UDS International Journal of Development [UDSIJD]
Volume 5 No. 1, June, 2018
http://www.udsijd.org
ISSN: 2026-5336

ANALYSIS OF RAINFALL AND TEMPERATURE EFFECTS ON YAM YIELD IN THE KRACHI EAST DISTRICT OF GHANA

Magna, E. K., Ofori, B. D., Ojo, S.

Institute for Environment and Sanitation Studies, Faculty of Basic and Applied Science, University of Ghana, P.O. Box 209, Legon-Accra, Ghana

Abstract

The study determined the relationship between selected climatic parameters and yam yield in the Savannah-transitional zone of Ghana. The study used descriptive and multiple linear regression analysis to analyse meteorological data (i.e. temperature and rainfall) from the Ghana Meteorological Service (GMA) and the yam yield data from the Ministry of Agriculture (MoFA) from 2005-2015. The Pearson product-moment correlation showed a weak negative and positive relationship for rainfall, temperature and yam yield. A multiple linear regression analysis for rainfall (X2), temperature (X1) and yam yield (Y) was derived as: Y=11.243+0.204X_1-0.002X_2. It therefore discovered that only 10.6% of the proportion of variation of yam yield was explained by rainfall and temperature during the period of study. 89.4 % of the yam yield as explained by the model was probably due to exogenous (external) factors. The research showed that climatic variables (i.e. rainfall and temperature) have little influence on yam yield in the Krachi East District during the period of study. In conclusion government should introduce new improved yam breeding programmes/technology, employ modern farming tools and avail farming inputs/credit facilities to farmers to expand and enhance their efficiency in yam production to ensure profitability of yam sales.

Keywords: Temperature, Rainfall, Yam, model, Dambai, Crop production

Introduction

Yams (*Dioscorea species*) are annual root tuber-bearing plants with more than 600 species out of which six are socially and economically important in terms of food, cash and medicine (Verter & Bečvářová, 2015). Yams are farmed on about 5 million hectares of land in about 47 countries in the tropical and subtropical regions of the world with more than 54 million tons of it produced in Sub-Sahara Africa annually on 4.6 million hectares (IITA, 2010). Yam is predominantly produced and consumed in West Africa, with Nigeria being the largest producer and Ghana the leading exporter of the commodity (Aidoo *et al*., 2009; Osei-Adu, 2016). Yam export brings foreign exchange for the country's development, providing jobs and income along the yam value chain. In Ghana, agriculture engages about 57 % of the economically active population in Ghana and contributes about 30% to Gross Domestic Product (GSS, 2005). Yam production alone contributes about 17 per cent of agricultural GDP, guaranteeing household food security (Osei-Adu, 2016; Adam *et al.,* 2014). In Ghana, Yam cultivation occupies 11.6% of the total cropped area and annual production is estimated to be 5.8 million metric tonnes in 2009 (Verter & Bečvářová, 2015). The table below shows the annual yam production in the world and in some selected West African countries (Cote d Ivoire, Nigeria and Ghana) from 1961-2012.

Table 1: Annual Yam production in the world, Ghana, Côte d Ivoire, and Nigeria (1961–2012)

Yams Elements	Areas	1961	1980	1985	1990	1995	2000	2010	2012
Output in MT									
Production (MT million)	World	8.32	12.01	12.11	21.76	33.24	39.55	53.60	58.75
Production (MT million)	Côte d Ivoire	1.15	2.41	2.65	3.17	3.62	4.45	5.39	5.67
Production (MT million)	Ghana	1.10	.650	.987	.877	2.13	3.36	5.96	6.64
Production (MT million)	Nigeria	3.50	5.25	4.74	13.62	22.82	26.21	34.16	38,00
Production (% of the world)	Nigeria	42	44	39	63	69	66	64	65
Yield									
Yield (Hg/Ha)	World	72,345	88,155	68,138	96,902	102,999	98,088	108,471	116,648
Yield (Hg/Ha)	Côte d Ivoire	76,667	106,978	103,781	99,609	97,751	88,172	65,000	67,960
Yield (Hg/Ha)	**Ghana**	**73,333**	**57,522**	**55,449**	**73,451**	**120,710**	**128,847**	**154,841**	**155,717**
Yield (Hg/Ha)	Nigeria	77,778	105,382	56,405	106,771	107,734	98,984	119,073	131,034
Yield (MT/Ha)	Nigeria	7.8	10.5	5.6	10.7	10.8	9.9	11.9	13.1

Source: FAOSTAT, 2013

The production, transportation, processing and marketing of yam also provides employment for rural smallholder farmers, especially women, who play a critical role as aggregated and marketers of yam (Zakaria *et al*., 2014). Mignouna *et al.,* (2015) observed that yam serves as vital source of calories in Benin, Côte d'Ivoire and Ghana and features prominently in social rites such as, thanksgiving, marriages and funerals in the region.

However, its production is confronted with some constraints and challenges. The key among them are the scarcity of good quality planting material (seed yam) among local farmers and improved seed varieties, high levels of post-harvest losses, high production costs, low and declining soil fertility, moisture stress, incidence of pests and diseases, and limited opportunities for smallholder farmers mainly rural women (Asante *et al.,*2014*;* Toba, 2014).

The climate in Ghana varies by agro-ecological zones and is broadly divided into three ecological zones: Savannah, Forest and Coastal zones (Issahaku & Maharjan, 2014). The Forest-Savannah transition zone is considered as the food hub of the country and holds great potential for increased food productivity (Oppong-Anane, 2001; Ofori *et al.,* 2015). The Savannah zone where most of the country's yam is produced is characterized by unimodal rainfall pattern (April–October). This together with the climatic, soil and other physical conditions makes the Savannah zone even more suitable for cultivation of cereals like maize, sorghum, millet and rice (Issahaku & Maharjan, 2014). The Ghana Environment Protection Agency (GEPA) concludes from analysis of climate change impact on cereals that it will reduce yield of maize by 6.9 % in 2020 but that of millet will remain unaffected because it is more drought-tolerant (Maharjan & Issahaku, 2014). The extent to which the climate variations in this ecological zone will affect the country's yam production is still unknown.

Global mean temperature has risen approximately by 0.74◦C in the past and this is likely due to anthropogenic activities that have elevated greenhouse gas concentrations to unprecedented levels (IPCC, 2014; Srivastava *et al.* 2012). Srivastava *et al*. (2012) further noted that in the case of agriculture, changes in temperature, rainfall and atmospheric CO_2 concentration can have significant effects on crop production. Analysis of a 40-year data (1960-2000) from the Ghana Meteorological Agency reveals a progressive and visible rise in temperature with a simultaneous decline in rainfall across all agro-ecological zones (EPA, 2007). This situation will affect the national economy because it is dependent on climate sensitive-sectors such as agriculture, energy and forestry (Nyuor *et al.,* 2016).

Yams are annual rain fed crops which grow for 6-12 months depending on the cultivar, ecology and soil properties in the production area. Eruola, *et al.,* (2012) suggested a temperature range of 21-30.5℃ and optimal annual rainfall of 1000-1500mm for a good yam growth and yield. A research conducted by Zakaria *et al., (*2014) stated that there is a statistically significant relationship between rainfall variability and yam yield. This indicates that there is an important relationship between rainfall and yam production. Previous climate impact studies on crop production in Ghana tend to be more reliant on crop simulation models, describing the relationship between climate and crop growth (Issahaku & Maharjan, 2014). In spite of the newly developed technique of propagating yam through vine cuttings by the Council for Scientific and Industrial Research-Crops Research Institute (CSIR-CRI) and its partners to farmers (Asante *et al*., 2011), subsidies in agrochemicals by the government and increasing global market demand for yams from Ghana (Ansah & Tetteh, 2016), the potential for higher production and export volumes is dwindling. Climate change over the next few decades will affect agriculture and that will adversely affect food security (Chukwuone, 2015). The extent to which this climate change will impact on yam yield in Ghana especially within the transitional Savannah zones and the semi-deciduous zones is still unknown. It is against this backdrop that this study focuses on examining the variation of some climatic variables and their impacts on yam production in the Savannah ecological zone of Ghana. The study used meteorological data (2000-2016) and yam yield from the Krachi East District from the period 2005–2016.

Profile of the Study Area

The Krachi East District was created on the 19th of August, 2004 with Dambai as its capital under Legislative Instrument (L.I. 1755). The study area, Dambai has an estimated surface area of 2,759.4 square kilometres with water covering about 15%. It lies between latitude 7º 40'N and 8º 15'N and longitudes 0º 6'E and 0º20'E. Agriculture accounts for about 72.2% of the District labour force, commerce for about 11% while manufacturing and other sectors account for about 16.8%. The main crops grown in the District include yam, cassava, maize, rice, and groundnut. The principal cash crops grown in the District include oil palm, soya beans, groundnuts and tomatoes.

The District is located in the transitional zone between the Northern Savannah and the moist semi-deciduous forest characterized by short scattered drought resistant trees that get usually burnt by bushfires and scorched by the sun during the long dry season. Significant portion of the forest vegetation could be found in the southern part of the district.

The District has a tropical climate and a mean maximum temperature of 30^0C usually recorded in March while mean minimum temperature of 25.5^0C is usually recorded in August. The District experiences alternating wet and dry seasons each year. The annual rainfall for the South-Eastern part of the District is a double maxima rainfall. It occurs between May to June and October to November. The northern portion, however, experiences single maxima over the period July to September which peaks in August. The dry season starts from November to March. Relative humidity is high in the rainy season, about (85%) and very low in the dry season (25%).

The district has a total population of 116,804. The male population is 48% whilst the female population constitutes 52% of the projected population. It is basically rural with about 72.3% of the population concentrated in rural settlements (GSS, 2005).

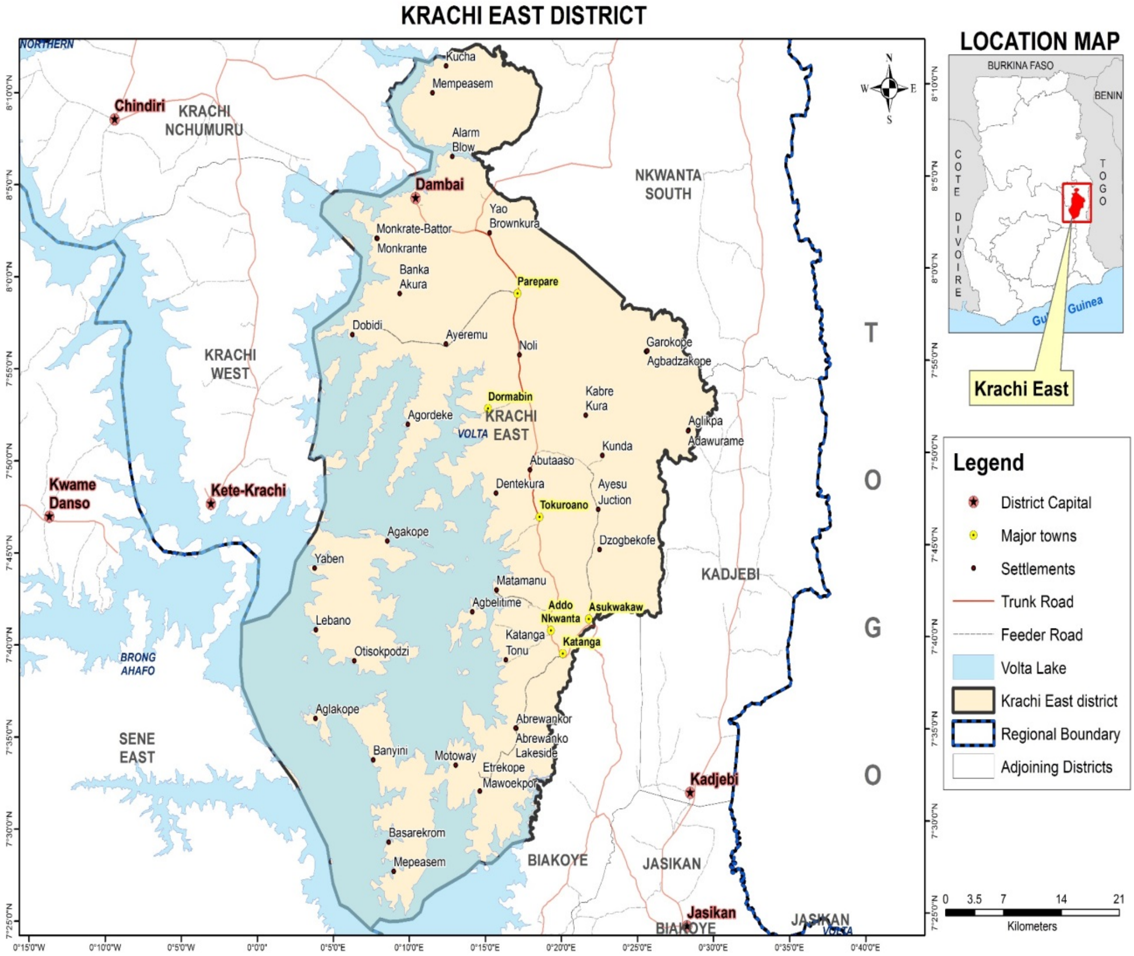

Figure 1: *Map of Krachi East District of Ghana*

Materials and Methods

Data collection and analysis

Climate data was sourced from Ghana Meteorological Agency and yam yield statistics from Ministry of Food and Agriculture. Data was analyzed with the Statistical Package for Social Scientists (SPSS 23.0 version) specifically using multivariate correlation and linear regression. Graphs were produced with Microsoft Excel 2010.

The 2000-2016 data on the environmental variables (temperature and rainfall) was sourced from the Ghana Meteorological Agency (GMA), while the corresponding yam production data (in metric tons) over the last eleven years (2005-2015) in the Krachi East District from the Ministry of Food and Agriculture. Interviews and a focus group discussion (FGD) were held with the yam farmers in Addo Nkwanta and the Krachi East District capital, Dambai. FGD of yam farmers in these communities was done with assistance from the District Agricultural Extension Officer. The issues discussed in the FGD as well as the interviews included: 1. Their experiences of the climate change on their yam farming and the adaptive mechanisms they implored to boost yam production 2. Their knowledge and awareness of climate change issues and the constraints confronted by the farmers during yam cultivation.

Figure 2: ***A photograph showing a Focus Group Discussion by farmers in Dambai***
Source: ***Photographed by Authors in 2017***

Six FGDs were held in both Addo Nkwanta and Dambai. Each group was made of about 25 yam farmers including women. An average of 30 minutes was spent by each group in the discussions. The FGD and the interviews were conducted in the local dialects (Twi and Konkomba) but were subsequently translated into the English language by the Agricultural Extension Officer. All the farmers selected were involved in cassava and yam-based cropping, and other crops cultivation. Other methods of collecting data included reviewing books, journals and analysing data from the GMA and the MoFA, which were related and relevant to the topic of study.

Model Specification

The study employs multiple linear regression model, to determine the relationship between yam production and the variabilities that exist between rainfall and temperature in the Krachi East District from 2005 to 2015.

The multiple regression analysis model specified below was used: $Y = \propto + \beta_1 X_1 + \beta_2 X_2 + \varepsilon_i$

Where: $\propto = intercept\ on\ Y \quad Y = Yam\ yield\ (mt/Ha)$

β_1 and β_2 $= coefficients\ of\ temperature\ and\ rainfall\ respecively$

$X_1 = temperature \quad X_2 = rainfall \quad \varepsilon_1 = model\ error$

Results and Discussion

As mentioned in the introduction, the yam production data was obtained from the Ministry of Food and Agriculture (SRID, 2005-2015).

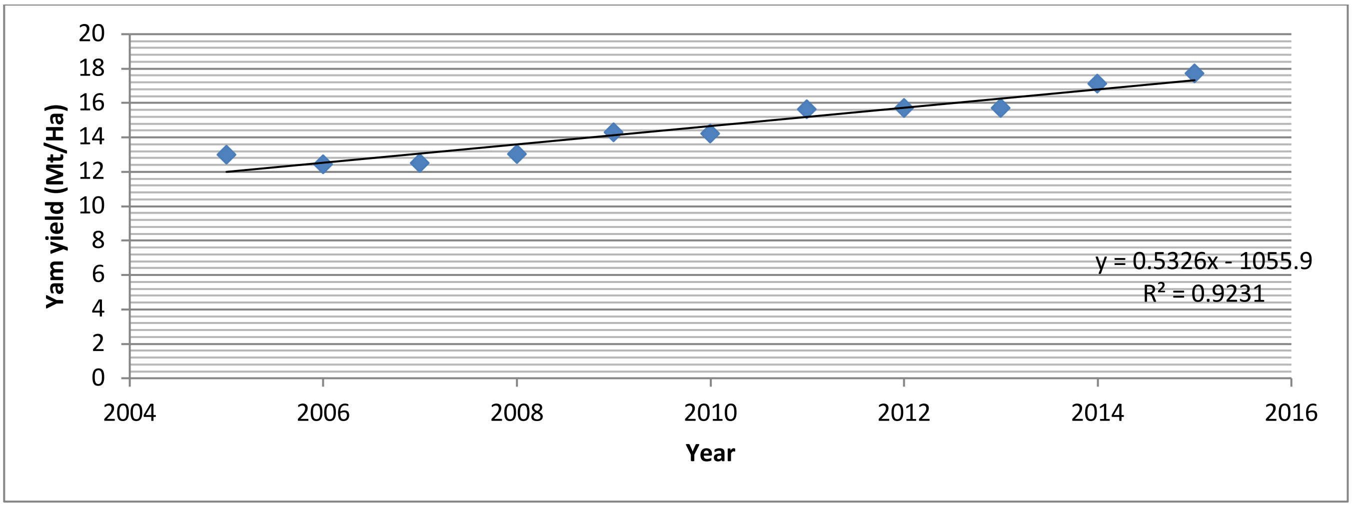

Figure 3: ***Trend in the Yam production in the Krachi East District from 2005-2015***

Source: ***Authors computation from MoFA data (SRID, 2005-2015)***

Production of yam tubers in the eleven years of the study period, in 2005 dropped from12.97 metric tons per Ha to 12.50 metric tons per Ha in 2007. There was a continuous rise in the production of yams from 2008 to 2015 (17.70 Metric tons per Ha). There was therefore a minimal variation in the yam yield throughout the study period in the Krachi East District as shown in figure 3 above.

Table 2: **Multiple linear regression model summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.325[a]	.106	-.118	1.94407

Predictors: (Constant), Annual average temp, Annual aver. Rainfall

Source: Authors' computation from GMA data from 2000-2016

Table 3: Dependent Variable: Yam Production Coefficient

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.243	49.092		.229	.825
	Annual aver. rainfall	-.002	.002	-.295	-.736	.483
	Annual aver. temp	.204	1.668	.049	.122	.906

Source: Authors' computation from GMA data from 2000-2016

The coefficients in Table 3 were used to test the predictive values of all the variables in this study which included average annual rainfall and average annual temperature. Rainfall and temperature were not statistically significant at 0.483 and 0.906 respectively. The coefficients in Table 3 shows that the annual average rainfall has a negative effect on the annual yam yield while rainfall has a more pronounced positive effect on yam production. Between the variables, average annual rainfall $B = -0.295, t(-0.73), p > 0.05$ predicts better influence on yam production than the annual average temperature $B = 0.049, t\ (0.12),\ p > 0.05$.

From Table 3, the multiple linear regression model for Yam yield, temperature and rainfall is:

$$\boldsymbol{Y = 11.243 + 0.204X_1 - 0.002X_2}$$

Relationship between Rainfall, Temperature and Yam yield in Krachi East District

There was a continual decrease in the amount of rainfall in the Krachi East District in the study period as shown in Figure 4 below. The highest and least rainfall during the period of study was $1853.50mm$ and $760.60mm$ recorded in 2008 and 2015 respectively. The results showed that the rainy season starts from the month of May and ends in October. Occasionally, there were a few recorded rainfall in March. The trend in the annual rainfall for the study area is illustrated in Figure 4 below:

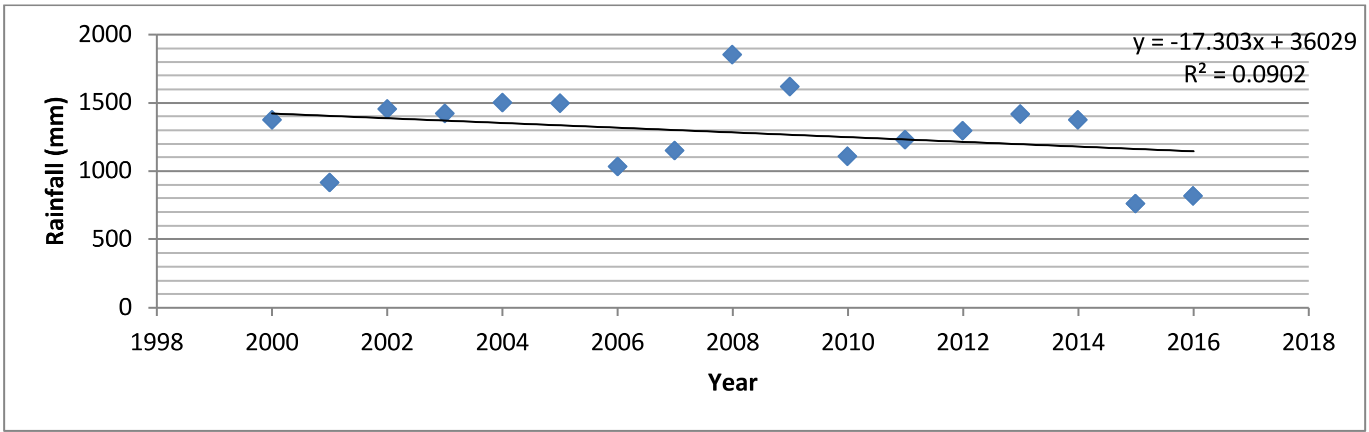

Figure 4: ***Trend of annual rainfall in the Krachi East District of Ghana from 2000-2016***
Source: Authors computation from GMA data from 2000-2016

Pearson product-moment correlation establishes a relationship between the average annual rainfall and yam yield with a correlation coefficient of -0.32. This means that there was a very weak negative correlation between the variables, thus an increase in the average annual rainfall will result in a decrease in the annual yam yield and vice versa. This claim is supported by the results in Figures 3 and 4; as the rainfall decreases over the period, the yam yield increases. The result of the intercept indicates that the annual yam yield produced will be 11.243 metric tons per hectare if the average annual rainfall and average annual temperature were $0mm$ and 0°C respectively. The coefficient of regression of rainfall (-.002) from the regression model also showed that an increase in the average annual rainfall by $1mm$ will decrease the annual yam yield by $0.002 metric\ tons\ per\ hectare$. There was therefore an inverse relationship between annual yam yield and the average annual rainfall in the Krachi East District during the period of study.

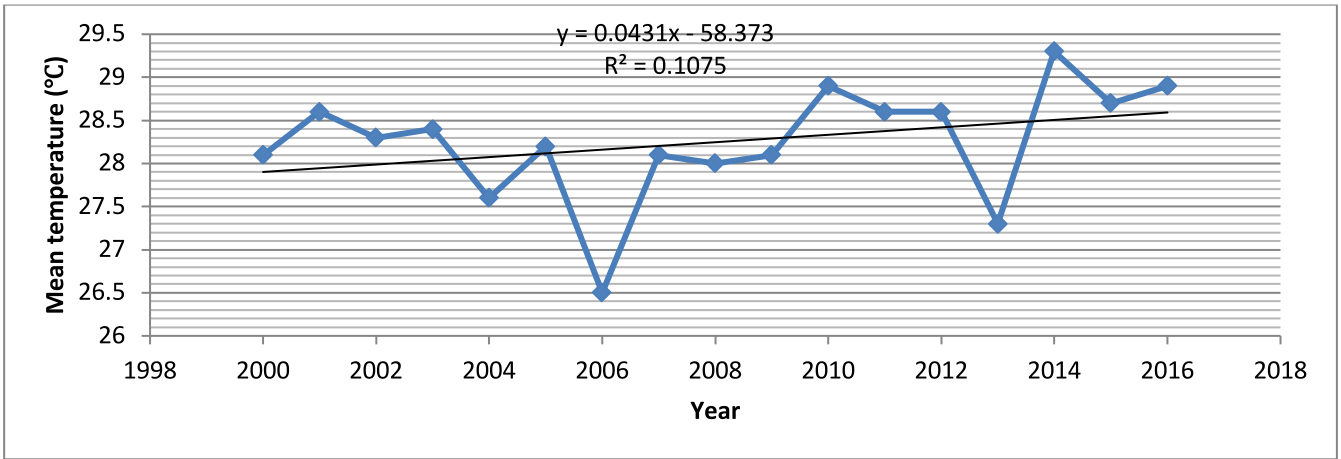

Figure 5: Trend in the mean annual temperature of Krachi East District of Ghana
Source: Authors computation from GMA data from 2000-2016

There was a fair increase in the mean annual temperature over the study period ($R^2 = 0.1075$). This was a reflection of the overall annual mean temperature range of 2.8℃ and the trend as indicated in Figure 5. The study revealed a maximum and minimum mean annual temperature of 29.30℃ in 2014 and 26.50℃ in 2006 respectively over the study period. The mean temperature range showed that there were very little fluctuations in temperature for the years under consideration. It was worth noting from the results that the average temperature of 28.30℃ and the average rainfall of 1303.47mm were not different from the optimum requirement for suitable yam production suggested by Eruola, *et al.,* (2012).

To establish the relationship between the average annual temperature and annual yam yield, Pearson product-moment correlation was computed. The results revealed a positive correlation coefficient of 0.21 indicating a very weak relationship between the average annual temperature and annual yam yield. It was also shown from the model that for an average increase in temperature by 1℃, the average variation in the annual yam yield will increase in Krachi East District by 0.204 metric tonnes per hectare. It also observed that, the model could explain about 10.6% (*i.e.* R square = 0.106) of the variation in the annual yam yield in the study area as shown in Table 2. Therefore, about 89.4% of the variation in the yam production in the Krachi East District at the time of study was explained by other exogenous/external factors such as; improved yam setts, good soil fertility, regular extensive services and better farm practices.

Farmers interviewed during the Focus Group Discussion indicated the following extreme climatic conditions that militate against yam production: They were particularly concerned about the frequent increase in dry days (drought) and high temperatures during the yam farming times. They also complained about the late coming of rains and the decrease in its intensity over the years. One of the farmers said; *"In the past, we used to plant the yams early and do early harvesting to sell and make so much profit. The rains of late come very late causing the yam setts to go bad. We run at a loss during late harvest"*. The results from the FGD concerning the rise in temperature and ultimate decrease in the rainfall and its intensity were not different from the research findings. To reduce the effect of climate change on their yam production, farmers proposed the following strategies: increasing farm size, early planting and harvesting, rearing livestock, practicing afforestation, increase in number of weeding of cropped land, use of weather-resistant yam varieties and encouraging mixed cropping. The constraints on the yam farming activities were not different from the findings of Asante *et al., (*2014) and Toba, (2014). Other constraints included; high cost of farm machineries, poor access to roads and inadequate market infrastructures for yams.

Conclusion

The result from the research showed that the mean annual temperature increases over the years, but rainfall pattern decreases. The climatic factors (temperature and rainfall) have little influence on yam yield in Krachi East over the period of study. The increase in yam yield within the locality over the period of study was probably due to an improvement in the agriculture technologies, regular extension services, quality yam setts, good soil fertility and improved farm practices by the yam farmers. The results also showed a decrease in the amount of annual rainfall over the period.

In view of the results obtained, it is suggested that further research be conducted to understand better the relationship between yam yield and soil fertility, yam setts varieties and farmers' knowledge on climate adaptation strategies. Also, since a bulk of Ghana's economy relies on agriculture, adequate budget should be allocated to the agricultural sector to assist farmers invest in irrigation farming; acquire machinery and other agrochemicals to boost yam production in Ghana.

References

Adam, H., Zakaria, H., & Abujaja, A. M. (2014). Sociocultural implications on innovation adoption: the case of adoption of yam minisett technology among farmers in Northern Region, Ghana. ***Journal of Agricultural Economics, Extension and Rural Development,*** 7: 105-113.

Aidoo, R., Ohene-Yankyera, K., Marfo, K., & Blaise, N. G. (2009). Patterns and determinants of yam consumption in a Ghanaian urban center: Household demographics, income and gender Perspectives. ***Securing Livelihoods through Yams,*** 129.

Ansah, I.G.K., & Tetteh, B.K. (2016). Determinants of yam postharvest management in the Zabzugu District of Northern Ghana. ***Advances in Agriculture***, 2016.

Asante, B. O., Otoo, E., Acheampong, P., Osei-Adu, J., Nsiah-Frimpong, B. (2011). Willingness to adopt the vine multiplication technique in seed yam production in the forest savanna transition agro-ecological zone, *Ghana. Journal of Development and Agricultural Economics,* 3(16), 710-719

Asante, B.O., Villano, R.A., & Battese, G.E. (2014). The effect of the adoption of yam minisett technology on the technical efficiency of yam farmers in the forest-Savanna transition zone of Ghana. ***African Journal of Agricultural and Resource Economics,*** 9(2): 75-90.

Nyuor, B. A., Donkor, E., Aidoo, R., Saaka Buah, S., Naab, J. B., Nutsugah, S. K., Zougmoré, R. (2016). Economic impacts of climate change on cereal production: implications for sustainable agriculture in Northern Ghana. ***Sustainability*** 8(8): 724.

Chukwuone, N. (2015). Analysis of impact of Climate Change on growth and yield of yam and cassava and adaptation strategies by farmers in Southern Nigeria ***AGRODEP Working Paper*** 0012. Available at http://www.agrodep.org/sites/default/files/AGRODEPWP0012.pdf

EPA (2007). Climate change and the Ghanaian economy. ***Policy Advice Series*** (1), Accra: EPA.

Eruola, A. O., Bello, N. J., Ufoegbune, G. C., & Makinde, A. A. (2012). Effect of variety selection on growth, development and yield of white yam in south-western Nigeria. ***International Journal of Agriculture and Forestry,*** 2(3): 101-104.

FAOSTAT, D. (2013). Food and agriculture organization of the United Nations. Statistical database. Available at http://www.fao.org/docrep/018/i3107e/i3107e.PDF

Ghana. Statistical Service, (2005). ***2000 Population and Housing Census,*** [Krachi East District]: Greater Accra Region (Vol. 5). Ghana Statistical Service.

International Institute of Tropical Agriculture (2010). Yams, Facts and Figures. Available at https://www.integratedbreeding.net/731/communities/communities/facts-figures/yam-facts-figures

Issahaku, Z. A., & Maharjan, K. L. (2014). Climate change impact on revenue of major food crops in Ghana: Structural Ricardian Cross-sectional analysis. In ***Communities and Livelihood Strategies in Developing Countries*** (pp. 13-32). *Springer Japan*.

Maharjan, K.L., & Issahaku, Z.A., (2014). Communities and Livelihood Strategies: An Overview. In ***Communities and Livelihood Strategies in Developing Countries*** (pp. 1-11). *Springer Japan.*

Mignouna, D. B., Abdoulaye, T., Akinola, A. A., Alene, A., & Nweke, F. (2015). Factors influencing the use of selected inputs in yam production in Nigeria and Ghana. ***Journal of Agriculture and Rural Development in the Tropics and Subtropics*** (JARTS), 116(2): 131-142.

Ofori, B. D., Ayivor, J. S., Pabi, O., & Gordon, C. (2015). Agro ecological niches as ecosystem-based adaptive option to environmental change in the forest-savannah transition zone of Ghana. ***Journal of Sustainable Development***, 8(9): 281.

Oppong-Anane, K., (2001). ***Country Pasture/Forage Resource Profiles, Ghana***. Rome: Food and Agriculture Organization of the United Nations (FAO).

Osei-Adu, J., Amengor, P. P. A. N. E., & Sagoe, R. (2016). Input supply structure for yam production in Ghana. ***Journal of Economics and Sustainable Development***, 7(2).

Pachauri, R.K., Allen, M.R., Barros, V.R., Broome, J., Cramer, W., Christ, R., Church, J.A., Clarke, L., Dahe, Q., Dasgupta, P. and Dubash, N.K., (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and

III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p.151). IPCC.

SRID. ***Agriculture in Ghana 2005-2015***, Statistics, Research and Information Directorate – Ministry of Food and Agriculture, Accra-Ghana. 2005-201

Srivastava, A. K., Gaiser, T., Paeth, H., & Ewert, F. (2012). The impact of climate change on Yam (*Dioscorea alata*) yield in the savannah zone of West Africa. ***Agriculture, ecosystems & environment***, 153: 57-64.

Toba, O. J. (2014). Gross margin analysis and constraints to yam production in Osun State, Nigeria. ***World Journal of Agricultural Sciences*** 2(4): 062-068.

Verter, N., & Bečvářová, V. (2015). An analysis of yam production in Nigeria. ***Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis***, 63(2): 659-665.

Zakari, D. M., Mohammed, A. B., Medugu, N. I., & Sandra, I. (2014). Impact of climate change on yam production in Abuja, Nigeria. ***International Journal of Science, Environment and Technology*** 3: 458-472.