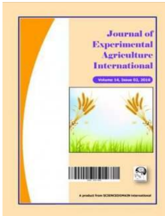

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Analysing the Nexus between Climate Variability and Tomato (*Lycopersicon esculentum*) Production in the Offinso North District, Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author LG conceptualized and designed the study as well as the first draft of the manuscript. Author FA reviewed the relevant literature and the methodology of the study. Author GE analyzed the qualitative aspect of the study. All authors read and approved the final manuscript.

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ABSTRACT

Climate variability which is characterized by rising temperature and rainfall variability is significantly impacting crop yield and livelihoods of farmers. The study analyzed the nexus between climate variability and tomato production in the Offinso North District of Ghana using the hierarchical regression model. Structured questionnaires and focus group discussion guide were instruments for data collection covering 378 tomato farmers randomly selected from three communities in the study area. Frequency counts and percentages were used to describe the perception of farmers about the causes of climate variability. A regression model was used to analyse the effects of climatic variables (temperature and rainfall) on tomato production while controlling other confounding variables. The findings showed that, farmers perceive climate variability to be caused by anthropogenic factors (such as vehicular emissions [66.2%], deforestation [98.4%], slash and burn [70.4%], bush burning [85.2%] and spiritual forces (retributions by the gods, ancestors, and

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the Almighty God [76.2%]). At 5% level, the regression model indicated a significant negative relationship between temperature and tomato production (P = .05) as well as rainfall and tomato production (P = .05). In sustaining the knowledge of farmers, it is imperative to provide them with the requisite education on the adverse effects of greenhouse gas emissions in the atmosphere and the need to reduce it through appropriate mitigating measures.

Keywords: Climate variability; hierarchical regression; tomato production; Offinso North District; Ghana.

1. INTRODUCTION

Climate variability which is characterized by rising temperature and rainfall variability is significantly impacting crop production and livelihood of farmers in the agricultural production systems of most economies across the globe (Intergovernmental Panel on Climate Change [IPCC], [1,2]. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change has also given an indication to the effect that, the climate has been changing since the mid- 20th century [1]. Sub-Saharan Africa (SSA) is one of the most vulnerable regions to global climate change as a result of its reliance on agriculture which is highly sensitive to weather and climate variables such as temperature, precipitation, light and extreme events and the low capacity for adaptation [3]. The magnitude of impact of the phenomena cannot be underestimated as it has the propensity to affect the output of most agricultural crops, including vegetables [4,5]. The extent of impact of the changing climate, especially on the agricultural sector has necessitated a public debate on the appropriate measures to mitigate the effects to ensure food security.

Anthropogenic factors are widely argued as the major drivers that have influenced the oscillations of key climatic variables such as temperature and rainfall [1]. Among these human forcings include deforestation and burning of fossil fuels [1]. These activities increase the carbon dioxide concentration in the atmosphere. In view of the emissions of these greenhouse gases in the atmosphere, crops and forage plants continue to be influenced by the increasing temperatures and changing precipitation patterns with the cumulative effects of reduced plant growth and yield [6]. The IPCC projections and regional level studies suggest that a changing climate is likely to impact agricultural production [7]. The concern is that, if the climate keeps changing without the development of cutting-edge technologies to respond to the situation, it may cause food insecurity and poverty especially, among food crop farmers.

Globally, especially in developing countries, climate variability has caused yield declines for most important crops [8]. Lobell [9] argues that, for each degree that a crop spends above 30℃, its yield reduces by 1 percent. They further intimated that, a rise in temperature above 30℃ under drought conditions has a corresponding decrease in crop yield by 1.7 percent. Extreme climate conditions, such as dry spells, sustained drought, and heat waves have been projected to have large effects on crops [6]. High temperatures also impact on vegetable crops like lettuce, carrot and cucumber to the extent that it suppresses bisexual flowers, decreases the number of flowers and inhibits flower differentiation and development, which result in low yield [10]. Basak [11] reiterates the fact that when maximum temperature increases by 2℃ and 4℃, there is a drastic reduction in crop yield from 13.5 percent to 2.6 percent and from 28.7 percent to 0.11 percent respectively. The study further showed that, even though both maximum and minimum temperature cause a reduction in crop yield, the effect of high temperatures on yield is high as compared to the effect of low temperatures on yield. Deressa and Hassan [12] argue that, a marginal increase in temperature in summer and winter causes a reduction in crop yield and revenue. The reduction in the yield of farmers has significant impact on their livelihoods and the socio-economic roles (e.g. payment of school fees and utility tariffs) they play in the family.

As a result of the impact of changing climate on agricultural production, the argument has now been limited to mitigating, adapting or combining the two [13]. It is in the light of this that farmers in various countries continue to develop strategies to cope with the stress and damage the changing climate can impose on the countries agricultural sector [14]. Beside farmers' efforts to adapt to the changing climate, governments through its institutions are also seeking ways of fashioning out policies to mitigate the impact to prevent food insecurity. The development and implementation of adaptation strategies will go a long way to help offset the unpredictable nature of the climate in order to sustain food production.

According to the Ministry of Food and Agriculture (MoFA), the crop sub sector contributes about 66.2 percent of the Gross Domestic Product (GDP) of the agricultural sector in Ghana [15]. This sub sector includes tomato production which is heavily cultivated in the Offinso North District. Tomato (*Lycopersicon esculentum*) is a popular food item in Ghana and the Offinso North District in particular with an overall consumption rate of 25,000 tons a year at a total cost of about US$25 million [16]. Apart from supplying the body with vitamins, iron and phosphorus on a daily basis by many households, tomato is also a major source of livelihood to many people in both rural and urban Ghana.

However, notwithstanding the relevance of tomato to the socio-economic development of Ghanaians, its production keeps declining, necessitating the importation of fresh tomatoes from neighbouring countries especially Burkina Faso to supplement what is locally produced [17]. Some empirical studies have focused on the production systems and productivity of tomatoes [18,19]. However, there is paucity of empirical evidence on the effects of climate variability on tomato production in the Offinso North District of Ghana. Hence, the study specifically analysed the perceived causes of climate variability and the nexus between climate variability and tomato production in the Offinso North District, Ghana. The study was based on these hypotheses: H_0= temperature (maximum) has no significant relationship with tomato yield and H_0= rainfall has no significant relationship with tomato yield.

2. MATERIALS AND METHODS

2.1 Study Area

The Offinso North District is one of the districts in the Ashanti region of Ghana. The district was formerly part of the Offinso District with Offinso as the capital. In 2008, the Offinso North District was carved from the Offinso District with Akomadan as the District capital. The district lies between longitudes 10 60^1 W and 10 45^1 E and latitudes 70 20^1 N and 60 50^1 S (Fig. 1). The total land area is about 741 kilometers square.

The Offinso North District lies in the semi-equatorial climatic zone and experiences a double maxima rainfall regime. While the first rainfall season begins from April to June, the second period starts from September to October. The mean annual rainfall is around 1161 mm (Fig. 2). The district experiences a protracted dry season which occurs between the months of November and March.

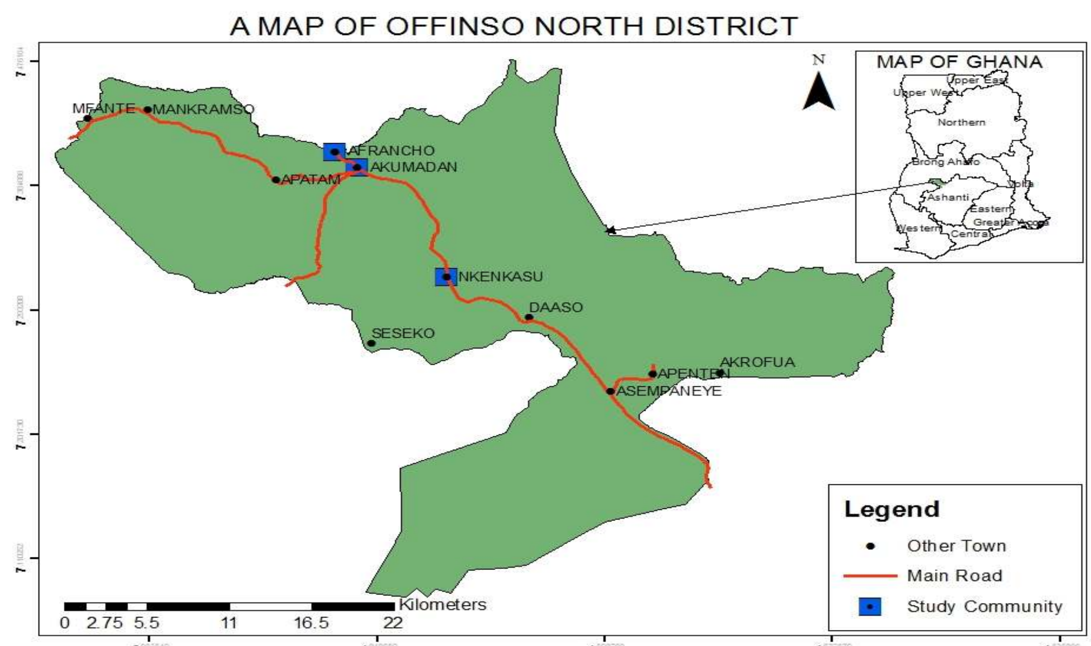

Fig. 1. Map of Offinso North District showing the selected communities

The protracted dry season affects crop cultivation especially vegetables e.g. tomato in the district, and this drives farmers to adopt some adaptive strategies like irrigation to help improve crop yield. Again, the district experiences bush fires in the dry season which destroys the vegetation, and hence increase the amount of carbon dioxide in the atmosphere with the potential of altering the rainfall pattern in the area. Relative humidity is generally high ranging between 75-80 per cent in the rainy season and 70-72 per cent in the dry season. A maximum temperature of 30℃ is experienced between March and April. The mean monthly and annual temperatures are 27℃ and 28.8℃ respectively (Fig. 3).

2.2 Types, Sources and Methods of Data Collection

The mixed method approach involving quantitative and qualitative data collection and analyses was used for the study. Mixing both quantitative and qualitative methods in a single study provides a better appreciation and understanding of the research problem than either type by itself [20]. Data used for the study were collected from both primary and secondary sources. Primary data were collected from key informants such as tomato farmers and Agricultural Extension Officers while the secondary data were obtained from the District

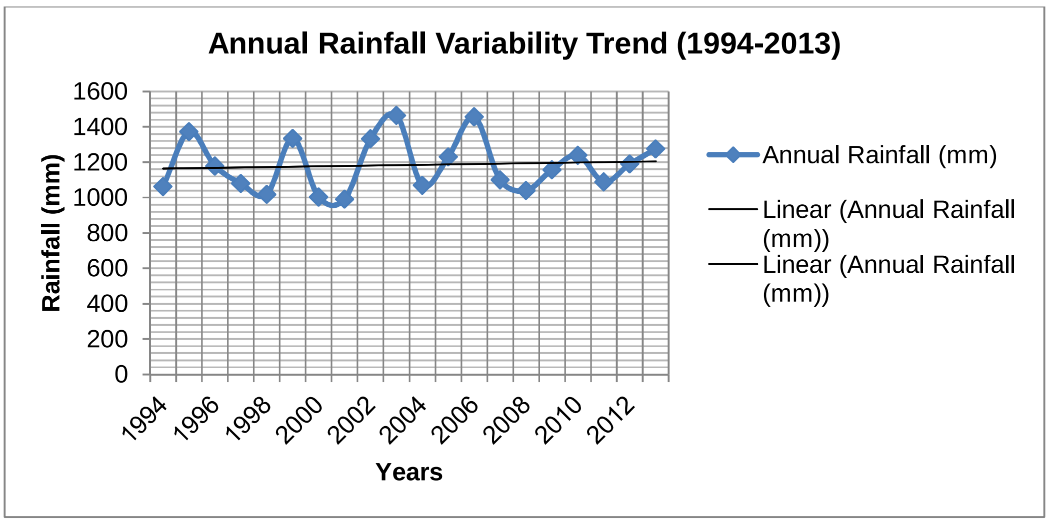

Fig. 2. Rainfall variability trend (1994-2013)

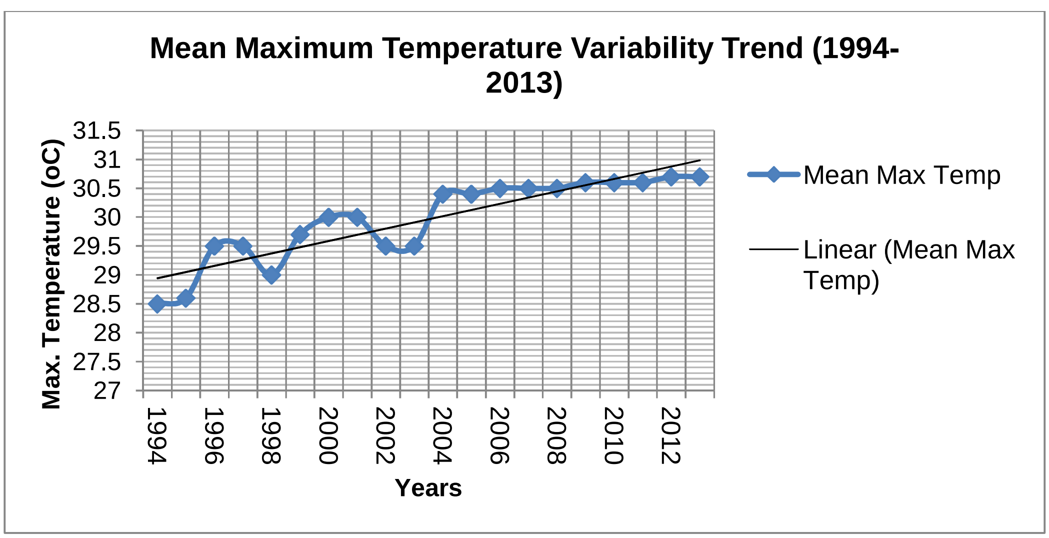

Fig. 3. Maximum temperature variability trend (1994-2013)

Meteorological Agency and the District Directorate of the Ministry of Food and Agriculture (MoFA). A cross-sectional survey involving 378 smallholder tomato farmers were sampled for the study using the systematic sampling strategy. This particular sampling strategy was employed because of the availability of a sample frame and the fact that it also gave every respondent an equal chance of being selected. The sample size (378) out of the total population of 7063 registered tomato farmers was obtained using the mathematical model [$n = N / 1+ N (e^2)$]: where ‘n’ denotes the sample size; ‘N’ denotes the sampling frame and ‘e’ denotes the margin of error which was set at 5 percent with 95 percent confidence level. The equivalent sample size in the study communities were then determined using the principle of proportionality (Table 1).

Farmers were interviewed using questionnaires which had both closed and open-ended questions. The survey lasted for one month through the help of some research assistants. The interviews were conducted face-to-face with the respondents. In the event that respondents were unable to read the questions, the interviewer read it to them in their local dialect to facilitate a better understanding and to respond to the questions appropriately. The quantitative responses were analysed descriptively (frequency, percentages and tables) and inferentially (hierarchical regression) using the IBM SPSS Statistics version 21. Also, sixteen (16) tomato farmers who have been in the business for over twenty years were also selected to gather qualitative responses through two separate focus group discussions organized for the male (8) and female (8) farmers in the study area. The selection of the farmers for the focus group discussion was based on their vast experience in the tomato farming business. The qualitative responses were analysed thematically through a transcription and categorisation of recorded voices.

2.3 Description of the Hierarchical Regression Model

To measure the effect of key climatic variables (temperature and rainfall) on tomato yield while controlling the influence of other confounding (independent) variables such as irrigation, regular weeding and tomato variety, the hierarchical regression model (HRM) was used. The HRM is relevant when analyzing the variance in the outcome variables when the predictor variables are at varying hierarchical levels [21,22]. The model is also preferred because it requires fewer assumptions than other statistical methods [22]. The HRM is also capable of accommodating non-independence of observations, missing data, small and/or discrepant group sample sizes and heterogeneity of variance across repeated measures [23]. The hierarchical multiple regression values were therefore used to measure changes that occurred in the dependent variable with changes in the independent (predictor) variables. Two stages (blocks) of the hierarchical regression were employed. The first stage involved the entry of the controlled independent variables (irrigation, regular weeding and tomato variety) which explained the variance in crop yield. The second stage involved the entry of the major independent variables of prime interest (temperature and rainfall) to assess their contribution in predicting the dependent variable. The entry of all the sets of variables meant that, the overall model was assessed in terms of its ability in predicting the dependent measure. At each stage of the process, the hierarchical regression model identified the key variables and eliminated the weaker ones. The Analysis of Variance (ANOVA) was used to assess the significance of the regression model and the standardized Beta values as well as the P-values were used to evaluate the contribution of each of the predictors (Appendix 1). Variables with 0.05 or less probability ($P \leq .05$) were considered significant while variables with more probability ($P \geq .05$) were considered insignificant. The confidence level in the multiple regression data for the study was determined using the adjusted co-efficient of determination (Adjusted R^2).

2.4 Test of Violations of Assumptions of the Regression Model

Prior to conducting the hierarchical regression, preliminary analyses were conducted to ensure there had been no violation of the assumptions underpinning the regression analyses. The residual and scatter plots indicated that the assumptions of normality, linearity, homoscedasticity and multicollinearity were all satisfied [21]. The collinearity statistics (Tolerance and Variance Inflation Factor-VIF) were all within the accepted limits as indicated by Pallant [21]. From the analysis the tests for multicollinearity indicated that a low level of multicollinearity was present (tolerance = .993, .749, .619, .572 and .803 for irrigation, tomato variety, regular weeding, rainfall and temperature) (See Table 2).

Table 1. Study communities and their respective total number of farmers and sample sizes

Study communities	No. of farmers (N)	Percentage (%) [No./Total*100]	Proportionate sample percentage/100*Total sample size
Akomadan	2966	2966/7063*100 =42	42/100*378= 159
Afrancho	2754	2754/7063*100 =39	39/100*378= 147
Nkenkaasu	1343	1343/7063*100 =19	19/100*378= 72
Total:	7063	100	378

Source: Authors fieldwork, 2014

**--: multiplication sign*

Table 2. Test of violations of regression assumptions

Model	Correlations			Collinearity statistics	
	Zero-order	Partial	Part	Tolerance	Variance inflation factor (VIF)
1 (Constant)					
Irrigation	.209	.247	.224	.998	1.002
Tomato variety	.321	.350	.328	.998	1.002
Regular weeding	.275	.297	.274	1.000	1.000
2 (Constant)					
Irrigation	.209	.468	.276	.993	.1007
Varieties of tomato	.321	.061	.032	.749	1.335
Regular weeding	.275	.137	.072	.619	1.615
Rainfall	-.272	-.365	-.204	.572	1.747
Temperature	-.741	-.804	-.706	.803	1.245

3. RESULTS AND DISCUSSION

3.1 Socio-demographic Characteristics of Respondents

Descriptive statistics was employed to analyse the biographic data of tomato farmers in the Offinso North District (See Table 3).

In terms of the age distribution of the respondents, majority of the farmers 155 (41%) were between the ages of 31 and 40. This means that the farming population in the district is relatively youthful and has a relatively greater potential for sustainable tomato production.

On the sex distribution, the responses indicate that majority of them were males. Out of the total respondents of 378, 262 of them (69.3%) were males while 116 (30.7%) were females. This implies that males continue to dominate in the area of farming activities possibly due to their physical nature and capabilities as compared to females who are less energetic and lack the physique to engage in rigorous farming activities like tomato cultivation.

Also, the study shows that 234 (61.9%) of the respondents were married, 116 (30.7%) of them were single and 28 (7.4%) were divorced. This means that the married farmers who engaged in the farming activities had their livelihood dependent on the tomato business.

The educational levels of respondents as shown in Table 3 indicates that, majority of them 168 (44.4%) had no formal education at all. Again, 134 (35.5%) had education up to the Middle school or Junior High level and 56 respondents (14.8%) had education up to the Primary school level. The least number of respondents (20) were farmers who had education up to the Secondary school level. They constituted 3.7 percent. This implies that majority of the respondents have no or little educational attainment which may influence their adaptive strategies through the adoption of traditional instead of scientific strategies in responding to the impact of the climate variability.

The descriptive statistical analysis indicates that tomato farmers experience decreasing trend in their seasonal income. From the results, 275 (72.7%) of the total respondents indicated a decreasing trend of their seasonal income while 97 (25.7%) of them indicated a fluctuations in their seasonal income with only 6 (1.6%) of them indicating an increase in their seasonal income. This implies that the effect of the changing climate could potentially affect the income levels of tomato farmers with an overall effect on their livelihood.

Table 3. Biographic characteristics of respondents = (378)

Socio-demographic characteristics	Frequency (n)	Percentages (%)
Age:		
<20	14	3.7
20-30	32	8.5
31-40	155	41
41-50	150	39.7
>50	27	7.1
Sex:		
Male	262	69.3
Female	116	30.7
Marital status:		
Married	234	61.9
Single	116	30.7
Divorce	28	7.4
Educational level:		
Primary	56	14.8
Middle/Junior High	134	35.5
Senior High	20	5.3
No formal education	168	44.4
Farming experience:		
<10	12	3.1
10-20 years	162	42.9
21-30 years	161	42.6
31-40 years	37	9.8
>40 years	6	1.6
Income level:		
Increasing	6	1.6
Decreasing	275	72.7
Fluctuating	97	25.7
Access to extension service:		
Yes	30	7.9
No	348	92.1
Farm size:		
1-2 acres	49	13
3-4 acres	158	41.8
5-6 acres	118	31.2
7-8 acres	38	10
9 and above	15	4.0

Regarding the longevity of how the farmers have been engaged in tomato cultivation, it was observed that majority of the respondents, 162 (42.9%) have been cultivating tomatoes for between 10 and 20 years. Similarly, 161 (42.6%) respondents have been cultivating tomatoes for between 21 and 30 years. Thirty seven (9.8%) of the respondents have been doing same for between 31 and 40 years. Twelve (3.2%) respondents have been cultivating tomatoes for less than 10 years. Those with the least years of farming experience were represented by 6 (1.6%) respondents who have been engaged in tomato farming for more than 40 years.

It is also obvious from the analysis that about 354 (93.7%) majority of the respondents indicated that they did not get access to credit facilities to boost their tomato business. This means that the farmers' adaptive measures would be affected and this might have far-reaching implications on their yield and livelihood. Again, without adequate credit farmers cannot produce more tomatoes for future generation, thereby threatening the sustainability of tomato production in the District and the country at large.

Regarding farmers' access to extension services as a means of enhancing their adaptive capacities, majority of the respondents, 348 (92.1%) indicated that they do not have access to extension services. This means that, most of the farmers will be faced with difficulties in applying scientific adaptive measures on their farms. Therefore, the farmers may be used to their local methods of adaptation which also require some level of adaptive capacity through extension services. The lack or inadequacy of extension services could adversely affect the yield of farmers with an overall effect on sustainable tomato production and socio-economic improvements of their livelihood.

The farm size of respondents was also obtained. The results indicate that majority of the farmers, 158 (41.8%) cultivated between 3 to 4 acres of farmland, 118 (31.2%) cultivated farm sizes of between 5 to 6 acres, 49 (13%) of the farmers cultivated between 1 to 2 acres of land, 38 (10.1%) farmers cultivated between 7 and 8 acres of land while 15 (4.0%) of the farmers cultivated 9 acres or more. This may be due to urbanization which has culminated in the conversion of most agricultural lands for construction purposes. It could also be attributed to the fact that most of the farm lands have lost their fertility thereby preventing farmers from using such lands.

3.2 Causes of Climate Variability

This section focuses on how farmers perceive the causes of climate variability as demonstrated in Table 4.

From Table 4, the study revealed that, anthropogenic factors are the major cause of climate variability in Ghana as perceived by the farmers. This is consistent with the IPPC's [1] scientific position that anthropogenic factors are the major causes of climate variability in the developed and developing countries including Ghana. On the issue of vehicular emission being a major cause of climate variability in the study area, the study showed that, 298 (66.2%) out of the total of 378 respondents affirmed this fact. Also, an overwhelming majority of the respondents, 372 (98.4%) confirmed that deforestation is a major cause of climate variability. On slash and burn method of farming as a cause of climate variability, majority of the respondents, 266 (70.4%) also attested to this fact. Farmers also attributed climate variability to the upsurge of bush burning which is normally triggered by people in their quest for game as food and livelihood option. This was revealed in the analysis when a total of 322 (85.2%) indicated that, indeed bush burning is a major cause of climate variability. This was revealed in one of the FGD sessions when the farmers unanimously agreed that, the way and manner they keep cutting down the trees and burning the bush for game has affected the rainfall pattern in the area. Beside the anthropogenic factors, spiritual forces or factors were also perceived as possible causes of climate variability. The results showed that, 288 (76.2%) respondents attributed the cause of climate variability to the retributions of God, the lesser gods and the ancestors. "*Because we cut down the trees along our river which are supposed to protect the lesser gods, we are punished through delays in rainfall. Also, nowadays we commit so much sins that God and our ancestors have decided to punish us by refusing us rainfall at a time we need it*". However, fertilizer applications and industrial emissions were not seen by the respondents as possible cause of climate variability. Only 69 (18.3%) and 59 (15.6%) of the respondents perceived that fertilizer applications and industrial emissions were possible causes of climate variability. This may be attributed to the fact that, there are no industries in the study area.

3.3 Nexus between Climate Variability and Tomato Yield

This section explores the relationship between climate variability on tomato production using a regression model. The purpose for this analysis was to establish the relationship between the independent and outcome variables. It is clearly evident from the regression analysis that, temperature has a significant relationship with tomato yield while controlling the confounding variables. Again, the result indicates a significant relationship between rainfall amount and tomato yield holding other factors constant. Table 5 shows the hierarchical multiple regression analysis of the independent variables in predicting the behavior of the dependent variable.

Table 4. Causes of climate variability

Causes of climate variability	YES		NO	
	Frequency (n)	Percent (%)	Frequency (n)	Percent (%)
Vehicular emissions	298	66.2	80	21.2
Deforestation	372	98.4	6	1.6
Slash and Burn	266	70.4	112	29.6
Bush burning	322	85.2	56	14.8
Fertilizer application	69	18.3	309	81.7
Retributions by God, gods and the ancestors	288	76.2	90	23.8
Industrial emissions	59	15.6	319	84.4

Table 5. Multiple regression predictors of tomato yield

Variable	Beta coefficients	Sig. P-value	Adjusted R^2
Irrigation	.28	.07	
Tomato variety	.04	.82	
Regular weeding	.09	.61	.631
Rainfall	-.27	.00	
Temperature	-.79	.00	

Dependent Variable: Tomato yield- (negative sign)
Source: Field data (2014)

A two stage hierarchical multiple regression was conducted with tomato yield as the dependent variable. Soil type (obtained from the District Directorate of the Ministry of Food and Agriculture), application of agro-chemicals, irrigation, regular weeding and tomato variety were entered at stage one of the regression explaining 23.0 percent (.23 x 100) of the variance in crop yield. This means that the "control variables" part of the model alone predicted 23 percent of the tomato yield [24]. After entry of the temperature and rainfall at stage two, the total variance explained by the model as a whole was 73.0 percent (.73 x 100), $F (5, 14) = 7.5$, $P = .05$. This means that by adding temperature and rainfall to the model, the variables accounted for a significant 50 percent variance in tomato yield, after controlling for irrigation, regular weeding and tomato variety, R Squared change = .50, F Change (2, 14) = 12.90, $P = .05$. This means that when all the independent variables are considered, temperature and rainfall predicted 50 percent of the tomato yield [24]. Generally, it is evident that irrigation, tomato variety, regular weeding, temperature and rainfall predicted 63.1 percent of low tomato yield considering the adjusted coefficient of determination (Adjusted R^2) which is .631. This implies that some other factors or variables such as pests and diseases can also influence low tomato yield [24].

In the final model where the predictive power of all the independent variables were assessed, only temperature and rainfall were statistically significant with temperature showing a higher beta value (beta = -.79, $P = .05$) than that of rainfall (beta= -.27, $P = .05$). The direction of the relationship is negative (-.79) indicates that, there is an inverse relationship between temperature and tomato yield. Therefore, an increase in temperature led to a decrease in tomato yield with all possible factors held constant. This supports the study of Kalibbala [25] who asserted that high diurnal temperatures above 27℃ are likely to induce pollen sterility of tomato with high night temperatures adversely affecting flower initiations of tomato with the ultimate effect on yield. This is also in consonance with the views of the Field Officer of the District Directorate of MoFA when he remarked that: "*Tomato is a warm season crop which needs an optimum temperature of about 28℃ for survival. However, a high temperature beyond its capacity causes scorching of the tomato plant and increases the incidence of decay which affects the tomato fruits*". However, the result is inconsistent with the study of Tshiala and Olwoch [26] who observed an increase in tomato yield in the wake of high temperature in the Limpopo Province, South Africa, between the periods of 1971 and 2006. The reason for the increase in tomato yield was due to the application of good farming practices, fertilizer application and the employment of irrigation. Therefore, the study's hypothesis that there is no significant relationship between temperature and tomato yield is rejected ($P = .05$) and hence the alternative hypothesis that temperature has a significant relationship with tomato yield is maintained [24].

Again, the contribution of rainfall in predicting tomato yield was also statistically significant, (beta = -.27, $P = .05$) and hence the hypothesis that rainfall has no significant relationship with tomato yield is rejected and the alternative hypothesis is maintained. The direction of the relationship is negative (-.27) indicates that, there is an inverse relationship between rainfall and tomato yield. Therefore, an increase in rainfall will lead to a decrease in tomato yield holding all possible factors constant. This finding supports the study of Mensah et al. [27] who alluded that excessive rainfall (above 750mm) reduces light intensity and thus adversely affects the yield of tomato as well as increases the incidence of fungal diseases of the crop.

Another implication is that excessive annual rainfall can also affect the yield of tomato. This was also supported during the FGD when a male discussant retorted that: "*In fact prolonged drought and erratic rainfall affect our yield to the extent that, it even becomes a disincentive to go to the farm. This is due to the fact that, you may not even harvest a box of tomato from the farm*" This result is also consistent with the study of Kalibbala [25] who found that high rainfall could be harmful to tomato crops and affect its yield. The *beta* value of temperature and rainfall indicates that the effect of temperature on tomato is higher than that of rainfall. The implication is that, even though tomato is considered a warm season crop, a higher temperature above its threshold can be detrimental to the crop.

4. CONCLUSION

Since climate variability is perceived by farmers to be caused by human activities, it is important that farmers are given the requisite knowledge and skills needed to reduce the production and emission of greenhouse gases into the atmosphere. Attention should be focused on how to build the capacities of farmers in their activities to mitigate their contribution of greenhouse gases which are the primary source of global warming. Cultural values and systems that seek to prevent deforestation and farming along water bodies should also be upheld and given the needed attention to improve carbon sinks.

The temperature and tomato yield relationship means that temperature rise affected tomato yield with some confounding variables such as irrigation, tomato variety and regular weeding held constant. Since high temperature is a limiting factor that affects tomato yield, it is therefore important to develop heat resistant tomato varieties which can withstand high temperature conditions and help improve yield. Research institutes such as the Crops Research Institute of the Center for Scientific and Industrial Research (CRI- CSIR) in Ghana should develop more heat resistant tomato varieties which can withstand the vagaries of the weather and improve production.

The significant negative relationship between rainfall and tomato yield implies that as rainfall increases, it potentially causes a reduction in tomato yield. This means that even though tomato needs water, excessive rainfall is detrimental to its cultivation. Access to weather information could also be an effective avenue to enhance their adaptive strategies of tomato farmers in the Offinso North District. This could reduce the adverse effects of climate variability on their farming activities. Therefore, effort should be made to provide a forecast of the weather on a regular basis through the electronic media such as the radio stations in the district to update farmers on the weather dynamics to enable them plan well for their farming activities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Results of multiple (Hierarchical) regression analysis

Model summary									
Model	**R**	**R square**	**Adjusted R square**	**Std. error of the estimate**	**Change statistics**				
					R square change	**F change**	**df1**	**df2**	**Sig. F change**
1	.477[a]	.228	.083	790.581	.228	1.571	3	16	.235
2	.853[b]	.728	.631	501.295	.501	12.897	2	14	.001

ANOVA						
	Model	**Sum of squares**	**Df**	**Mean square**	**F**	**Sig.**
1	Regression	2945166.380	3	981722.127	1.571	.235
	Residual	1.000E7	16	625018.211		
	Total	1.295E7	19			
2	Regression	9427308.095	5	1885461.619	7.503	.001
	Residual	3518149.655	14	251296.404		
	Total	1.295E7	19			

Coefficients

Model		Unstandardised coefficients		Standardised coefficients	T	Sig.	Correlations			Collinearity statistics	
		B	Std. error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	17560.213	1815.422		9.673	.000					
	Irrigation	844.399	829.701	.224	1.018	.324	.209	.247	.224	.998	1.002
	Tomato variety	353.662	236.795	.328	1.494	.155	.321	.350	.328	.998	1.002
	Regular weeding	710.604	570.490	.274	1.246	.231	.275	.297	.274	1.000	1.000
2	(Constant)	45144.637	5564.746		8.113	.000					
	Irrigation	1044.265	527.573	.277	1.979	.068	.209	.468	.276	.993	1.007
	Varieties of tomato	39.522	173.323	.037	.228	.823	.321	.061	.032	.749	1.335
	Regular weeding	237.713	459.618	.092	.517	.613	.275	.137	.072	.619	1.615
	Rainfall	-1.496	1.021	-.270	-1.465	.000	-.272	-.365	-.204	.572	1.747
	Temperature	-924.148	182.408	-.788	-5.066	.000	-.741	-.804	-.706	.803	1.245

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