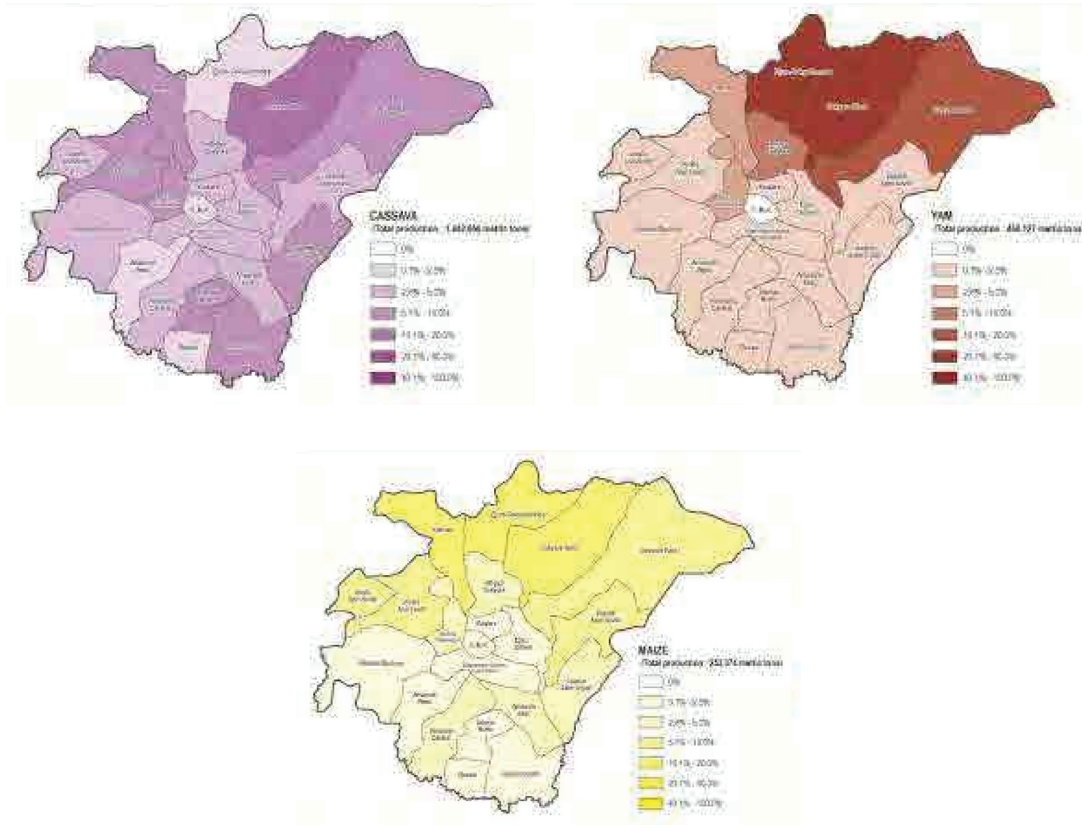
FIGURE 3: Production of cassava, yam, and maize in the Ashanti Region based on data from MoFA (source: https://openjicareport.jica.go.jp/pdf/1000014018_01.pdf).
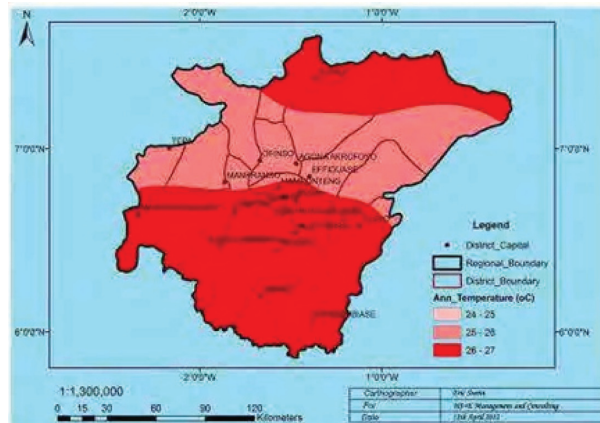

FIGURE 4: Average annual temperatures in the Ashanti Region (source: https://openjicareport.jica.go.jp/pdf/1000014018_01.pdf).

rainfall and annual average monthly relative humidity slightly increases the maize yield. The R-square values for maize yield on annual rainfall and annual humidity were 0.010 and 0.205, respectively. Thus, annual rainfall accounts for 1.00% of the variations in maize yield, while annual average monthly relative humidity accounts for 20.50% of the variations in maize yield. These results contradict the results of Atiah et al. [30].

For cassava yield per hectare of land, there was a significant low negative correlation with minimum temperature ($r = -0.378$, p − value = 0.040) and a significant high negative correlation with maximum temperature ($r = -0.776$, p − value < 0.001). This is an indication that increases in the minimum and maximum temperatures will reduce cassava yield. The R-square values for cassava yield at minimum temperature and cassava yield at maximum temperature were 0.143 and 0.602, respectively. Thus, 14.30% of the variations in cassava yield are accounted for by minimum temperature, while 60.20% of the variations in cassava yield are accounted for by maximum temperature.
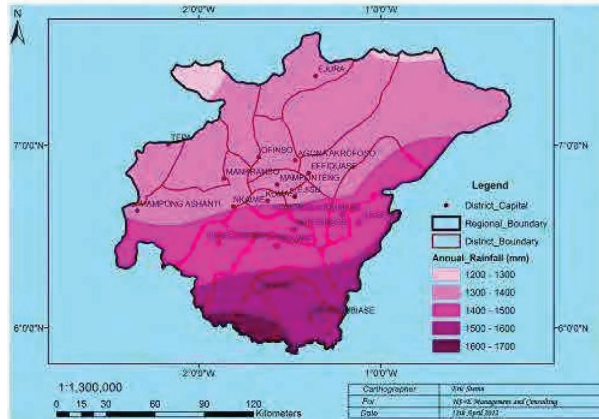
FIGURE 5: Average annual rainfall in the Ashanti Region (source: https://openjicareport.jica.go.jp/pdf/1000014018_01.pdf).
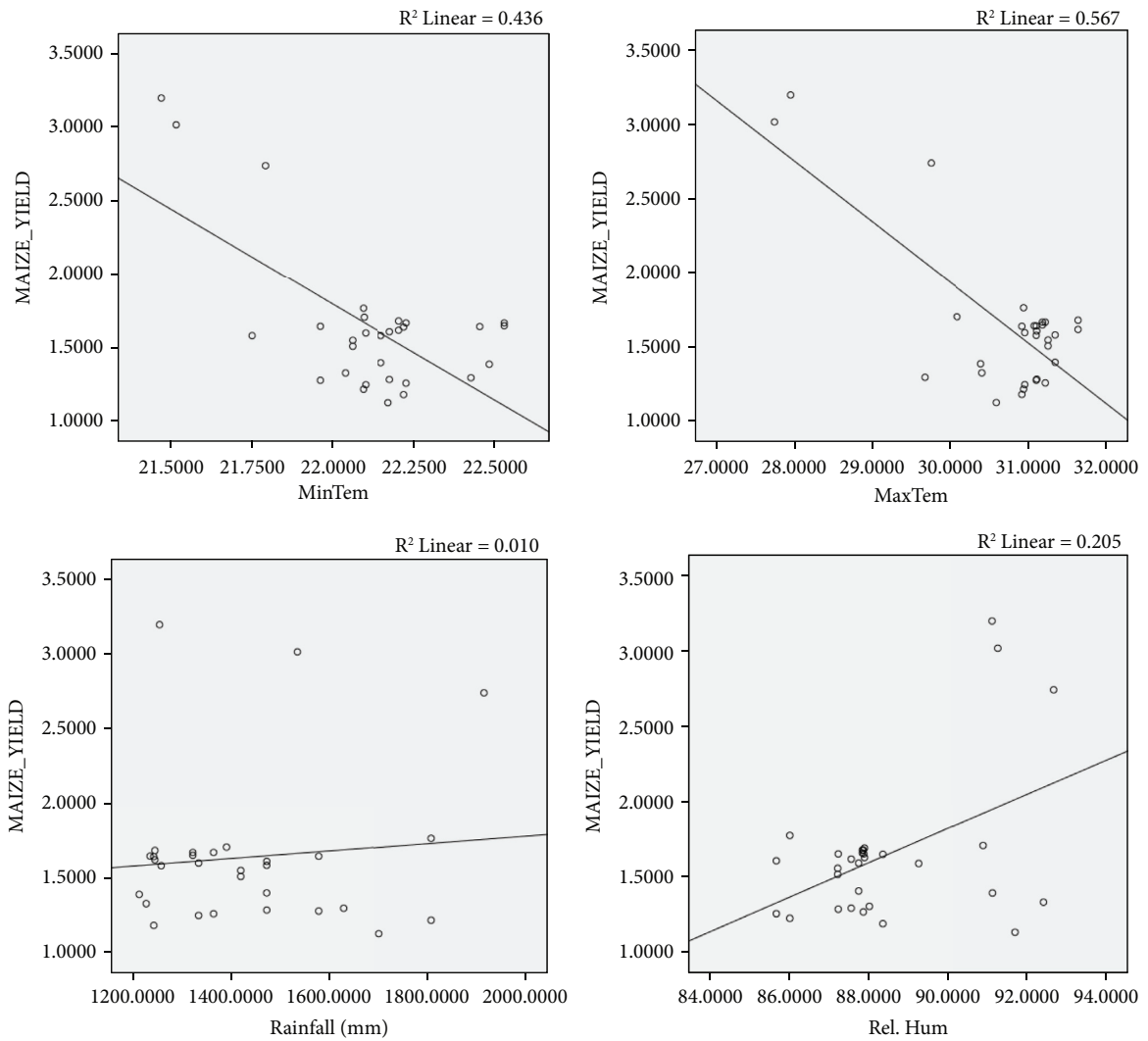

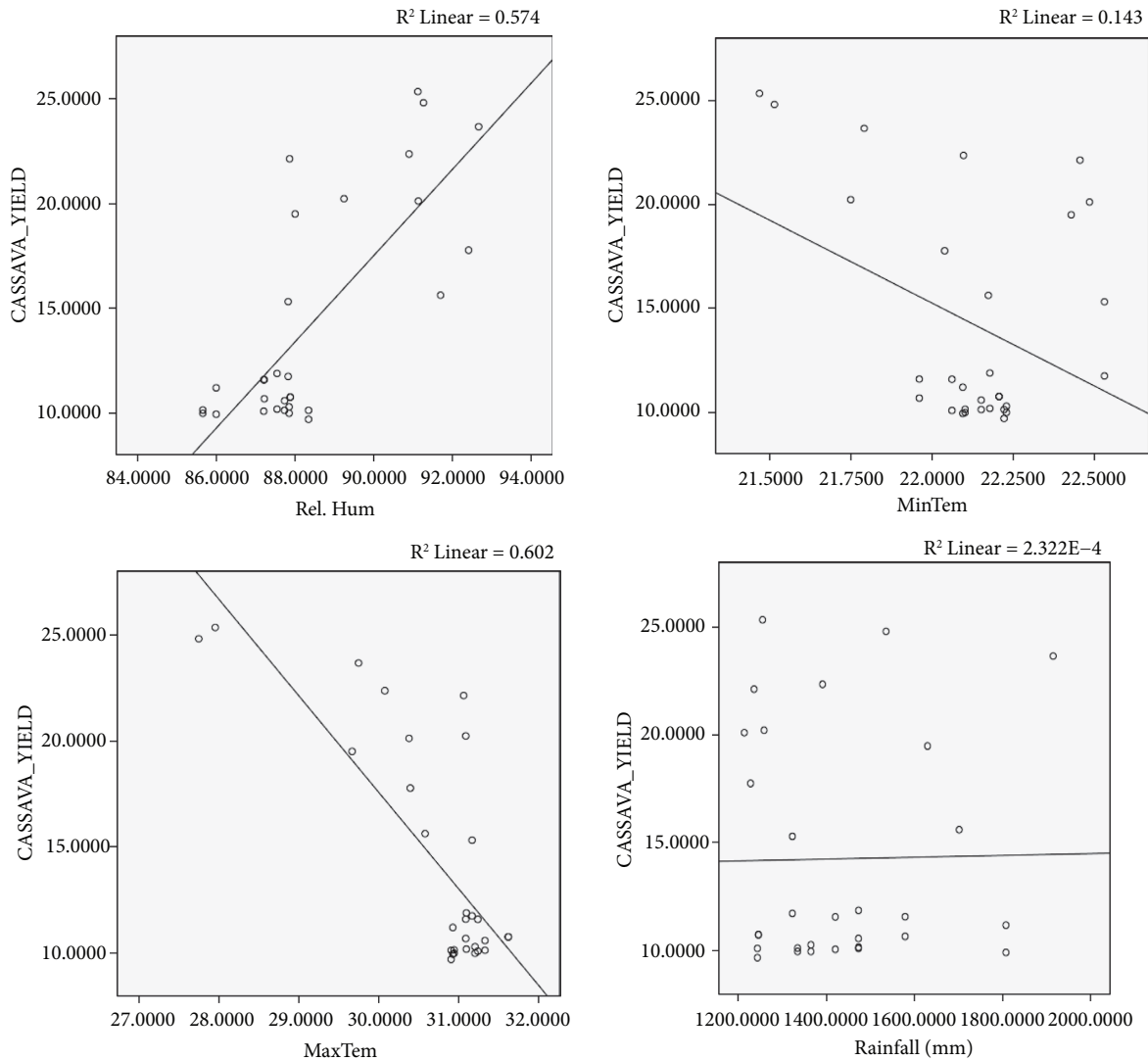FIGURE 6: Scatter plot of maize yield on each climatic condition.

FIGURE 7: Scatter plot of cassava yield on each climatic condition.

There was a low-significant positive correlation between cassava yield and rainfall $(r = 0.015, p-\text{value} = 0.049)$, whereas a high-significant positive correlation $(r = 0.758, p-\text{value} < 0.001)$ was observed between cassava yield and relative humidity. Therefore, increases in rainfall slightly increase the cassava yield, while increases in relative humidity adversely increase the cassava yield. The R-square values for cassava yield on rainfall and relative humidity were 2.322×10^{-4} and 0.574, respectively. This means that rainfall accounts for 0.02% of the variations in the cassava yield, while relative humidity accounts for 57.40% of the variations in the cassava yield. These results are similar to that of Akinwumiju et al. [12] and Osabutey et al. [9].

Yam yield per hectare of land had a significantly lower negative correlation with minimum temperature $(r = -0.407, p-\text{value} = 0.026)$ and a higher negative correlation with maximum temperature $(r = -0.744, p-\text{value} < 0.001)$. This signifies that increases in minimum temperature will marginally reduce yam yield, while increases in maximum temperature will lead to a high

reduction in yam yield. The R-square values for yam yield on minimum and maximum temperatures were 0.165 and 0.554, respectively. Thus, 16.50% of the variations in yam yield are accounted for by minimum temperature, whereas 55.40% of the variations in yam yield are accounted for by maximum temperature. There was a significantly low positive correlation between yam yield and rainfall $(r = 0.035, p-\text{value} = 0.049)$ while there existed a significantly high correlation between yam yield and relative humidity $(r = 0.681, p-\text{value} < 0.001)$. That is, increases in rainfall somewhat increase yam yield, while increases in relative humidity highly increase annual yam yield. The R-square values for annual yam yield on rainfall and relative humidity were 0.001 and 0.463, respectively. This means 0.10% of the variations in annual yam yield are accounted for by rainfall, while 46.30% of the variations in annual yam yield are accounted for by relative humidity. These results contradict those of Magna et al. [41].

Table 2 shows the multiple linear regression results for maize yield per hectare of land under the climatic conditions. The intercept (constant) was 25.902 with a $p-\text{value}$ of
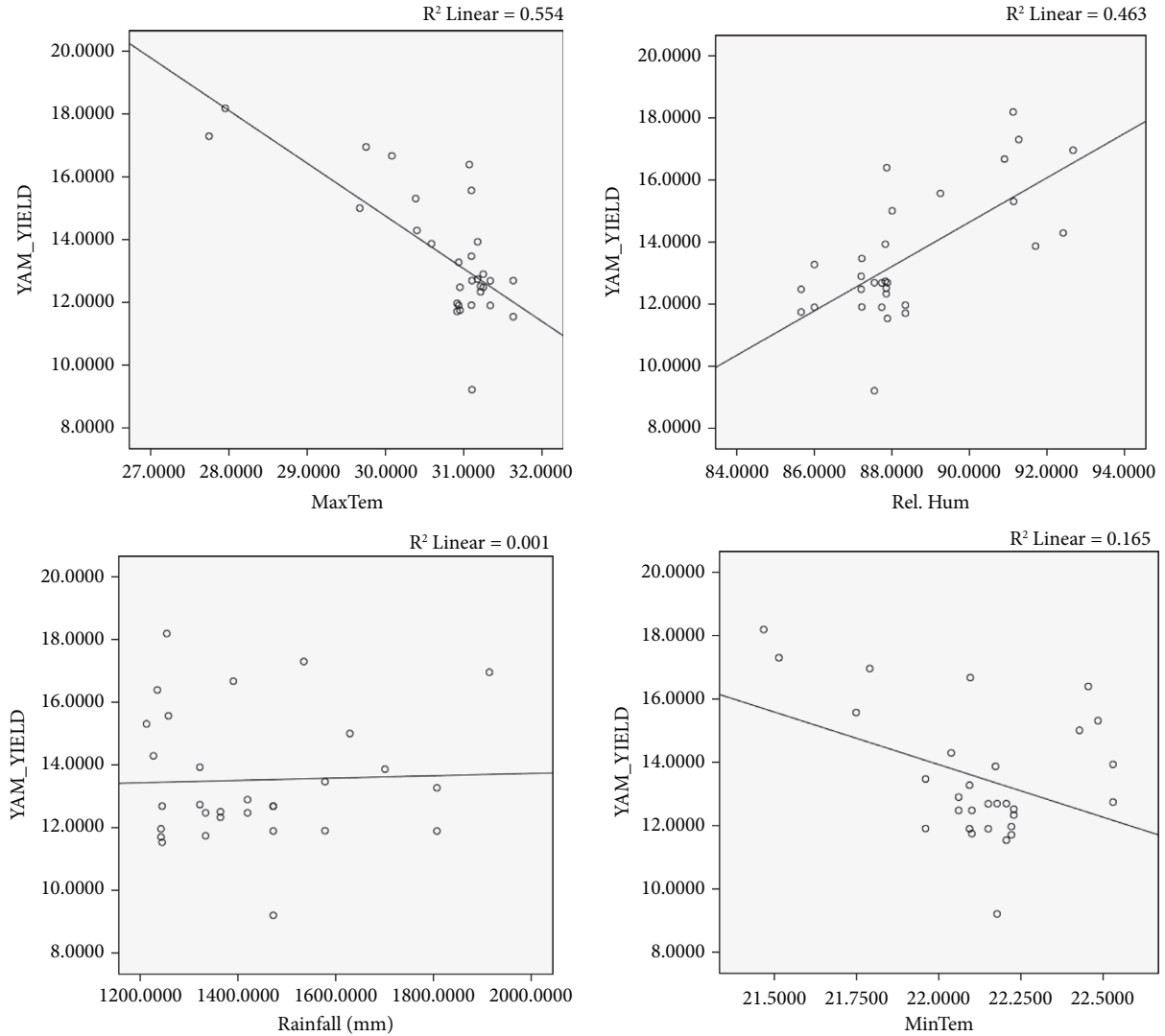
FIGURE 8: Scatter plot of yam yield on each climatic condition.

TABLE 1: Correlation analysis of maize yield, cassava yield, and yam yield with climatic conditions.

Variable	Pearson correlation	Sig.
Maize yield with climatic conditions		
Minimum temperature	−0.660	<0.001
Maximum temperature	−0.753	<0.001
Relative humidity	0.453	0.012
Rainfall	0.098	0.047
Cassava yield with climatic conditions		
Minimum temperature	−0.378	0.040
Maximum temperature	−0.776	<0.001
Relative humidity	0.758	<0.001
Rainfall	0.015	0.049
Yam yield with climatic conditions		
Minimum temperature	−0.407	0.026
Maximum temperature	−0.774	<0.001
Relative humidity	0.681	<0.001
Rainfall	0.035	0.049

TABLE 2: Multiple linear regression output of maize yield under climatic conditions.

	Unstandardized coefficients		Standardized coefficients	t	Sig.	95% Confidence interval for estimates	
	Estimates	Standard error	Beta			Lower bound	Upper bound
Constant	25.902	1.825		3.310	0.003	9.752	42.052
Minimum temperature	−0.641	0.378	−0.326	−1.697	0.005	−0.421	0.139
Maximum temperature	−0.306	0.100	−0.563	−3.045	0.006	−0.513	−0.098
Relative humidity	−0.001	0.040	−0.003	−0.019	0.035	−0.084	0.082
Rainfall	0.001	0.001	−0.061	−0.448	0.049	−0.001	0.002
Model summary							
R	R-square	Adjusted R	Standard error of the estimate	Regression sum of squares	Residual sum of squares	F	Sig.
0.798	0.638	0.562	0.328	4.553	2.588	8.445	<0.001

0.003 and a 95% confidence interval (CI) of (9.752, 42.052). That is, the intercept is statistically significant at the 0.05 significance level. This means that the yield of maize per hectare of land will be 25.902 tons when climatic conditions remain constant. The estimate of minimum temperature was −0.641 with a 95% CI of (−0.421, 0.139). With a p − value of 0.005, the estimate of minimum temperature is statistically significant. This means that a unit increase in the minimum temperature will decrease maize yield per hectare of land by 0.641 tons if the maximum temperature, relative humidity, and rainfall remain constant. Maximum temperature had an estimate of −0.306 with a 95% CI of (−0.513, −0.098) and significant at 0.05 level of significance. Thus, a unit in the maximum temperature will reduce the maize yield per hectare of land by 0.306 tons if the remaining climatic conditions

remain constant. The estimates of relative humidity and rainfall were −0.001 and 0.001 with 95% CIs of (−0.084, 0.082) and (−0.001, 0.002), respectively. Therefore, a unit increase in relative humidity reduces maize yield per hectare of land by 0.001 tons when all other climatic conditions remain constant, while a unit increase in rainfall increases maize yield by 0.001 tons when all other climatic conditions remain constant. The overall model was significant with an R-square value of 0.638. This indicates that minimum temperature, maximum temperature, relative humidity, and rainfall account for 63.8% of the variations in the annual yield of maize per hectare of land. These results are similar to those of Cudjoe et al. [10] and Maital et al. [29] but contradict those of Atiah et al. [30]. The overall model for annual maize yield per hectare can be written as

$$\text{maize yield} = 25.902 - 0.641 \text{ minimum temperature} - 0.306 \text{ maximum temperature} \\ - 0.001 \text{ relative humidtity} + 0.001 \text{ rainfall.}$$

(6)

The results of the multiple linear regression model for cassava yield per hectare of land on the climatic conditions are shown in Table 3. The intercept was not significant at the 0.05 significance level. The estimate of minimum temperature, maximum temperature, relative humidity, and rainfall were all significant. Minimum temperature had an estimate of 3.227 with a 95% CI of (−3.834, 10.288). This indicates that a unit increase in the minimum temperature increases cassava yield per hectare of land by 3.227 tons if the maximum temperature, relative humidity, and rainfall remain constant. Maximum temperature had an estimate of −3.382 with a 95% CI of (−5.257, −1.506). That is, a unit increase in the maximum temperature reduces cassava yield per hectare of land by 3.382 tons when all the remaining climatic conditions remain constant. The estimates of

relative humidity and rainfall were 1.219 and −0.001, respectively with 95% CI of (0.468, 1.971) and (−0.002, 0.006), respectively. Thus, a unit increase in relative humidity increases cassava yield by 1.219 tons per hectare of land if the other climatic conditions remain constant, while a unit increase in rainfall reduces the annual cassava yield by 0.001 ton when the remaining climatic conditions remain constant. The R-square value of 0.743 means that 74.3% of the variations in the annual cassava yield per hectare of land are accounted for by minimum temperature, maximum temperature, relative humidity, and rainfall. These results are in line with those of Akinwumiju et al. [12]. The main model for cassava yield per hectare was significant and can be written as

$$\text{cassava yield} = 3.227 \text{ minimum temperature} - 3.382 \text{ maximum temperature} + 1.219 \text{ relative humidtity} - 0.001 \text{ rainfall.} \quad (7)$$

TABLE 3: Multiple linear regression output of cassava yield under climatic conditions.

	Unstandardized coefficients		Standardized coefficients	t	Sig.	95% Confidence interval for estimates	
	Estimates	Standard error	Beta			Lower bound	Upper bound
Constant	−43.107	2.851		−0.608	0.109	−189.752	103.123
Minimum temperature	3.227	3.421	0.153	0.943	0.035	−3.834	10.288
Maximum temperature	−3.382	0.909	−0.579	−3.722	0.001	−5.257	−1.506
Relative humidity	1.219	0.364	0.450	3.349	0.003	0.468	1.971
Rainfall	−0.001	0.003	−0.024	−0.209	0.039	−0.002	0.006
			Model summary				
R	R-square	Adjusted R	Standard error of the estimate	Regression sum of squares	Residual sum of squares	F	Sig.
0.862	0.743	0.689	1.973	613.273	212.163	13.875	<0.001

TABLE 4: Multiple linear regression output of yam yield under climatic conditions.

	Unstandardized coefficients		Standardized coefficients	T	Sig.	95% Confidence interval for estimates	
	Estimates	Standard error	Beta			Lower bound	Upper bound
Constant	9.524	2.370		0.294	0.071	−57.285	76.333
Minimum temperature	0.830	1.563	0.101	0.531	0.006	−2.396	4.056
Maximum temperature	−1.262	0.415	−0.558	−3.040	0.006	−2.119	−0.405
Relative humidity	0.385	0.166	0.366	2.314	0.030	0.042	0.728
Rainfall	0.002	0.001	−0.011	−0.081	0.039	−0.003	0.003
			Model summary				
R	R-square	Adjusted R	Standard error of the estimate	Regression sum of squares	Residual sum of squares	F	Sig.
0.802	0.642	0.568	1.358	79.558	44.286	8.623	<0.001

The intercept for the multiple linear regression model for yam yield on the climatic conditions was not significant (Table 4). The estimates of all the climatic conditions were significant in predicting yam yield per hectare of land. The estimates of minimum temperature and maximum temperature were 0.830 and −1.262, respectively with 95% CIs of (−2.396, 4.056) and (−2.119, −0.405), respectively. Therefore, a unit increase in the minimum temperature increases the yam yield by 0.830 tons when the other climatic conditions remain constant, whereas a unit increase in the maximum temperature reduces the yam yield per hectare of land by 1.262 tons when the other climatic conditions remain constant. The estimates of relative humidity and rainfall were 0.385 and 0.002, respectively with 95% CIs of (0.042, 0.728) and (−0.003, 0.003), respectively with 95% CIs of (0.042, 0.728) and (−0.003, 0.003), respectively. The overall model was significant with an R-square value of 0.642. Thus, minimum temperature, maximum temperature, relative humidity, and rainfall account for 64.2% of the variations in the yield of yam per hectare of land. These results are in line with Olakojo and Onanuga [14] but contradict the results of Magna et al. [41]. The multiple linear regression model for yam yield per hectare of land on the climatic conditions can be written as

$$\text{yam yield} = 0.830\,\text{minimum temperature} - 1.262\,\text{maximum temperature} + 0.385\,\text{relative humidtity} + 0.002\,\text{rainfall}. \tag{8}$$

4. Conclusion

The study examined the influence of minimum temperature, maximum temperature, relative humidity, and rainfall on the annual yields of maize, cassava, and yam per hectare of land in the Ashanti region of Ghana. Correlation analysis of each climatic condition on the yield of each crop per hectare of land revealed that each of the climatic conditions was significant in predicting the yields of each crop per hectare of land.

Separate multiple linear regression models were obtained for yields of maize, cassava, and yam per hectare of land on the basis of annual average monthly minimum temperature, annual average monthly maximum temperature, annual average

monthly relative humidity, and annual rainfall. Again, all the climatic conditions were significant in each regression model. The overall regression model for each yield of crop per hectare of land was significant. The multiple linear regression model for each crop revealed that 63.8% of the variations in the yield of maize per hectare of land, 74.3% of the variations in the yield of cassava, and 64.2% of the variations in the yield of yam per hectare of land are accounted for by minimum temperature, maximum temperature, relative humidity, and rainfall. The regression model revealed that increases in minimum temperature, maximum temperature, and relative humidity reduce the annual maize yield per hectare of land, while increases in rainfall increase maize yield. Increases in maximum temperature and rainfall also reduce cassava yield per hectare of land, while increases in minimum temperature and relative humidity increase it. Also, increases in maximum temperature reduce yam yield per hectare of land, whereas increases in minimum temperature, relative humidity, and rainfall increase it.

Therefore, to mitigate the effects of climate change on these crops in order to achieve the Sustainable Development Goals 1 and 2 in the Ashanti Region of Ghana, we encourage the Government of Ghana, the Ministry of Food and Agriculture, and all stakeholders in the agriculture sector to increase their campaign on the consequences of climate change on these crops. They should educate farmers on the effects of overreliance on rainfed and traditional agricultural methods, introduce them to modern methods of agriculture, and provide them with varieties of these crops with higher yielding capacities in higher temperatures.

Data Availability

The data used are made of maize yields, cassava yields, and yam yields in tonnes per hectare of land with their corresponding minimum temperature, maximum temperature, and relative humidity in the Ashanti Region of Ghana provided by the Ministry of Food and Agriculture, Accra, Ghana.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

All authors contributed equally to this work. All authors read and approved the final manuscript.

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