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Adaptation Strategies to Climate Extremes among Smallholder Farmers: a Case of Cropping Practices in the Volta Region of Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Author NN designed the study and wrote the first draft of the manuscript. Author MD managed data capturing and analysis together with Author NN. Author OTF coordinated the data collection and logistics with the enumerators. All authors read the manuscript and approved the contents presented in the final manuscript.

Research Article

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ABSTRACT

Climate extremes threaten livelihoods of smallholder farmers in Sub-Saharan Africa hence the need for adaptations strategies. The objective of the study was to analyze adaptation strategies used by smallholder farmers by examining their knowledge of climate extremes and the perceived effects of climate extremes on agriculture activities. The study was conducted using data generated from 70 randomly selected farm families from 4 villages in Hohoe district, the Volta Region in Ghana, in July 2009. Information sought included household socio-economic characteristics, cropping systems, experience with climate variability and adaptation strategies to weather extremes and climate risk. Descriptive statistics were run on household characteristics, chi-square tests and analysis of variance were used to separate means ($P<0.01$ and 0.05) using the Statistical Package for Social Sciences (SPSS). Results showed that farmers experienced either drought or flood once in every two seasons over the past 3 years. Among the adaptation strategies currently used to reduce the impact of climate extremes were early planting, use of hybrid

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seed and soil moisture conservation techniques such as within-field ridge construction. Awareness of the climate change phenomena was high among farmers (94%), and the main sources of climate change-related information were radio, television, agricultural extension agents and local experts. Farmers perceived deforestation and forest fires as major factors contributing to climate extremes. Limited use of fertilizer, hybrid seed and lack of planned crop sequences reduced the benefits from the mixed cropping system. Low resource endowment limited effective use of improved and modern crop production technologies. Current adaptation strategies to climate extremes especially drought are not enough to reduce risk and loss in agricultural production. However, improved drainage infrastructure and mulching were reported to increase crop production; important innovations against droughts and floods. We conclude that inputs and modern crop management techniques are key to minimizing the effects of climate extremes on crops. Delivery of high quality weather forecasting information could better prepare farmers and improve planning of seasonal calendars. The study showed close relationships between adaptation capacity and resource endowment and rural infrastructural development. The results are important in planning intervention on climate extremes and rural agricultural development.

Keywords: Farmer survey; weather extremes; rural poverty; global change awareness; droughts and floods; West Africa.

1. INTRODUCTION

The current global predictions based on scientific studies show that increasing climate extremes will continue to negatively impact millions of smallholder farmers that are dependent on agriculture for their livelihoods [1,2]. Studies have shown that in sub-Saharan Africa (SSA), exposure to extremes of weather e.g. droughts, floods and high temperatures will exacerbate the problem of crop failure from fragile farmlands (about 70 percent of surface area is classified as semi-arid tropics and deserts), increasing hunger, malnutrition and disease [3,1,4]. Projections show that there shall be an increase in the frequency of occurrence of droughts and these will impact negatively on crop and livestock production by smallholder farmers in East, Southern and West Africa [5]. The per-capita food production has gone down in Southern Africa and some of the events can be closely related to the effects of changing weather patterns in recent years [6]. Similarly, low precipitation has led to reduced land cover and flora in Sahelian West Africa [7]. The trends analyzed so far are indicative that the impacts of biotic and abiotic stresses are evolving and could lead to major reductions in production [8]. Climate extremes defined as, the occurrence of a weather or climate variable above (or below) the threshold value near the upper (or lower) ends of the range of observed values of the variable [9], need to be managed to safeguard agricultural production.

In order to better prepare farmers for extreme weather events caused by global change and to collaboratively learn about the evolution of weather patterns, efforts to focus on the smallholder farmers and their current activities, knowledge and perceptions are imminent [10,11]. The discussion on knowledge of potential adaptation strategies need to be guided by empirical data on local and regional farmers' circumstances, and that of the potential agricultural systems used for food production. Currently, models used in these predictions are at a global scale and these need to be downscaled to accommodate realities at regional and local levels. Work of [8] in East Africa showed that there is a correlation between variability of crop yields and the ability of a household to adapt to climate change hence the need to make these analyses at household and local community levels. This study has taken the household approach as an entry point in understanding the options available for farmers to adapt to climate extremes.

Low crop yields being experienced in many smallholder farms in the SSA can be attributed to poor agronomic practices, low utilization of improved gemplasm, limited use of soil fertility inputs, droughts, floods and land degradation [3]. Unlike large scale commercial farmers, smallholder farmers' capacity to adapt to climate extremes can be weakened by resource constraints leading to poor infrastructure at farm level, as well as their lack of advanced knowledge on crop management. However, the smallholder farmers are often endowed with indigenous knowledge and farming experience which may influence their choice of the adaptation strategies to climate change. Indigenous knowledge can be viewed as a base for developing innovative technologies and building improved knowledge systems [6]. Farmers have, in some instances, used methods that though not tested or documented are suitable for managing the effects of unfavorable weather patterns. The climate change-related challenges that farmers face now and in future can be overcome through improved knowledge systems that encompass some aspects of indigenous knowledge. In mixed cropping systems, moderate yield losses can be offset by improved cultivars and agronomic practices while major losses may need crop type changes or opting for livestock production instead [8].

As countries in SSA strive to achieve the United Nations' Millennium Development Goals by 2015, including the reduction of extreme poverty and hunger (MDG1) and achieving environmental sustainability (MDG7), it is important to understand how climate extremes can derail the achievement of the MDGs, particularly in the developing countries [12].

1.1 Study Objectives

The study focuses on examining the current adaptation strategies to climate extremes, the current level of awareness of weather and climate changes and their effects on farm level crop production. The main objective of the study was to determine practical adaptation strategies that can be applied by smallholder farmers on crop production practices to minimize the effects of climate extremes. The specific objectives were to analyze: (i) crop production factors (access to agricultural land, household labour, crop diversity and soil fertility management, rainfall patterns, field management of soil water), (ii) knowledge of climate extremes (frequency of droughts and floods, awareness of causes and effects of climate extremes and sources of weather information) and (iii) adaptation strategies used by smallholder farmers in relation to household characteristics and cropping practices.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in four villages in the Volta Region of Ghana located at different elevation measured in meters above sea level (m.a.s.l) i.e., Akpafu Mempeasem (N 07^o 14' 37" E 000^o 28' 53"; 259 m.a.s.l.), Akpafu Odomi (N 07^o 16' 41" E 000^o 28' 50"; 57 m.a.s.l.), Santrokofi Bume (N 07^o 13' 09" E 000^o 28' 24"; 245 m.a.s.l.), and Ve-Wegbe (N 07^o 06' 40" E 000^o 27' 15"; 161 m.a.s.l.). The villages formed a transect of increasing altitude from 57 to 259 m.a.s.l. The Volta region, found in agro-ecological zone I of Ghana, has an equatorial climate with two cropping seasons per year. The major season runs from March to July and the minor one from September to November. Rainfall and temperature variability is characteristic of the region; both delayed onset of the season and long mid-season droughts are increasingly becoming a common feature of the rainfall distribution. The length of the growing period for the area ranges between 270 and 300 days. Soils are predominantly lithosols on upland fields and low inherent fertility is a major constraint to crop production on these soils [13]. Therefore, these study sites are representative of smallholder farms on which climate change effects are being experienced and are posing a major risk to livelihoods.

Agriculture and fisheries are important economic activities that support the livelihoods of the communities in the Volta region [14]. At the national level smallholder agriculture contributes about 35% to the gross domestic product with 57.1% of the total land under agriculture. Rainfed agriculture employs about 70% of the population and about 80% of the agricultural produce comes from smallholder farmers [4]. Cassava, maize and rice are major sources of calories whereas cocoa is the main cash crop and mixed cropping is commonly practiced [13].

2.2 Methodology

A structured questionnaire survey was administered to solicit perception of farmers to the effects of climate extremes on cropping systems and suitable adaptation strategies. The Volta region was purposively sampled as an important region where climate variability is evident. A stratified random sampling was applied to select villages from which the 70 households under the study were drawn using a sampling frame from the district agricultural office. Information sought included household socio-economic characteristics, cropping systems, experience in climate extremes and adaptation strategies to climate risk. Data was captured and analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics were used to analyze the characteristic of respondents’ household, labour availability and climate change indicators. Chi-square tests and one way analysis of variance were used to separate means at $P < 0.01$ and $P < 0.05$ significance levels.

3. RESULTS AND DISCUSION

3.1 Household Data

The basic characteristics of the surveyed households are described in Table 1. Among the studied households, 34% were female-headed, with an average age of 46 years. For the male-headed households, the average age was 51 years. Furthermore, the level of education for the heads of the sampled households relatively high, with the females having an average of 9 years in school and their male counterparts having around 12 years of schooling. In particular, 77% of the respondents attained senior high school education level. Less than 2% of the respondents did not have any education beyond primary school level. These results further showed no significant gender bias in educational qualification. Both female and male respondents in the sample were experienced farmers with an average of 18 and 21 years of farming respectively. With the exception of the minority who did not finish primary school education the majority of farmers were relatively literate and could read the local newspaper.

Table 1. Household characteristics of farm families interviewed on perception on climate change adaptation in the Volta region, Ghana

Characteristic	Female	Male
Household head age (years)	46	51
Gender of household head (%)	34	66
Number of years in school (years)	9	12
Experience in farming (years)	18	21
Farm sizes (acres)	3.3	7.9
Household labour (man hours)	2.67	2.91
Labour sources	Household, hired	Household, hired
Household sources of income	Crop and livestock sales	Crop sales

Source: Field Survey, 2009.

3.2 Access to Agricultural Land

Cultivated land was under three land tenure systems; family owned, leased land and a combination of the two. In the sample, around 72.9% indicated that they used their family land for cultivation, while 12.9% leased land and the remaining 14.2% used a combination of family and leased land. The results further showed a significant difference in the farm sizes owned by male (7.9 acres) and female-headed households (3.3 acres). The willingness to undertake long-term investments was higher for those who cultivated family land compared to those who leased land. Maintaining contour ridges and growing agroforestry tree species were common practices for farmers who used family land. However, female-headed households were less willing to undertake such investment compared to their male counterparts.

With population increase farm sizes have become small and this has negative effects on the overall production and the level of potential investment for agriculture. [15] found a strong relationship between access to land and household income. Land fragmentation was found to reduce production efficiency [16]. In the light of climate extremes farmers with smaller land sizes face greater risk of losing production. Smaller land sizes of female headed households suggest improved management would be required to attain higher production.

3.3 Labour for Crop Production

Both male and female-headed households appear to be labour constrained. In particular, the average labour force for female-headed households was 2.7 and 2.9 man-hours for the male-headed ones. Under these circumstances, it was common practice to hire supplementary labor to work on the farm. From the respondents, 63% of female headed households used both household and hired labor compared with 44% male headed households (Table 2). Cooperating groups was not a common source of labor though a few mostly among very small households used it. Therefore, any climate change interventions targeting smallholder farmers from these communities needed to take into consideration the potential labour bottle-necks. Adoption of labour intensive intervention in agriculture production was reported to be low [17]. Hence the low availability in labour exhibited in Table 2 suggests that alternative methods of resolving the labour-bottleneck challenge need to be sorted. Mechanization of farm operation has been suggested as a solution but however it is questionable whether the farmers have the capacity to make such invest.

Table 2. Major sources of labor for female and male headed households in the Volta region, Ghana

Source of labor (%)	Female	Male	Significance
Household	12.5	6.5	*
Hired	16.7	34.8	*
Household & hired	62.5	43.5	*
Household, hired & community groups	8.3	15.2	**

**Statistical differences between male and female headed household; * P<0.05 and ** P<0.01*
Source: Field Survey, 2009

3.4 Agricultural Productivity

The dominant crops that were reported by the farmers were rice (61%) and maize (39%) a finding is consistent with government of Ghana statistics on the Volta region [13]. In addition to the two cereals, crop diversification was one way of managing climate risks, especially drought and floods. Table 3 shows a diverse range of crops used by farmers mainly for food and income generation. Cropping followed a distinct topographical distribution on the catena where rice was dominantly grown on the lowlands while maize and cassava were the main upland crops. A mixed cropping pattern was practiced by the majority of farmers (88.4%) on the upland farms comprising cereals, legumes, vegetables and fruits. Despites the popularity of mixed cropping only a few farmers (<5%) followed planned intercropping and crop rotations. Maize, cassava, plantain and garden egg plant featured most prominently in the list of combinations of crops reported for production on upland fields. The main purpose for crop production was for both consumption and sale (income generation). However often farmers who grew particular crops on smaller acreages used them more in barter trade than for cash sales. Market for agricultural produce and inputs were far away from the villages and farmers often relied on informal markets in order to obtain relevant inputs. Furthermore there were no organized marketing of produce except for cocoa whereby middlemen established collection points within the villages before sending them to external markets.

Table 3. The characteristics of crops grown by farmers in the Volta region, Ghana

Crop type	Crop	Purpose	Seed source	Soil type
Cereals	Rice	Sale/Consumption	Local/hybrid	Clayey
	Maize	Sale/Consumption	Local/hybrid	Sandy
	Sorghum	Sale/Consumption	Local	Sandy
Tubers	Cassava	Sale/Consumption	Local	Sandy
	Yam	Sale/Consumption	Local	Sandy
Legumes	Groundnut	Sale/Consumption	Local/hybrid	Sandy
	Beans	Consumption	Local/hybrid	Sandy
	Cowpea	Sale/Consumption	Local	Sandy
Other	Plantain	Sale/Consumption	Local	Clayey
	Cola nut	Sale	Local	Sandy
	Cocoa	Sale	Local	Sandy
	Pepper	Consumption	Local/hybrid	Sandy
	Vegetables	Consumption	Local/hybrid	Sandy

Source: Field Survey, 2009.

3.4.1 Crop diversity and soil fertility management

Most farmers (62%) in the Volta region applied limited amounts of fertility inputs on the dominant staple crops. On average farmers applied 45 kg ha^{-1} on rice and 28 kg ha^{-1} on maize. A few reported N fertilizer application on cocoa trees in order to improve yields. However, fertilizer use was not consistent in terms of quantity and extent across years. Whereas the common method of disposing crop residues after each cropping season was through burning, neither use of ash nor residues as sources of crop nutrients was considered to be important by farmers. Burning was more rampant in lowland rice systems compared to upland maize-cassava dominated systems. Farmers had limited access (as they sourced inputs from far away) and capacity (due to limited financial resources) to procure fertilizer for use on their farms. A large proportion of the fertilizer used by farmers was obtained through a government scheme of subsidized inputs and distribution was through coupons.

Diverse cropping systems in the study area supported a combination of cereals, legumes, tree-based and vegetable crops that are sources of carbohydrate and protein hence satisfying the needs of the farm families (Table 3). However, limited use of minor crops suggests that farmers benefit less from the numerous crops on the farms. Whereas the need for diverse crops stems from both food security and support of ecosystems services perspectives, the current practices were more consumption than fully market oriented [11]. Currently legumes found on the farms were not used to recycle biologically fixed nitrogen in the cropping systems. Given the limited use of fertilizer, largely explained by high cost of imported materials and limited availability, harnessing the benefits of biologically fixed nitrogen from legumes could be used to improve the nutrient budgets on the farms [18]. However, there is a limit that the low external input systems can support agriculture production more-so within an environment experiencing climate extremes. Work of [19] explained to detail the need for a balanced systems approach which supports sustainable production practices within the context of low input agriculture.

Farmers perhaps placed less emphasis on the sustainable ecosystem and climate change mitigation practices. Crop production affect climate change through its contribution to greenhouse gas emissions and in turn climate change affect productivity, hence it is important to manage use of appropriate cultivars and crop combinations [20]. Furthermore, the subsistence farming systems practiced by farmers in the study area also led to low utilization of crop diversity as limited planning was used on the mixed cropping. There seemed to be a minimal market development for all the crops hence the marginalization of some (minor) crops, such as cassava and pepper. These are important crops that could shield households from droughts and other climate-related shocks. In particular, as a drought-resistant crop, cassava could be a reliable source of food in drought-prone areas, while pepper sales could complement household income.

The gender of the household head influenced the number of crops cultivated with women headed households cultivating more crops than male counterparts in the Volta region. A similar observation was reported by [14], who showed that cultivation of food crops, watering, storage and processing was a preoccupation for women farmers than their male counterparts. More male headed households tended to specialize on one or two cash crops e.g., rice and cocoa production. This suggests that the positive rotational effects between legumes and cereals crops were not exploited by male farmers. There are opportunities of developing value chains for crop commodities in order to increase the benefits of farmers from the cropping program.

In both low- and upland ecologies the lack of water conservation and fertility programs reduced the yield potentials. Work of [21] showed a clear relationship between climate variables and crop yields. Given the frequency farmers experienced droughts (Fig. 1), the two crop ecologies could be prone to mid-season droughts as no water harvesting techniques were being practiced currently. The need to innovatively increased resource use efficiency especially water has been highlighted by [22]. In the current form, the cropping program lacked innovation and investment in water and fertility inputs hence narrowed its productivity. In addition, production is based on mining the soil of nutrients, a practice which is not sustainable. Results from a study by [10] showed that climate extremes adaptation significantly improved both farm productivity and net revenues from smallholder farms.

3.5 Knowledge of Weather Extremes and Climate Extremes

Most farmers had observed significant weather changes in recent years (5 to 10 years back). About 94 % of the respondents reported that they were aware of the climate change phenomena and that some of its effects were significantly affecting cropping programs and natural resources. They perceived indicators of climate change included; changes in the rainfall pattern (31%), a reduction in the amount of rainfall received (27%), high temperatures (24%) and low yields (18%). Further, the farmers reported experiencing extremes of weather more than once in the last three years (Fig. 1).

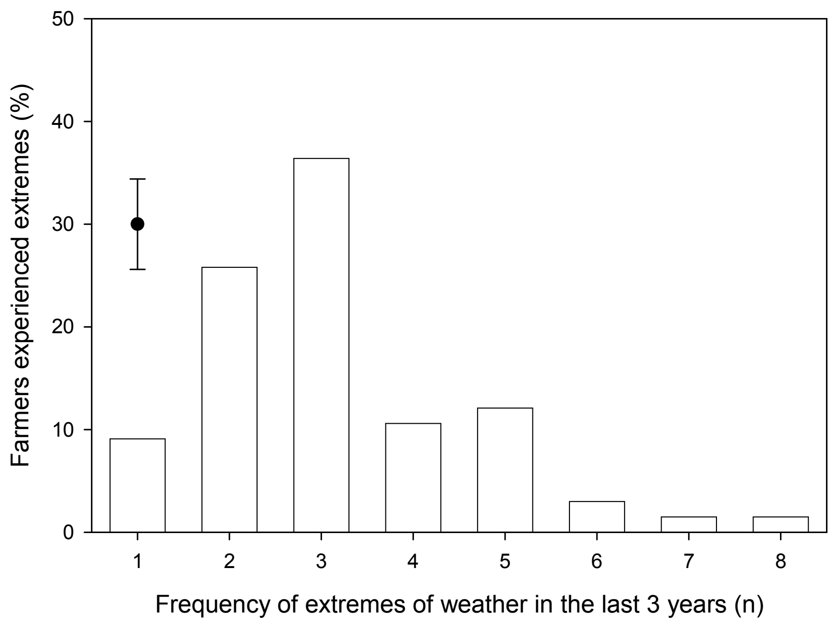

Fig. 1. Frequency of occurrence of weather extremes experienced by farmers in the last 3 years, 2006-2009. Source: Field Survey, 2009

During the weather extremes the crop sub-system (97%) was affected more than the livestock (3%). Farmers perceived that the weather changes were a direct result of deforestation (44%), wild bush fires (37%) and natural causes (10%). Less than 2 % of the farmers thought that the changes were caused by God i.e. supernatural power (Table 4).

Table 4. Factors contributing to climate extremes as perceived by farmers in Volta region, Ghana

Cause of climate change	Frequency (%)
Deforestation	44.1
Natural	10.2
Vegetation changes	6.8
Bush fires	37.3
God (Supernatural power)	1.7

Source: Field Survey, 2009.

Besides their own experience, most farmers (90%) also received information on climate and weather changes mainly from the radio, television, extension agents and local experts (Table 5). Due to the widespread awareness only less than 10% of the farmers did not factor in climate change in their seasonal cropping program. Rainfall forecasting information was important for planning farming activities and 90% of them used rainfall-related information in planning the cropping calendar. However, farmers perceived that reliability of the forecasts was low. Other than the rainfall forecast farmers considered other information such as temperature and humidity difficult to use in planning cropping activities.

3.5.1 Climate extremes awareness

Farmers were aware of the changes in weather patterns and the radio was a major source of information on climate change (Table 5), which can be linked to high literacy level. However, the lack of solutions to drought and flooding events (Fig. 2), suggests limited preparedness to climate extremes. Given that farmers rely on agriculture for food and income, frequent drought and floods make them vulnerable. Climate change effects will negatively affect livelihoods if no improvement in coping capacity occurs. Coping could entail external investment in technical interventions. This result reflects that currently there is limited utilization of weather forecast information towards reduced impact of climatic events. Unavailability of weather forecast in the most useful form was cited as a draw back to the radio and television broadcast to farmers. Farmers considered the information too general for accurate translation into action on the farm. [23] highlighted collaboration between climate forecasters, agro-meteorologists, agricultural research and extension agencies in developing appropriate products for the user community as an important step to achieve effective utilization of forecasts. This can be linked to the general low infrastructural development found in sub-Saharan Africa [24]. Accurate weather forecasting is a prerequisite for improved planning of adaptation strategies to climate extremes. The mechanism of linking climate related information sources and users is yet to be put in place and this can help farmers.

The observed changes in pest incidence, crop and forestry production, and occurrence of forest fires were considered important indicators of climate change (Table 4). The observations, suggest an interrelation between climate change and agriculture. There is therefore, a need to mitigate the negative contribution of agriculture to climate change e.g. by reducing emissions from cropping fields. Anthropogenic influenced drought and floods for instance have been reported as highlights of the social and biophysical connectivity. This suggests that adaptation strategies require consideration of several factors [6,17].

Table 5. Sources of information on climate change and weather forecast for farmer in the Volta Region

	1st	2nd	3rd
Source of information	**Frequency (%)**		
Agricultural Extension	0	12.1	24.1
Local experts	1.6	3.4	20.7
Meteorological services	3.3	3.4	5.2
Newspaper	1.6	5.2	5.2
Non-governmental organizations	0	0	3.4
Radio	90.2	0	0
School	0	6.9	0
Television	0	44.8	3.3
Others	3.3	24.1	37.9

Source: Field Survey, 2009.

Farmers reported that there were indications of an increased pest and disease causing crop damage that was linked to changes in weather patterns. Furthermore, crop damage by wild animals especially birds and rodents and yield losses also increased. A combination of drought, insect and animal damage accounted for about 60% of crop losses on the farms (Table 6).

Table 6. Frequency of occurrence of crop damage at the farm and the observed changes in trends in the recent past in the Volta region, Ghana

Cause of damage	Rice	Maize	Recent trend (Frequency)
Drought	15.3	21.3	Increased
Floods	5.3	3.3	No change
Insect damage	16.9	27.9	Increase
Disease	5.1	4.9	No change
Animal damage	25.4	13.1	Increase
Animal and drought damage	28.8	26.2	Increase
None	3.4	3.3	n/a

Source: Field Survey, 2009.

3.6 Adaptation Strategies to Climate Extremes

Early planting, crop diversity, tillage and water conservation were key practices used by farmers in minimizing the effects of changes in weather and climate. In order to counteract the effect of drought and low rainfall farmers suggested the use of mulching (soil cover) and water conservation techniques whereas canals and drainage channels were potential solutions for flooded conditions. However, about a third of the farmers had no immediate solution to deal with either drought (32.8%) or flooded conditions (34.4%) (Fig. 2).

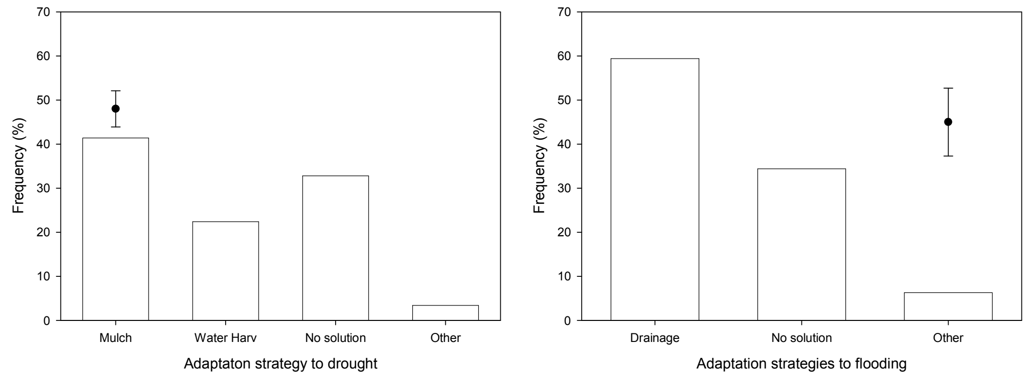

Fig. 2. Adaptation practices used by farmers to minimize the effect of (A) drought and (B) flooding events on their farms. Source: Field Survey, 2009

While the majority suggested the use of crop management techniques as one of the adaptation strategies resource availability was a major limitation. Early planting, hybrid seed, mulching and in-field water management were common among the suggested adaptation strategies. It is important to note that all the adaptation strategies reported do not require any financial investment except for hybrid seed (Fig. 3). Most of the interventions discussed with farmers apply both to rice and maize systems.

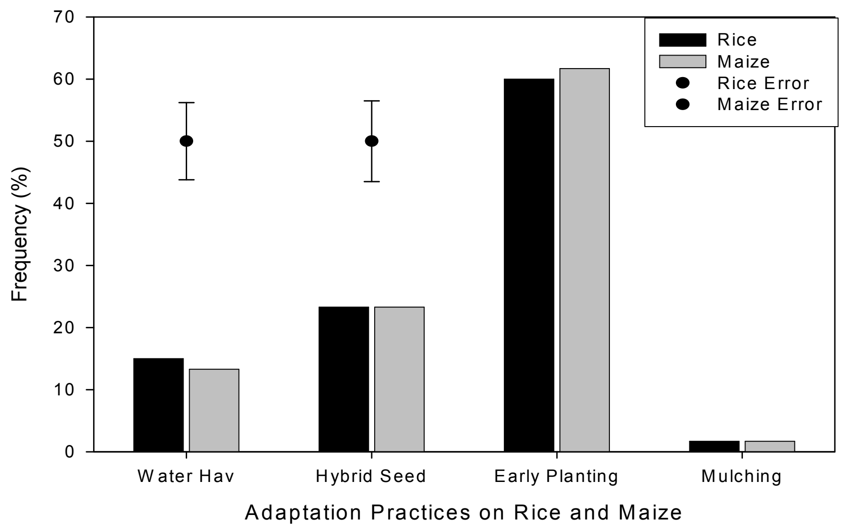

Fig. 3. Adaptation strategies suggested by farmers in the Volta region to minimize the effects of weather and climate changes on rice and maize systems. Source: Field Survey, 2009

3.6.1 Adaptation Options

The need to invest in farmers' access to knowledge and innovation, assets, risk management and markets has been put forward as an important strategy to strengthen food production in communities affected by climate change [25]. Among strategies used by farmers in adapting to extremes of weather, early planting (used by 90% of the respondents) was important to the community. It seemed that there was a high preference to non-cash but labour intensive interventions by farmers. This reflects on their limited capacity to pay for external inputs. Studies on technology adoption have also shown low uptake figures mainly due to lack of cash to purchase external inputs [17]. Similarly a study on the use of weather forecast information at household level also showed that technical interventions that require payment offer little to resource-constrained farmers [26]. Fertilizer, hybrid seed and mechanization all of which entail financial investment did not come up as highly preferred management strategies because of the cost involved and availability constraints (Fig. 3). However, these remain potential and immediate options for the few well-to-do farmers. The results suggest that the capacity of poor farmers to adapt to climate change will depend on level of infrastructural development [8] and resource endowment at the farms. Furthermore access to credit, improved extension service and accurate weather forecasting can be key drivers to adoption of improved crop production practices and hence adaptation to climate changes [10].

3.7 Challenges to Adaptation

Smallholder farmers will rely on crop and livestock for food and income. In order to sustainably adapt to climate extremes small scale agricultural innovation to achieve the same objectives is required [27]. Given the inability of farmers to invest in external inputs, alternative sources of income could help build the farmers' capacity to eventually adapt. [28] reported that off-farm income generation activities could be used by farmers to reduce vulnerability and hence adaptation capacity to climate changes. The techniques which involve financial investment and purchase of equipment were not popular with farmers in the Volta region and were related to the low income generated by the farming enterprise. Financial stability and high resource endowment can dictate the ability to respond to weather extremes and climate change effects [29]. The socio-economic status of farmer is a major challenge to applying current climate change adaptation strategies.

Use of indigenous knowledge solely will not lead to sustainable solutions to climate change and land degradation problems as some of the current practices are less efficient compared to improved modern ones [5]. For instance farmers used own seed kept from previous harvests which has lower vigor than hybrid seed. While it is noble for farmers to keep seed that carries their preferred taste and cooking characteristics, use of unimproved seed reduce crop yield potential over time. [30] reported that farmers preferred the taste of local varieties especially when it comes to preparation of traditional dishes. While farmers prefer the taste of the local varieties of rice especially, the practice reduce chances of escaping extremes of weather compared to use of improved varieties. Local seed is prone to biotic and environmental stresses and yields lower. However, improved agronomic practices alone may not address climate change and food security issues hence there is a need to combine different elements that provide ecosystem services and increase resource productivity [22,2]. At the current knowledge base farmers face challenges in adapting to climate extremes.

Limited innovation during extremes of weather reported by farmers is a major limitation to preparedness of farmers [25]. Among the actions taken by farmers, a large number still did not have a solution in both low and high rainfall scenarios (Fig. 2). Farmers currently rely on indigenous knowledge passed on from generations as well as information through the radio and extension personnel. Often, innovations based on indigenous knowledge hardly match the requirements of complicated and rapidly changing climate scenarios [25,17]. There also seemed to be a disconnection among the information received by farmers, indigenous knowledge, practices and solutions to extremes of weather. Ideas are required to apply innovatively available information to solve problems. Access to extension services was found to be an important factor of adaptation to climate change [29]. Labor could be limited given the manual labor that most farmers use on their farms and no draught power.

3.8 Recommendations

The study affirms that indigenous knowledge systems were not strong enough to overcome the effects of climate extremes on agriculture. There is therefore need for increased investment in capacity building to improve options for adapting to climate extremes [31]. Awareness of climate extremes and its effects was high however the range of adaptations strategies was limited and future awareness programs should include adaptation and mitigation options for farmers. Farmers require technical knowledge in order to effectively invest in modern agricultural methods to include use of equipment (mechanization), hybrids and fertilizers. Relevance of climate change information passed to farmers vis-a-vis their farming activities need to be examined possibly through targeted programming on radio and television. Local extension agents need to be trained to handle climate change issues beyond rainfall forecasts. Furthermore there is need for collaborative efforts among stakeholders in working out suitable information that can be used by farmers in planning e.g. daily weather forecasting [32]. The study provided a good basis for running simulation models on the sustainability of potential interventions to the effects of weather extremes and climate changes.

4. CONCLUSION

There was high awareness of climate change and its effects on agricultural production among farmers in the Volta region in Ghana. Cropping systems practiced by farmers in the Volta region were diverse but did not contribute directly to improved food security, resilience to weather extremes and harnessing environmental services goals which are important in adapting to the effects of changes in climate. There was limited use of modern agricultural technologies and inputs which reduced resilience of current adaptation strategies. Low cost crop management techniques were preferred by farmers in order to overcome extreme climate extremes especially droughts caused by erratic rainfall patterns. However the current knowledge of relationships between climate change and production was not strong enough to resolve the climate extremes related risks hence more innovative methods are required. Farmers received information on climate change through radio, television, extension agents and local experts. However, the information was made up of temporal and spatial averages of weather parameters and could not be used for planning purposes. Increased investment in modern crop production techniques; fertilizer, use of improved cultivars and mechanization can raise the production potential of crops grown by farmers. The study confirmed the important link between adaptation capacity and rural livelihood development. More information need to be collected from regions where climate change effects on agricultural production have become evident in order to strengthen adaptation strategies to climate change.

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COMPETING INTERESTS

No competing interests exist for the work reported in this manuscript.

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