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Assessing the Impact of Change in Rainfall and Temperature on Crop Yields (Maize and Cassava) in Some Selected Areas in Ghana

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Abstract: ***The agriculture sector is the largest source of employment for Ghanaians and is dominated by smallholder farmers. Not much technical knowledge or scientific skills arerequired for individual local farming, this makes agricultural the major driver of poverty reduction. However, agricultural growth heavily depends on climatic variables such as rainfall patterns, atmospheric temperature, etc. the current growth is still driven by land expansion. The objective of this paper was to investigate the impact and relationship between the climatic variables mentioned above on crop yield such as maize crop and cassava crops. The said crops were selected the among the top local food crops cultivated in almost every district. In other to examine the relationship between the climatic variables on crop yield, regressionmodel's analysis was used. The significate p-value were set at 5%. We observe that there is a statistically significant difference between rainfall, temperature and area per hectare on crop yield in the three selected districts in Ghana. The results indicate that in Kwahu South district average temperature has a statistically significant relationship on crop yield (maize yield). Also, in Offinso North district, there is an indication that average temperature, average rainfall and area per hectare has a statistically significant relationship on crop yield (cassava yield). We also found that in Twifo Praso district area per hectare has a statistically significant relationship on crop yield (cassava yield). Food insecurity, and some policy plans to reduce food insecurity were also highlighted.***

Keywords: Crop yield, Regression, Temperature, Rainfall, Maize, Cassava, area per hectare

1. Introduction

Globally, various climatic studies have estimated a reduction of crop yields due to changes in surface temperature and precipitation especially for the developing countries which is heavily dependent on agriculture and lacks resources to counter the negative effects of climate change (A.KikoyoJoelNobert, 2016).

In Ghana agriculture plays a vital role in the socio-economic development of the district and the region at large, it contributes 10 percent to the national revenue (Ghana Statistical Service, 2014). Maize and cassava are some of the most important cereals crops in the whole of Africa and they are key crops for Ghana's agriculture due their diversity in use. Ghana's agricultural sector has and continues to be the largest sector of the Ghanaian economy since independence(Ghana Statistical Service, 2014). Crop framing is traditionally cultivated without any sophisticated equipment or skills. Hence this paper considers it very important to assess the factors that affect the yields of these crops. The relationship between crop yield and water supply traditionally has been based on empirical production functions which cannot be extrapolated reliably beyond the location for which they were developed (Foster e.a., 2017). (Weldearegay & Tedla, 2018)Said Food availability is diminished by change in **agricultural** productivity, decreasing in rainfall quantity and lands devoted for crop production. Food availability decline is an attribute of environmental tribulation like rainfall, atmospheric temperature, population and fluctuation in food price (Weldearegay & Tedla, 2018). However, a community where their livelihood is substance farming, rainfall is the main determinate for food production (Weldearegay & Tedla, 2018). According to (Ghana Statistical Service, 2014) published about Twifopraso estimated, 72 percent of households are engaged in agriculture. Nearly nine outof every ten households (85.7) in the rural areas as compared with about 14.3 percent ofhouseholds in the urban areas are engaged in agriculture. Majority of these farmers (86.6) are involved in crop farming. This study aimed at finding answers to the following research questions

1) How does the change in rainfall and temperature affects crop yield?
2) How significate is that impact if it does at all?
3) Does rainfall have any relationship with temperature?
4) How significate is the relationship of rainfall on temperature, if it does.

Research and policy debates on the world's drylands are increasingly focused on the challenges of undertaking coupled human-environmental assessments (Antwi-Agyei, Fraser, Dougill, Stringer, & Simelton, 2012).
The purpose of this paper is to use regression model to show the relationship between climatic variables (Rainfall and Temperature) in some selected areas in Ghana. The paper also observed the relations of rainfall and temperature on crop yield in those selected areas in Ghana.

Twifopraso
TwifoAtti-Morkwa District is one of the twenty administrative districts in the central region of Ghana(Ghana Statistical Service, 2014). The district has a soil type soils developed over granite that are well drained and respond well to phosphorus fertilizer application. They can be found in the northern part of the district around Mampoma, Morkwa, Agona and Nkwankyemaso. They are excellent for the cultivation of tree crops such as cocoa, oil palm, citrus, and coffee, and food crops such as plantain, cocoyam, banana, maize and cassava(Ghana Statistical Service, 2014).

Climatically, The District falls within the semi equatorial climatic zone marked by double maximal rainfall with a total annual mean rainfall between 1,200mm and 2,000mm. The first rainy season spans from May to June with the heaviest in June while the second rainy season is from September to October(Codjoe, Ehlers, & Vlek, 2005) (Dickson and Benneh, 2001). The main dry season is from November to February. It has fairly high uniform temperatures ranging between 26°C (in August) and 30°C (in March)(Ghana Statistical Service, 2014). The District is located between latitudes 5'50˚N and 5'51˚N and longitudes 1'50W and 1'10˚W. The general altitude is between 60 – 200 metres above sea level. The highest point in the district is Bepotsin (212 metres), west of Mfuom. The Pra River and its tributaries including Obuo, bimpong and Ongwa drain the district. The Kakum River also takes its source from the Kakum forest reserve. The District has a rolling landscape(Agricultural, 2019).

Figure 1: Shows, the district map of TwifoAtiMorkwa, where Twifopraso is Capital

OffinsoNorth Municipality

The OffinsoNorth Municipality is one of the 27 administrative districts in the Ashanti region created in the year 2007. As high as 67.7 percent of households in the district are engage in agriculture. In the rural localities, seven out of ten households (73.6%) are agricultural households while in the urban localities, 54.5 percent of households are into agriculture. Most households in the municipality (97.2%) are involved in crop farming("Offinso municipality", z.d.). Food crops for the local market such as maize, yam, cocoyam, cassava, plantain, banana, etc are predominantly produced. The Municipality experiences a wet semi-equatorial type of climate characterized by moderate to heavy rainfall annually with temperatures ranging between 21°C and 32°C. The rainfall regime is double maxima with a mean annual rainfall of 953.4mm.

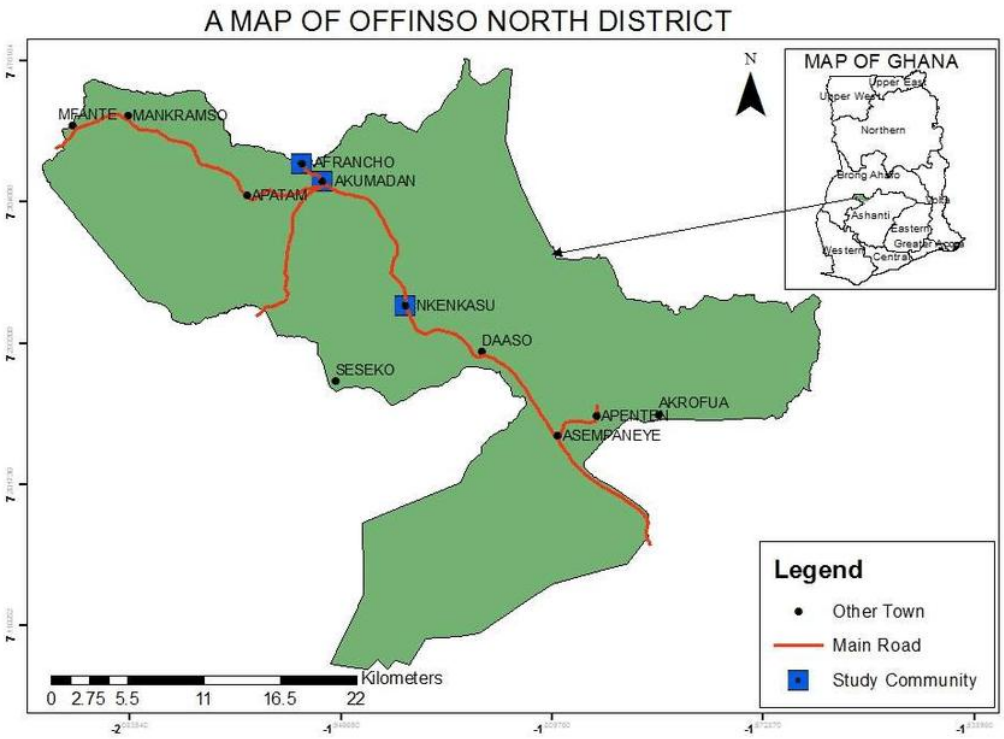

Figure 2: Shows, The district map of offinso north

Kwahu South District

The District is located between Latitudes 6° 40' N and 7° 10' N; longitudes O° 40' E and 0° 10' E; at the North-Western corner of Eastern Region with a total land area of approximately 3,095 sq km. The District is bounded to the west by Volta River, which helps in irrigation farming both for small and large scale("Kwahu afram plains south", z.d.) ("Kwahu afram plains south", z.d.)Indicated that; Of the employed population in Kwahu South District, about 77.2 percent are engaged as skilled agricultural and as high as 77.4 percent of households in the district are engage in agriculture. That's is about eight out of ten in every ruralhouseholds'localities. It has two main rainfall seasons occurring in June and October; the first rainy season starts from May to June and the second from September to October. The mean annual rainfall is between1150mm and1650mm. The dry seasons are distinct starting between November and late February. Temperatures are found to be hot ranging between February and March (36.80C and 36.60C on the average respectively), while the coldest ones are December and January (19.90C and 20.10C on the average respectively). Relative humidity is generally high throughout the year, ranging between 68.2% to 71.6% in the dry season and 81.6% and 71.6%.in the wet season.The soils are suitable for the cultivation of both food crops cassava, plantain, yam, cocoyam, maize etc.

Figure 3: Shows, Kwahu south district map

2. Methods and materials

Historical yearly weather data, including total rainfall, average atmospherictemperatures for seventeen years period (2000-2017) were acquired from theMeteorological authorities in the three catchmentsdistricts were selected.To observer interaction between temperature and crop yields per hector, the catchment temperature data were based on average daily temperature recoding from the weather stations positioned at the catchment districts.

Crop cultivation statistics (harvested area, production and yield) of maize and cassava were acquired from the Statistical Office of the Ministry of Food and Agricultural (MoFA). Some physical observations were made through primary data collection and secondary authentication. Statistical significance was defined on the 0.05 level of significance. To investigate the correlations between climate variables and crop yields on annual basis, R and E-View statistical software were used.

2.1 Temperature effects on crops

Generally, plants grow faster with increasing air temperatures up to a point. Extreme heat will slow growth and also increase moisture loss(Milošević, Savić, Stojanović, & Popov-Raljić, 2015). Various plant has various temperatures for its optimal growth. Some plants and vegetables are extremely sensitive to cold, whiles some are very sensitive to heat as well. Extremely hot or cold soil temperatures can also hamper plant growth, as well as affect seed germination. Cool temperatures can trigger the plant to reduce growth and store energy.

2.2 Statistical analysis of climatic data for trends and patterns

For calculation, R software package and E-view were used. Statistical significance was defined on the 0.001, 0.01, 0.05 and 0.1 level of significance(Nasher & Uddin, 2015). This type of test are mostly done in field of environmental science because of itssimplicity and it has a cope for missing values and values below a detection limit (Libiseller, 2004). To investigate the correlations between climate variables and crop yields on a yearly basis, daily values temperatures and rainfall were converted to yearly values. Annual or yearly values from the crop'syields were also calculated. According to the investigated correlation between crop yield variables andclimatic (rainfall and temperature) variables, influences of non-climatic factors such as improvements in crop genetics and technical factors are omitted. Furthermore, climatic influences are better detected.

3. Results

Figure 3.1 below indicate the rainfall time series plot to compare the rainfall dynamics for the three districts. The plot shows that the TwifoPraso district recorded the highest average rainfall whilst Kwahusouth district recorded the lowest average rainfall from 2000 to 2017 among the three selected districts under study. Also, we observed that the year 2013 recorded the lowest rainfall across the three selected districts in Ghana.

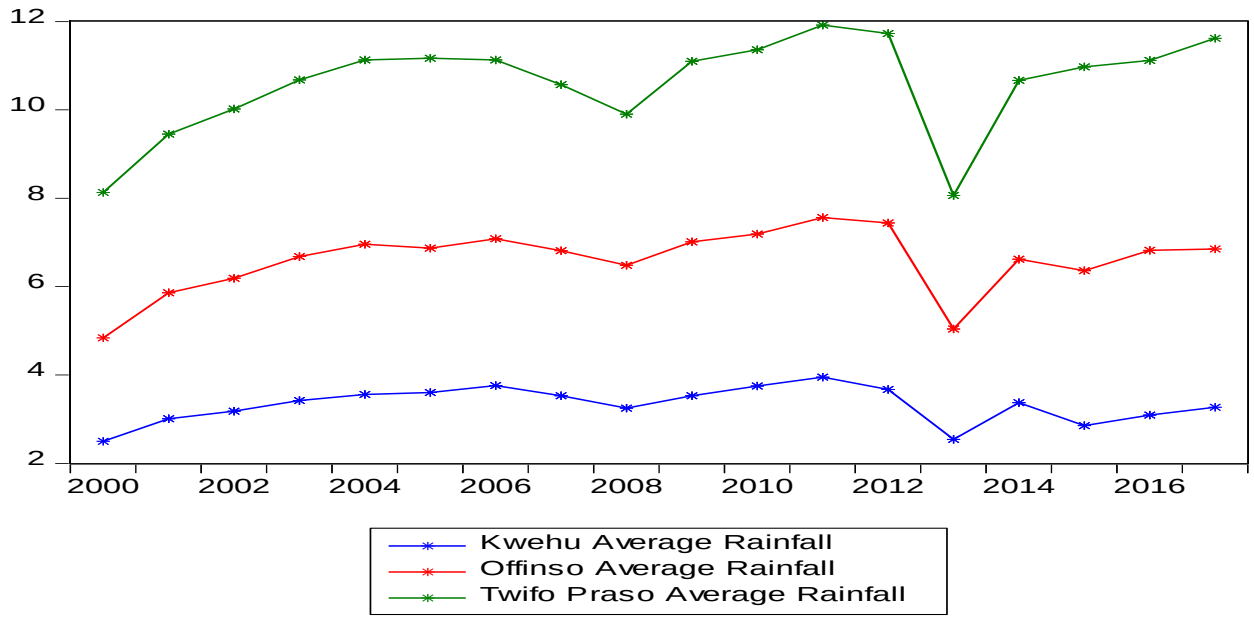

Figure 3.1: Rainfall time series plot for the three districts in Ghana from 2000 to 2017

Figure 3.2 shows the yield of cassava time series plot for the three selected districts in Ghana from 2000 to 2017. We observed that TwifoPraso districts recorded the highest yield of cassava whilst Kwahu south district recording the lowest yield of cassava across the years under study among the three selected districts in Ghana. Also, Figure 3.3 indicates that TwifoPraso districts recorded the highest yield of maize whilst Kwahu south district recorded the lowest yield of maize from 2000 to 2017 among the three selected districts in Ghana. This is an indication from Figure 3.1 that, rainfall might have a significant impact on crop yield.

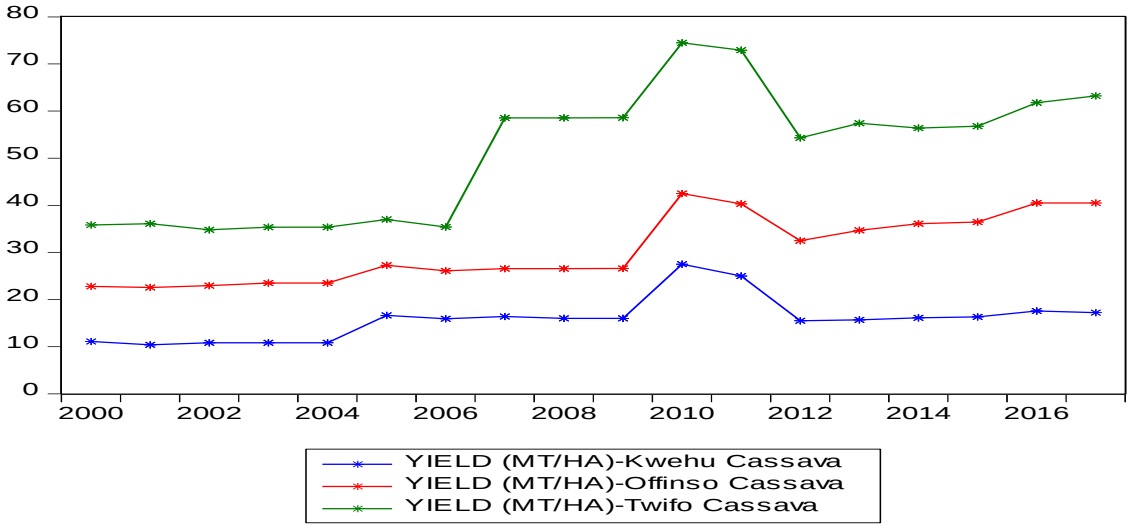

Figure 3.2: Cassava Crop Yield time series plot for the three selected districts in Ghana from 2000 to 2017.

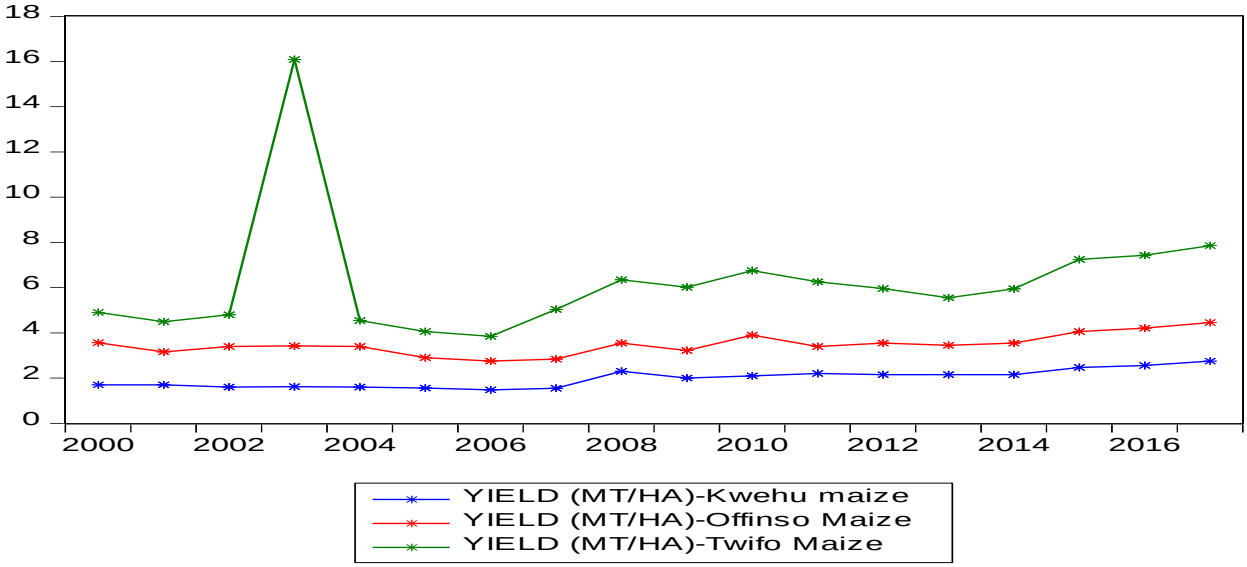

Figure 3.3: Maize Crop Yield time series plot for the three selected districts in Ghana from 2000 to 2017

Table 3.1: Linear regression summary of crop yield (Cassava and Maize) in Kwahu South District

Kwahu South Cassava				
Coefficients	Estimates	Std. Error	t-value	P-values
Intercept	-123.7007	111.0215	-1.1142	0.2840
Average Temperature	4.3214	3.7413	1.1550	0.2674
Average Rainfall	8.2833	3.5399	2.3400	0.0346
Area per Hectare	-0.0002	0.0012	-0.2147	0.8331
F.Stats=2.16, p-value=0.14, Residual std. Error=4.16, R^2=0.316, Adjusted-R^2=0.169				
Kwaahu South Maize				
Intercept	-16.1141	7.7953	-2.0672	0.0577
Average Temperature	0.6905	0.2723	2.5356	0.0238
Average Rainfall	0.0825	0.2841	0.2905	0.7757
Area per Hectare	-8.33e-05	4.15e-05	-2.0075	0.0644
F.Stats=3.47, p-value=0.045, Residual std. Error=0.327, R^2=0.427, Adjusted-R^2=0.304				

a. Dependent Variable: Crop Yield

Table 3.1 above shows the regression summary of the yields of cassava and maize in Kwahu South district. The R^2 (0.316) indicates the proportion of variance in crop yield (cassava yield) that can be explained by the independent variables.The Adjusted R^2 (0.169) value which is an estimate of the effect size, indicates that the independent variable explains 0.169 (16.9%) of the variability of the dependent variable, crop yield.The F-value of the model shows that the model is not a good fit (F=2.16, p>0.05). We observe that average temperature and average rainfall has no significant relationship on cassava yield (β_1=4.32, β_2=8.28, p>0.05). Again, there is no significant relationship between area per hectare and cassava yield (β_3=-0.0002, p>0.05). This indicates that average temperature, average rainfall and area per hectare has no statistically significant relationship on crop yield (cassava yield) in Kwahu south district.

However, the result from Table 3.1 shows that there is significant relationship between average temperature and maize yield (β_1=0.69, p<0.05). We also found that average rainfall and area per hectare has no significant relationship on maize yield (β_2=0.08, β_3=-0.00008, p>0.05). The R^2 (0.427) indicates the proportion of variance in crop yield (maize yield) that can be explained by the independent variables. The Adjusted R^2 (0.304) value which is an estimate of the effect size, indicates that the independent variable explains 0.304 (30.4%) of the variability of the dependent variable, crop yield. The F-value of the model shows that the model is a good fit (F=3.47, p<0.05). This is an indication that average temperature has a statistically significant relationship on crop yield (maize yield) in Kwahu south district.

Table 3.2: Linear regression summary of crop yield (Cassava and Maize) in OffinsoNorthDistrict

OffinsoNorthCassava				
Coefficients	Estimates	Std. Error	t-value	P-values
Intercept	-217.6802	86.5137	-2.5161	0.0247
Average Temperature	8.4020	3.0826	2.7257	0.0164
Average Rainfall	7.1907	2.5292	2.8431	0.0130
Area per Hectare	-0.0018	0.0006	-3.2211	0.0062
F.Stats=7.56, p-value=0.003, Residual std. Error=3.066, R^2=0.618, Adjusted-R^2=0.537				
OffinsoNorthMaize				
Intercept	-15.7560	5.3262	-2.9582	0.0104
Average Temperature	0.6293	0.1907	3.3004	0.0053
Average Rainfall	0.2914	0.1600	1.8217	0.0899
Area per Hectare	-1.82e-05	1.42e-05	-1.2812	0.2209
F.Stats=4.35, p-value=0.023, Residual std. Error=0.190, R^2=0.482, Adjusted-R^2=0.372				

a. Dependent Variable: Crop Yield

Table 3.3: Linear regression summary of crop yield (Cassava and Maize) in TwifoPraso District

TwifoPraso Cassava				
Coefficients	Estimates	Std. Error	t-value	P-values
Intercept	58.7215	91.1440	0.6443	0.5298
Average Temperature	-2.5446	3.4239	-0.7432	0.4697
Average Rainfall	-1.5210	1.8856	-0.8067	0.4334
Area per Hectare	0.0046	0.0005	10.1112	0.0000
F.Stats=38.56, p-value=0.0001, Residual std. Error=3.112, R^2=0.892, Adjusted-R^2=0.869				
TwifoPraso Maize				
Intercept	-75.0978	72.8594	-1.0307	0.3201
Average Temperature	2.6527	2.7128	0.9779	0.3447
Average Rainfall	1.7031	1.6356	1.0413	0.3154
Area per Hectare	0.0005	0.0007	0.6617	0.5189
F.Stats=0.592, p-value=0.630, Residual std. Error=2.686, R^2=0.113, Adjusted-R^2=-0.078				

a. Dependent Variable: Crop Yield

Table 3.2 above displays the regression summary of the yields of cassava and maize in OffinsoNorthdistrict. The R^2 (0.618) indicates the proportion of variance in crop yield (cassava yield) that can be explained by the independent variables. The Adjusted R^2 (0.537) value which is an estimate of the effect size, indicates that the independent variable explains 0.537 (53.7%) of the variability of the dependent variable, crop yield. The F-value of the model shows that the model is a good fit ($F=7.56$, $p<0.05$). We observe that average temperature, average rainfall and area per hectarehas a significant relationship on cassava yield ($\beta_1=8.40$,$\beta_2=7.19$, $\beta_3=-0.0018$,$p<0.05$). This indicates that average temperature, average rainfall and area per hectare has a statistically significant relationship on crop yield (cassava yield) in Offinso North district.

Conversely, from Table 3.2,the R^2 (0.482) indicates the proportion of variance in crop yield (maize yield) that can be explained by the independent variables. The Adjusted R^2 (0.372) value which is an estimate of the effect size, indicates that the independent variable explains 0.372 (37.2%) of the variability of the dependent variable, crop yield. The F-value of the model shows that the model is a good fit ($F=4.35$, $p<0.05$). The result shows that average temperature has a significant relationship on maize yield ($\beta_1=0.63$, $p<0.05$). We also found that average rainfall and area per hectare has no significant relationship on cassava yield ($\beta_2=0.29$, $\beta_3=-0.00002$, $p>0.05$). This is an indication that average temperature has a statistically significant relationship on crop yield (maize yield) in Offinso North district.

Table 3.3 above shows the regression summary of the yields of cassava and maize in TwifoPraso district. The R^2 (0.892) indicates the proportion of variance in crop yield (cassava yield) that can be explained by the independent variables. The Adjusted R^2 (0.869) value which is an estimate of the effect size, indicates that the independent variable explains 0.869 (86.9%) of the variability of the dependent variable, crop yield. The F-value of the model shows that the model is a good fit ($F=36.56$, $p<0.05$). We observe that average temperature and average rainfall has no significant relationship on cassava yield ($\beta_1=-2.54$, $\beta_2=-1.52$, $p>0.05$). However, we found that area per hectare is significantly related to cassava yield ($\beta_3=0.0046$, $p<0.05$). This indicates that area per hectare has a statistically significant relationship on crop yield (cassava yield) in TwifoPraso district.

Also, from Table 3.3, the R^2 (0.113) indicates the proportion of variance in crop yield (maize yield) that can be explained by the independent variables. The Adjusted R^2 (-0.078) value which is an estimate of the effect size, indicates that the independent variable explains -0.078 (-7.8%) of the variability of the dependent variable, crop yield. The F-value of the model shows that the model is not a good fit ($F=0.598$, $p>0.05$). The result shows that average temperature, average rainfall and area per hectare has no significant relationship on maize yield ($\beta_1=2.65$, $\beta_2=1.70$, $\beta_3=0.0005$,$p<0.05$). This is an indication that average temperature, average rainfall and area per hectare has no statistically significant relationship on crop yield (maize yield) in TwifoPraso district.

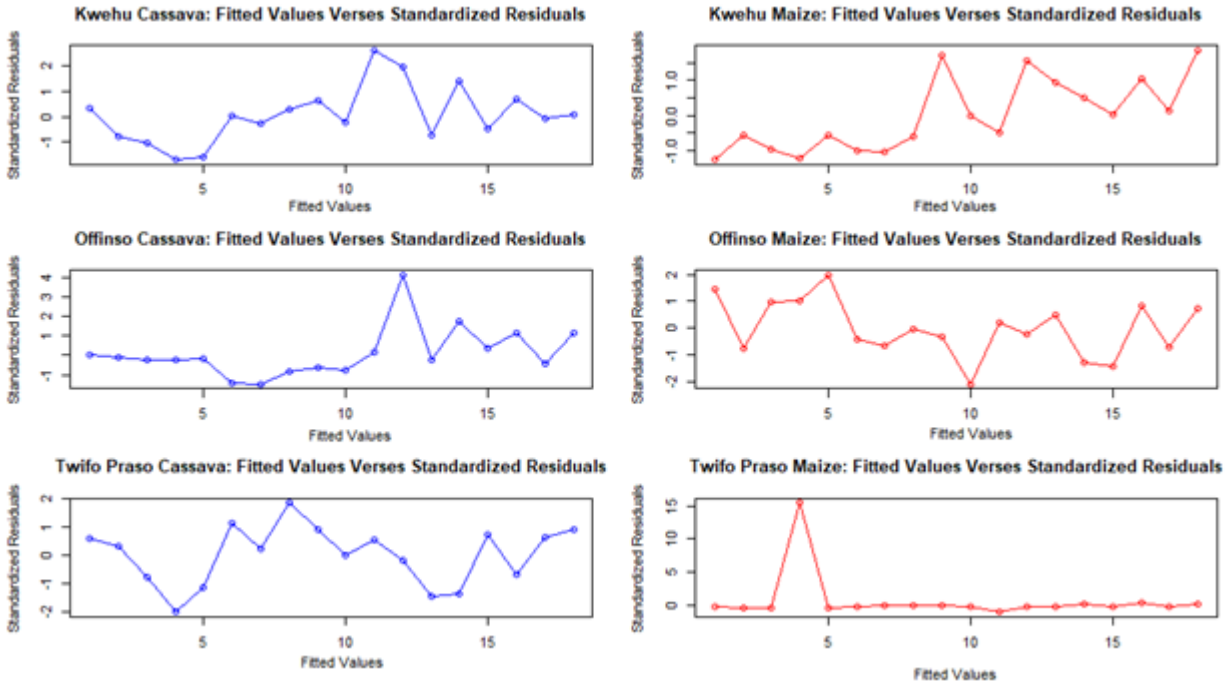

Figure 3.4: Fitted values versus standardized residuals for the three districts in Ghana

Figure 3.4 shows the fitted values against the standardized residuals for modelling rainfall, temperature and area per hectare on crop yield (cassava and maize) in the three selected districts to illustrate their graphical relationship. The three graphs on the left of the figure indicates the fitted values versus the standardized residuals for the three selected districts (Kwahu South, OffinsoNorthand TwifoPraso), whilst the remaining three graphs on the right side of the figure represent the fitted values versus the standardized residuals for the three districts in Ghana.

We observe that there is a statistically significant difference between rainfall, temperature and area per hectare on crop yield in the three selected districts in Ghana. We found that the plots across the three districts doessuggest some form of distribution with distinct trends indicating that the stochastic component is white noise. Thus, there is a no striking departure of randomness in this figure.

4. Recommendation

Even though not all the current knowledge about future climate projections and its impact on maize crops and cassava crops production in Ghana has been reviewed in this paper. The findings from the concentrated area of this paper has reveal a lot that is very helpful for every future researcher and policy makers.
Although variations existed within mostof the future climate projections, the common agreement was that temperatures may keep on rising.Rainfall patterns may become more erratic and many areas are likely to experience reduction in rainfall.Areas suitable for the cultivation of maize and cassava are likely to decrease.

1) Even though farmers in Ghana already adopting to heat and drought tolerant varieties crops even for maize and cassava, the future climatic scenarios would need more better resistant tolerant varieties.
2) Plant breeding institutions both local and international should be involve to get better breeds of crops for the farmers.
3) The local farmers need to be train about water conservation practice.
4) More irrigation framing, means more equipment, more cost for framing hence increase food price. Farmers need to diversify their crops in order in lessen the impact of climate change should a specific crop fails.

5. Conclusion

The study concludes that, in Kwahu South district average temperature has a statistically significant relationship on crop yield (maize yield). Also, in OffinsoNorth district, there is an indication that average temperature, average rainfall and area per hectare has a statistically significant relationship on crop yield (cassava yield). We also found that in TwifoPraso district area per hectare has a statistically significant relationship on crop yield (cassava yield).

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7. Contributions

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8. Declaration

W. Osabutey, Y. Shaofeng , X. Jianchun and P.Gbolonyo certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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