Smallholder farmers' perceptions and strategies for adaptation to climate change in Brong Ahafo and Upper West Regions of Ghana

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CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

With data collected from 750 farming households using survey questionnaire and 25 Focus Group Discussions (FGD), this report documents farmers' perception of climate change and adaptation strategies in the Brong Ahafo and Upper West regions of Ghana. Results showed that DTM varieties are a viable strategy for adaptation to climate change. The use of drought tolerant or early maturing varieties ranked among the top three adaptation strategies used by farmers to combat risks from climate change in their production activities. Other strategies include growing different crops or engaging in mixed cropping and changing planting dates. The key determinant of DTM adoption in Brong Ahafo is occurrence of drought shock. In Upper West, farmers' age, awareness about climate change, distance from input markets, access to credit, and training on DT varieties affect the probability of adoption of DTM. Widespread adoption of DTM has the potential of minimising farm-level impacts of climate change in Ghana.

Keywords

Climate change; smallholder farmers; adaptation strategies; DTM varieties, Ghana

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Contents

Acronyms

^0C	Degree Celsius
^0F	Degree Fahrenheit
AEZ	Agroecological Zone
CIMMYT	International Maize and Wheat Improvement Centre
CSIR	Council for Scientific and Industrial Research
DT	Drought tolerant
DTM	Drought Tolerant Maize
DTMA	Drought Tolerant Maize for Africa
FGD	Focus Group Discussion
IITA	International Institute of Tropical Agriculture
MoFA	Ministry of Food and Agriculture
NPK	Nitrogen-Phosphorus-Potassium
SARI	Savanna Agricultural Research Institute
TLU	Total Livestock Unit

Executive summary

Drought tolerant maize (DTM) varieties are being developed and disseminated in Ghana since 2007 as a potential adaptation strategy for farmers facing drought. Using data from 750 selected farm households in Ghana and 25 FGDs with various groups of farmers of both men and women, this report documents farmers' perceptions of climate change and the causes, assesses the strategies used in response to climate change effects; evaluates DTM as an adaptation strategy; and identifies the drivers of DTM adoption in two contrasting agro-ecologies (Brong Ahafo and Upper West regions of Ghana) with different rainfall and cropping systems.

Results show that farmers first heard of the term "climate change" in 2006 from the Ministry of Food and Agriculture but a large proportion of the farmers (>90%) became aware of climate change through personal observations. Farmers perceived climate change as a state of increasing temperatures, depicted by dry and rainy season temperatures and frequent drought; increasing wind, depicted by greater intensity in both seasons, and a pattern of decreasing rainfall as indicated by the intensity and quantum of both annual and rainy season rainfall. Farmers' attributed climate change to agricultural activities such as indiscriminate bush burning, deforestation for the purpose of producing charcoal, use of fertilizer, pesticide application, release of chemicals from anaerobic fermentation of agricultural produce, car and generator exhausts, and improper waste disposal. In Brong Ahafo, 92.6% of the farmers agreed that deforestation was the major cause of climate change associated with agricultural activities and 88% agreed that indiscriminate bush burning was the cause. Similarly in the Upper West region, 90.7% of the farmers agreed that deforestation was the cause of climate change and 88.3% suggested indiscriminate bush burning. Intensifying enlightenment programs to curb indiscriminate bush burning and deforestation as well as embarking on afforestation programs to check the negative impact of climate change in the study area is imperative. Results of the FGDs revealed different perceptions of climate change by male and female farmers. Different causes were indicated by men, women, and young farmers. From these perceived causes there are obviously some misconceptions. The report then suggested

the need for more awareness campaigns to increase people's understanding of the causes of climate change and potential solutions.

The use of drought tolerant or early maturing varieties ranked among the top three adaptation strategies adopted by farmers to combat risks from climate change. The other top three strategies are growing different crops or engaging in mixed cropping and changing of planting dates. The remaining adaptation strategies include production of more livestock, planting trees for shading and shelter, engaging in off-farm jobs, using soil conservation techniques and irrigation facilities, increasing water conservation through water harvesting schemes, and farming in Fadama areas. About 63% of the entire sample of farmers had been affected by drought over the past 5 to 10 years, 54.4% in Brong Ahafo and 80.7% in Upper West. Therefore, there is a high potential for adoption of DTM, since being affected by drought was found to be among key factors determining their adoption in both Brong Ahfo and Upper West.

1. Introduction

1.1. Background

Ghana's economy relies heavily on rain-fed agriculture, energy, and forestry. About 70% of the population depend on agriculture and forestry. Climate change modelling projections indicate that the country is very vulnerable to climate variability and change with projected rises in temperature, declines in rainfall, and shifts in the timing and intensity of weather events (Smith et al. 2002). Evidence abounds in Ghana that the temperature in all ecological zones has been rising, whereas rainfall levels and patterns have been generally reducing and becoming increasingly erratic (Agyemang-Bonsu et al. 2008). Based on 20-year baseline climate observations, it was forecasted that maize and other cereal crop yields will fall by 7% by 2050 (Akah, 2011). Climate change is causing intense hardship to the majority of the farming population. Unless mechanisms are carefully and systematically put in place to ensure resilience in development and reduce vulnerability, climate change and variability pose serious challenges to national development. The losses from climatic variations and extremes are substantial and, in some situations, increasing (Bekele et al. 2014).

The agricultural sector, in particular, and the economy at large will be highly threatened if the trend continues unabated without the introduction and continuous use of adaptive measures. Actions for adaptation refer to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (Smit et al. 2000; Pittock and Jones 2000). The adaptation process, however, depends greatly on the perceptions and adaptive capacities of the affected community to cope with the impacts and risks of climate change. The capacity of communities to adapt is, however, determined by their socioeconomic characteristics. Thus any attempt made at enhancing the adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancing adaptive capacities reduces vulnerabilities and promotes sustainable development. Adoption of drought tolerant varieties is one of the adaptation strategies being promoted in Africa. The Drought Tolerant Maize for Africa (DTMA) project of IITA/CIMMYT implemented in collaboration with the Council for Scientific and Industrial Research (CSIR) has been developing and promoting drought tolerant maize (DTM) varieties in Ghana since 2007 as a potential adaptation strategy for farmers facing drought. The questions remains about Ghanaian farmers perception of climate change and whether they are using DTM as part of their adaptation strategies to climate.

1.2. Study objectives

The main objective of this report is to documents farmers' perception of climate change and their causes, assesses the adaptation strategies used in response to climate change effects and evaluates DTM as an adaptation strategy in two contrasting agro-ecologies (Brong Ahafo and Upper West regions) with different rainfall and cropping systems.

The specific objectives are to

- examine farmers' perceptions of climate change in the two regions;
- determine the strategies used by farmers in response to climate change effects;
- assess farmers' perception and evaluate DTM as an adaptation strategy for climate change; and
- determine the factors influencing the adoption of DTM in the study area.

This report is categorized into seven main sections. The next section presents the methodology which consists of a description of the study area, sampling procedure, sample size, and data collection methods as well as the analytical techniques used. Section three provides information on awareness and causes of climate change, and farmers' perceptions about key climate parameters, especially the rainfall pattern and its stability over the past 5 to 10 years. In section four, farmers' strategies for adaptation to climate change are reported. The fifth section describes the different maize varieties cultivated by farmers in the communities, their sources of information and complementary inputs used. The role of DTM as an adaptation strategy and the key factors driving its adoption are discussed in section six. Section seven ends the report with a summary of major findings and a conclusion.

2. Methodology

2.1. Study area

The study was conducted in Brong Ahafo and Upper West, two of the ten regions in Ghana (Figure 1). According to the Government of Ghana official portal (2014) Brong Ahafo, formerly a part of Ashanti region, was created in 1959. It has 19 Administrative Districts with Sunyani as the regional capital, covers an area of 39,557 km^2 and is the second largest region in the country (with about 17% of the total land area and a population of 1,815,408). It is bordered by the Northern Region to the north, Ashanti and Western regions to the south, Volta Region to the east, Eastern Region to the southeast, and Côte d'Ivoire to the west. The central point of the landmass of Ghana is at Kintampo. Brong Ahafo has a tropical climate with a high temperature averaging 23.9 ^{0}C (75 ^{0}F) and a double maxima rainfall pattern. Rainfall ranges from an average of 1000 mm in the northern part to 1400 mm in the south that lies in the forest zone and is a major cocoa and timber producing area. The northern part lies in the savanna zone and is a major grain and tuber producing area. The region has two main vegetation types, the moist semi-deciduous forest, mostly in the southern and south-eastern parts, and the Guinea savanna woodland, which is predominant in the northern and north-eastern parts. The level of development and variations in economic activity are largely due to these two vegetation types.

On the other hand, Upper West, with Wa as the regional capital, covers a geographical area of approximately 18,478 km^2 (about 13% of the total land area of Ghana). The region is bordered by the Republic of Burkina Faso to the north, Upper East Region to the east, Northern Region to the south, and Côte d'Ivoire to the west. The region is located in the Guinea savanna vegetation belt consisting of grass with scattered drought resistant trees such as Shea, Baobab, Dawadawa, and Neem. The heterogeneous collection of different trees provides all domestic requirements for fuel wood and charcoal, construction of houses and cattle kraals, and fencing of gardens while the shorter shrubs and grasses provide fodder for livestock. The climate of the region is one that is common to the three northern regions, with two seasons, the dry and the wet. The wet season commences from early April and ends in October. The dry season, characterized by the cold and hazy harmattan weather, starts from early November and ends in the latter part of March when the hot weather begins and ends only with the onset of the early rainfall in April. The temperature of the region is between a low of 15^{0}C at night time during the harmattan season and a high of 40^{0}C in the day during the hot season.

With the exception of the coastal savanna, drought tolerant maize (DTM) has been promoted in all the agro- ecologies of Ghana (forest, forest-savanna transition, Sudan and Guinea savannas). Since 2007, promotion of DTM has been spearheaded by the DTM Country Working Group consisting of the Council for Scientific and Industrial Research (comprising the Savannah Agricultural Research Institute - SARI - and Crops Research Institute - CRI), Seed Companies (such as M&B, Antika, and Heritage among others) and the Ministry of Food and Agriculture (MoFA). In consultation with the DTM Country Working Group (Management level), the forest-savanna transition (Brong Ahafo) and Guinea savanna (Upper West) were identified as the agro-ecologies (AEZs) that had benefited most from DTM promotional activities. The Working Group opined that climate change and its adaptation options were most likely to be clearly expressed in these two AEZs.

Figure 1. Map of Ghana showing different regions

Source: Government of Ghana Official Portal (2014)

2.2. Sampling procedure, sample size and data collection method

Sampling was carried out at two levels - household and community. At the household level, a multi-stage sampling technique combining both random and non-random sampling methods was used to select respondents for the study. The first stage involved a purposive selection of two regions with contrasting AEZs (forest/forest-savanna transition and Guinea savanna). Within these two regions, a list of districts that had benefited from DTM dissemination efforts was generated. On the basis of geographical area and population, four districts in Brong Ahafo and two districts in Upper West were selected through simple random sampling. A list of communities in each district was generated with the help of the DTM Country Working Group (involving technicians and extension officers). Random sampling method was used to select 15 communities in Brong Ahafo and 10 in Upper West. A total of 750 households were selected (500 in Brong Ahafo and 250 in Upper West).

At the community level, Focus group discussions (FGD) with en and women farmers are also used to provide additional insight about difference in perception among these different groups in the 2 regions of Ghana. Each Focus group is composed of 6 to and 12 people who were knowledgeable about their community and had experience in maize production were primarily selected by their opinion leaders (chiefs, elders, and assemblymen) to participate in focus group discussions (FGD). A total of 25 FGD sessions (15 in Brong Ahafo and 10 in Upper West) were held, usually at the center of the community. Other interested farmers also joined the group discussions. The study used both qualitative and quantitative data collection and analytical techniques. First, at the community level, an interview guide was used in FGD sessions to understand climate change as perceived by different groups (men, women, and the youth) in the communities. In the second stage, structured questionnaires were developed and administered to a representative sample of the selected communities in each region. Data were collected on farmers' perceptions of DTM as an adaptation strategy for climate change, their evaluation of this strategy in responding to climate-related risks and on factors driving the adoption of DTM in the study area. The field survey was conducted in November 2014.

2.3. Analytical techniques

Both descriptive and inferential statistics were used for data analyses. The descriptive statistics involved the use of means and percentages to describe the variables in the study while the inferential statistics relied on probit regression to determine the factors influencing the adoption of improved maize varieties, specifically DTM varieties, in the study area. Note that one of the adaptation strategies adopted by farmers to militate against the negative impact of climate change in the study area is the decision to adopt DTM varieties. Thus, we implemented a probit model to examine the determinants of adoption of DTM varieties. The dependent variable in the probit equation is the farmers' adoption of DTM varieties. This variable takes a value of 1 if the farmer adopts DTM and 0 if otherwise. We assumed that a particular farm household would consider adopting DTM varieties if the expected benefit from adoption is higher than non-adoption. Empirically, the decision to adopt DTM varieties is estimated using the specification:

$$Y_h^* = \beta_0 + \gamma X_h' + \vartheta Z_h' + \mu_h$$

For the latent variable Y_h^* , the estimation is based on the observable binary discrete choice of whether the farmer adopts DTM varieties or not.

$$Y_h = \begin{Bmatrix} 1 if Y_h^* > 0 \\ 0, otherwise \end{Bmatrix}$$

Where, X_h' includes access, institutional and household characteristics while Z_h' includes social capital variables and μ_h is the error term. γ and ϑ are vector of parameters to be estimated.

3. Climate change: awareness and perceptions

3.1. Climate change perceptions by gender groups

A FGD was employed to capture the perceptions of men and women farmers on climate change parameters that included temperature, precipitation, and wind. In Brong Ahafo, male farmers (over 80%) agreed that the temperature (dry season, rainy season, and temperature itself) has increased in recent years and the length of the cold period has decreased. Similarly, the female farmers were also of the opinion that dry and rainy season temperature as well as the frequency of drought and length of the hot period have been increasing in recent years.

In Upper West, the vast majority of farmers (men not less than 95% and women 80%) argued that the dry season temperature has increased considerably over the years. However, the majority of both women and men farmers (not less than 85%) perceived that there was no change in the average rainy season temperature over the years. However, most of the men and women farmers (over 95%) perceived that the frequency of drought had overwhelmingly increased. Responding to the length of cold and hot periods, nearly all the farmers (over 90%) in Upper West indicated that both parameters have been increasing in recent years. However, a sizeable proportion of women (about 60%) agreed that the length of cold period has been decreasing (Table 1).

In both regions, the majority of men and women farmers observed that rainfall and wind have been decreasing but the length of the dry spell during rainy season had been increasing. Similarly, the intensity of rainfall and flooding of fields and villages has decreased. While nearly all the men farmers in Upper West agreed that the intensity of the wind during the dry and rainy seasons has generally increased, women in same region indicated that they have not observed any change in wind intensity during either the dry or rainy season. This contrasting result can be attributed to the type of activities that men and women farmers are engaged in during those periods but require more in-depth investigation to understand the cause of differing perception on wind intensity. In Brong Ahafo where not less than 90% of the men farmers agreed that the wind intensity has decreased in recent years, only 60% of women were of the same opinion (Table 1).

Table 1. Farmers' perception of climate change parameters (% of respondents) based on FGDs (Multiple responses allowed)

Parameter	Region															
	Brong Ahafo								Upper West							
	Male farmers				Female farmers				Male farmers				Female farmers			
	Increase	Decrease	No change	Don't know	Increase	Decrease	No change	Don't know	Increase	Decrease	No change	Don't know	Increase	Decrease	No change	Don't know
Temperature (%):																
General temperature	80	10	5	5	100	0	0	0	90	0	0	10	90	0	5	5
Dry season temperature	95	5	0	0	95	5	0	0	95	0	5	0	95	0	5	0
Rainy season temperature	5	5	85	5	60	15	5	0	80	5	5	10	90	0	5	5
Frequency of drought	95	5	0	0	85	10	5	0	90	0	5	5	5	90	0	5
Length of cold/harmattan	90	5	0	0	10	20	70	0	0	90	10	0	5	85	5	5
Length of hot period	85	5	0	0	80	15	5	0	100	0	0	0	5	80	5	10
Rainfall (%):																
Annual precipitation	5	90	5	0	10	80	5	5	0	90	5	5	0	80	10	10
Rainy season precipitation	0	100	0	0	10	75	5	10	0	100	0	0	0	85	5	10

Length of dry spell during rainy season	10 0	0	0	0	70	20	5	5	100	0	0	0	100	0	0	0
Intensity of rainfall	5	90	5	0	20	60	10	10	0	90	5	5	5	5	80	10
Flooding of field/village by rain water	0	95	5	0	30	60	5	5	0	85	5	10	0	5	85	10
Wind (%):																
Intensity during dry season	95	0	5	0	30	65	5	0	0	90	0	10	0	0	90	10
Intensity during rainy season	95	0	5	0	20	70	5	5	0	100	0	0	0	0	100	0

Source: Survey results

3.2. Awareness and sources of information on climate change

Nine out of ten farmers are aware of climate change (Table 2). The majority of farmers became aware of climate change from personal observations (70.8%) followed by radio (13.2%). Other sources of information on climate change include extension agents from agricultural development projects (ADPs) and non-governmental organizations (NGOs) and other farmers. The extent of farmers' contact with extension officers and their participation in field days and seminars on climate change was low as indicated by 41.8% of respondents in the entire sample. This is made up of about 41% of the farmers in Brong Ahafo and 34.9% in Upper West, suggesting the need for extension delivery services to increase extension contact with farmers in the regions.

Table 2. Awareness and sources of information on climate change (% of respondents)

Item	Region		
	Both (n=747)	Brong Ahafo (n=498)	Upper West (n=249)
Awareness level (%):	92.2	91.0	94.7
Source of Information (%):			
Extension contact	8.5	3.7	18.0
Radio	13.2	12.2	15.3
Personal observations	70.8	74.0	64.4
Fellow farmers	7.4	9.9	2.3
Others	0.1	0.2	0.0
Extension contact/field days			
Extension contact/visit (%)	41.8	41.0	34.9
Participation in field days/seminars (%)	30.2	29.4	34.9
Participation in on-farm demonstration/ training on DTM	27.9	29.6	30.2

Source: Survey results

Though a relatively large proportion of farmers with extension contacts on climate change participated in field days and seminars, there was generally a low level of participation in these activities with ample room for improvement. The level participation in Upper West shows that there is a great potential and possibility to facilitate the participation of all farmers with extension contact in field days and related activities. A relatively larger proportion (30.2%) participated in on-farm demonstration trials and training on DTM in Upper West while a slightly lower proportion of farmers were involved in Brong Ahafo (29.6%) and in the entire sample (27.9%). This suggests that programs for awareness creation are required to brief farmers on the importance of field days, seminars, and training on DTM for sustainable production in the study area.

3.3. Perception about key climate parameters

The perception of farmers about key climate parameters such as temperature, rainfall, and wind is shown in Table 3. The majority of farmers (84.4%) perceived an increase in temperature over time. A large proportion of farmers perceived an increase in the dry season temperature (84.4%), rainy season temperature (51.6%), frequency of drought (77.8%), length of cold/harmattan period (50%), and length of hot period (75.1%). A similar trend was observed in each region for all the variables of temperature. Similarly, a relatively large proportion of farmers perceived an increase in the variables associated with wind, such as wind intensity during dry season (53.5%) and intensity during rainy season (50.6%). However, farmers perceived a decrease in rainfall features such as annual rainfall (49.8%), rainy season rainfall (61.6%), intensity of rainfall (64.7%), and flooding of fields/communities (55.7%). About 56% of the farmers reported an increase in the length of dry spell during the rainy season. The same trend was reported on rainfall variables in each region.

In general, farmers perceived an increase in temperature and wind but a decrease in rainfall. This supports the FGD in Chingchang community in Upper West where climate change was perceived to be changes in the rainfall pattern. The participants perceived changes in the climate of their locality when they started noticing that the moisture content of their soils did not stay as long as it used to do, coupled with the reduction in the amount of rainfall. The farmers first heard about the term "climate change" in 2006 when an agricultural extension agent from the Ministry of Food and Agriculture (MoFA) used the terminology in their community.

Table 3. Farmers' perception of climate change parameters (% of respondents) (multiple responses allowed)

Parameter	Region											
	Both (n=747)				Brong Ahafo (n=478)				Upper West (n=249)			
	Increase	Decrease	No change	Don't know	Increase	Decrease	No change	Don't know	Increase	Decrease	No change	Don't know
Temperature (%):												
General temperature	85	10	4	2	91	6	3	1	74	17	5	5
Dry season temperature	84	12	3	1	87	8	4	1	79	19	0	2
Rainy season temperature	52	39	8	1	64	24	11	2	27	70	2	1
Frequency of drought	78	11	9	3	75	10	1	4	84	15	0	0
Length of cold/harmattan	50	36	8	6	53	27	12	8	44	54	2	0
Length of hot period	75	17	6	3	81	7	8	4	63	35	0	1
Rainfall (%):												
Annual precipitation	36	50	6	8	33	54	4	8	42	41	10	7
Rainy season precipitation	30	62	5	4	31	58	6	4	28	69	2	2

Length of dry spell during rainy season	56	32	10	3	60	24	14	2	47	48	2	3
Intensity of rainfall	28	65	7	1	32	58	9	1	19	78	1	0
Flooding of field/village by rain water	14	56	27	4	12	45	38	5	17	78	5	0
Wind (%):												
Intensity during dry season	54	35	7	5	61	25	9	5	39	55	4	3
Intensity during rainy season	51	43	4	2	59	34	5	2	34	62	2	2

Source: Survey results

3.4. Perceptions of farmers about changes in rainfall pattern

The perceptions of farmers about changes in the quantity and distribution of rainfall as a climate variable is shown in Table 4. The specific features that relate to changes in the rainfall pattern in order of importance are as follows: delay in rain onset, annual rainfall ending early, annual rainfall starting early, annual rainfall ending late, irregular rainfall breaks, shift/unpredictable harmattan, heavy downpours within a short period, and a dry spell during the rainy season.

In the entire sample 66% of farmers strongly agreed that there has been a change in the timing of rains over the past 5 to 10 years and a delay in the onset of rains (44%). Also, about 46% agreed that annual rainfall ended early; 61% indicated irregular rainfall breaks; 62% agreed the harmattan was shifting and becoming unpredictable; 52% claimed there were heavy downpours within a short period and 63% agreed about the dry spell during the rainy season becoming more evident. About 42%, however, disagreed that annual rainfall started early and 38% disagreed that annual rainfall ended late. These differences show that climate change is evident in the study area.

In both Brong Ahafo and Upper West, more than 75% of the farmers agreed that there was a change in the timing of rainfall, irregular rainfall breaks, delay in the onset of rain, dry spells during the rainy season, heavy downpours within a short period, shift/unpredictable harmattan, and an early end to annual rainfall. It therefore implies that change in the timing of rain is an important indicator of rainfall as a climate change parameter and the use of early maturing crop varieties will help to circumvent the negative effects of climate change in the area.

Table 4. Farmers' perceptions about changes in rainfall pattern

Perception	Region														
	Both (n=747)					Brong Ahafo (n=498)					Upper West (n=249)				
	SA	A	DA	SD	DK	SA	A	DA	SD	DK	SA	A	DA	SD	DK
Change in timing of rain	66	31	3	0	0	72	25	3	0	0	53	44	3	0	0
Delay in rain onset	44	41	13	1	1	47	42	9	1	1	37	39	23	1	0
Annual rainfall ends early	29	46	18	2	5	26	40	24	2	7	33	58	5	2	1
Annual rainfall starts early	13	34	42	8	3	12	24	51	8	4	13	53	25	7	2
Annual rainfall ends late	11	35	38	8	9	11	36	35	5	13	10	32	43	13	2
Irregular rainfall breaks	26	61	9	1	3	34	56	7	2	2	11	71	13	1	4
Shifting/unpredictable harmattan	21	62	11	2	4	24	57	11	2	6	17	71	11	0	2
Heavy downpours within a short period	30	52	15	2	1	36	46	14	2	2	17	64	17	1	1
Dry spells during rainy season	24	63	10	1	3	29	58	9	1	3	15	71	12	0	2

Note: SA= Strongly agree, A=Agree, DA=Disagree, SD=Strongly disagree, DK=Don't know.

Source: Survey results

3.5. Perceptions about the stability of climate change parameters

Farmers' perceptions about the stability of climate parameters, particularly the rainfall pattern over the past 5 to 10 years are shown in Table 5. A relatively larger percentage of farmers in Brong Ahafo (44%) agreed that the stability of climate over the past 5 to 10 years has been less regular, compared with 12% of farmers in Upper West. The average number of years that farmers started noticing that the climate was changing was about 8 years.

Table 5: Farmers' perception about climate stability and rainfall pattern

Item	Region		
	Both (n=747)	Brong Ahafo (n=498)	Upper West (n=249)
Stability of climate (%):			
More regular	16.2	16.5	15.7
Less regular	33.4	43.7	12.4
Highly irregular	50.4	39.8	71.9
Average years of climate change	8.1 (6.74)	8.3 (7.65)	7.7 (4.34)
Rainfall pattern (%):			
Regular	8.3	8.4	8.1
Irregular	40.2	52.3	16.6
Highly irregular	51.5	39.3	75.3

Note: Figures in parentheses are standard deviations.

Source: Survey results

More than half of the respondents (51.5%) in the total sample described the rainfall pattern as highly irregular; just over 40% reported that it was irregular and only 8.3% indicated that it was regular. The same trend was reported in each region. In Brong Ahafo, 52.3% agreed that the rainfall pattern was irregular and 39.3% said that it was highly irregular while the majority (75.3%) in Upper West agreed that rainfall was highly irregular. These results are consistent with the results of the FGDs in Brong Ahafo which indicated that male farmers (about 80%) and female farmers (over 60%) agreed that rainfall pattern was irregular. However, male and female farmers in Upper West attested to the highly irregular rainfall pattern. This suggests an erratic pattern of rainfall in the regions and calls for strategic meteorological tools to monitor the rainfall pattern to guide farmers' farm production activities.

3.6. Perceptions about flood and drought

Climate change parameters; drought, flood, and extreme weather conditions that can lead to food and water insecurity affect men and women farmers differently. The effects of climate change risks such as flood and drought on farmers are shown in Table 6. Nearly two-thirds (63%) of the households in the entire sample reported having been affected by drought over the past 5 to 10 years, with the highest percentage (80.7%) of households affected in Upper West. This suggests that promoting DT technologies in the area would enhance crop and livestock production and improve the livelihood of the people. However, inadequate knowledge, lack of access, and high cost of certified seeds and other inputs were reported by FGD participants in Pulima, Sibelle, and Sakai as the main constraints limiting the adoption of climate-related adaptation measures in the Upper West.

Difficulty in identifying those who burn the bush and in getting access to climate information was reported as constraints in Brong Ahafo. Also, some farmers were affected by flood during the 5 to 10 year period as a result of irregular and abnormally heavy rainfall. A relatively larger percentage of farmers (about 38%) were affected by flooding in Upper West, while 17.1% were affected in the Brong Ahafo.

Table 6: Effect of climate change variables (flooding and drought) on farmers.

Item	Region		
	Both (n=747)	Brong Ahafo (n=478)	Upper West (n=249)
Households affected by drought in past 5 to 10 years (%)	63.1	54.4	80.7
Households affected by flooding in past 5 to 10 years (%)	23.8	17.1	37.6

Source: Survey results

4. Perceptions about the causes of climate change

4.1. Perceptions of the causes of climate change by gender groups (FGD)

Based on results of FGDs (Table 7), women in both Brong Ahafo and Upper West showed mixed understanding of the causes of climate change. In Brong Ahafo, most women farmers suggested that climate change was God's punishment for sins committed and therefore should be ascribed to these sins. However, more than half of the women interviewed in Upper West did not attribute the cause of climate change to a spiritual effect. Similarly, a majority of the women (about 70%) disagreed that climate change was caused by agricultural activities in both regions (Table 7). Men and young farmers held different views about the causes of climate change. About 50% of the young farmers disagreed that it was caused by spiritual factors. About 50% of the men agreed that it was a sign of the End-time with about only 25% agreeing that climate change is a punishment for human sins committed against a supreme being. In addition, men farmers (not less than 40%) in both regions disagreed that the cause has neither a scientific nor an agriculture-related explanation (Table 7).

However, most of the men farmers (over 80%) also disagreed that climate change was caused by a distortion of the atmospheric composition and any agricultural related activity. This implies low understanding of the real causes of climate change thereby necessitating appropriate trainings and education. Different reasons for climate change and the ensuing misconceptions emphasize the need for awareness-creation efforts.

Table 7: Perception of the causes of climate change based on results of FGDs.

Perceived causes of climate change	Region															
	Brong Ahafo								Upper West							
	Male farmers				Women farmers				Male farmers				Women farmers			
	SA	A	D	SD	SA	A	D	SD	SA	A	D	SD	SA	A	D	SD
Spiritual (%):																
Natural occurrence	2	8	40	50	2	3	45	50	25	20	40	15	15	25	40	20
Sign of the End-time	4	6	50	40	50	20	20	10	20	30	26	24	15	20	45	20
Punishment for human sins by God/gods	15	25	25	35	20	40	25	15	24	28	25	25	10	10	60	20
Scientific phenomenon (%):																
Distortion of atmospheric composition	2	3	40	45	8	12	50	30	20	20	40	20	5	5	70	20
Human causes (%):																
Indiscriminate bush burning	0	5	45	40	5	40	50	35	15	25	50	15	10	10	50	30

Deforestation	5	5	50	40	5	10	45	40	10	15	55	20	10	20	40	30
Fertilizer application	2	3	60	35	7	8	50	35	10	10	60	20	8	12	40	40
Pesticide application	5	0	50	45	5	5	40	50	10	10	60	20	5	10	50	35
Chemical from anaerobic fermentation of agric. produce	5	5	30	60	5	5	50	40	10	15	60	15	10	10	60	20
Car exhausts	3	2	45	45	4	6	60	30	5	20	60	15	5	10	40	45
Automated machine/ exhaust generator	0	4	48	48	5	5	55	35	8	12	65	15	0	0	50	50
Improper waste disposal	2	3	50	45	4	6	40	50	10	20	50	20	10	10	50	30

Note: SA= Strongly agree, A=Agree, DA=Disagree, SD=Strongly disagree, DK=Don't know.

Source: Survey results

4.2. Perceptions about the causes of climate change based on household survey

While the FGDs provide a general understanding of the farmers' perceptions about climate change, results may not be representative of the study population. Hence, a household survey was implemented using a representative sample of the study population to generate information on farmers' perceptions about different reasons given for climate change. Responses to farmers' perceptions about the causes of climate change in the household survey are shown in Table 8. The causes of climate change were categorized into three: spiritual, scientific, and agricultural. Farmers associated the spiritual causes with natural occurrences, sign of the End-time and punishment for human sins by God/gods. A larger percentage of the farmers associated the causes of climate change with a natural occurrence (76% in the entire sample, 79% in Brong Ahafo, and 70% in Upper West). The scientific cause was associated mainly with the distortion of atmospheric composition as agreed by 54% of farmers in the entire sample, 59% in Brong Ahafo, and 44% in Upper West. The agricultural activities that cause climate change are indiscriminate bush burning, deforestation (for producing charcoal), fertilizer and pesticide application, release of chemicals from anaerobic fermentation of agricultural produce, car and generator exhausts, and improper waste disposal, in declining order of importance. In Brong Ahafo, 93.0% agreed that deforestation was a major cause of climate change and 88.0% of farmers agreed that indiscriminate bush burning was a major cause. Similarly, in Upper West, 91% attributed it to deforestation and 88% to indiscriminate bush burning. In general, deforestation and indiscriminate bush burning are the agricultural activities that were perceived to cause climate change in the study area.

Table 8: Farmers' perception of the causes of climate change.

Perceived causes of climate change	Region														
	Both (n=747)					Brong Ahafo (n=498)					Upper West (n=249)				
	SA	A	DA	SD	DK	SA	A	DA	SD	DK	SA	A	DA	SD	DK
Spiritual (%):															
Natural occurrence	35	41	15	6	3	43	36	12	4	4	19	51	21	8	0
Sign of End-time	13	36	31	11	10	15	34	26	12	14	49	41	8	2	0
Punishment for human sins by God/gods	15	32	35	10	8	16	33	29	10	12	13	29	47	11	1
Scientific phenomenon (%):															
Distortion of atmospheric composition	16	38	29	9	8	17	42	22	9	11	14	30	45	9	2
Human causes (%):															
Indiscriminate bush burning	56	33	8	2	3	60	28	6	2	3	46	42	10	0	2
Deforestation	64	28	5	1	2	70	23	4	1	2	51	40	7	1	2
Fertilizer application	9	23	37	12	19	12	19	35	15	20	4	32	41	5	17
Pesticide application	6	25	37	11	20	8	21	35	14	22	3	34	43	5	15
Chemical from anaerobic fermentation of agric. produce	8	22	32	5	33	9	18	27	6	40	5	32	42	2	19
Car exhausts	14	28	32	7	18	18	24	25	8	25	7	34	46	5	9
Automated machine/exhaust from generators	14	27	32	8	19	18	24	25	9	24	7	34	46	5	9
Improper waste disposal	11	32	32	7	19	11	27	28	8	25	9	41	41	3	6

Note: SA= Strongly agree, A=Agree, DA=Disagree, SD=Strongly disagree, DK=Don't know. Source: Survey results

5. Farmers' adaptation strategies to climate change

5.1. What strategies are farmers using?

Farmers employed different strategies to mitigate the effects of climate change in the study area. The adaptation strategies are presented in Table 9. The top three strategies in descending order of importance in the sample were (i) changing planting dates (21.4%), (ii) growing different crops or engaging in mixed cropping to reduce the likelihood of total crop failure relative to mono-cropping (18.2%), (iii) using DT or early maturing crop varieties (17.4%), and (iv) using different crop varieties (14.9%). Other strategies used included changing from crop to livestock production, planting trees for shade and shelter, engaging in off-farm jobs, using soil conservation techniques, using irrigation facilities, increasing water conservation by building water harvesting schemes, and farming in Fadama areas.

In Brong Ahafo, growing different crops or mixed cropping ranked first among the strategies used (about 27% of farmers), followed by changing planting dates (26%), use of DT or early maturing varieties (12.8%), and use of different crop varieties (10.4%). FGD participants in Akrobi community in the Brong Ahafo Region revealed specific adaptation strategies such as the creation of fire belts, planting of economic trees (e.g., cocoa and cashew) and planting when the rains are stable. Though mixed cropping ranked first in Upper West as agreed by 36% of the farmers, the use of DT or early maturing crop varieties (24.3%) ranked second and changing planting dates (14.5%) was third. This implies that farmers generally employed three main adaptation strategies to combat climate change risks in the study area.

The use of DT or early maturing crop varieties as an adaptation strategy ranked second in Upper West and third in Brong Ahafo. The above strategies are however labor intensive and require the use of other inputs which invariably increases the cost of production and serves as a disincentive to their future use.

Table 9: Farmers' strategies for adaptation to climate change

Item	Region		
	Both (n=747)	Brong Ahafo (n=478)	Upper West (n=249)

Plant different crops/mixed cropping	30.6	27.2	36.0
Change planting dates	21.4	26.0	14.5
Use drought/early maturing crop varieties	17.4	12.8	24.3
Use other varieties	14.9	10.4	21.4
Other adaptations(specify)	5.2	6.7	-
Change from crops to livestock	3.0	4.4	0.8
Plant trees for shading and shelter	2.3	3.8	0.2
Find off-farm jobs	1.1	1.4	0.6
Implement soil conservation techniques	1.0	1.3	1.3
Use more irrigation	0.7	1.1	0.1
Increase water conservation	0.6	1	0.1
No adaptation	0.4	2.3	-
Non-farming to farming	0.3	0.4	0.2
Farm in Fadama areas	0.3	0.5	0.1
Change from non-farming to farming	0.3	0.4	-
Migrate to urban areas	0.2	0.2	0.4
Change from livestock to crop	0.1	0.1	-

Source: Survey results

It is important to note that the marital status and age of household decision-makers are important factors influencing the choice of adaptation strategy (Feder et al. 1985; Abdoulaye et al. 2012). In about 56% of households in Brong Ahafo, 93.1% in Upper West, the head of the household constituted the main decision-maker on household farming activities. The joint decision of farmers and their spouses accounted for 30% in Brong Ahafo, 5.3% in Upper West, and 22% in the entire sample. Children contributed very little to decision-making on farming activities, and this was particularly pronounced in Upper West where children were not involved at all. This suggests that farmers and their spouses are important contacts on issues relating to household decisions on climate change and the choice of adaptation strategies in their farming activities. This is supported by the larger percentage of farmers (85% in Brong Ahafo, 96% in Upper West, and 88% in the entire sample) that are married, and this could aid joint decision-making on the choice of appropriate adaptation measure to use. Similarly, older and experienced farmers are expected to be more conversant with climate change risks and the use of different mitigating measures (Smit et al. 2000). Farmers averaged 45 years in age for the entire sample with about 20 years of farming experience; farmers had 22 years of farming experience in Brong Ahafo and 17 years in Upper West. Also, a relatively large proportion of the farmers (about 53% of the entire sample, 60.3% in Brong Ahafo, and

38.3% in Upper West) had some form of education, with a mean of 4 years. This suggests that farmers in the study area fall within the active and productive age bracket of the population and could read or write to easily understand and get access to any information to guide their decision to adopt appropriate adaptation strategies targeted at mitigating the risks and negative impacts of climate change.

5.2. Varieties of maize cultivated

5.2.1. Maize varieties cultivated in the communities and regions

The different maize varieties cultivated in the two regions are shown in Table 10. Both local and improved varieties (including DT/early maturing varieties) were cultivated. In Upper West, two local varieties were reported: 'Let me prosper' and Hasuan Diwe in Chingchang community; five varieties – Komi kuuwie, Komi doli, Diawarey, Kail, and Komi Borsu in Pulima community; and two varieties – 'Yellow maize' in Silbelle and '4-month' variety – in Sakai community. In general, Yellow maize was predominant among the varieties cultivated. In Brong Ahafo, Aburotia, Aburohuma (Appiah), and Tispanu were reported as the local varieties in Babatu-kuma community; Obatia, Aburohuma (Appiah) and 'Yellow maize' in Yipala; Denkye, Aburo Kokoo, Aburo Twene, and Aburo Paraa in Fiaso; Taspine and Aburohuma in Awurowa; Nkran Aburo, Awona Aburo, Taspine, and Aburohuma in Akrobi; Aburohuma in Awisa; Taspine, Denkye, and 'Yellow maize' in Pramposo; Aburohuma in Nante Zongo, and 'Yellow maize' in Ankroma communities. Aburohuma (Appiah) variety was cultivated in seven out of 10 communities in Brong Ahafo, hence it was considered predominant. This was followed by Taspine and 'Yellow maize' that were each cultivated in four communities.

The improved varieties cultivated in the Upper West were Panaar, Etubi, Mamaba, Aburohemaa, Obatanpa, Aburotia, Pan 53, Pan 12, Laposta, Omankwa, and Dobidi. Obatanpa was cultivated in four communities while Mamaba, Aburohemaa, Pan 53, and Laposta were each cultivated in three communities. This suggests that in descending order of importance, Obatanpa, Mamaba, Aburohemaa, Pan 53, and Laposta were the predominant improved varieties cultivated in the Upper West. In Brong Ahafo, Okomasa was cultivated as an improved variety in Babatu-kuma community; Dobidi in Yipala; Mamaba, Dadaba, Obatanpa, Pan 53, Dobidi, Abelehe, and Okomasa in Fiaso; Obatanpa, Dobidi, and Okomasa in Awurowa; Obatanpa, Laposta, Dobidi, and Abelehe in Kuntunso; Obatanpa, Dobidi, and

Okomasa in Akrobi; Okomasa in Awisa; Obatanpa and Dobidi in Pramposo; ‘Golden Jubilee’, Obatanpa, Laposta, and Okomasa in Nante Zongo; and Obatanpa, Dobidi, and Abelehe in Abkroma communities. Obatanpa and Dobidi were the predominantly cultivated varieties, each with coverage of seven communities in the region. This was followed by Okomasa which was cultivated in six communities and Abelehe cultivated in three communities. This suggests that Obatanpa, Dobidi, and Okomasa are the three predominant improved maize varieties cultivated in Brong Ahafo. In all, Obatanpa was predominantly cultivated in the two regions and its traits are therefore important for consideration in the development of new maize varieties in the study area.

Table 10: Maize varieties cultivated in communities in Brong Ahafo and Upper West region in Ghana.

Maize variety Cultivated	Upper West Region					Brong Ahafo Region										Total
	Communities					Communities										
A. Local	Chingchang	Pulima	Sakai	Sorbelle	Bakwala	Babatu-Kuma	Yipala	Fiasco	Awurowa	Kuntunso	Akrobi	Awisa	Pramposo	Nante-Zongo	Ankroma	
Let me Prosper	X															1
Hasuan Diwe	X															1
Komi Kuuwie		X														1
Komi Doli		X														1
Diawarey		X														1
Kailu		X														1
Komi Borsu		X														1
Yellow Maize			X	X			X						X	X	X	6
4-Month Variety			X													1
Obatia						-	X									1
Aburohuma (Appiah)						X	X		X		X	X		X	X	7
Tispanu						X										1
Nkran Aburo										X	X					2
Awona Aburo										X						1
Aboshie											X					1
Taspine									X	X	X	-	X			4
Denkye								X	-	X	-	-	X			3

Aburo Kokoo								X								1
Aburo Twene								X								1
Aburo Paraa								X								1
B. Improved																
Etubi (DTM)	X															1
Mamaba	X	X	-	X				X								4
Aburohemaa (DTM)	X	X	X	-												3
Obatanpa	X	X	X	X				X	X	X	X		X	X	X	11
Aburotia	X	X	-	-		X										3
Pan 53 (DTM)	-	X	X	X				X								4
Pan 12 (DTM)	-	X	X	-												2
Laposta	-	X	X	X						X				X		5
Omankwa (DTM)	-	-	X	-												1
Dobidi	-	-	-	X			X	X	X	X	X		X		X	8
Golden Jubilee (DTM)														X		1
Dadaba								X								1
Abelehe								X		X					X	3
Okomasa (DTM)						X		X	X		X	X		X		6

Source: Survey results

5.2.2. Source of information on maize varieties

The sources of information on maize varieties cultivated in 2013 and 2014 in the two regions are shown in Table 11.

Table 11: Sources of information on maize varieties (multiple responses allowed)

Source of information	Region					
	Both (n=747)		Brong Ahafo (n=498)		Upper West (n=249)	
	2013	2014	2013	2014	2013	2014
Media	12.8	6.3	10.4	7.3	17.9	4.4
Agricultural extension agent	17.3	12.2	10.8	8.9	30.7	19.9
Participation in on-farm trials	2.6	3.2	2.5	2.6	2.8	5.0
MoFA	9.6	12.2	3.1	4.5	23.1	30.5
Input dealers	5.2	5.3	3.9	3.9	8.0	8.2
Other farmers	47.4	53.6	68.9	72.6	2.4	8.8
Research Institutes (e.g., IITA)	5.1	7.2	0.4	0.2	15.1	23.2
At purchase	30.2	21.8	16.5	12.9	58.8	42.9

Source: Survey results

In Brong Ahafo, a relatively larger percentage of farmers (68.9% in 2013 and 72.6% in 2014) obtained information from other farmers on the maize varieties cultivated. This was followed by purchase from market centers by a few farmers (16.5% in 2013 and 12.9% in 2014). In Upper West, most farmers (58.8% in 2013 and 42.9% in 2014) sourced information on maize varieties at the time of purchase. Information from agricultural extension agents followed with 30.7% in 2013 and 19.9% in 2014. In all, the three top sources of information on maize varieties cultivated are other farmers (47.4% in 2013 and 53.6% in 2014), purchase (30.2% in 2013 and 21.8% in 2014) and agricultural extension officers (17.3% in 2013 and 12.2% in 2014). Other sources of information in the study area are the media, MoFA, input dealers, research institutes, and participation in on-farm trials, in descending order of importance.

5.2.3. Types of maize varieties and quantity of seeds planted

Table 12 presents the different maize varieties cultivated and the rate of adoption of DTM in the study area. The land area cultivated and quantity of seeds planted by farmers in 2013 and 2014 are also presented.

Table 12: Maize varieties cultivated by farmers and quantity of seeds.

Item	Both (n=747)	Brong Ahafo (n=478)	Upper West (n=249)
Maize variety:			
Local (%)	28.1	39.8	4.2
Improved (%)	71.9	60.2	95.8
Rate of DTM adoption (%)	45.0	36.2	61.5
Land area cultivated (ha):			
Land area cultivated in 2013	4.2	1.9	5.6
Land area cultivated in 2014	4.3	1.6	6.8
Quantity of seeds planted (kg):			
Qty of local maize seeds in 2013	24.3	30.9	8.5
Qty of local maize seeds in 2014	21.9	27.0	9.6
Qty of improved maize seeds in 2013	23.5	14.1	38.8
Qty of improved maize seeds in 2014	24.4	13.3	42.8
Maize output (kg):			
Maize output in 2013	4250.6	4236.7	4277.6
Maize output in 2014	1691.6	736.2	3255.5

Source: Survey results

On average, the rate of adoption of improved maize varieties including DT and early maturing varieties was estimated at 60.2% in Brong Ahafo, 95.8% in Upper West, and 71.9% (above the national average) in the entire sample. However, the estimated rates of adoption of DTM varieties were 36.2% in Brong Ahafo, 61.5% in Upper West, and 45% in the entire sample. The mean land area cultivated to maize in 2013 was 1.9 ha in Brong Ahafo and 5.6 ha in Upper West with an average of 4.2 ha for the two regions combined. The trend was the same in 2014 except that Brong Ahafo recorded a decrease in the average land area cultivated from 1.9 ha in 2013 to 1.6 ha in 2014 while Upper West recorded an increase from 5.6 ha in 2013 to 6.8 ha in 2014. This suggests that farmers in Upper West allocated more of their land area to maize cultivation within the periods.

More local maize seeds were planted by farmers in Brong Ahafo (with an average of about 31 kg in 2013 and 27 kg in 2014) than in Upper West (with an average of 8.5 kg in 2013 and 9.6

kg in 2014). The average quantity of local maize seeds planted in the study area was 24.3 kg in 2013 and 21.9 kg in 2014. A relatively higher quantity of improved maize seeds was planted by households in the Upper West \ than the Brong Ahafo. This may be linked with the higher maize output in Upper West. In general, there was a reduction in maize output and yield from 2013 to 2014 in the study area which was specifically attributed to drought. This calls for improved extension service delivery system to brief more farmers on the use of improved maize seeds particularly of DTM and early maturing varieties to increase productivity in the study area and particularly, in Brong Ahafo. These results are similar to the findings reported by Smit et al. (1999).

5.2.4. Farmers' use of complementary inputs in maize production

The use of complementary inputs such as fertilizers has a positive relationship with the adoption of DTM and early maturing crop varieties in combating the negative effects of climate change (Adesina and Zinnah 1993). Farmers used three different types of fertilizer in 2013 and 2014 (NPK, urea, and manure) either singly or in combination. Farmers in Upper West used the highest quantity of NPK singly with about 589 kg in 2013 and 656 kg in 2014; those in Brong Ahafo used about 156 kg in 2013 and 117 kg in 2014. The average for the area was 317 kg in 2013 and 321 kg in 2014. A greater quantity of urea was used singly in Brong Ahafo 158.4 kg in 2013 to 272.2 kg in 2014. A decrease was, however, noted from 80.6 kg in 2013 to 53.5 kg in 2014 for Upper West. Farmers in Brong Ahafo also applied more of the combination of NPK and urea in their farms than those in the Upper West. The quantity of manure applied in Brong Ahafo region was also greater than that applied in the Upper West. More manure was applied in 2014 than in 2013.

Table 13: Types and quantity of complementary inputs used in maize cultivation.

Input	Region					
	Both (n=747)		Brong Ahafo (n=498)		Upper West (n=249)	
	2013	2014	2013	2014	2013	2014
Qty of NPK applied (kg)	317.0 (69.907)	320.7 (66.433)	156.1 (49.85)	116.6 (26.24)	588.6 (88.255)	655.5 (93.490)
Qty of urea (kg)	132.2 (65.887)	198.8	158.4 (77.58)	272.2	80.6 (31.752)	53.5 (26.518)

Qty of NPK and urea applied (kg)	56.1 (18.185)	54.9 (16.396)	72.8 (19.90)	73.6 (18.34)	15.5 (12.297)	9.5 (1.020)
Qty of manure (kg)	5.4 (4.747)	6.1 (5.736)	7.9 (6.63)	8.9 (6.95)	0.2 (0.157)	0.1 (0.114)
Qty of other fertilizers (kg)	48.5 (17.295)	63.3 (32.487)	39.5 (17.9)	36.8 (14.33)	68.0 (15.782)	119.0 (53.028)
Qty of herbicides (liters)	12.6 (2.349)	12.59 (1.956)	11.9 (2.71)	11.1 (2.15)	14.1 (13.427)	15.5 (14.468)
Qty of pesticides (liters)	1.90 (0.543)	1.70 (0.566)	1.9 (0.60)	1.7 (0.62)	1.9 (0.413)	1.9 (0.439)
***Output*:**						
Maize output (kg)	4250.6	1691.6	4236.7	736.2	4277.6	3255.5

Source: Survey results

Apart from the three predominant fertilizers, other fertilizer types were also applied by farmers in the two regions. Farmers in Upper West applied more NPK, those in Brong Ahafo applied more manure, urea, and a combination of NPK and urea. The farmers also applied herbicides and pesticides in their farms with slight variations in the quantity applied in 2013 and 2014. More herbicides were applied in Upper West region than in Brong Ahafo.

5.2.5. Farmers' source of seeds

The sources of seeds planted by farmers in 2013 and 2014 are shown in Table 14. There were slight variations in the proportion of farmers that sourced seeds from the different points in each of the regions and the study area.

In 2013, farmers sourced seeds from their own farms, markets, seed companies, MoFA, other farmers, and research institutes such as CSIR-SARI, in order of importance. In 2014, farmers sourced seeds from other farmers, markets, MoFA, own farm, purchase, research institutes, seed companies, and seed growers. This shows that more farmers moved from sourcing seeds from their own farm (40.8%) in 2013 to sourcing from other farmers (26.6%) and the public market (24%) in the study area. The same trend was observed in Brong Ahafo where most farmers (50.8%) sourced seeds from their own farms in 2013 and from other farmers (38.5%) in 2014.

Table 14: Sources of seeds planted.

Item	Region		
	Both (n=747)	Brong Ahafo (n=498)	Upper West (n=249)

	2013	2014	2013	2014	2013	2014
Sources of seeds (%):						
Seed company	14.6	5.5	3.3	2.0	37.6	5.7
Public market	16.7	24.0	21.7	28.9	5.8	20.0
MoFA	12.0	19.3	7.9	8.5	20.5	25.7
Research institute (e.g., IITA)	4.4	6.0	0.4	0.3	12.5	22.9
Own farm	40.8	10.3	50.8	12.3	20.5	5.7
Other farmers	8.8	26.6	13.1	38.5	0.4	0.0
Others (purchase/brothers)	2.7	8.2	2.8	9.3	2.7	20.0
Seed growers	-	0.1	-	0.2	-	-

Source: Survey results

In the Upper West, however, a relatively larger percentage of the farmers (37.6%) sourced seeds from seed companies in 2013 and from research institutes (22.9%) in 2014. This shows that while most farmers in Brong Ahafo sourced seeds from their own farms and other farmers, those in Upper West sourced seeds from seed companies and research institutes such as CSIR-SARI, probably reflecting their adoption of DTM or early maturing varieties from these sources. In other words, own farms, other farmers, seed companies, and research institutes are important points where farmers sourced seeds in the study area.

6. DTM as an adaptation strategy

6.1. Potential roles of DTM

DTM is expected to be an important adaptation strategy to coping with climate change because of its inherent characteristics. FGD participants in Chingchang in Upper West claimed to be aware of DTM varieties, and described them as varieties that are able to produce even with some drought. They reported using DT varieties and claimed that its performance was good. FGD participants in Awisa described DT varieties as effective in circumstances that could result in the wilting of local varieties. The farmers' views are associated with the highly irregular trend in climate over the years affecting more than 80% of them. This suggests greater awareness of DT crop varieties in Upper West and further promotion of DT technologies in the area could have the potential of being effective. Similar strategies should be embarked upon in other parts of the study area where farmers reported having been affected by drought over the years.

Some DTM varieties are early maturing and extra-early maturing – attributes that enable them to escape dry spells. Most of the DTM varieties have the ability to withstand harsh weather conditions. DTM varieties grown in the study area included Omankwa, Aburohemaa, Etubi, Golden Jubilee, Okomasa, Panaar, Pan 53, and Pan 12. Most of these varieties are available in all the regions.

6.2. Key factors affecting use of DTM as adaptation strategy

Farmers' decision to adopt DTM varieties depends on several factors such as their socio-economic characteristics, institutional and climatic related variables, and perception about the technology. Farmer and farm characteristics that are expected to influence adoption of DTM include household size, age and educational level of household head, farm size, and livestock assets. The institutional factors considered include access to extension services, credit, distance to input markets, and membership of associations. Farmers' perception about climate change, awareness of DTM varieties, and participation in training on DTM and climate change were also considered. Spatial variations on the effect of climate change were captured using AEZs. The main purpose of the zonal dummy variables was to control for agro-climatic differences that could affect the adoption of DTM varieties. The detailed discussion of the variables that are hypothesized to affect the adoption of DTM as adaptation strategy is as follows:

Farmer's age: This is the age of the farmer measured in years. Studies have shown that the age of an individual affects the attitude to new ideas and may influence the adoption decision in one of several ways. Younger farmers are more interested in and knowledgeable about new agricultural practices and may be more willing to bear risks and adopt a new technology because of their longer planning horizon (Polson and Spencer 1991). The older the farmer, the less likely he is to adopt new ideas, having gained more confidence in his old ways and methods. On the other hand, older farmers may have more experience, resources, or authority that may make it possible for them to experiment with new ideas or adopt a new technology. There is therefore no general agreement on the sign of the coefficient of this variable in the adoption literature as the direction of the effect is location or technology-specific.

Level of education: Education is a measure of human capital which is the ability to acquire and process information about a new technology such as DTM for adoption against risks from climate change. Individual perceptions are influenced by information and human capital and the level of education is capable of positively affecting their adoption behavior (Nelson and Phelp 1966; Feder et al. 1985). The variable is measured by the number of years spent in formal schooling.

Household size: This is the number of persons living under the same roof and eating from the same pot. Some previous studies show this variable to be positively related with adoption behavior as it depicts labor availability, providing a larger supply of family labor. Other studies show that increased household size increases household consumption expenditure and hence negatively influences the adoption of a new technology. The effect of household size is not determined, *a priori*.

Distance to market: Market access affects adoption decisions. The proximity to the source of distribution of an innovation or new technology influences the adoption decision of farmers. This is because distance to the source of the technology is associated with some costs. These include costs for transportation and risks which increase as the distance travelled by the farmer to purchase the technology increases. The greater the distance between the input buying station and the farmer's farm, the higher the acquisition cost. The variable is, therefore, expected to have a negative relationship with adoption decisions. It is measured in kilometers (km).

Participation in training programs: This variable is expected to have a positive relationship with adoption behavior. The more the farmer participates in training opportunities that relate to agricultural activities and climate change, the more knowledgeable he is about adopting new ideas and technology (DTM) to improve his farm activities. It is measured as a dichotomous variable with participation scored 1 and non-participation 0.

Farm size: This variable is expected to have a positive relationship with technology adoption decisions as shown by Norris and Batie (1987), and Polson and Spencer (1991). This is because the larger the land area allocated to a crop, the higher the tendency to adopt new ideas/knowledge relating to that crop. Though maize varieties are expected to be scale-neutral, wealthier farmers with more land are more likely to adopt new technologies such as DTM. The variable is measured in hectares (ha).

Access to credit: A positive sign was hypothesized for this variable and farmers' adoption decisions. Farmers that have access to credit are able to easily acquire/purchase a new technology for use on their farms. The variable is measured as a dummy with access to credit scored 1 and non-access 0.

Awareness of climate change: Information plays a key role in planning and guiding decisions relating to different farm management activities. Farmers' awareness of climate change is expected to guide their decision to adopt DTM varieties as an adaptation strategy. The variable is positively related to the adoption decision and is measured as a dummy with awareness scored 1 and non-awareness 0.

Farmers affected by drought/climate change: A farmer who is affected by climate change will definitely look for some ways to cope with the challenge. This variable therefore has a positive relationship with adoption decisions for DTM varieties. It is measured as a dummy with farmers' affected by climate change scoring 1 and those not affected scoring 0.

Livestock assets: Livestock assets are the total number of livestock owned by the farmer and represent an important capital asset base for the farmer's productive capability. The variable has a positive relationship with adoption behavior because a farmer with large number of livestock is capable of taking risks and trying out new ideas or technology such as DTM.

Membership of associations: Associations such as cooperative societies enhance the interaction and sharing of ideas among farmers. Belonging to an association is very important in the adoption of a technology since it indicates higher social capital. A positive sign is hypothesized for this variable and it is measured as a dummy, with membership attracting 1 and non-membership 0.

Access to extension services: This variable takes into consideration all the information which farmers obtain during the year on the importance and application of innovations through counseling, demonstrations, and the provision of technical information by extension officers on a regular basis. The impact of this information on adoption decisions varies according to its content, motivation, and frequency. Thus, based on the innovation-diffusion literature, the expected sign for the coefficient of this variable is positive (Feder et al. 1985; Feder and Umali 1993). It is measured as a dichotomous variable with access to extension scored 1 and non-access, 0.

Agroecological location: An AEZ that is much more prone to drought will encourage farmers to use DTM varieties as an adaptation strategy. For example, the savanna AEZ (represented by Upper West) is much more prone to drought effects than the forest zone in Brong Ahafo. This variable is expected to have a positive relationship with adoption decisions about DTM. It is measured by a dummy with savanna AEZ taking the value 1 and the forest zone taking 0.

6.3. Analysis of factors driving adoption of DTM

The factors that determine farmers' adoption of DTM varieties in the study area are shown in Table 15. Distance to input market, AEZ, and the incidence of drought significantly influenced the probability of farmers' adopting improved maize varieties in Ghana. The coefficient on the incidence of drought was positive while those of distance to input markets and AEZ were negative. The marginal effects of the probit estimates were also presented (Table 15). The result shows that experiencing drought shocks increases the probability of adoption by 11.9%. The relatively large coefficient on drought may be associated with farmers' low level of access to irrigation facilities in the study area (only 13.3% in the entire sample, 11.2% in Brong Ahafo, and 17.3% in Upper West).

Access to input market is also critical as distance affects the probability of adoption negatively. For the entire sample, the average distance of maize farms was 4.3 km from farmers' dwellings and 7.6 km from input/grain markets. This suggests that farmers have to transport themselves some distance to get to their farms. There was a significant difference ($p<0.5$) between the average distance recorded for Brong Ahafo (6.5 km) and for Upper West (9.6 km), suggesting that farmers in the regions, particularly in Upper West, move through a longer distance before getting to input and grain markets. This could be a limiting factor to the use of adaptation strategies such DTM varieties. Providing good road networks close to farm sites as well as easy transport facilities will enhance farmers' adoption of DTM for increased production activities. Another important determinant of adoption is attending DT training. Our probit results suggest that attending DT training increases the probability of adoption of DT varieties by about 14%. This result suggests that lack of access to information is an important constraint to the adoption of important practices for adaptation such as DT varieties.

Table 15: Determinants of adoption of DTM varieties in Brong Ahafo and Upper West regions of Ghana.

	Both		Brong Ahafo Region		Upper West Region	
	Coef	Marginal effects	Coef	Marginal effects	Coef	Marginal effects
Age	-0.000149	-0.00003	-0.00910	-0.00123	0.0220*	0.00484*
	(0.00610)	(0.00108)	(0.00799)	(0.00108)	(0.0120)	(0.0026)
Education	0.0183	0.00325	0.0187	0.00253	0.0103	0.00228
	(0.0150)	(0.00266)	(0.0234)	(0.00316)	(0.0213)	(0.00468)
Household size	0.0118	0.00210	0.0226	0.00305	-0.00535	-0.00118
	(0.0144)	(0.00256)	(0.0219)	(0.00295)	(0.0219)	(0.00483)
Distance to input market	-0.0653***	-0.0116***	-0.0283	-0.00382	-0.0764**	-0.0169**
	(0.0180)	(0.00316)	(0.0208)	(0.0028)	(0.0331)	(0.00714)
Participation in DT training	0.767***	0.1364***	0.521	0.07039	1.028**	0.2268**
	(0.280)	(0.04936)	(0.438)	(0.0590)	(0.419)	(0.0897)
Farm size	0.000443	0.00008	0.0177	0.00239	-0.00942	-0.00208
	(0.0226)	(0.00401)	(0.0283)	(0.0038)	(0.0454)	(0.010)
Access to credit	0.140	0.02491	-0.434	-0.05858	0.464*	0.10236*
	(0.178)	(0.03160)	(0.287)	(0.03867)	(0.277)	(0.0599)
Awareness of climate change	0.00303	0.00054	0.0236*	0.0032*	-0.0788*	-0.0174*
	(0.0128)	(0.00228)	(0.0141)	(0.0019)	(0.0413)	(0.00894)
Affected by drought	0.667***	0.1187***	1.099***	0.1484***	0.196	0.04315
	(0.174)	(0.03052)	(0.254)	(0.0351)	(0.287)	(0.06309)
Livestock asset (TLU)	-0.00205	-0.00036	-0.0147	-0.00198	-0.00422	-0.00093
	(0.0166)	(0.00296)	(0.0251)	(0.0034)	(0.0322)	(0.0071)
Membership of association	-0.0887	-0.01577	-0.306	-0.04136	-0.0392	-0.00865

	(0.176)	(0.03134)	(0.285)	(0.0384)	(0.274)	(0.06053)
Access to extension service	-0.435	-0.07742	-0.142	-0.01911	-0.687	-0.15150
	(0.277)	(0.04914)	(0.381)	(0.05134)	(0.440)	(0.09623)
Agroecological location	-0.524***	-0.093***				
	(0.188)	(0.03321)				
Constant	-1.135***		-1.947***		-0.973	
	(0.371)		(0.435)		(0.640)	

Dependent variable: planting of DTM/early maturing varieties

Note: *** Significant at 1%, ** Significant at 5%, * Significant at 10%

Source: Survey results

Our disaggregated probit analysis based on AEZs also suggests heterogeneity effects across the two AEZs considered in this study. In Brong Ahafo, experiencing a drought shock is the single largest reason for the adoption of DT varieties. In particular, experiencing a drought shock in this AEZ increases the probability of adoption of DT varieties by 15%. In Upper West, five variables (farmers' age, awareness about climate change, distance from input markets, access to credit, and training on DT varieties) affect the probability of adoption of DT varieties. While the coefficients of age, training about DT varieties and access to extension are positive, the coefficient of awareness about climate change and distance from input markets are negative.

7. Summary and conclusion

This report documents farmers' perception of climate change and adaptation strategies used to mitigate climate change effects in the Brong Ahafo and Upper West regions of Ghana. It also assessed farmers' perceptions about climate change and evaluated DTM varieties as a strategy for adaptation to climate change; and identified the factors affecting its adoption in the two regions.

Results revealed that over 90% of the farmers are aware of climate change mainly through personal observations and first heard of the term in 2006 from extension officers from MoFA. Farmers perceived climate change as a state of increasing temperature (as depicted by dry and rainy season temperatures and the frequency of drought), increasing wind (depicted by wind intensity during dry and rainy seasons), and decreasing rainfall (depicted by amount and intensity of annual and rainy season rainfall). Farmers depicted the irregular rainfall pattern by a change in the timing of rains, delay in the onset of rain, early ending of annual rainfall, irregular rainfall breaks, heavy downpour of rain within a short period, and dry spells during rainy seasons. The causes of climate change were categorized into spiritual, scientific, and agricultural domains. Spiritual causes are associated with natural occurrences, a sign of the End-time and God/gods' punishment for human sins; scientific causes are related to the distortion of atmospheric composition, and agricultural causes to indiscriminate bush burning and deforestation. Among agricultural causes of climate change, about 93% of the farmers in Brong Ahafo attributed it to deforestation and 88% to indiscriminate bush burning while in

Upper West, 90.7% attributed it to deforestation and 88.3% to indiscriminate burning. Results from FGDs with women and young men indicated a low level of understanding of the meaning and causes of climate change in both regions. The women (about 7%) and young men (about 50%) attributed the causes of climate change to spiritual factors. The top three adaptation strategies used by farmers to mitigate the effects of risks from climate change are changing planting dates, growing different crops/mixed cropping, and using DT or early maturing crop varieties. Cutting fire belts, planting economic trees such as cocoa and cashew, and planting when rains are stable were strategies specific to some communities in the regions.

Farmers cultivated both local and improved maize varieties. On average, the use of improved maize varieties including DTM and early maturing crop varieties was relatively high. It was estimated at 60.2% in Brong Ahafo, 95.8% in Upper West, and 71.9% in the entire sample (above the national average). Obatanpa ranked highest among the improved maize varieties cultivated in the two regions. Obatanpa, Dobidi, and Okomasa were predominantly grown in Brong Ahafo while Obatanpa, Mamaba, and Aburohemaa were predominantly cultivated in Upper West. The use of DT and early maturing maize varieties to escape drought is becoming popular in both study regions, although there is currently greater awareness in Upper West than in Brong Ahafo and promoting DT technologies has the potential of being more effective in these areas. The DT varieties cultivated in the two regions included Omankwa, Aburohemaa, Etubi, Golden Jubilee, Okomasa, Panaar, Pan 53, and Pan 12. Most of the varieties are available in the study area.

The key determinant of DTM adoption as an adaptation strategy to risks from climate change in Brong Ahafo is experiencing a drought shock. In Upper West, farmers' age, awareness about climate change, distance from input markets, access to credit, and training on DT varieties affect the probability of adoption of DT varieties. These factors constitute the drivers of DTM adoption in each of the two regions and therefore need to be considered in any developmental strategy aimed at improving the food security status and livelihood of farmers in the regions. In general, distance to input market, AEZ, drought effect, and training on DT varieties significantly influences the probability of farmers' adoption of DT/early maturing maize varieties in Ghana.

In conclusion, farmers perceive that climate change is evident in the study area and intensifying enlightenment programs to curb indiscriminate bush burning and deforestation while embarking on afforestation programs is imperative to mitigate the negative impact of climate change. A lack of clear understanding of the underlying causes of climate change by women and young farmers emphasize an urgent need for awareness-creating efforts and the training of farming households on the meaning, causes, and coping strategies for climate change. Farmers' low contact with extension services and their participation in field days, seminars, and on-farm demonstration trials/ training on DTM suggests the need for awareness creation programs to enlighten more farmers on the importance of this adaptation strategy in the study area. Given that the majority of the farming households had access to agricultural information through radio, friends/relatives, and extension agents; it is clear that these are the most effective media for promoting agricultural technologies, particularly DTM varieties in the study area.

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