

Research Paper

Adaptation strategies to climate change among smallholder farmers in the Volta Region of Ghana

ABSTRACT

Aims: The aim of the study was to elicit farmers' knowledge of climate change, its effects on the cropping systems and perceived adaptation strategies.

Place and Duration of Study: Hohoe district, the Volta Region in Ghana, in July 2009.

Methodology: A questionnaire survey was conducted on 70 randomly selected farm families from 4 villages in Hohoe district. Information sought included household socio-economic characteristics, cropping systems, experience in climate change variability and coping strategies to weather extremes and climate risk. Data was captured and analyzed using the Statistical Package for Social Sciences (SPSS).

Results: Results showed that farmers experienced either drought or flood once in every two seasons over the past 3 years. Awareness of the climate change phenomena was high among farmers (94%), and the main sources of climate change-related information were radio, agricultural extension agents, television and local experts. Farmers perceived deforestation and forest fires as major factors contributing to climate change. Limited use of fertilizer, hybrid seed and lack of planned crop sequences reduced the benefits from the mixed cropping system. Among the strategies currently used to reduce the impact of extremes of weather were early planting, use of hybrid seed and soil moisture conservation techniques such as within-field ridge construction. Low resource endowment limited use of improved seed cultivars, fertilizers and labour saving mechanical interventions to adapt to extremes of weather. However, improve drainage infrastructure and mulching were reported to increase crop production.

Conclusion: The study showed close relationships between adaptation capacity and resource endowment and rural infrastructural development. Delivery of high quality weather forecasting information especially on the on-set of the cropping season could better prepare farmers and improve planning of seasonal calendars for smallholder farmers. The results are important in planning intervention on extremes of weather 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 climate change effects will continue to negatively impact millions of smallholder farmers that are dependent on agriculture for their livelihoods [11; 10]. 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 [2; 11; 26]. 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 on smallholder farmers in East, Southern and West Africa [3]. The per-capita food production

has gone down South Africa and some of the events can be closely related to the effects of changing weather patterns in recent years [16]. Similarly, low precipitation has led to reduced land cover and flora in Sahelian West Africa [25]. The trends analyzed so far are indicative as the impacts of biotic and abiotic stresses are evolving and could lead to major reductions in production [19].

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 [6; 12]. The discussion on knowledge of potential adaptation and mitigation 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 [19] 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 extremes of weather.

Low crop yields being experienced in many smallholder farms in the SSA can be attributed to poor agronomic practices, low utilization of improved germplasm, limited use of soil fertility inputs, droughts and land degradation [2]. Unlike large scale commercial farmers, smallholder farmers' capacity to adapt to extremes of weather 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 source of innovative technologies and as a base on which to build improved knowledge systems [16]. 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 [19].

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 change can derail the achievement of the MDGs, particularly in the developing countries.

The study focused on examining the current level of awareness of weather and climate changes, their effects at farm level and farmers' perceived adaptation strategies. The objective of the study was to determine practical adaptation strategies that can be applied by smallholder farmers to minimize the effects of extreme weather and climate events.

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92 **2. MATERIAL AND METHODS**

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94 **2.1 Study area**

The study was conducted in four villages in the Volta Region of Ghana i.e., Akpafu Mempeasem (N 07° 14' 37" E 000° 28' 53"; 259 m.a.s.l.), Akpafu Odumi (N 07° 16' 41" E 000° 28' 50"; 57 m.a.s.l.), Santrokofi Bume (N 07° 13' 09" E 000° 28' 24"; 245 m.a.s.l.), and Ve-Wegbe (N 07° 06' 40" E 000° 27' 15"; 161 m.a.s.l.). The villages formed a transect

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99 increasing in altitude from 57 to 259 m.a.s.l. The Volta region, found in agro-ecological zone
100 I of Ghana, has an equatorial climate with two cropping seasons. The major season runs
101 from March to July and the minor one from September to November. Rainfall and
102 temperature variability is characteristic of the region; both delayed onset of the season and
103 long mid-season droughts are increasingly becoming a common feature of the rainfall
104 distribution. The length of the growing period for the area ranges between 270 and 300
105 days. Soils are predominantly lithosols on upland fields and low inherent fertility is a major
106 constraint to crop production on these soils. Therefore, these study sites are representative
107 of smallholder farms on which climate change effects are being experienced and pose a
108 major risk to livelihoods.

109 Agriculture and fisheries are important economic activities that support the livelihoods of the
110 communities in the Volta region (Duncan and Brants, 2004). At the national level smallholder
111 agriculture contributes about 35% to the gross domestic product with 57.1% of the total land
112 under agriculture. Rainfed agriculture employs about 70% of the population and about 80%
113 of the agricultural produce comes from smallholder farmers (World Bank 2009). Cassava,
114 maize and rice are major sources of calories whereas cocoa is the main cash crop and
115 mixed cropping is commonly practiced (FAO 2005).

116 2.2 Methodology

117 A structured questionnaire survey was administered to solicit perception of farmers to
118 climate change effects on cropping systems. The Volta region was purposively sampled as
119 an important region where climate variability is evident. A stratified random sampling was
120 applied to select villages from which the 70 households under the study were drawn using a
121 sampling frame from the district agricultural office. Information sought included household
122 socio-economic characteristics, cropping systems, experience in climate change variability
123 and coping strategies to climate risk. Data was captured and analyzed using the Statistical
124 Package for Social Sciences (SPSS).

126 3. RESULTS

128 3.1 Household data

129 The basic descriptive statistics of the surveyed households are described in Table 1. Among
130 the studied households, 34% were female-headed, with an average age of 46 years. For the
131 male-headed households, the average age was 51 years. Furthermore, the level of
132 education for the heads of the sampled households is relatively high, with the females
133 having an average of 9 years in school and their male counterparts having around 12 years
134 of schooling. In particular, 77% of the respondents attained senior high school education
135 level. Less than 2% of the interviewees did not have any education beyond primary school
136 level. These results further showed no significant gender bias in educational qualification.
137 Both female and male respondents in the sample were experienced farmers with an average
138 18 and 21 years of farming respectively. With the exception of a few who did not finish
139 primary school education the majority of farmers was relatively literate and could read the
140 local newspaper.

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144 Table 1: Household characteristics of farm families interviewed on perception on
145 climate change adaptation in the Volta region, Ghana.
146

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

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148 3.2 Access to agricultural land

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

159 3.3 Labour for crop production

160 Both male and female-headed households appear to be labour constrained. In particular, the
161 average labour force for female-headed households was 2.7 and 2.9 for the male-headed
162 ones. Under these circumstances, it was common practice to hire supplementary labor to
163 work on the farm. From the respondents, 63% of female headed households combined
164 household and hired labor compared with 44% male headed households (Table 2).
165 Cooperating groups was not a common source of labor though a few mostly among very
166 small households used it. Therefore, any climate change interventions targeting smallholder
167 farmers from these communities needed to take into consideration the potential labour
168 bottle-necks.

169 Table 2: Major sources of labor for female and male headed households in the Volta region,
170 Ghana
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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	**

172 *Statistical differences between male and female headed household; * $P < 0.05$ and ** $P < 0.01$
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175 3.4 Cropping systems and diversity

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

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

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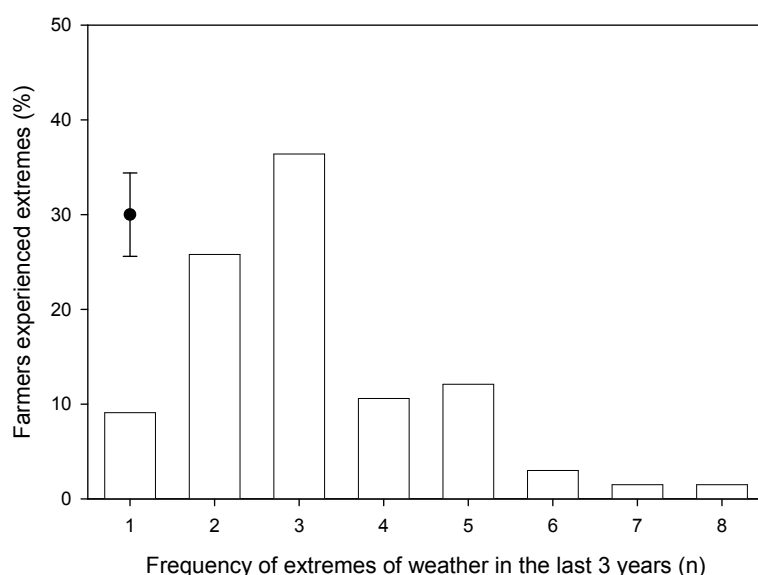
196 3.5 Soil fertility management

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

207 was obtained through a government scheme of subsidized inputs and distribution was
208 through coupons.

209 3.6 Knowledge of weather extremes and climate change

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



217 Frequency of extremes of weather in the last 3 years (n)
218 Figure 1: Frequency of extremes of weather experienced by farmers in the last 3 years,
219 2006-2

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

224 Table 4: Factors contributing to climate and weather changes as perceived by farmers in
225 Volta region, Ghana
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Cause of climate change	Frequency (%)
Deforestation	44.1
Natural	10.2
Vegetation changes	6.8
Bush fires	37.3
God	1.7

227

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.

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

	1 st	2 nd	3 rd
<i>Source of information</i>	<i>Frequency (%)</i>		
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

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

3.7 Minimizing effects of climate change

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).

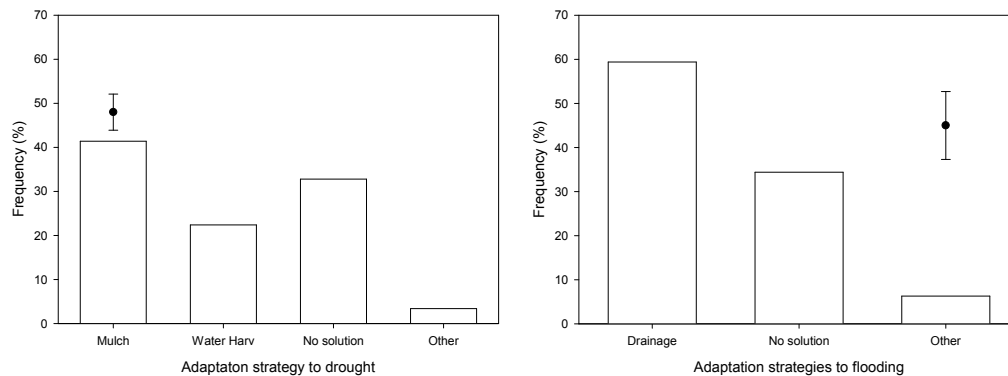


Figure 2: Adaptation practices used by farmers to minimize the effect of (A) drought and (B) flooding events on their farms

3.8 Suggested adaptations

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.

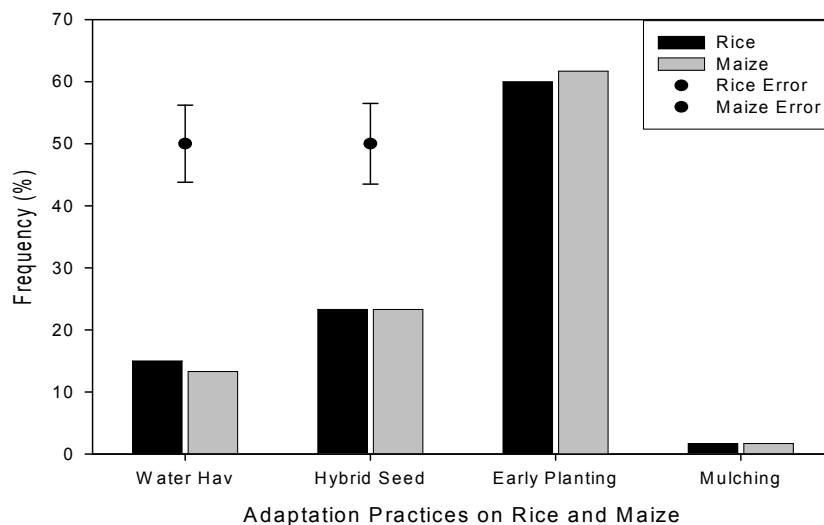


Figure 3: Adaptation strategies suggested by farmers in the Volta region to minimize the effects of weather and climate changes on rice and maize systems

271 4. DISCUSSION

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274 4.1 Crop husbandry and diversity

275 Diverse cropping systems in the study area supported a combination of cereals, legumes,
 276 tree-based and vegetable crops that are sources of carbohydrate and protein hence
 277 satisfying the needs of the farm families (Table 3). However, lack of attention to the
 278 management of diversity and neglect of minor crops suggest farmers benefit less from the
 279 numerous crops on the farms. Whereas the need for diverse crops stems from both food
 280 security and support of ecosystems services perspectives, the current practices are more
 281 consumption than fully market oriented [12]. Currently legumes found on the farms were not
 282 used to recycle biologically fixed nitrogen in the cropping systems. Given the limited use of
 283 fertilizer, largely explained by high cost of imported materials and limited availability,
 284 harnessing the benefits of biologically fixed nitrogen from legumes could be used to improve
 285 the nutrient budgets on the farms [14].

286 Farmers perhaps place less emphasis on the sustainable ecosystem and climate change
 287 mitigation practices. Crop production affect climate change through its contribution to
 288 greenhouse gas emissions and intern climate change affect productivity hence it is important
 289 to manage use of appropriate cultivars and crop combinations [23]. Furthermore, the
 290 subsistence farming systems practiced by farmers in the study area also led to low utilization
 291 of crop diversity as limited planning was used on the mixed cropping. There seemed to be a
 292 minimal market development for all the crops hence the marginalization of some (minor)
 293 crops, such as cassava and pepper. These are important crops that could shield households
 294 from droughts and other climate-related shocks. In particular, as a drought-resistant crop,
 295 cassava could be a reliable source of food in drought-prone areas, while pepper sales could
 296 complement household can income.

297 The gender of the household head influenced the number of crops cultivated with women
 298 headed households cultivating more crops than male counterparts in the Volta region. A
 299 similar observation was reported by [7], who showed that more cultivation of food crops,
 300 watering, storage and processing was a preoccupation for women farmers than their male
 301 counterparts. More male headed households tended to specialize on one or two cash crops
 302 e.g., rice and cocoa production. This suggests that the positive rotational effects between
 303 legumes and cereals crops were not exploited by male farmers. There are opportunities of
 304 developing value chains for crop commodities in order to increase the benefits of farmers
 305 from the cropping program.

306 In both low- and upland ecologies the lack of water conservation and fertility programs
 307 reduced the yield potentials. Work of [21] showed a clear relationship between climate
 308 variables and crop yields. Given the frequently farmers experienced droughts (Fig. 1), the
 309 two crop ecologies could be prone to mid-season droughts as no water harvesting
 310 techniques are being practiced currently. The need to innovatively increased resource use
 311 efficiency especially water has been highlighted by [4]. In the current form, the cropping
 312 program lacked innovation and investment in water and fertility inputs hence narrowed its
 313 productivity. In addition, production is based on mining the soil of nutrients, a practice which
 314 is not sustainable. Results from a study by [6] showed that climate change adaptation
 315 significant impacted both farm productivity and net revenues from smallholder farms.

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318 4.2 Climate change awareness

319 Farmers are aware of the changes in weather patterns and the radio was a major source of
 320 information on climate change (Table 5), which can be linked to high literacy level. However,
 321 the lack of solutions to drought and flooding events (Fig. 2), suggests limited preparedness
 322 to extremes of weather. Given that farmers rely on agriculture for food and income, frequent
 323 drought and floods make them vulnerable. Climate change effects will negatively affect
 324 livelihoods if no improvement in coping capacity occurs. Coping could entail external
 325 investment in technical interventions. This result reflects that currently there is limited
 326 utilization of weather forecast information towards reduced impact of climatic events.
 327 Availability of weather forecast in the most useful form was cited as a draw back to the radio
 328 and television broadcast to farmers. Farmers considered the information too general for
 329 accurate translation into action on the farm. [22] highlighted collaboration between climate
 330 forecasters, agro-meteorologists, agricultural research and extension agencies in developing
 331 appropriate products for the user community as an important step to achieve effect utilization
 332 of forecasts. This can be linked to the general low infrastructural development found in sub-
 333 Saharan Africa [24].

334 The observed changes in pest incidence crop and forestry production, and occurrence of
 335 forest fires were considered important indicators of climate change. The observations, which
 336 are not a coincidence, showed the interrelation between climate change and agriculture;
 337 agriculture contributes to climate change and climate change adversely affects agriculture.
 338 Drought and floods e.g., have been reported as highlights of the social and biophysical
 339 connectivity and coping requires engagement of several factors [16; 18]

340 4.3 Adaptation options

341 The need to invest in farmers' access to knowledge and innovation, assets, risk
 342 management and markets has been put forward as an important strategy to strengthen food
 343 production in communities affected by climate change [17]. Among strategies used by
 344 farmers in adapting to extremes of weather, early planting (used by 90% of the respondents)
 345 was important to the community. It seemed that there was a high preference to non-cash but
 346 labour intensive interventions by farmers reflects on their limited capacity to pay for external
 347 inputs. Studies on technology adoption have also shown low uptake figures mainly due to
 348 lack of cash to purchase external inputs [18]. Similarly a study on the use of weather
 349 forecast information at household level also showed that technical interventions that require
 350 payment offer little to resource-constrained farmers [28]. Fertilizer, hybrid seed and
 351 mechanization all of which entail financial investment did not come up as highly preferred
 352 management strategies because of the cost involved and availability constraints (Fig. 3).
 353 However, these remain potential and immediate options for the few well-to-do farmers. The
 354 results suggest that the capacity of poor farmers to adapt to climate change will depend on
 355 level of infrastructural development [19] and resource endowment at the farms. Furthermore
 356 access to credit, improved extension service and accurate weather forecasting can be key
 357 drivers to adoption of improved crop production practices and hence adaptation to climate
 358 changes [6].

359 4.4 Challenges to adaptation

360 Smallholder farmers will rely on crop and livestock for food and income. In order to
 361 sustainably adapt to climate change small scale agricultural innovation to achieve the same
 362 objectives is required [13]. Given the inability of farmers to invest in external inputs,
 363 alternative sources of income could help build the farmers' capacity to eventually adapt. [8]
 364 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 [5].

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 [3]. 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. [1] 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 [4; 10].

Limited innovation during extremes of weather reported by farmers is a major limitation to preparedness of farmers [17]. 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 [17; 18]. 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 [5]. Labor could be limited given the manual labor that most farmers use on their farms and no draught power.

4.5 Relevance of the study

The study affirms that indigenous knowledge systems in the region were not strong enough to overcome the challenges of climate change effects on agriculture. Awareness is high but there is need to explore opportunities to save agriculture production through use of available information. Investing in modern agricultural methods to include use of equipment (mechanization), hybrids and fertilizers is required to sustain production. 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. 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.

5. CONCLUSION

- There was high awareness of climate change and its effects among farmers in the Volta region in Ghana.
- Crop systems practiced by farmers in the Volta region were diverse but did not contribute directly to the sustainable crop production, food security and harnessing

411 environmental services goals which are important in adapting to the effects of changes in
412 climate.

413 • Though farmers received information on climate change disseminated through radio,
414 extension agents, television and local experts the usefulness was limited by the quality and
415 the general nature of the information

416 • Low cost crop management techniques were preferred by farmers in the Volta
417 region in order to overcome problems with extreme rainfall patterns however the current
418 knowledge systems was not strong enough to solve the climate change related problems
419 hence more innovative methods are required

420 • Increased investment in fertilizer, use of improved genetic materials and
421 mechanization can raise the production potential of crops grown by farmers.

422 • The study confirmed the important link between adaptation capacity and rural
423 livelihood development and more information need to be collected from regions where
424 climate change effects have become evident.
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427 **COMPETING INTERESTS**

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