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Smallholder farmers' adoption of technologies for adaptation to climate change in Northern Ghana

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Climate change introduces numerous uncertainties in the livelihoods of farming communities that depend heavily on the weather and climate. Technologies have been developed to help smallholder farmers better adapt to the changing climatic conditions. This study seeks to determine the factors that influence the adoption of climate related technologies introduced by research institutions. A Multinomial Logit Model was estimated using data from 320 households in Northern Ghana. The empirical results reveal that sex, age, farm size, access to formal agricultural extension, agro ecology and noticing of unpredictable temperatures were the factors influencing farmers' adoption of a climate related strategies introduced by research institutions. The empirical results imply that targeting females, increasing access to agricultural extension services and creating more awareness about changes in temperatures are important in promoting the adoption of climate related technologies introduced by research.

Key words: Adoption, climate change, technologies, multinomial logit, Northern Ghana.

INTRODUCTION

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Climate change has been defined by the Intergovernmental Panel on Climate Change, IPCC (2007) as any change in climate over time which arises as a result of both human activity and natural variability. Climate change impacts are already felt by many people and ecosystems in many parts of the world and have the potential to cripple the drive for sustainable growth and development (World Bank, 2008). The evidence of climate change includes increased temperatures, reduced precipitation, frequent droughts and scarcity of water (Adger et al., 2003; IPCC, 2007). The climate is projected to change in the coming decades at unprecedented rates with its attendant adverse consequences. According toIPCC (2007), Africa is expected to experience the highest levels of warming with some countries, Ghana inclusive, also experiencing decline in rainfall.

Climate change introduces numerous uncertainties over the livelihoods of farming communities that depend heavily on the weather and climate (Al-Hassan and Poulton, 2009; Athula and Scarborough, 2011). It impacts on land use and livestock management by altering crop, forage and livestock growth and yield (Mu and McCarl, 2011). Climate change negatively affects the basic elements of food production such as soil, water and biodiversity (FAO, 2009). Smallholder farmers have therefore been modifying their practices to better adapt to the changing climate. The FAO (2009) however opines that traditional coping mechanisms are not sufficient for dealing with medium to long-term impacts of climate change. Hence, innovative or modern technologies are expected to play a critical role in the mitigation of, and

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adaptation to climate change (IISD, 2005).

According to Clements et al. (2011), innovative technologies and practices do exist, or have been developed in different parts of the world to help facilitate adaptation to climate change in the agricultural sector. These include improved weather prediction, water conservation, sustainable soil management, better livestock management and improved crop varieties among others. A challenge for agricultural researchers is to understand how and when these technologies are used by farmers and with what impacts (Doss, 2006). An understanding of the factors that influence the adoption of an innovation is therefore important in the process of technology development and dissemination.

Several technologies and practices are available for smallholder farmers in northern Ghana to enable them better adapt to the effects of climate change. These technologies have largely been developed by the Council of Scientific and Industrial Research and the universities in Ghana mostly in collaboration with international research institutions and donors. It however appears these technologies and practices have not been comprehensively documented in the adaptation literature in Ghana. Farmers are also not able to fully take advantage of the technical and economic opportunities around them since adoption only takes place after awareness. There are a number of studies (Hisali et al., 2011; Below et al., 2012; Tambo and Abdoulaye, 2012) on farmer's adaptation to climate change in Africa; however, there is limited research on Ghana (Fosu-Mensah et al., 2012) and especially northern Ghana. This paper therefore seeks to add to the adaptation literature in Ghana.

This paper documents farmers adaptation practices to climate change but unlike Tambo and Abdoulaye (2012), it focuses on technologies introduced by research institutions and also goes a step further to estimate the factors that influence farmers adoption of such technologies. This study therefore attempts to explain farmer's adaptation behaviour using socioeconomic data as opposed to adaptation capacity as estimated by Below et al. (2012).

According to Bediane (2012), smallholder farmers in Africa must first of all overcome the hurdle of adapting to climate change and variability in order to make more meaningful contributions towards a green economy. There is however limited evidence of efforts to build the resilience of the smallholder farmer to adopt best agricultural practices that improve their adaptation capacity to climate change and variability. Supporting the coping strategies of local farmers through appropriate public policy and investment, and collective actions can help increase the adoption of adaptation measures that will reduce the negative consequences of predicted changes in future climate, with great benefits to vulnerable farming communities (Hassan and Nhemachena, 2008). This paper therefore studies the factors that influence the adoption of climate related strategies introduced by research. This information is important in facilitating the promotion and dissemination of adaptation technologies introduced by research. This paper is a follow up to Etwire et al. (2013a), Kuwornu et al. (2013) and Al-Hassan et al. (2013).

METHODOLOGY

Method of analysis

The endogenous variable considered for this study are climate related adaptation technologies that were identified during field enumeration and have been broadly classified into four strategies namely improved varieties or breeds strategies (IVB); soil and plant health strategies (SPH); recommended agricultural practice or management strategies (RAS); and other introduced strategies (OIS) which do not fall in any of the previous categories. There are however some farmers who reported not adopting any introduced adaptation technology in response to climate change and variability. A fifth category named 'no introduced strategy' (NIS) was therefore included as an endogenous variable and was also used as the base outcome for the model.

This study employs the multinomial choice model with logistic distribution to determine the factors that influence the choice of climate related strategies introduced by research.

The theoretical framework adopted for this study is based on the random utility model as specified by Green (2003). A common formulation is the linear random utility model:

$$U = XB + e \tag{1}$$

Following from Greene (2003), the probability of a farmer adopting a technology in response to climate change is assumed to be a function of a number of attributes; namely socioeconomic, institutional and environmental characteristics, X, as presented in Equation (2); where B_j is a vector of coefficients on each of the exogenous variable X.

$$\Pr ob(Y_i = 1) = \frac{e^{B_j^{'} X_i}}{\sum_{k=0}^{3} e^{B_k^{'} X_j}}, \quad j = 0, 1, \ldots, 3 \tag{2}$$

Equation (2) is normalized to remove indeterminacy by assuming that $B_0 = 0$ and the probability is estimated as;

$$\text{Prob}(Y_i = 1 \mid x_i) = \frac{e^{\beta_j^{'} X_i}}{1 + \sum_{k=1}^{3} e^{\beta_k^{'} X_j}}, \quad j = 0, 2 \ldots J, B_0 = 0 \tag{3}$$

Maximum likelihood estimation of Equation (3) yields the log-odds ratio presented in Equation (4):

$$In\left(\frac{P_{ij}}{P_{ik}}\right) = x_i^{'}\left(B_j - B_k\right) = x_i^{'} B_j, \quad \text{if } k = 0 \tag{4}$$

The choice of any improved technology is therefore the log-odds in relation to the base alternative. According to Greene (2003), the

Table 1. Exogenous variable description.

Factor	Exogenous variable	Measurement
Household	Sex of household head	Dummy: 1=female, 0=otherwise
	Age of household head	Years
	Total farm size	Hectares
	Own radio	Dummy: 1=yes, 0=otherwise
Institutional	Received formal extension service	Dummy: 1=yes, 0=otherwise
Environmental	Noticed unpredictable temperature	Dummy: 1=yes, 0=otherwise
	Noticed decreased rainfall	Dummy: 1=yes, 0=otherwise
	Agro ecology	Dummy: 1= Guinea Savannah, 0=Sudan Savannah

coefficients of the Multinomial Logit are difficult to interpret and associating B_j with the j^{th} outcome is tempting and misleading. Instead, the marginal effects are usually derived to explain the effects of the independent variables on the dependent variable in terms of probabilities as presented in Equation (5).

$$\frac{\partial P_j}{\partial x_i} = P_j \left[B_j - \sum_{k=0}^{J} P_k B_j \right] = P_j \left(B_j - \overline{B} \right) \quad (5)$$

The marginal effects measure the expected change in the likelihood of choice of a particular climate related strategy with respect to a unit change in an exogenous variable (Greene, 2003).

Exogenous variables considered for the models

Based on literature, availability of data and statistical significance, the exogenous variables discussed below were used to estimate the factors that influence the adoption of a climate related strategy introduced by research institutions. The exogenous variables are summarised in Table 1 and discussed under three main headings namely household, institutional and environmental factors.

Household factors

Age of household head

The effect of age on the decision to choose an adaptation strategy is mixed in the literature. Whereas Deressa et al. (2010) report that age has a positive influence on the choice of livestock sale as an adaptation strategy by farmers during extreme climatic events, Hassan and Nhemachena (2008), have found age to have no significance in influencing the choice of an adaptation strategy to climate change.

Sex of household head

The influence of gender on the choice of an adaptation strategy to climate change and variability is not straight forward. Whiles some studies (Deressa et al., 2010; Hassan and Nhemachena, 2008) have concluded that a male headed household is more likely to adopt an adaptation strategy because males have more access and control of resources, Nhemachena and Hassan (2007), report that female headed households are more likely to take up adaptation options to climate change and variability since much of the agricultural work is done by women.

Farm size

Deressa et al. (2010) observe that farmers with larger farm sizes are also wealthier farmers who can depend on savings and are therefore less likely to adopt strategies such as livestock sale and borrowing from relatives as adaptation options to climate change and variability. Gbetibouo (2009), however, holds a different view indicating that large scale farmers are rather more likely to adopt adaptation strategies since they have the capital and resources to easily invest in strategies that demand a high investment cost.

Ownership of radio

According to Deressa et al. (2010), owning a radio is an indicator of wealth in rural Africa and therefore increases the probability of selling livestock and borrowing from relatives as a coping strategy to climate change and variability. Mandleni and Anim (2011) also report that access to information on climate change and variability through for example, a radio, positively affects adaptation.

Institutional factor

Agricultural extension visits

Agricultural extension service has been reported in the literature to have a positive effect on the adoption of improved technologies. Extension service is an important source of information on climate change as well as adaptation options hence farmers who have contact with extension agents are more likely to be aware of climate change and available adaptation options, and subsequently adopt these options (Nhemachena and Hassan, 2007; Gbetibouo, 2009; Deressa et al., 2010). Farmer to farmer extension has also been reported by Deressa et al. (2010) to have a positive influence on the adoption of adaptation technologies in response to climate change.

Environmental factors

Temperature

Researchers seem to disagree on the influence of temperature on the adoption of climate related adaptation technologies. Whereas

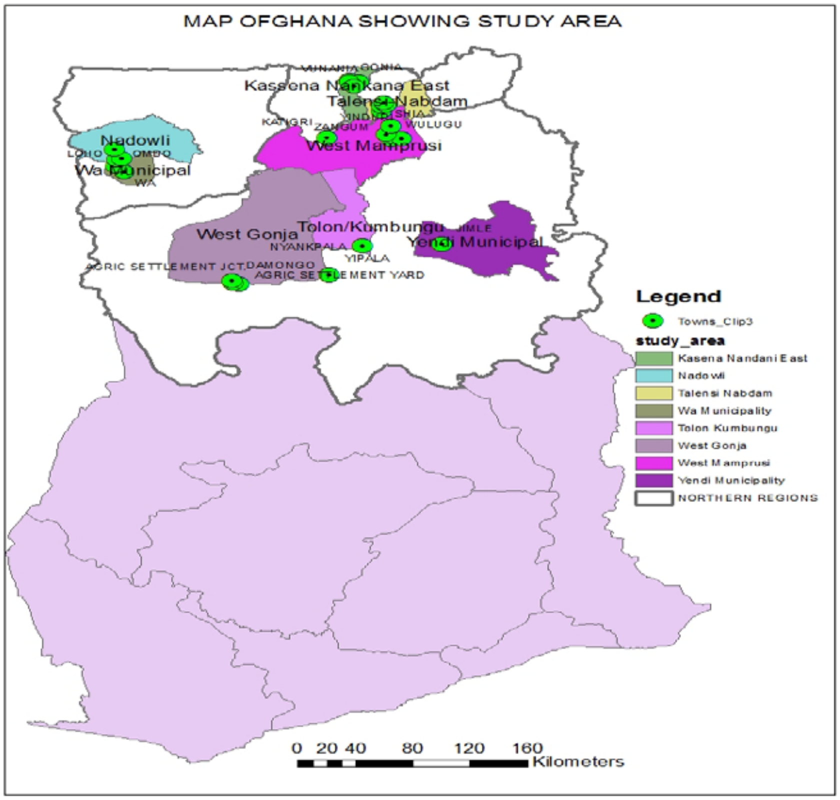

Figure 1. Study area.

Nhemachena and Hassan (2007), Gbetibouo (2009) and Deressa et al. (2010) all report a positive relationship between temperature and uptake of climate related technologies, Mandleni and Anim (2011) observed an inverse relationship between temperature and adoption of adaptation measures. This study measures farmer's perception of temperature as a binary outcome, whether they have observed unpredictable temperatures in the past decade or not.

Rainfall

Rainfall has been observed by different authors to have either a positive or negative influence on the adoption of climate related adaptation technologies. Deressa et al. (2010) observed a negative relationship between precipitation and adoption of climate related technologies in Ethiopia. Increasing rainfall means a reduction in drought hence a decrease in the likelihood of adoption of drought related technologies. Gbetibouo (2009) observed that a reduction in rainfall in South Africa is likely to result in the adoption of climate related technologies. Nhemachena and Hassan (2007) reports that, farmers in southern Africa adapt to both increasing and decreasing precipitation by adopting appropriate technologies. Rainfall is captured in this study as a binary outcome, that is, whether farmers have noticed a decrease in rainfall in the past twenty years or not.

Agro ecology

Impacts of climate change may have a varying effect on different agro ecologies. Farmers in different agro ecologies would probably have to adopt different adaptation technologies in response to climate change and variability. Mensah-Bonsu et al. (2011) reported a positive and significant relationship between agro ecology and a farmer's uptake of improved technologies. Morris et al. (1999) also observed that the level of adoption of improved technologies varied across agro ecologies opining that improved technologies may be better suited in some agro ecologies than others.

The maximum likelihood method was used to estimate the parameters. The overall significance of the model was tested using likelihood ratio (LR) statistic. The model was also subjected to the assumption of Independence from Irrelevant Alternatives (IIA) which is also based on the assumption that the disturbance term is independent and homoscedastic (Greene, 2003). This implies that the parameter estimates of the multinomial logit remain unchanged even if a new endogenous variable is introduced to the model. According to Greene (2003), the Hausman test can be used to determine if the IIA assumption has been violated or otherwise. The statistic has a limiting chi-squared distribution with K degrees of freedom and tests the null hypothesis that the odds are independent of irrelevant alternatives. STATA software was used for the estimation.

Study area

Three regions in Ghana, namely Northern, Upper East and Upper West are most jointly referred to as northern Ghana (Figure 1). The climate of northern Ghana is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 700 and 1100 mm. The dry season starts in November and ends in April with maximum temperatures occurring towards the end of the dry season (March-

Table 2. Descriptive statistics of socio-demographic factors.

Socio-demographic factors	Minimum	Maximum	Mean
Age of household head (Years)	20	100	51.59
Total farm size (Hectares)	0.40	19	3.07

Source: Computations from field survey, 2011.

April) and minimum temperatures in December and January. The harmattan winds, which occur during the months of December to early February, have considerable effect on the temperatures in the region, which may vary between 14°C at night and 40°C during the day (Ghana Nation, 2012).

Data and sampling procedure

The study uses primary data collected through household survey, community focus group discussion and key informant interviews in the Northern, Upper East and Upper West regions of Ghana. Questionnaires were developed, tested and administered to smallholder farm households. The questionnaire covered key areas such as household composition and resources, institutional setting, perception about changes in temperature among others.

A multi-stage sampling technique was adopted. The three northern regions were purposively selected since the region represents the Savannah zone of Ghana with Northern Region being Guinea Savannah and Upper West and Upper East regions being Sudan Savannah. Through a simple random technique, 8 districts and 31 communities were selected. A total of 320 households were enumerated for the analysis.

RESULTS AND DISCUSSION

Descriptive statistics of explanatory factors used in the multinomial models

Socio demographic factors

An overwhelming majority (90%) of households in northern Ghana are headed by males according to results of the survey. Most communities in northern Ghana are traditionally patrilineal in nature; this implies that households are normally headed by males. Female headed households are therefore mostly de facto and in some cases widowers. According to Etwire et al. (2013a), it is not uncommon for male household heads across the three regions to leave and work outside their communities. Economic migration to nearby cities and to southern Ghana, especially during the long spell of dry season is common in northern Ghana (ibid). For this study, a female is also considered the head of the household if the substantive male head has been away for more than six months.

Majority of households (77.2%) in northern Ghana own at least a radio set. Radio is an important source of information, entertainment and most importantly education for most households in northern Ghana. Civic education, health and agricultural programs are usually aired in the local dialects in both community and regional radio stations and it is not uncommon to find farmers tuning in, since the radio sets are usually run on dry cells and are very portable, thus it can be carried to the farm and even moved within and around the community.

The average age of a household head was found to be 52 years as presented in Table 2. The Ghana Statistical Service (2008) estimates the average age of a household head in rural savannah as 46.8 years. The age of the household head, which is a proxy for experience in farming, is important in the process of making choices especially agricultural based decisions. Age of the household heads ranged between 20 and 100 years. Whereas relatively young household heads are mostly singles who are actively engaged in agriculture, relatively old household heads are mostly married and may not be actively engaged in agriculture.

The total farm size of the sample is about 3 ha on the average as shown in Table 2. Farming is practiced basically on a subsistence level and not as a large scale commercial activity. Every household visited therefore engaged in farming with or without a second source of income.

Institutional factor

Results of the survey indicate that about 33% of the sample had some interaction with agricultural extension agents. Awareness is a necessary condition for adoption and in Ghana, agricultural extension agents are mandated to extend agricultural knowledge to farmers. Farmers may receive extension services either on individual basis or as a group. The latter is however preferred and farmers are encouraged to form farmer based organisations in order to take advantage of extension services and economics of scale.

Environmental factors

Unpredictable temperatures have been observed by about 23% of the sample with respect to the last two decades. Farmer's inability to correctly predict temperatures over the season has implications for adoption of adaptation responses.

An overwhelming majority of agriculture in Ghana is practiced under rain-fed conditions (MoFA, 2011). A change in either rainfall pattern or quantum therefore has

Table 3. Identified introduced adaptation strategies.

Improved varieties and breeds strategies	% of sample	Soil and plant health strategies	% of sample	Recommended agricultural-practice strategies	% of sample	Other introduced strategies	% of sample	No introduced strategy
High yielding varieties	2.8	Inorganic fertilizers	42.8	Harrowing	4.7	Planting of trees	3.1	
Early maturing varieties	2.2	Compost	5.6	Conservation agric.	3.1	Irrigation	3.1	
Drought tolerant varieties	0.9	Herbicides	5.6	Planting during recommended period	2.5	Reduce farm size	0.9	
Improved breeds (Livestock)	0.6	Insecticides	5.3	Planting in rows	1.6	Establish fire belt	0.6	
Percent of sample	6.6		59.4		11.9		7.8	14.4

Source: Computations from field survey, 2011.

serious implications on agriculture which is the mainstay of majority of people in the country. Majority (74%) of the sample reported that they have observed a decrease in rainfall over the last twenty years. This result agrees with the findings of Tambo and Tahirou (2012) who studied the perceptions of farmers in similar agro ecologies in Nigeria.

Level of adoption of introduced climate related strategies

Soil and plant health strategies are the most widely (59.4%) adopted climate related strategies in northern Ghana as shown in Table 3. The pervasiveness of these strategies is as a result of the effectiveness of the technologies, declining soil fertility and the increasing challenge posed by obnoxious weeds and insects. Many farmers would suffer huge losses in yield without improving soil fertility and managing insect pests and weeds. About 14% of the sample do not use any introduced strategy in response to climate change and variability. Such farmers relied mostly on indigenous strategies to adapt to extreme climatic events. Adoption of recommended agricultural management practices is used by about 12% of the sample. These practices such as planting in rows, conservation agriculture and planting during the recommended period are usually not costly but can make the difference in yield between farmers in the event of extreme weather events.

About 7% of the sample use either improved seeds or breeds as an adaptation response to climate change and variability. Improved seeds and breeds have special attributes that enable smallholder farmers to better adapt to extreme climatic conditions. These attributes include enhanced productivity, early maturing and drought tolerance. According to Etwire et al. (2013b), In Ghana, improved seed of any variety is delivered through the formal seed system. Majority of farmers in the country however obtain their seed from informal sources because the formal seed system is not fully develop and also faces a number of constraints. About 8% of the sample use other introduced strategies such as tree planting, irrigation and establishment of fire belts as adaptation mechanisms to climate change and variability. A few of the farmers sampled (0.9%) reported reducing their farm size in order to enhance farm management. The farmers reported that, the idea of concentrating resources on a relatively small piece of land instead of spreading out thinly is an idea that was propagated by research and extension.

Factors that influence the adoption of introduced climate related strategies

The diagonostics statistics of the Multinomial Logit regression results reveal that the log likelihood chi square ratio of 91.40 is highly significant implying that the overall model with predictor is to be preferred as compared to a model without any predictors. The results of the Hausman test for Independence from Irrelevant Assumptions failed to reject the null hypothesis of independence from irrelevant alternatives implying that the use of the Multinomial Logit is justified. For this analysis, no introduced strategy is used as the base outcome. Table 4 presents the marginal effects of the factors that influence the choice of introduced climate related strategies by smallholder farmers in northern Ghana.

Agro ecology and noticing of unpredictable temperatures are the factors that influence the adoption of soil and plant health related strategies in northern Ghana. Whereas agricultural extension service has a positive influence on the adoption of improved varieties and breeds as an adaption response to climate change and variability, agro ecology has a negative effect. Age, farm size, agro ecology and unpredictability of temperatures are the factors that influence the adoption of recommended agricultural-practice

Table 4. Marginal effects of the factors that influence the adoption of introduced climate related strategies by smallholder farmers in Northern Ghana.

Variable	Soil and plant health strategies	Improved varieties and breeds strategies	Recommended agricultural practice strategies	Other introduced strategies
Sex of household head	-0.0178	0.0112	-0.0315	0.0887**
Age of household head	0.0008	-0.0003	-0.0023**	-0.0002
Own radio	0.0305	-0.0286	0.0502	0.0585
Total farm size	-0.0202	-0.0075	0.0126**	0.0059
Received agricultural extension service	0.0357	0.0729**	-0.0651	0.0003
Noticed unpredictable temperature	-0.1667***	-0.0029	0.1409***	0.0418
Noticed decreased rainfall	-0.0355	-0.0219	0.0229	0.0312
Agro ecology	0.2601***	-0.0627**	-0.1632***	-0.0191
Base outcome: No Introduced Strategies				
Number of observations: 320				

, *, Statistical significance at 5 and 1% respectively; Source: Computations from field survey, 2011.

strategies in northern Ghana. Gender is an important factor in the choice of other introduced strategies (for example irrigation) as an adaptation option to climate change and variability.

A smallholder farmer, who has noticed that temperatures are unpredictable, is about 17% less likely to adopt a soil and plant health related strategy. Due to the cost involved, most smallholder farmers in northern Ghana are unwilling to adopt soil and plant health related strategies when temperatures are perceived to be unpredictable.

The possibility of farmers adopting improved breeds and varieties as an adaptation response to climate change increases by about 7% if they have access to extension service. Agricultural extension officers are the main linkages between agricultural researchers and farmers, hence agricultural extension officers are the main disseminators of introduced climate related strategies. Smallholder farmers who have access to agricultural extension officers are more likely to adopt introduced climate related strategies. This result confirms the finding of Nhemachena and Hassan (2007), who report that farmers who have extension contacts have better chances to be aware of changing climatic conditions and also of the various management practices that they can use to adapt to changes in the climatic conditions.

The probability of adoption of a recommended agricultural-practice reduces marginally as a farmer ages. Most elderly farmers do not usually want to try new technologies until they have been proven to be effective. Also, most elderly farmers do not usually have the physical strength and wealth to invest in recommend agricultural practice such as harrowing and planting in rows. This finding is contrary to that of Deressa et al. (2010) who reported that age has a positive influence on the choice of livestock sale as an adaptation strategy by farmers during extreme climatic events. Hassan and Nhemachena (2008), however, found age to have no effect in influencing the choice of an adaptation strategy to climate change and variability.

Noticing unpredictability in temperature increases the probability of adoption of recommended agricultural practice strategy by about 14% as against not adopting any introduced strategy. Smallholder farmers are more willingly to adopt recommended agricultural practices that may not require additional cash outlays (for example, planting during recommended periods and not planting too early or late) as against to not adopting any introduced strategy as a way of adapting to unpredictable temperatures.

Farm size significantly and positively affect the decision to adopt a recommended agricultural practice as an adaptation option to climate change and variability by smallholder farmers in northern Ghana. It is not uncommon for farmers to try new technologies on a small piece of land to determine its efficacy before large scale adoption. A farmer who is able to put an additional hectare of land into crop production is therefore more likely to try recommended agricultural practices and subsequently adopt them. Also, farmers who can afford to cultivate an additional hectare of land are usually not cash or labour constrained and can therefore adopt a recommended practice such as harrowing or planting in rows. Farmers who are able to cultivate an additional hectare of land are usually wealthy and progressive farmers and are therefore more likely to be preferred by agricultural extension agents and also likely to seek for extension information and subsequently put them into practice. These results are consistent with Gbetibouo (2009).

Female headed households in northern Ghana are 9% more likely to adopt ‘other introduced strategies’ such as irrigation, as opposed to not adopting any introduced strategy in response to climate change and variability. Females tend to be more aware of other introduced strategies because they are more networked socially and undertake most agricultural activities. Females were found to cultivate small pieces of land near their communities. These pieces of land were mostly used for the cultivation of vegetables and maize, and manually irrigated during periods of water stress. Whiles this result confirms the findings of Nhemachena and Hassan (2007) who report that female heads of household adopt adaptation strategies since much of the agricultural work is done by women, it however contradicts the findings of many studies (Deressa et al., 2010; Mandleni and Anim, 2011) who contend that male headed households are more likely to adopt adaptation strategies because males have more access and control over resources.

Agro ecology has a positive influence on the adoption of soil and plant health related technologies but a negative influence on the uptake of improved varieties and breeds, and recommended agricultural practices. A smallholder farmer in the Guinea Savannah agro ecology is about 26% more likely to adopt a soil and plant health strategy as compared to a farmer in the Sudan Savannah agro ecology. Even though farmers in both agro ecologies were found to be benefitting from some agricultural projects that are aimed at improving soil and plant health, there are some interventions that are limited in scope to only the Guinea Savannah or parts of the Guinea Savannah agro ecology. An example is a soil health project being implemented by Savannah Agricultural Research Institute with funding from Alliance for a Green Revolution in Africa. A farmer in the Guinea Savannah agro ecology is about 6 times less likely to adopt an improved variety or breed as an adaptation option to climate change and variability. The weather in the Guinea Savannah agro ecology is relatively less harsh as compared to the Sudan Savannah. In fact, the average annual rainfall in the Guinea Savannah agro ecology is estimated to be more than that of Sudan Savannah by 100mm (MoFA, 2011). A farmer in the Guinea Savannah agro ecology may therefore be able to cultivate a traditional variety and still reap a harvest unlike farmers in the Sudan Savannah agro ecology who may have to resort to cultivating early and extra early improved varieties. The probability of a farmer adopting recommended agricultural practices as an adaptation response to climate change and variability reduces by about 16% if the farmer is located in the Guinea Savannah agro ecology. According to the Ministry of Food and Agriculture (2011), the Guinea Savannah covers a wider geographical area (70.38 km^2) as compared to the Sudan Savannah (27.32 km^2). Also, the farm population in the Guinea Savannah (523,278) is higher than that of the Sudan Savannah (418,677). This implies that agricultural extension agents will have more farmers over a wider area to reach in the Guinea Savannah agro ecology. Hence ceteris paribus, a farmer in the Guinea Savannah agro ecology is less likely to be reached by an agricultural extension agent and consequently less likely to adopt recommendations from agricultural extension agents as compared to a farmer in the Sudan Savannah agro ecology. These findings are consistent with Morris et al. (1999) and Mensah-Bonsu et al. (2011).

CONCLUSION AND RECOMMENDATIONS

This study sought to determine the factors that influence the adoption of climate related technologies introduced by research. A Multinomial Logit Model was estimated using data from 320 households in Northern Ghana. The empirical results reveal that agro ecology and noticing of unpredictable temperatures are factors that have a positive and negative effect on the likelihood of adoption of soil and plant health strategies respectively. Whereas receiving agricultural extension service increases the chances of adoption of improved varieties and breeds, agro ecology was found to rather reduce the chances of adoption of these varieties and breeds. Age of household head and agro ecology were found to be inversely related to the uptake of recommended agricultural practices, noticing of unpredictable temperatures was however found to have a direct relationship. Women were found to be more likely to adopt other introduced strategies such as planting of trees, irrigation and fire belt establishment. The study provides the following recommendations:

1. There is the need to create more awareness about the phenomenon of climate change highlighting changes in temperatures in order to facilitate the adoption of recommended agricultural practices.
2. The capacities of change agents (such as self-motivated farmers and leaders of farmer based organisations) to deliver messages on the concept of climate change and available adaptation strategies could be built in order to enhance widespread adoption.
3. There is the need to make agricultural extension services widely available to smallholder farmers in northern Ghana in order to boost the adoption of improve breeds and varieties. More agricultural extension agents could be employed and resourced.
4. Effective group dissemination techniques such as farmer field forums could be adopted. Soil and plant health technologies should be promoted more in the Guinea Savannah agro ecology, and improved varieties and breeds as well as good agricultural practices should be promoted in the Sudan Savannah agro ecology.
5. Smallholder farmers in northern Ghana should be encouraged to cultivate farm sizes that they can effectively manage.
6. Intensification should be encouraged because it has the potential of increasing the adoption of recommended agricultural practices.

7. Beneficiaries of the Youth in Agriculture Project should be introduced to good agricultural practice related strategies, with females specifically targeted for maximum impact.

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