ISSN 2250-3153

Farm-level Adaptation Strategies to Climate Variability: Evidence from Smallholder Farmers in Offin River basin, Ghana

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Abstract: *Climate variability is a complex environmental problem facing the world with the smallholder farmers in sub-Saharan Africa and south Asia been the most vulnerable group. However, farm-level adaptation is considered an important option to mitigate the adverse effect of climate variability on the smallholder farmers. This paper examines farm-level adaptation strategies adopted by farmers in the Offin river basin. A total of Three hundred and ninety eight farmers from eight communities were randomly sampled using a multistage sampling technique. The results showed that about 78.39 % of smallholder farmers have adopted soil and crop management practices to abate the effects of climate variability. The study revealed that soil and water conservation practices, improved food crop varieties, utilization of inland valleys and wetlands, changing planting dates, crop diversification and mixed cropping were the most preferred adaptations practices adopted by the farmers. Educational attainment, farming experience, access to agricultural extension services, access to credit facilities, training on climate information and farmer-based organization were the factors found promoting the adaptations. The paper thus suggests investment in climate information and collaboration between media and research institutions in climate change and variability studies which have a great prospect in promoting adaptation among the farmers.*

Keywords- *Farm-level adaptation; Climate variability Smallholder farmers; Offin river basin*

I INTRODUCTION

Climate variability is a complex environmental problem facing the world with smallholder farmers in Sub-Saharan Africa and south Asia been the most vulnerable group. High temperatures, erratic rainfall pattern, dry spells and droughts have been hampering crop yield vis-á-vis food production in Africa.
For instance, Morton (2004) noted that the most harmful impact of climate variability will be felt by smallholder farmers in the developing countries.
FAO (2008) indicated that climate variability posed severe threat to crop production particularly to the smallholder farmers in Africa continent. Stanturf *et al*. (2011) also observed that recurrent droughts in African countries have demonstrated the effects of climate variability on food production resources.

In Ghana, climate variability has been affecting many farmers whose livelihoods depend largely on rainfall (Fosu-Mensah *et al*., 2012). Farm-level adaptation strategy is an important option to climate variability. A study by Temidayo (2011) found that farm-level adaptation strategies have the potential to increase crop production and build resilience of farming systems to climate variability. According to IPCC (2001), farm-level adaptation can greatly reduce the vulnerability to climate variability by making rural communities better able to adjust to the changing climatic conditions, cope with adverse consequences and moderating potential damages.

However, farm-level conservation practices such as crop, soil health, water management and agro forestry technologies are important adaptations but adoption and implementation remains low and challenging in sub-Saharan Africa. Boko *et al.* (2007) indicated that adaptation to climate variability is already taking place but limited at the farm-level. Similarly, despite the importance of farm–level adaptation to climate variability, it has attracted little attention and to our knowledge no attempts have been made to identify farm-level adaptation in the Offin river basin. This paper examines farm-level adaptations strategies adopted by smallholder farmers to lessen the adverse effects of climate variability in the Offin river basin.

II MATERIALS AND METHODS

A. Study Area

The basin is located between latitude 5°30′N to 6°64′N and longitude 1°30′W to 2°15′W. A large population in the basin lives in rural communities, with crop production as their main economic activity. The basin has a bi-modal rainfall pattern with major rainy season starts from March to July. The minor rainy season begins in September and ends in November (Figure 1). The mean annual minimum temperature is 22 °C, while maximum temperature for the hottest months is 33.2 °C.

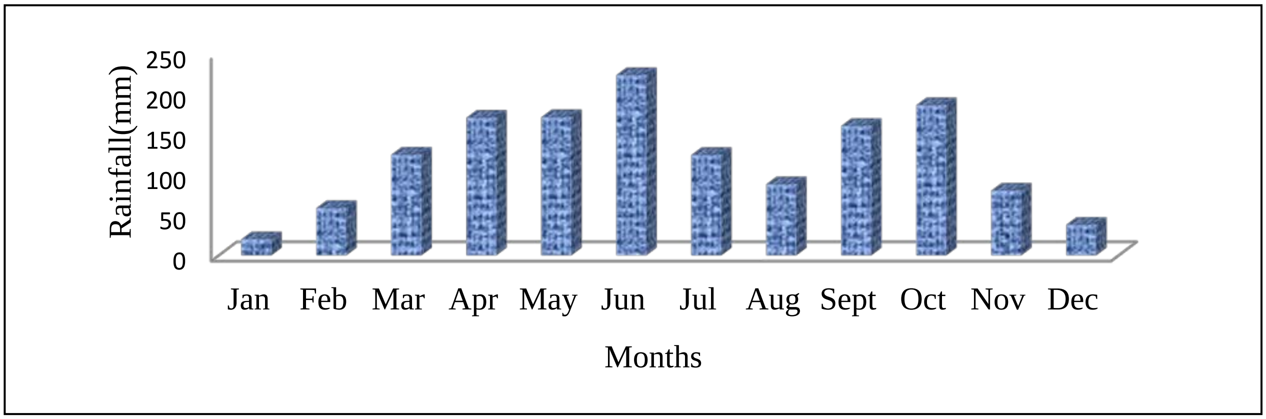

Figure 1: Average monthly rainfall from six climatic stations within Offin river basin (1983-2012)

B. Research Design

A multistage sampling technique was employed. First, four areas namely Dunkwa, Jacobu, Manso Adubia, and Nyinahin were purposively selected for the study. Sample size was estimated using

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

Where, n is the sample size, N is the population size and e is the margin error. With 5 % margin of error (95% confidence level), from a total population of 68,471, the sample size was estimated as 398 farming households. Secondly, two communities were randomly selected from each area. Proportional sampling techniques was used to determine sample size (s) of each selected community. The sample size (s) was calculated as:

$$s = \frac{Zn}{N}$$

Where s is sample size and Z is the population size. Thirdly, simple random sampling was used in the selection of 398 farming households on the field.

C. Data Collection

Climate data of 30 years period (1983-2012) from six weather stations within the basin were collected from Ghana Meteorological Department, Regional Office Kumasi for the assessment of the climate variables

A household questionnaire made up of semi-structured type was used to collect data related to farmers' perceptions of changing climate conditions and adaptation and copping strategies. Questionnaire was administered through face-to-face interview with the help of agricultural extension officers. A fellow up visit to each farm was done to validate the information given by farmers. The questionnaire was designed under the following headings:

Farmers' perceptions on climate variables

Information related to farmers' perceptions on the rainfall, dry spells, drought events and variations in temperature during the cropping seasons.

Farmer's adaptation strategies

Measures adopted on the farm to responses to the impacts of climate variability

D. **Data Analysis**

The data collected were processed and analyzed using the SPSS version 20.0. Descriptive statistics and multinomial logit (MNL) model were used to determine the factors influencing farmers' adaptation practices in the basin.

III RESULTS AND DISCUSSION

Farmers perceptions versus Climatic Data

The results showed that 100 %, 97.50 %, 96.00 %, and 99.20 % of smallholder farmers in the basin perceived rising temperatures pattern, high variability of rainfall, recurrent drought events and intermittent dry spells respectively within the cropping season. Comparing smallholder farmers perceptions with maximum and minimum temperatures from five weather stations (Figure 2and 3), showed a clear evidence of increasing temperatures intensity with severe implications among the smallholder farmers.

Table 1: Farmers responses to changing climatic conditions during the growing seasons

Variables	Offin basin n = 398	Nyinahin n = 100	Manso Adubia n = 88	Jacobu n = 84	Dunkwa n = 126
Increasing temperatures	398(100)	100(100)	88 (100)	84(100)	126(100)
High variability in rainfall	388(97.50)	90(99)	88 (100)	84(100)	126(100)
Frequent droughts	382(96.00)	96(96)	88(100)	79(94.0)	119(94.0)
Intermittent dry spells	395(99.20)	99(99)	88(100)	82(97.6)	126(100)
Low food crop production	318(79.90)	57(57)	78(89)	76(80)	107(84)
Adaptations measures	312(78.39)	64(64)	81(92)	79(89)	113(88)

*Values in bracket are percentage of smallholder farmers (%)

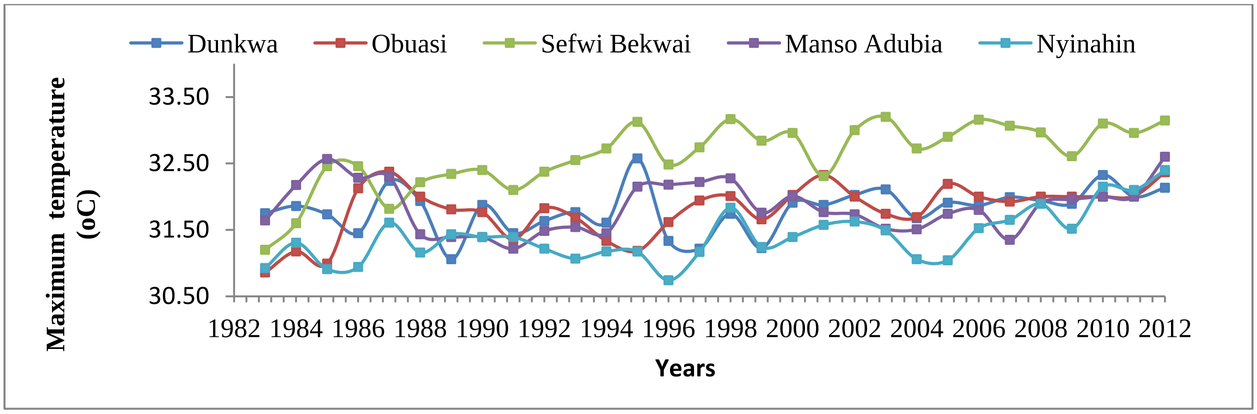

Figure 2: Maximum temperature within the cropping season from five weather stations (1983-2012)

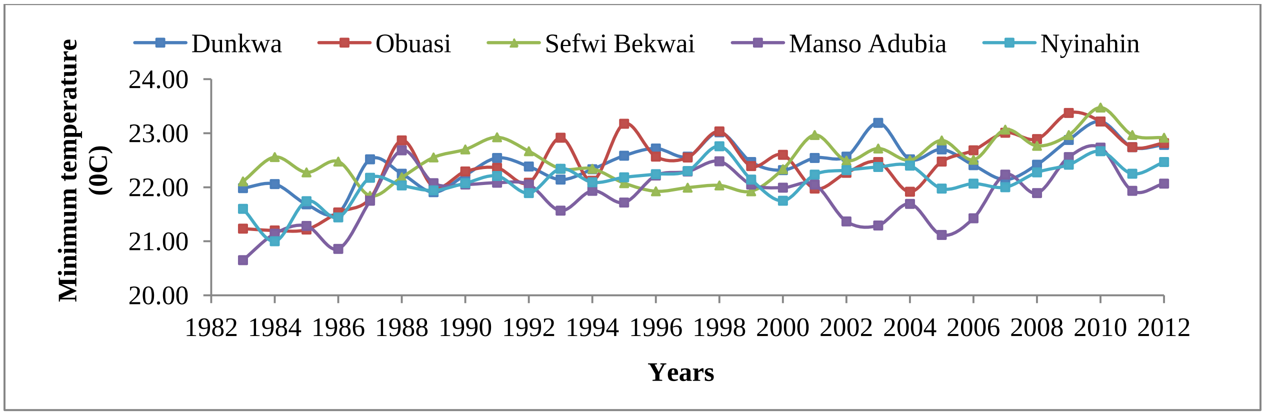

Figure 3: Minimum temperature within the cropping season from five weather stations (1983-2012).

To confirm farmers' perceptions regarding rainfall pattern in the cropping season, the annual rainfall data from six weather stations from 1983 to 2012 did not show an apparent confirmation of increasing or decreasing rainfall (Figure 4) but there was a clear evidence of higher inter-annual variability of rainfall (Figure 5). This indicated that there is high variability of rainfall pattern rather than decreasing or increasing trend. The variability in rainfall pattern over the years in the basin has translated into intermittent dry spells and frequent drought events between and within the growing season. The results indicated a consistency between climate data and the smallholder farmers' perception about intermittent dry spells and droughts events during cropping season. The study also indicated that about 79.90 % of smallholder farmers perceived that changing climatic conditions during the cropping season has adversely affected their food crop production and thus impacting food security systems.

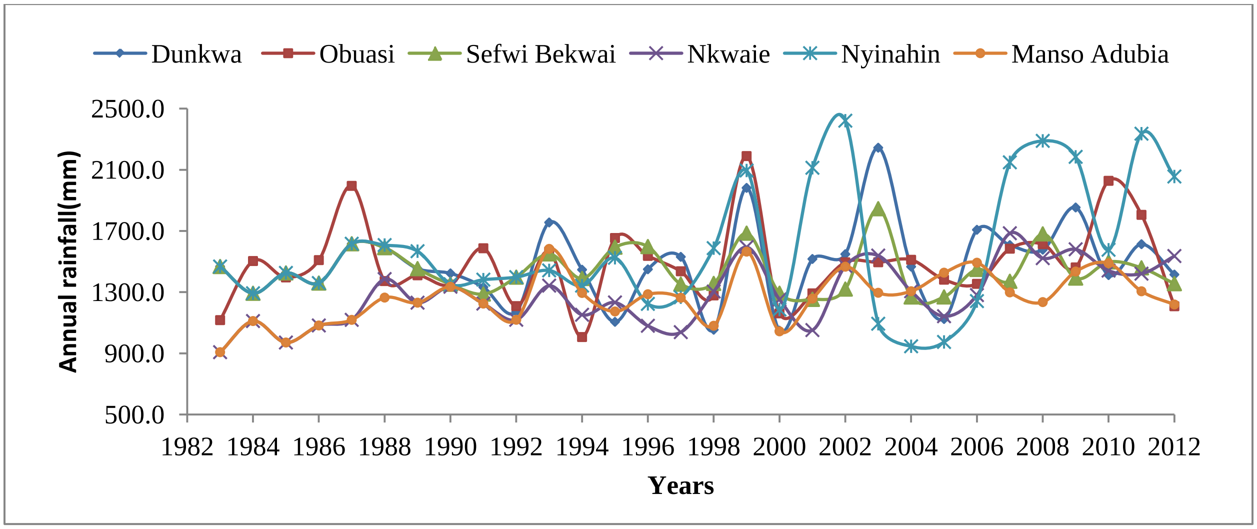

Figure 4: Annual rainfall pattern within the cropping season from six weather stations (1983-2012)

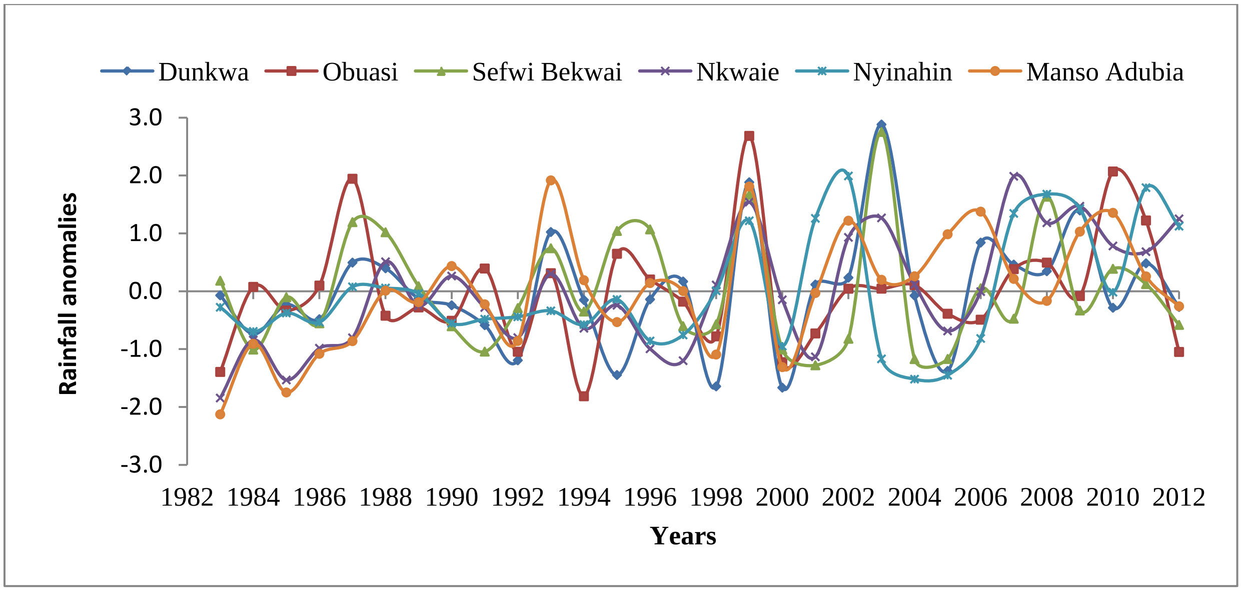

Figure 5: Variability of rainfall within the cropping season from six weather stations (1983-2012)

Famers' Adaptation Strategies

The results showed that 78.39 % of farmers have adopted soil and water conservation technologies and crop management practices to combat the effect of climate variability (Figure 6). The study revealed that changing planting dates, soil and water conservation practices, crop diversification, improved food crop varieties, mixed cropping; small-scale irrigation and utilization of inland valleys and wetlands resources were the most adopted strategies in the basin. Studies in Kenya (Evelyn *et al.*, 2017) and Nigeria (Ayanlade *et al.*, 2017) have observed similar adaptation measures to minimize effect of climate variability.

Improved Food Crop Varieties

The early maturing cassava varieties (Bankye Essam, Bankye Hemma), long maturing cassava variety (Dabo), high yielding maize varieties (Obatanpa, Mamaba and Dadaba) and rice varieties (Jasmine and AGRA) were found been planted by 45 % of farmers. The cultivation of early maturing and long-time maturing crop varieties found showed the tendency of smallholder farmers to take advantage of different maturing and harvesting time of crops to alleviate the effects of climate variability. These findings are in agreement with farmers in Kenya (Speranza, 2010) and Namibia (Newsham and Thomas, 2011) who plant early maturing and long-time maturing crop varieties to cope with drier conditions.

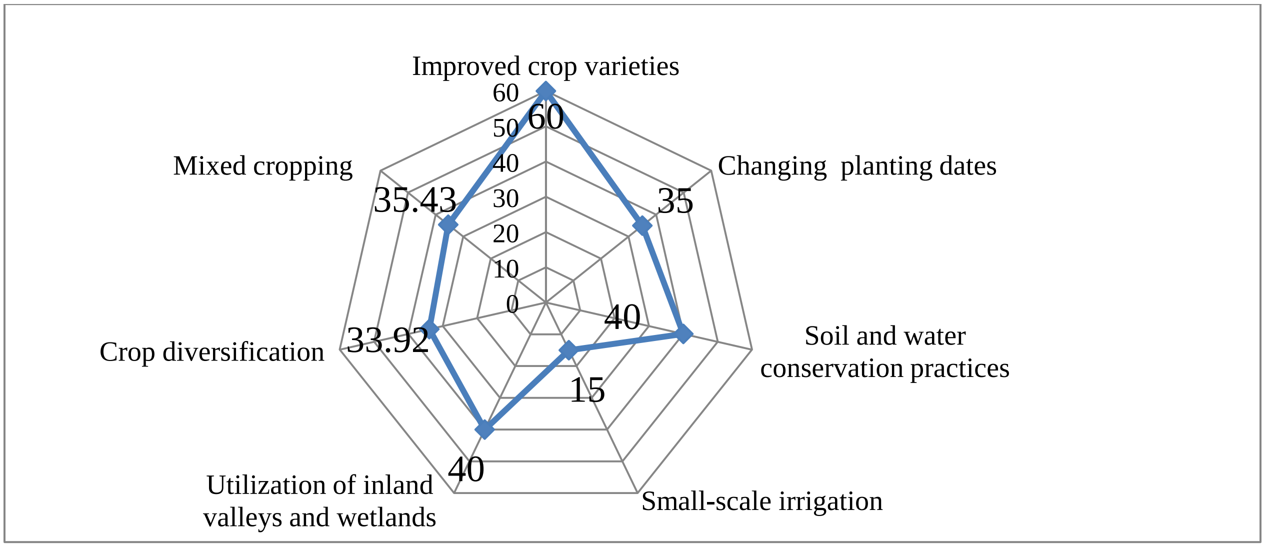

Figure 6: Farmer perceived adaptation and mitigation options to climate variability

Crop Diversification

Crop diversifications were found among 34 % of farmers to guard against crop failure under climate variability. Farmers in Malawi (Coulibaly *et al*., 2016) and Nigeria (Babatolu and Akinnubi, 2016) also grown diverse food crops to avert the climate risks. Njeru (2013) also observed that smallholder farmers grow diverse crops to halt the effect of climate variability and enhance food security.

Changing of planting dates

About 35 % of farmers were found changing planting dates during the cropping period to offset the effect of climate variability. Smallholder farmers were noted planting maize in May instead of recommended time of March/April. Studies by Iglesias *et al.* (2000) in Spain and Waha *et al*. (2012) noted that smallholder farmers are changing planting dates as mitigation measure to climate variability.

Inland valleys and wetland cultivation

Crop farmers in the Offin river basin (40 %) were found utilizing inland valleys and wetlands resources as an adaptation to produce crops and as well as to ensure continuous food supply. These strategies have been reported in similar studies by Rweyemamu (2009) in Tanzania and Turyahabwe *et al.* (2013) in Uganda where farmers have adopted inland valleys as a coping strategy to frequent and prolonged droughts and climate variability.

Small-scale irrigation practices

Irrigation practices were found among 15 % of farmers using water-pumping machine, PCV pipes, watering cans and buckets in taking water from rivers, streams and boreholes to water their crops.

Soil and Water Conservation Strategy

Smallholder farmers have adopted several soil and water conservation and management practices to retain soil moisture and promote soil health (Figure 7). The most dominant soil and water conservation practices include stone bunds, crop rotation, cover cropping, minimum tillage, agro-forestry, mulching, creation of bunds, ridging and manure application. These practices are significant in reducing negative effects of climate variability through increasing soil moisture, promoting soil health and plant growth and securing food crop yield. Zougmore *et al*. (2014) and Lagerkvist *et al*. (2015) in Kenya and Burkina Faso found that farmers have adopted soil and water conservation technologies to offset effects of climate variability.

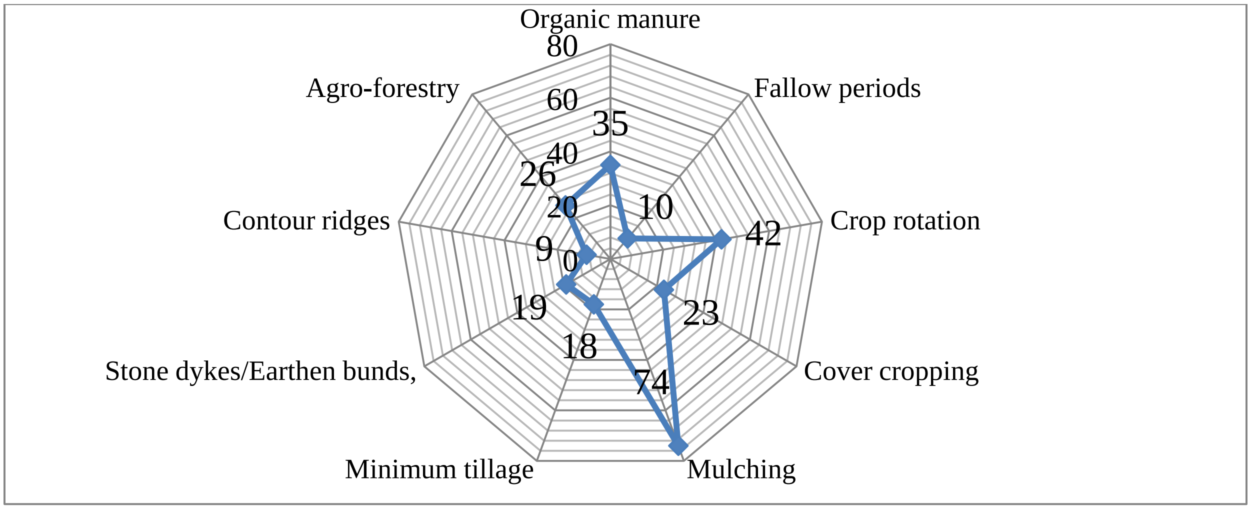

Figure 7: Soil and water conservation adaptation strategies

Agro-forestry

Adoption of agro-forestry was observed among 26 % of smallholder farmers to reduce the risks of cropping systems and build up resilience to climate variability. Malawi (Coulibaly *et al*., 2016) and Southern Africa (Syampugani *et al*., 2010) found that farmers used agro-forestry in building up resilience to climate variability.

Contour and terracing

Farmers (28 %) were noted using earthen bunds, stone bounds, contour ridges and terraces to tap run-off during and after rainfall, promote infiltration, minimize soil erosion and increase moisture at root zone. Farmers were found building stones with height of 20-30cm from the ground on their farms to reduce surface run-off, enhance rainwater infiltration and improve moisture retention and soil-plant nutrients uptake. Studies by Syampugani *et al*. (2010) and Zougmore *et al*. (2014) found contour and bunds as soil erosion prevention and water retention structures.
It is imperative to note that stone bund practices combined with organic sources of nutrients, is a promising climate and land use adaptation responses that could increase crop productivity and securing food security while contributing to strengthen the adaptive capacity of smallholder farmers.

Mulching

Using crop residue and grasses as a soil conservation practices were found among 74% of the smallholder farmers to improve and preserve soil nutrient and to retain soil moisture in the face of climate variability.

Determinants of Adaptation Strategies

The results highlighted that educational attainment, farming experience, access to agricultural extension services, access to credit facilities, training on climate information, household size and farmer-based organization were factors found promoting changing planting dates, mixed cropping, crop diversification, soil and water conservation, utilization of inland valleys and improved crop varieties as an adaptation to climate variability in the basin.

However, age of the farmer, land use activities, farm size, soil fertility were limiting factors to adaptation measures.

Table 2: Multinomial logit (MNL) adaptation model

Variables	Coefficients						
	Improved crop varieties	Changing planting date	Mixed cropping	Crop Diversifi - cation	Soil and water conservation	Inland Valleys	Irrigation

Age of farmer	0.02	-0.14	0.12	-0.02	-0.12	0.02	-0.12
	(0.42)	(-0.24)	(0.14)	(-0.12)	(-0.23)	(0.12)	(-0.12)
Household	0.01	0.18	0.24	-0.01	0.42	0.04	0.01
size	(0.00)	(0.26)	(0.29)	(-0.12)	(0.21)	(0.42)	(0.01)
Educational	0.08	0.32	0.21	0.09	0.22*	0.20	0.05
attainment	(0.50)	(0.41)	(0.34)	(0.00)	(0.51)	(0.47)	(0.06)
Farming	0.05	0.51	0.37	0.01	0.26	0.42	0.11
experience	(0.22)	(0.24)	(0.00)	(0.54)	(0.44)	(0.61)	(0.00)
Farm size	-0.5	-0.24	0.11	0.00	-0.10	-0.01**	0.12
	(-0.12)	(-0.09)	(0.21)	(0.01)	(-0.56)	(-0.01)	(-0.00)
Soil fertility	0.12	-0.50	-0.57	-0.94	0.61	-0.61	0.40
	(0.53)	(-0.08)	(-0.41)	(-0.81)	(0.32)	(-0.41)	(-0.27)
Land use	-0.22	-0.40	-0.11	-0.00	-0.12	-0.02	-0.18
activities	(-0.70)	(-0.51)	(-0.21)	(-0.01)	(-0.16)	(-0.03)	(-0.00)
Access to	0.10	0.31	0.19**	0.30	0.00	0.20	0.05
extension	(0.51)	(0.60)	(0.44)	(0.16)	(0.44)	(0.47)	(0.06)
Access to	0.42	0.12	0.64	0.10	0.01	0.20	0.05**
credits	(0.10)	(0.91)	(0.23)	(0.60)	(0.21)	(0.47)	(0.06)
Farmer- based	0.11	0.42*	0.33	0.10	0.23	0.01*	0.06
Organization	(0.80)	(0.16)	(0.54)	(0.01)	(0.41)	(0.44)	(0.01)
Perception	0.94*	0.62	0.75	0.31	0.17	0.14	0.11
	(0.21)	(0.21)	(0.22)	(0.17)	(0.24)	(0.47)	(0.89)
Training on	0.00	0.58*	0.31	0.00	0.22	0.41	0.12
climate	(0.13)	(0.00)	(0.02)	(0.00)	(0.43)	(0.21)	(0.00)

Note: ** and * are significant levels at 1 % and 5 %, Numbers in brackets refer to *p* values

IV CONCLUSION

The paper examines farm-level adaptations among the smallholder farmers in the Offin river basin. The results demonstrated that smallholder farmers have employed various soil and water conservation technologies and crop management practices to minimize the adverse impacts of climate variability. The study concludes that the various farm-level conservational technologies or practices adapted by farmers have the propensity to promote soil health, enhance crop growth and crop productivity.

V POLICY IMPLICATIONS

Integration of farmers' innovations of adaptation with scientific observations on soil conservation and crop management practices should be encouraged among stakeholders and research scientists particularly in the climate variability and land use change policies. Also communication between climate change/ variability researchers and media partners need to be intensified to facilitate the exchange of climatic information among smallholder farmers.

ACKNOWLEDGEMENTS

We are grateful to the Directors and staff of Ghana Meteorological Department, Regional Office Kumasi and Ministry of Food and Agriculture for providing climate data and assisting us in getting the farmers.

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