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Interplay of Climate Variability, Land Use Change, Crop Yield and Farm Households Food Security in Offin River Basin, Ghana

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Abstract: Climate variability and adapted land use systems have altered climate systems. Their impact on agro-ecosystems adversely affects crop yield, food security and livelihoods of farm households. This paper examines the coupled effects of climate variability and land use change on crop yield and food security among farm households in the Offin River Basin. The study used remote sensing, geographic information systems, time series climate and crop yield data and farm household survey in examining the impacts of climate variability and land use change on crop yield and farm household food security. Landsat Multi-Spectral Scanner (MSS), Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper plus (ETM+) were used to assess land use and land cover change and agricultural drought conditions in the area. Spline interpolation techniques and Spearmans' rank correlation were employed to assess the trend and spatial distribution of rainfall and temperatures in the basin. Multiple linear regression model (MLRM) and Pearson correlation were used to assess the effect of rainfall and temperature on major food crop yields. Household Food Balance Model (HFBM) was used to measure food security status at farm household level. The results revealed that climate variability coupled with adapted land use systems in Offin River basin have contributed to massive deforestation, accelerated soil degradation and recurrent agricultural droughts resulting in the loss of productive farmlands and low food crop yields. Household food balance model (HFBM) analysis revealed that 60.8% of the farm households in the basin could not meet the minimum recommended energy level of 2900 kilo calories intake per person per day while 39.2% of farm households were food secured subsisting on more than recommended kilo calories per person per day. Utilization of inland valleys, food crop management practices, soil and water conservation and management technologies, mixed cropping systems and crop diversification were found to have contributed positively and significantly to farm household food security. It is recommended that Government agencies such as MoFA, GASIP and existing Non-Governmental Organizations (NGOs) should increase investment in soil and water conservation strategies (SWCS) and inland valleys food production systems to enhance food production and food security systems among farm households.

Keywords: Climate Variability, Land Use Change, Food Security, Farm Households, Offin River Basin

1. Introduction

Climate variability and adapted land use pattern are rapidly changing climate systems. Their impact on agro-ecosystem threaten food security and exacerbate poverty particularly among farming households in Sub-Sahara Africa (SSA). Studies [1-4] have shown that climate variability and land use change adversely affect agricultural productivity and household food security [5-7]. FAO [8], Ludi [9] and Nelson et al. [10] indicated that severe and unpredictable climatic conditions coupled with environmental degradation negatively influenced length of growing season and cropping systems, which eventually affect household food security. In fact, changes in land use systems, temperatures and rainfall characteristics impact plant growth, food crop yield and household food security. According to the World Food Summit [11], food security exists when all people, at all times have access to sufficient nutritious food to meet their dietary needs and food references for an active and healthy life. Hussein and Janekarmkij [12] defined food security as adequate availability of and access to food for households to meet the minimum energy requirements as recommended for an active and healthy life. The bottom line is that the average daily per capita intake of energy range from 2,900 to 3,100 calories and individuals are required to meet this requirement.

Globally, climate variability coupled with wars, natural disasters and political instability are mentioned to be direct cause of food insecurity for millions of people in the world [13]. Previous studies have shown that changes in climatic condition largely affect food productions system and food security [14-16]. Wheeler and Von Braun [17] pointed out that climate variability is the main driver of food security in the developing world, because it affects the productivity of the agriculture, its stability and food systems. In Rome [18, 19] found that, more than 80% of the smallholder farmers in the world are food insecure and depend on land as their primary source of livelihoods. World Energy revealed that global warming will have significant negative impacts on food security, with people suffering from food insecurity globally estimated at 925 million [20]. World Bank [21] have noted that climate variability disturbs food utilization through changes in production rate and the pattern of food items and these affects nutritional requirements of the population.

At the continental level, changes in distribution and amount of rainfall and land degradation are the most important drivers of food production systems and food security, mostly in Africa, where food crop production is largely by smallholder farmers and under rain-fed conditions [22-24]. Yesuf et al. [25] and Morland [26] have shown that climate variability impacts household food security in Sub Saharan Africa (SSA). In Ethiopia, Mesfin [27] reported 56.0% of households to be food insecure. Hendriks [28] ascertained that between 58% and 73% of households experienced food insecurity in South Africa. In Nigeria, Babatunde et al. [29] found that 62.8% of households were food in secured. The World Food Programme [30] reported that 453,000 people in Ghana are food insecure. A study by Kuwornu et al. [31] in the Central Region, Ghana revealed that 60% of the farming households were found to be food insecure. Frimpong [32] found 78.5% of households to be food insecure in the Ashanti Region of Ghana.

The interplay of climate variability, land use change, crop yield and household food security are complex and dynamic, but they are inherently linked to soil degradation, erratic rainfall, droughts and food crop yields. Saina et al. [33] and Lobell and Field [34] have reported that the impact of climate variability on agricultural productivity and food security are strongly influenced by climate-induced soil degradation, agricultural droughts and heat stress. Soil degradation has impaired the productivity capacity of the soil to sustain crop yield and contribute to food security. Erratic rainfall, high temperatures and recurrent droughts have resulted in poor soil fertility, low food production and rising food insecurity. Higher temperatures at the reproductive stage affect pollen viability, fertilization, grain filling and fruit development, thus reducing crop yield [35]. A study in Ethiopia [36] shown that rainfall variability adversely limits crop production.

Marius [37] in Ethiopia and Al-Bakri *et al*. [5] in Jordan and El-ladan [38] in Nigeria have reported that changing climatic conditions and land use and land cover change limits agricultural productivity and worsen food insecurity. Rowhani [39] and Afifi *et al* [3] in Tanzania have shown that variability of rainfall and temperatures have had significant impacts on crop production. In Nigeria, rainfall variability has been found to have a greater influence on crop production [22, 23]. Merrey et al. [40] have indicated that many factors contribute food insecurity, but unpredictable and erratic weather patterns remain the most important factors. Trobe [41] reported that climate variability affects all four dimensions of food security: food availability, food accessibility, food utilization and food systems stability with direct impact on human health and food distribution systems.

Offin River Basin supports food crop production of farming households who are rain-fed farmers. Unfortunately, the production capacity of the river basin to support and sustain food crop production systems is threatened due to unpredictable climatic conditions and land use and land cover change. The land use and land cover in the basin has experienced considerable changes with the major driving force related to human actions. Besides human factors, climate variability over the years has created serious negative climatic conditions for crop production. Previous studies on climate change and variability and land use change in the basin did not consider the effects of climate variability and land use change on household food security. However, the extent to which climate variability and land use change affected farm household food security systems remains uncertain. The objective of the paper was to examine the effect of climate variability and land use and land cover change on farm household food security in Offin river basin. The paper further identified climate resilient strategies to lessen adversative impact of climate variability and land use and land cover change on farm household food security systems within the area.

2. Materials and Methods

2.1. Study Area

Offin River Basin is a sub-basin of the Pra basin in the south-western river system of Ghana. It is located between latitude 5°30′N to 6°64′N and longitude 1°30′W to 2°15′W (Figure 1). Lowest elevations range from 50-100 m whereas highest is 550 and 600 m. Offin River Basin covers a land area of 6,561 km^2 and its main tributaries originate from eastern and the northern fringes and flow southwards through uplands near Mampong in the Ashanti Region and discharge into the Pra River in the Central Region before entering the Gulf of Guinea near Shama in the Western Region of Ghana. The basin falls within the equatorial climatic zone with rainfall regime typical of moist semi-deciduous forest zone receiving annual rainfall between 1,250 mm and 1,700 mm. The long-term average maximum and minimum temperature is 33°C in February and 22°C in July. The basin is underlain by Birimian, Tarkwaian and Dahomeyan formations. Birimian consists of sediments and volcanic rocks. Birimian sediment is characterized by dark grey and black phyllite making up the most extensive formation covering 4278.68 km^2 (65.31%). Birimian volcanic is made up of quartzite, sandstone and shale, occupying an area of 217.74 km^2 (4.84%). Tarkwaian is known to be gold bearing rocks covering 1346 km^2 (20.55%). Dahomeyan consists of metamorphic rocks. Soils found in the basin are mainly Forest Ochrosols (Acrisols), Alisols, Fluvisols, Forest Lithosols (Leptosols) and Lixisols. Acrisols are wide-spread covering about 5,290.6 (80.64) km^2. Acrisols vary from reddish to dark brown. They have good moisture retaining capacity and low infiltration rates. Wawa *(Triplochiton scleroxylon)*, Mahogany *(Khaya ivorensis)* and *Onyina (Ceiba pentandra)* are the main tree species. Farming activities in the Offin river basin are mostly smallholding and rain-fed conditions. Among the food crops plantain, cassava, cocoyam, rice and maize are grown extensively with less than 1.5 ha per farmer.

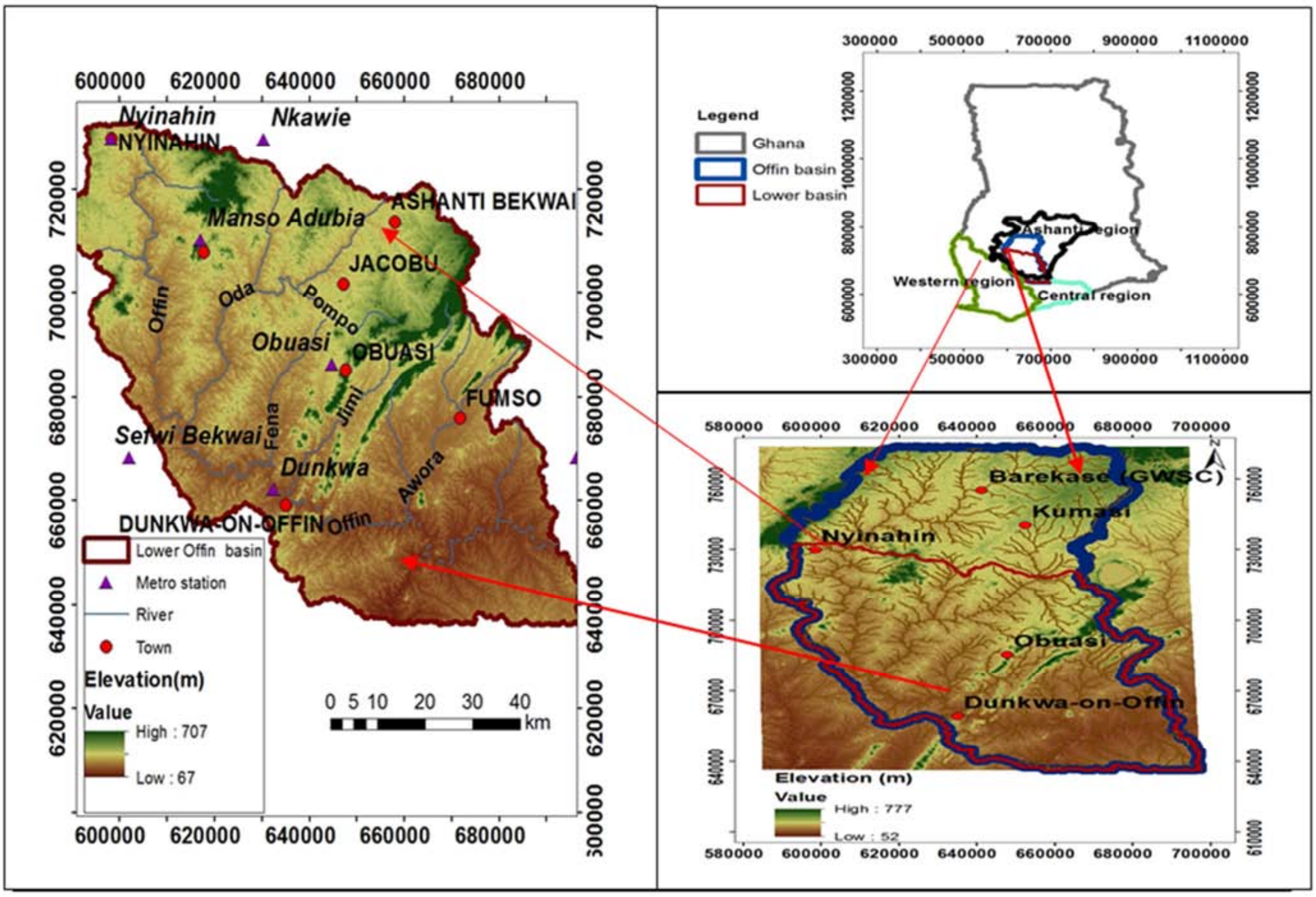


Figure 1. Location and DEM of Lower Offin River Basin.

2.2. Data Collection

The study used remote sensing, geographic information systems, time series climate and crop production data and household survey in examining the effect of climate variability and land use change on household food security. The Landsat Multi-Spectral Scanner (MSS) 1986, Landsat Thematic Mapper (TM) 2002, Landsat Enhanced Thematic Mapper Plus (ETM+) 2008 and 2015 images were used to analyze land use and land cover change and drought characteristics. All the landsat images were imported into ERDAS 10.1 for geometric correction, spectra enhancement, stacking, mosaicking, sub-setting and classification. Image differentiation tool in ArcGIS 10.4 and change detection tool in ERDAS were used to compute changes in land use and land cover classes. A thirty (30) years climate data from six weather stations were obtained from Ghana Meteorological Agency (GMet), Accra. The climate data were mapped in ArcGIS 10.4 using spatial spline interpolation. Spearmans' rank correlation was also used to examine trends and spatial distribution of rainfall and temperatures. The Analysis of Variance was used to test for variation among monthly, seasonal and annual rainfall of the six weather stations by comparing their means to see if there are any statistically significant differences among them.

Crop yield data from six food crops between 1986 and 2015 for the river basin were obtained from the Ministry of Food and Agriculture (MoFA), Accra.

Multiple linear regression and Pearson correlation were used to examine the relationship between the climate variables (rainfall and temperatures) and food crop yield in the Offin River Basin. The linear regression Equation (1) was used.

$$Y=b1 + b2X \quad (1)$$

where b1 is the intercept and b2, the regression constant, X is the independent variable (average annual rainfall, major season rainfall, minor season rainfall, maximum temperature and minimum temperature) and Y, the dependent variable (annual yield of maize, rice, cassava, yam, cocoyam and plantain yield). Multistage random sampling technique was used to select households. The sample size was determined using 68,471 farm households and was calculated using the formula proposed by Yamane [42] Equation (2).

$$n = \frac{N}{1 + N(e)^2} \quad (2)$$

Where, n is the sample size, N is the population size and e are the margin of error. With 5% margin of error, from a population of 68,471, the sample size was estimated as 398. Two communities were randomly chosen from each area and that the proportional sampling method was used to determine sample size of each selected area. Face-to-face household survey was carried out in November 2011 to December, 2014, March to May, 2015 and November 2016 to December 2017 to map farmlands and capture data on farming systems, crop yields and climate resilient practices using semi-structured questionnaires and GPS (Garmin eTrex).

Calorie availability and calorie consumption were used in assessing food security status among farm household in the basin. This is because most diets contain adequate amounts of nutrient required for good and healthy living once it is taken in the right quantity. The calorie available for each household was measured using Household Food Balance Model (HFBM) developed by FAO [43, 44].

The quantity of food crops produced and purchased for consumption was converted to kilograms and further to calorie based on food nutrient composition and then divided by household size adjusted for adult equivalent. To obtain the calorie consumed per day per household, the calorie was further divided by 365 days. For this study, 2900 kilo calories (kcal) per person per day, the International Food Policy Research Institute [45] standard used by Ghana Statistical Service in 2008 was used as minimum calories required per person per day. Household Food Balance Model Equation 3 was constructed to estimate calories available at the household.

$$NGA_i=(FP_i + FB_i + FR_i + FPS_i) - (HL_i+ FS_i + MO_i + FG_i + NS_i) \quad (3)$$

NFAi=Net food available/year/household
FPi=Food produced/year/household
FPi=Food bought/year/household
Fri=Food obtained from remittance /year/household
FPSi=Previous stock/year/household
HLi=Post harvest losses/year household
GSi=Quantity of food reserved for seed/year/household
MOi=Amount of marketed output /year/household
FGi=Food given to others as a gift within a year/household
FSi=Food planned for next season/year/household. Except post-harvest losses, all the data needed for the HFBM were collected through household survey. Post-harvest loss was estimated at 20%. Comparison between calories available and calories demanded by a household was made to determine the food security status of a household. The farm households whose daily per capita calorie intake were up to 2900 kcal were regarded as food secure while those below 2900 kcal were regarded as food insecure. Linear regression model was used to determine the extent to which biophysical factors explain food security of farm household.

3. Results and Discussion

3.1. Changes in Land Use and Land Cover Types in the Offin River Basin

The results revealed that, the study period (1986-2015), natural forest, secondary forest and water bodies have reduced by 49,261 ha, 24,076 ha and 8,376 ha respectively whereas cultivated land, settlement and degraded land increased by 33,678 ha, 14,389 ha and 48,035 ha respectively (Table 1). These changes in the land use and land cover classes in the basin have led to land and water degradation and deforestation resulting in the lowering the productive potential of food crops and farmlands, which in turn affects agricultural productivity and household food security stems. These land use and land cover changes observed in the area are in line with the findings of Boakye *et al.* [46] who reported a decreasing in the land cover and destruction of water bodies in Ghana.

The results revealed that out of 91,168.2 ha of natural forest in 1986, 41,709 ha (45.8%) remained unchanged, implying that 54% of the natural forests have been lost. Out of 10,655.60 ha of water body in 1986, only 2280 ha (21.4%) remained unchanged. The remaining 79% of the 1986 water bodies had also been lost. In addition, 299, 087 ha of cultivated lands estimated in 2015, about 33,678 ha (11.3%) which used to be part of the natural and secondary forest in 1986 had also been lost. The area of degraded land had shown 96.0% increased from its original coverage in 1986.

Table 1. *Changes in Land use and Land Cover Types (ha) in Offin River Basin.*

Land use and land cover types	Land use and land cover classes (ha)			
	1986-2002	2002-2008	2008-2015	1986-2015
Natural forest	-37,128 (-41)	1,686 (3)	-13,819 (-15)	-49,261 (-54)
Secondary forest	76,714 (32)	-106,873 (-34)	6,083 (3)	-24,076 (-10)
Cultivated land	-45,345 (-20)	71,455 (39)	-11,721 (-5)	14,389 (6)
Settlement	7,107 (21)	8012 (19)	4170 (8)	19,289 (55)
Water bodies	3,008 (28)	-2,634 (-19)	-8,750 (-82)	-8,376 (-79)
Degraded land	-4,356 (-9)	28,354 (62)	24,037 (48)	48,035 (96)

*Values in bracket are percentage of LULC changes (%)

Land degradation depresses productivity per unit area and thus increased in the degraded land will put more pressure on the limited farm lands and wetlands resources and directly affects soil fertility, water-holding properties and food production which in turn accelerating food insecurity in the basin. Relevant measures are therefore needed to curb soil and water degradation and deforestation among farmers.

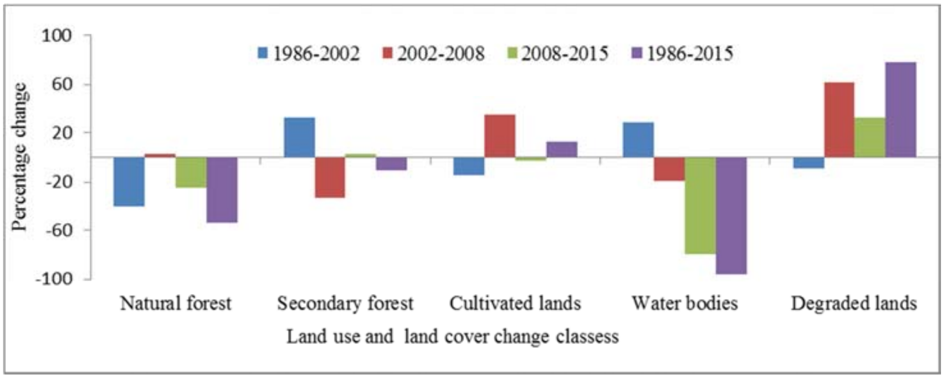


Figure 2. *Percentage Change of Land Use and Land Cover in each period (1986-2015).*

3.2. Trend of Climate Variables in Offin River Basin.

Time series rainfall data revealed that Nyinahin received the highest amount of annual rainfall (1620 mm) while Nkwaie recorded the lowest rainfall (125.2 mm). The differences in unevenly spatial distribution of rainfall pattern observed could have an unfavorable effect on major crop yields. Spearman rank trend analysis of rainfall indicated that mean annual rainfall showed positive and monotonic increasing trend for the period, contrary to popular belief that rainfall has reduced. Nkwaie and Manso Adubia areas were observed to follow positive trends while Nyinahin, Obuasi and Dunkwa did not reveal any distinct trend over time. In contrast, Sefwi Bekwai exhibited a negative and statistically downward trend (Table 2). Statistically, this decreasing trend has adverse impacts on crop production and agro-ecosystems services.

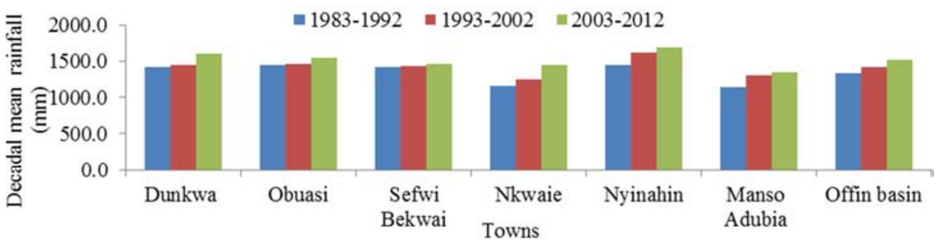


Figure 3. *Decadal Mean Rainfall from Six Rainfall Station between 1983 and 2012 in the Offin River Basin.*

Monthly mean rainfall revealed a uniform positive and significant increasing trend in May, June, September, October and November. Rainfall amount in February, March and April recorded downward trends. This result provided clear evidence of insufficient, erratic rainfall in the first four months of the year in the basin. Although there were increasing trend in the mean annual rainfall, the declining trend in the months of February, March, and April poses serious threats to land preparation, soil moisture availability and poor germination.

Further, farmers in the basin confirmed a declining trend in rainfall and claimed to constrain land preparation and trigger poor seed germination in March and April where planting of most food crops occurs. The reduction in the monthly rainfall patterns could have significant impacts on the flowering, fruiting and yield of major food crops in the basin.

Findings from this study implied that new crop varieties and cropping systems that utilize less water and produce more crop yield should be adopted. A similar observation has been made by Saina et al. [33], concerning how unpredictable and unreliable rainfall has become a threat to agricultural activities.

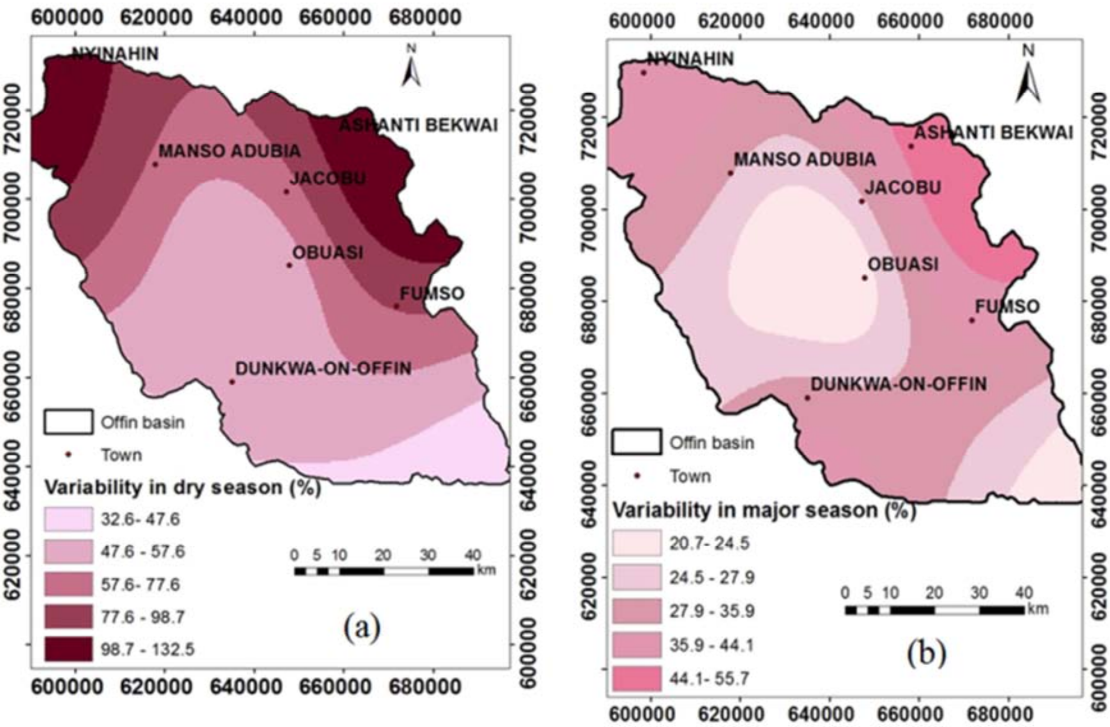
Table 2. *Trend of Monthly Rainfall in the Offin River Basin.*

Mt	Rainfall station					
	Dunkwa-offin	**Obuasi**	**Sefwi Bekwai**	**Manso Adubia**	**Nyinahin**	**Nkwaie**
Feb	2.09 (-0.07)	2.09 (-0.03)	2.09 (-0.04)	2.09 (0.04)	2.09 (0.04)	2.35 (0.46)
Mar	1.99 (-0.31)	2.09 (-0.04)	2.13 (-0.21)	2.14 (-0.22)	2.14 (-0.22)	2.10 (-0.10)
Apr	2.060 (-0.16)	2.10 (-0.20)	2.10 (-0.10)	2.92 (0.24)	2.16 (-0.26)	2.09 (-0.08)
Ma	2.17 (0.28)	2.14 (0.21)	2.16 (0.27)	2.10 (0.11)	2.10 (0.11)	2.94 (0.70)
Jun	2.11 (0.13)	2.13 (0.19)	2.09 (0.05)	2.16 (0.26)	2.16 (0.26)	2.22 (0.34)
Jul	2.19 (-0.30)	2.09 (0.06)	2.09 (-0.01)	2.09 (0.03)	2.09 (0.03)	2.09 (0.03)
Aug	2.09 (-0.05)	2.09 (0.01)	2.10 (-0.10)	2.09 (-0.06)	2.09 (-0.06)	2.15 (-0.25)
Sep	2.19 (-0.31)	2.09 (-0.07)	2.20 (-0.32)	2.12 (-0.18)	2.13 (-0.2)	2.09 (0.05)
Oct	2.33 (0.44)	2.09 (0.03)	2.15 (0.24)	2.66 (0.62)	2.65 (0.62)	2.33 (0.44)
Nov	2.16 (0.27)	2.12 (0.18)	2.14 (0.23)	2.34 (0.45)	2.30 (0.42)	2.14 (0.23)
Dec	2.09 (0.09)	2.14 (0.23)	2.09 (0.05)	2.09 (0.01)	2.09 (-0.35)	2.23 (-0.06)

Negative sign indicates decreasing shift; Numbers in brackets refer to P values

3.3. Variability in Annual and Seasonal Rainfall Pattern in the Offin River Basin

Mean variability of dry season (December–February), major season (March-July) and minor season (September-November) rainfall were found to be 77.5%, 40.2% and 50.4% respectively with mean annual variability ranged from 10.2% in Manso Adubia to 48.5% in Ashanti Betwai. Dunkwa-on-Offin, Obuasi, Jacobu and Ashanti Bekwai experienced the moderate variability in rainfall amount. Ashanti Bekwai and Fumso recorded the highest variability of long-term annual rainfall between 35% and 49% whereas the lowest variability was observed in Manso Adubia and thus ranged between 10.2% and 15%. These results have shown clear evidence of increasing irregularities in spatial and seasonal rainfall patterns which could influence crop growth and yield with negative impacts on crop productivity and human livelihood. In line with this finding, a study by Ayalew et al. [47] in Ethiopia also reported variability in rainfall. This result also supports assertion of IPCC [48] that there has been variability in rainfall across the African continent.



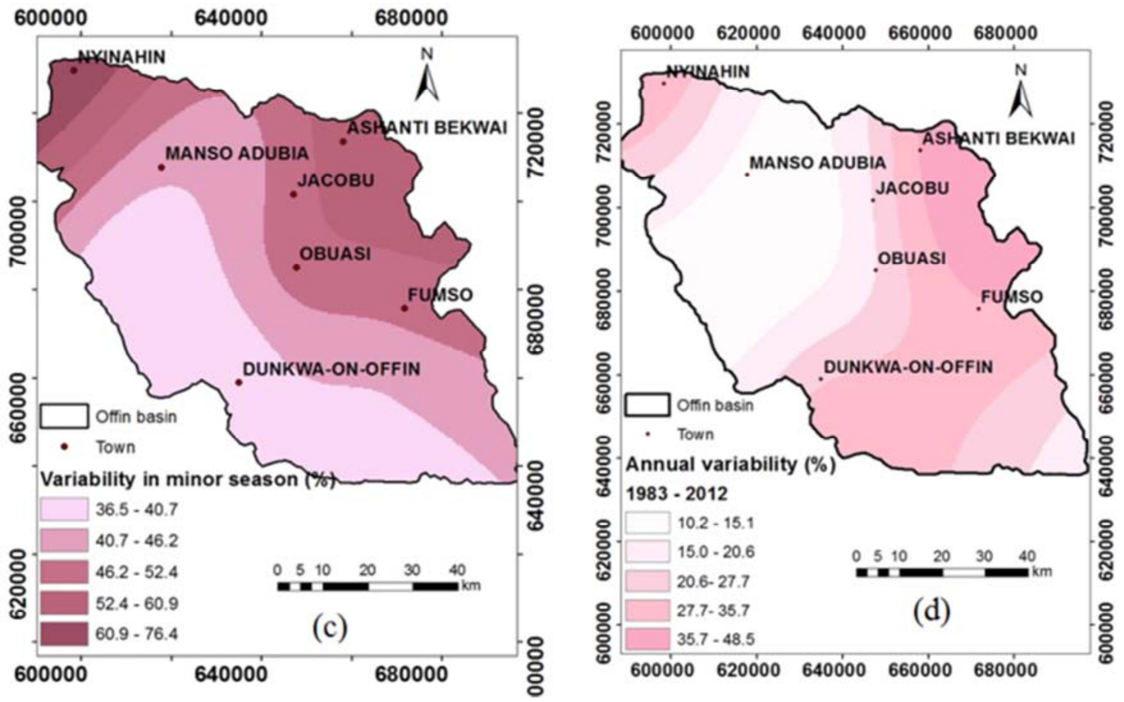
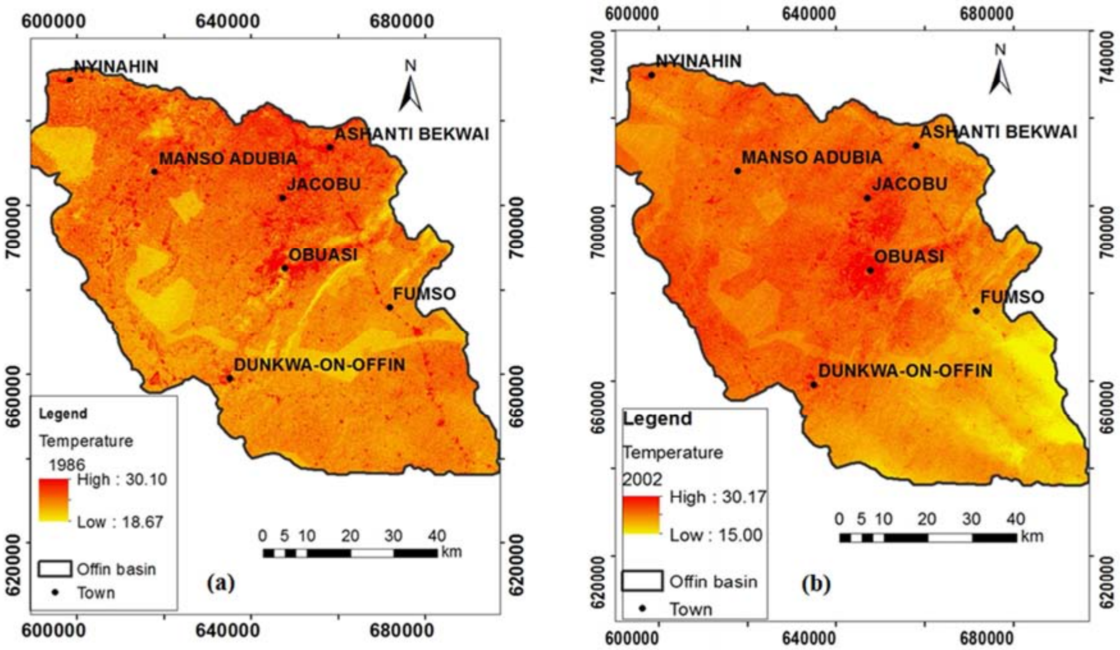


Figure 4. *Variability of (a) Dry season (December–February), (b) Major season (March-July; (c) Minor season (September-November and (d) Annual rainfall between 1983-2012 in the Offin River Basin.*

3.4. Landsat Derived Drought Characteristics in the Offin River Basin

The Land surface temperatures (LST) extracted from landsat data shows monotonic increasing trend. Maximum temperatures ranged from 30.10°C to 35.00°C. Minimum temperature did not show any trend. Obuasi, Jacobu, Dunkwa and Manso Adubia recorded highest LST values (>35.06°C). Temperature increases affect agriculture and food production through increase evapotranspiration and heat stress on food crops. High temperature observed in the basin may have a detrimental effect on rain-fed food crop production. Higher temperature leads to a reduction in photosynthetic rates by affecting photosystem II and Rubisco function and thus crops that are less resistant to high temperatures will be seriously affected. Daze [49] observed risen in temperature across the different ecological zones in Ghana.



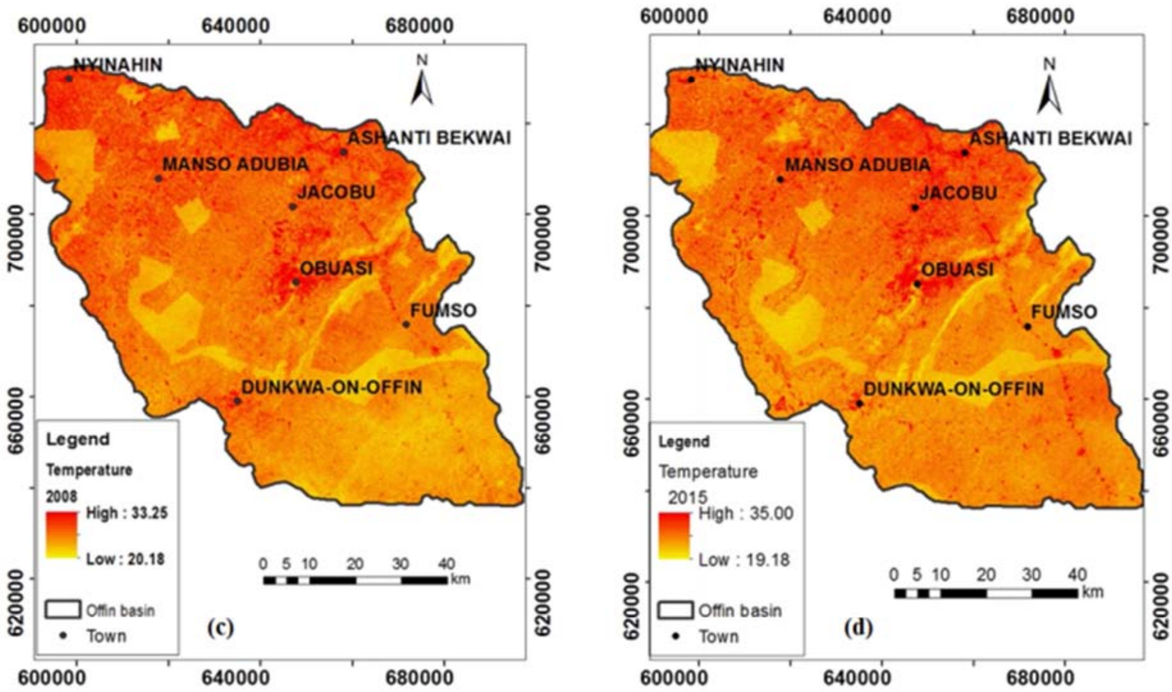
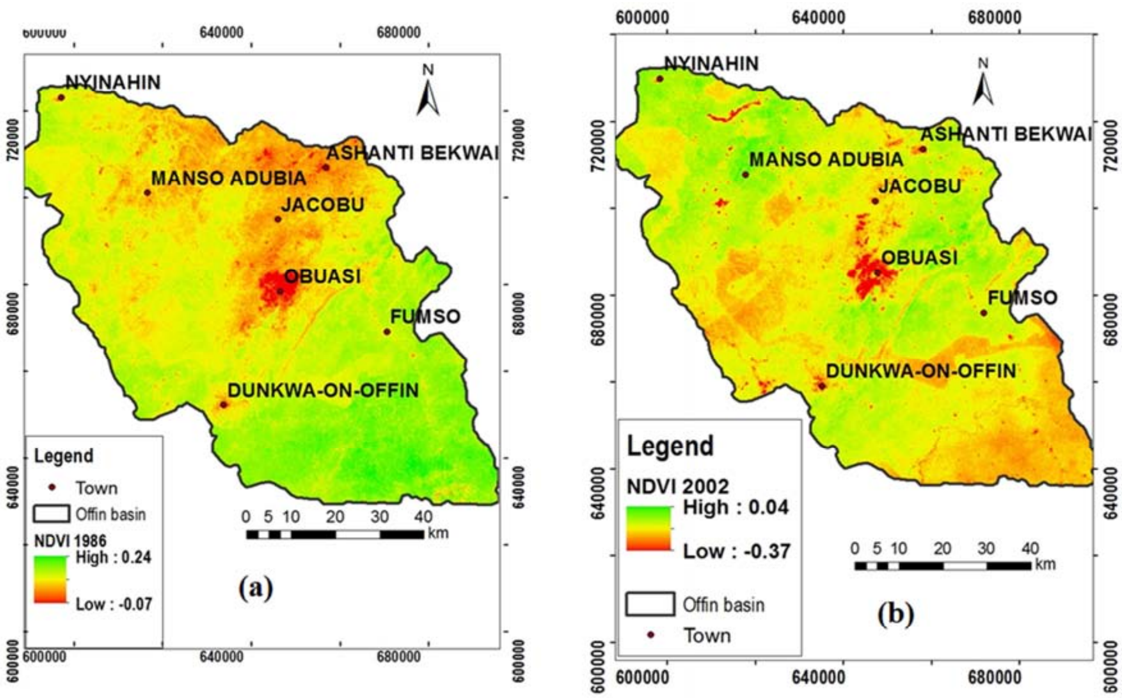


__Figure 5.__ Land Surface Temperature of (a) 1986 (20.18°C -33.25°C); (b) 2002 (15.18°C -30.17°C); (c) 2008 (20.18°C -33.25°C) and (d) 2015 (19.19°C -35.00°C) in the Offin River Basin.

The landsat based derived NDVI values for 1986, 2002, 2008 and 2015 yielded different values (Figure 6). The mean NDVI values recorded in 2008 and 2015 show vigorous vegetation growth compared to 1986 and 2002 which showed droughts conditions. Obuasi, Jacobu and Manso Adubia areas were characterized by pixels exhibiting negative values of NDVI, an indication of soil water deficit, poor vegetation growth and soil degradation [50]. With regards to the land use type, degraded lands had the lowest values of NDVI than natural forest and secondary forests. The vegetation drought characteristics recorded in the basin is an indication that recurrent agricultural droughts prevail in the area with negative impact on crop yields. The vegetation drought characteristics observed will most likely increase agricultural water demand and crop stress worsening food production, leading to serious implications on food security [51].



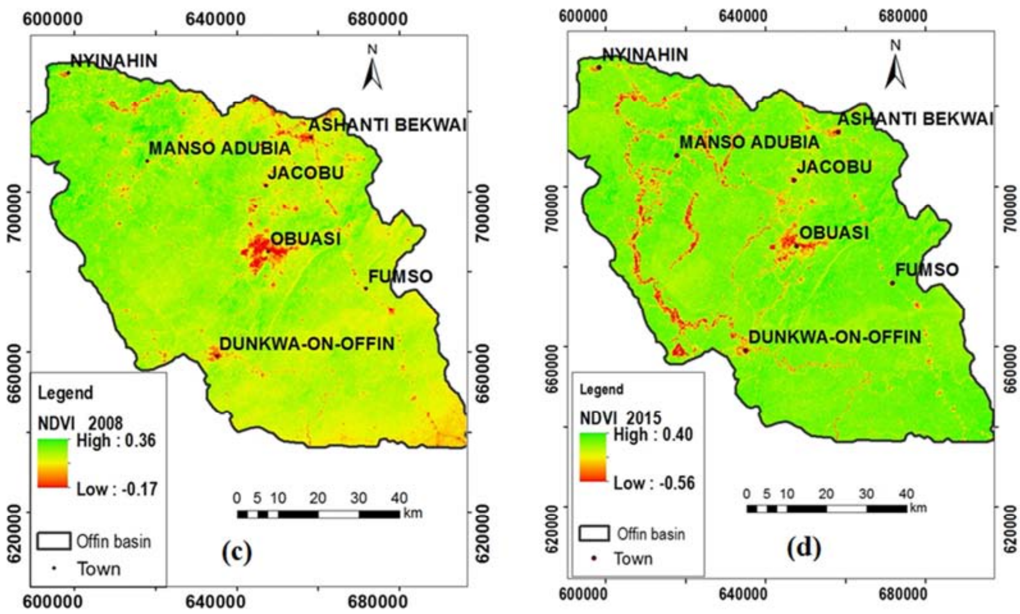


Figure 6. Normalized Vegetation Index of (a) 1986 (-0.07-0.24); (b) 2002 (-0.37-0.04); (c) 2008 ((-0.17-0.36) and (d) 2015 (-0.56-0.40) in the Offin River Basin.

3.5. Climate-Food Crop Yield Relationship in the Offin River Basin

Pearson correlation results revealed strong and positive correlation between rainfall and crop yield. This implies linear relationship (crop yield increases with increased seasonal rainfall and reduces with decreased seasonal rainfall). Previous studies have observed stronger positive correlation between rainfall and crop production in Nigeria, Ethiopia, Uganda and Tanzania [39, 22, 23]. Studies in Ethiopia [36], Uganda [52], Rwanda [53] and Nigeria [54] observed similar linear relationship between rainfall and crop yield.

***Table 3.** Correlation between Climate Variables and Food Crop Yield in the Offin River Basin.*

Major Food crops	Climate variables				
	Annual rainfall	Growing season rainfall		Temperature	
		Major season	Minor season	Maximum	Minimum
Rice	0.236	0.381*	0.521**	-0.518**	0.070
Maize	-0.465	0.659**	0.671	-0.573**	-0.003
Plantain	-0.802	0.323*	0.571	-0.332*	0.009
Cassava	-0.821	0.142	0.189	0.122*	0.093
Yam	0.034	0.628**	0.096	-0.682**	-0.296
Cocoyam	-0.671	0.606**	0.583	-0.663**	-0.087

** Significant at 1% level * Significant at 5% level

The maximum and minimum temperatures showed negative effects on crop yield, except cassava. Thus, increase in maximum temperature suppresses the yield of crops. These will surely have negative effect on food availability and food security status of farm households. Studies by Eregha et al. [55] found elastic relationship between temperatures and food crop yields. A study of crop yield response to climatic variability in Bangladesh by Al-Masud et al. [56] and Amin et al. [4] observed negative effect of temperatures on food crop yield. Awotoye and Matthew [57] in Nigeria reported similar relationship between crop production and temperature.

***Table 4.** Regression between Monthly Rainfall and Food Crop Yield in the Offin River Basin.*

Major Food Crops	R	R^2	P-value								
			March	April	May	Jun	Jul	Aug	Sept	Oct	Nov
Rice	0.845	0.844	0.359	0.645	0.815	0.455	0.200	0.083	0.475	0.874	0.372
Maize	0.939	0.961	0.671	0.572	0.989	0.925	0.780	0.257	0.631	0.891	0.589
Plantain	0.924	0.991	0.073	0.018	0.463	0.546	0.795	0.452	0.961	0.973	0.563
Cassava	0.891	0.910	0.016*	0.147	0.432	0.567	0.467	0.331	0.429*	0.432	0.232
Cocoyam	0.874	0.974	0.060*	0.049	0.458	0.764	0.672	0.117	0.916	0.231	0.158
Yam	0.919	0.850	0.047	0.054	0.294	0.562	0.817	0.214	0.917	0.231	-0.14

**=Significant at 0.01 level *=Significant at 0.05 level

Regression coefficient (Table 4) shows that rice, maize, plantain, cassava, cocoyam and yam have coefficient of determination of 0.844, 0.961, 0.991, 0.910, 0.974 and 0.850, respectively. These indicate that 84.44%, 96.01%, 99.10%, 91.00%, 97.40%, and 85.0% of the variations in crop yield is explained jointly by the variations in rainfall in the Offin river basin. This study corroborates the findings of Miloševic et al. [58] in Serbia, Bhandari, [59] in Nepal and Eregha et al. [55] in Nigeria which asserted that climate variability revealed varied effects on food crop yield depending on the food crop type.

In middle belt of Nigeria, Mijinyawa and Akpenpuun [54] found that 80% to 98% of variability in yield of food crops was explained by the effect of the climate change and climate variability. Mikova et al. [53] found that rainfall variability explained 64% to 88% of food crop production in Rwanda.

3.6. Food Security Status of the Farm Households

Household Food Balance Model analysis (Table 5) revealed that the mean calorie consumption of households was 2575.10 kcal per person per day which is below 2900 kcal per person per day. The minimum and maximum calorie intake were 224.4 and 7412.7 kcal per person per day, respectively, which showed large disparities of calorie intake among smallholder farming households in the Offin river basin. Nyinahin area recorded the highest mean kilocalorie intake of 2911.20 kcal per person per day followed by Jacobu with 2713.10 kcal per person per day, while Dunkwa-on-Offin had the lowest of 2153.21 kcal per person per day in the area. This result could be attributed to the effect of climate change and climate variability and land use change and land cover changes in the basin. These indicate that climate change and climate variability and anthropogenic factors are major causes of low agricultural food production and increasing food insecurity among smallholder farming households.

Table 5. *Food Availability in Calorie among Farm Households in the Offin River Basin.*

Calorie availability (kcal/person/day)	Offin River Basin			Town			
	Min	**Max**	**Mean**	**Nyinahin**	**Manso**	**Jacobu**	**Dunkwa**
Household Calorie Produced	11924.6	933394	40402.8	58762.8	30346.8	30370.8	32130.9
Household Calorie Sold	4587.0	50086.2	18861	29921.6	17934	13270	14320.1
Household Calorie Purchased	552.33	16252.6	4061.8	2525.6	6529.1	4147.2	3045.2
Household Daily Calorie Intake	1279.1	48704.1	15423.8	16361.4	15597.1	16913.4	12823.30
Household Daily Calorie Req	9860.0	28710.0	15209.6	14822.6	14086.8	17400.0	14529.00
Per Capita Daily Calorie Intake	224.4	7412.7	2575.1	2911.2	2522.9	2713.1	2153.21
Per Capita Daily Calorie Req	1189	5002.5	2507.0	2565.2	2304.5	2768.3	2392.01
Food security Index	0.1	3.8	1.0	1.1	1.1	1.0	0.89
Calorie Deficiency	2.7	-0.9	0.03	0.1	0.1	0.0	-0.11

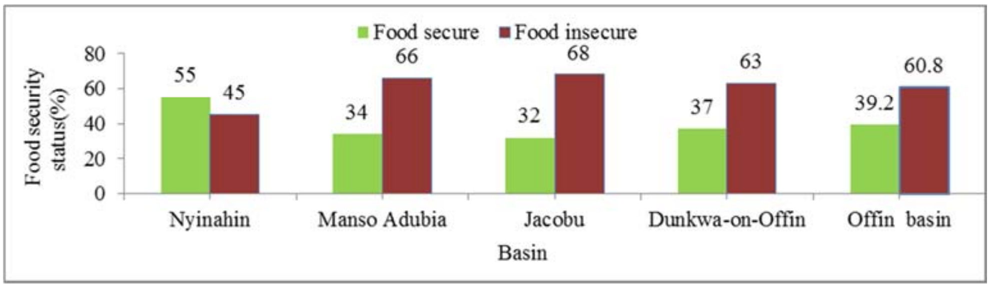


Figure 7. *Household Food Security Status among Farm Households.*

The model further showed that farm households in the basin could be classified as food insecure given that 60.8% of households were found food insecure subsisting on less than the recommended daily calorie requirement, while 39.2% of households were able to meet the recommended daily calorie intake of 2900 kcal per capita per day (Figure 7) and this could be attributed to land degradation and recurrent agricultural droughts observed. Kuwornu et al. [31] and Frimpong [32] in Ghana found 78.5% and 60% of the households respectively food insecure, which falls to meet the minimum calorie requirement. Mesfin [27], Weldearegay and Tedla [15] and Mekonnen et al. [16] observed in their studies of the impact of climate variability on household food in Ethiopia that 56.0%, 84.3% and 60.5% of the households respectively were food insecure fell below the daily recommended calorie intake.

High prevalence of food insecure farm households was pronounced in Jacobu (68%) followed by Manso Adubia (66%) and Dunkwa (63%). Contrary, majority of food secured households (55%) were observed in Nyinahin (Figure 7) and this could be attributed to household capacity to produce their own food (Table 5) This is in sharp contrast to Manso Adubia, Jacobu and Dunkwa-on-Offin which were found more prone to soil degradation, deforestation and recurrent agricultural droughts. Yesuf et al. [25] asserted that drought is associated with food insecurity. Paavola [60] and Mongi *et al*. [61] in Tanzania, Demeke et al. [62] and Shishay and Messay [63] in Ethiopia and Saina et al. [33] emphasized that climate variability and anthropogenic factors are major causes of increasing food insecurity among farming households.

3.7. Determinants of Status Among Farmers

Farmers identify factors such as land degradation, mining, poor crop harvest, erratic rainfall, low soil fertility and droughts as the main factors causing food insecurity in the area (Table 6). Studies by Berhanu [64] and Tilaye [65] in Ethiopia reported these factors as major causes of food insecurity. This observation is in line with the findings of Mesfin [27] that soil degradation reduces per capita arable land, depressed land productivity per unit area and thus one of the major limitations causing food insecurity. The finding further corroborates with Shisanya [66] and Gomiero [67] that soil degradation posed a threat to food security as it reduces crop yield.

Table 6. *Farmer's Response to causes of Household Food Insecurity in the Offin River Basin.*

Biophysical factors	**Offin basin n=398**	**Town**			
		Nyinahin n=100	**Manso n=88**	**Jacobu n=84**	**Dunkwa n=126**
Low soil fertility	354 (89)	71 (71)	83 (94)	78 (93)	122 (97)
Mining	383 (96)	89 (89)	88 (100)	83 (99)	123 (98)
Bush fires	32 (8)	12 (12)	5 (6)	10 (12)	5 (4)
Erratic rainfall pattern	358 (90)	64 (64)	87 (99)	83 (99)	124 (98)
Sand winning	335 (84)	97 (97)	74 (84)	78 (93)	86 (68)
Deforestation	323 (63)	59 (59)	88 (10)	79 (94)	97 (77)
Land degradation	346 (97)	56 (56)	88 (100)	83 (99)	119 (94)
Recurrent droughts	314 (68)	79 (79)	86 (98)	81 (96)	68 (54)
Poor crop harvest	382 (96)	100 (100)	81 (92)	81 (96)	120 (95)
Poverty	228 (57)	56 (57)	74 (84)	50 (60)	48 (38)

*Values in bracket are the percentages (%); n=total number of samples

The regression result showed education and training positively associated with household food security. Education and training increase farmers' adoption to climate smart practices, which in turn translate into higher agricultural productivity. This work agrees with the findings of Amaza et al. [68] that the higher the educational level of a household head, the more the food security conditions of the households. This is further supported by Ndambiri et al. [69] in Kenya and Ayanwuyi *et al*. [70] and Shisanya [66] in South Africa who alluded that households with higher level of education are less vulnerable to climate variability and make better adaptation.

A unit increase in size of household landholdings and household croplands were found positive and significantly associated with household food security. This is because increase in household landholdings and household farm size imply that household members could have enough farm land size for multiple cropping for consumption and also for sale and thus have better chances to be food secure than those having relatively small size of cropland. The finding is consistent with studies conducted by Jayne et al. [71] and Mesfin [27] that land holding size play a significant role in ensuring households food security. Kahsay and Mulugeta [72] in Ethiopia opined that that land size positively affects calorie intake of households. Smith [73] reported that food production can increase by expanding agricultural area.

Coefficients of age of the household head, sex of household head, household size and crop yield (plantain, cassava, cocoyam, yam and maize) were found to have negatively associated with household food security. The negative sign of the regression coefficients indicates that, increasing values of these variables significantly caused a decrease in household food security. In Zimbabwe [74] and Kenya [75] also observed a negative linkage between household size and food security.

The negative relationship observed between food crop yield and household food security, implies that food production at farm household level could not meet household food needs, leaving households high risks of food insecurity. The study thus concludes that the produce from major food crops in the basin has not been enough to suffice household food security requirement. Thus, good strategies are needed to increase the food production systems in the area. These concerns have been raised by Lobell et al. [76] and Lobell and Field [34].

The result indicates that the coefficient of crop management practices (growing drought tolerant, high yielding and early maturing crop varieties, varying planting and harvesting dates), soil and water conservation and management practices (crop residue retention management, cover cropping, minimum tillage, crop rotation), crop diversification and utilization of moist valley bottoms were positive and significantly related to household food security in the basin (Table 7). The study supports the findings made by Chijioke et al. [77] that climate variability affects food security of farmers depending on the adaptation strategies put in place. Beyene and Muche [78] in Ethiopia reported positive and significant relationship between soil and water conservation practices and household food security. Neufeldt et al. [79] and Harvey et al. [80] opined that soil management practices have significant contribution to increase crops yield and eventually improve household food security. Codjoe et al. [81] in Ghana argues that crop diversification reduces vulnerability by serving as an assurance to rainfall and temperature variability as different crops are affected differently by climatic events.

The high food security status observed among farmers utilizing inland valleys and wetland resources proved that these resources have high positive impact in boosting crop production, enhancing livelihood and food security systems.

In Uganda [82], reported that wetland resources contribute to household food security. A study by Shisanya [66] in Ehiopia, observed that utilization of moist valley bottoms for food crop production has positive and significant impact in reducing food insecurity. The findings from this study further joined the argument by Mkavidanda and Kaswamila [83] in Tanzania that wetlands resources make appreciable contribution to rural livelihoods and food security.

Table 7. *Determinants of Food Security Status among Farm Households in the Offin River Basin.*

Parameter Estimates	Ordinary Least Squares Linear Regression Model				Pearson chi-square test		Symmetric measures (phi)	
	B	SE	T	Sig	Value	P-Value	Value	P-Value
Constant	1.990	0.184	10.807	0.000				
Age of household head	0.060	0.023	-2.638	0.008	6.222	0.183	0.131	0.183
Sex of household head	0.006	0.048	- 0.121	0.904	20.468	0.005	0.238	0.005
Level of education	0.006	0.022	0.300	0.000	15.591	0.003	0.211	0.003
Training	0.022	0.046	0.467	0.000	1.245	0.001	0.354	0.000
Household size	-0.049	0.017	-2.906	0.004	0.287	0.339	-0.028	0.592
Total land holdings	0.035	0.012	2.883*	0.001	14.900	0.005	0.643	0.000
Household crop land	0.035	0.016	1.909*	0.057	16.637	0.000	0.641	0.000
Inland valleys	0.067	0.057	1.126**	0.016	1.314	0.000	0.575	0.001
Upland	-0.042	0.053	-0.787*	0.000	5.121	0.000	0.367	0.000
Monocropping	-0.032	0.034	-0.918***	0.000	1.812	0.000	0.123	0.000
Mixed farming	0.124	0.038	3.240**	0.000	72.757	0.000	0.428	0.000
Crop diversification	0.174	0.140	1.245***	0.000	1.755	0.000	0.324	0.000
Soil conservation	0.037	0.128	0.265***	0.000	1.737	0.000	0.364	0.003
Crop management	0.238	0.140	1.703***	0.000	1.727	0.000	0.259	0.000
Cocoa yield	0.021	0.036	0.568**	0.570	1.175	0.000	0.571	0.000
Plantain yield	-0.049	0.009	-5.251	0.000	1.145	0.000	0.564	0.000
Cassava yield	-0.075	0.011	-6.744	0.000	1.144	0.000	0.564	0.000
Cocoyam yield	-0.025	0.032	-0.793	0.428	46.734	0.000	0.360	0.000
Maize yield	-0.200	0.069	-2.904	0.004	30.107	0.000	0.289	0.000
Yam yield	-0.375	0.211	-3.724	0.100	1.121	0.000	0.366	0.100
Rice yield	0.591	0.211	4.849**	0.000	18.838	0.001	0.229	0.001

*Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2- tailed)

4. Conclusion and Policy Considerations

The study has shown that unfavorable climatic conditions coupled with adapted land use systems have resulted into massive deforestation, severe soil and water degradation and recurrent agricultural droughts, affecting major food crop yield and exacerbating household food insecurity among the farm households in the basin. Utilization of inland valley and wetland resources, soil and water conservation and management practices and crop management practices were found to have contributed positively to the household calorie availability and household food security. Thus, these practices adopted by farm households were effective and have the propensity to improve soil fertility, boost food crop production systems and enhance household food security.

Policy Considerations

Enforce environmental laws to protect valley bottom and wetlands resources from illegal mining and sand winning to ensure sustainable food production and enhance food security

Educate farm households on increased uncertainty in commencement and duration of rainfall, agricultural droughts, soil moisture retention management practices and drought-tolerant food crop varieties to build-up resilience of farmers to climate variability as well as enhancing household food security.

Local Government Agencies and existing NGOs should increase investment in crop management and soil and water conservation management strategies as a climate resilient practice to boost food crop systems and food security systems.

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