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Climate change and farmers' adaptive capacity to strategic innovations: The case of northern Ghana

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Abstract

Northern Ghana is noted for perennial low and varying agricultural production and this is manifest by persistent vulnerability of inhabitants (mostly farmers) to food insecurity. The low agricultural production has been linked to effects of climate change. New technologies and cultivation practices aimed at enabling farmers to maximise their production to reduce risks associated with changes in climatic conditions in agriculture have been introduced in Northern Ghana. The nagging question is '"what influences the adaptive capacities of farmers to innovations introduced to them with the advent of climate variability'? This study has therefore been motivated by the interest in finding the determinants of adaptive capacity of farmers to various innovations targeted at adaptation to climate change and variability. The influence of education on the adaptive capacity of farmers to dugout construction and improvement suggest education will only make a difference for those with low adaptive capacity. This result, which also holds for the innovation on organic matter and composting, suggests that there is a threshold below which education or access to financial services exerts a positive influence on a farmer's adaptive capacity. Technology appears to widen the gap between the different adaptive capacity categories of farm households.

Keywords: Adaptive capacity, Climate change, Strategic innovations, Education, Technology

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1. Introduction

The climatic conditions in Northern Ghana are often considered to be a primary reason for the perennial low and varying agricultural production, which is often accompanied by “hunger food gaps”. These natural and physical resource constraints in Northern Ghana impinge on the livelihood of inhabitants who are predominantly farmers and make them vulnerable. One important reason for the high degree of vulnerability in this area is the fact that crop production is principally precipitation–based and hence characterised by seasonality, variability and unreliability. Current global trends indicate that precipitation is affected to a large extent by climate change. Intrinsic in the efforts at minimising the effects of climate variability on a wide range of development issues including agriculture is adaptation to climate change which refers to any response to "risks associated with the interaction of environmental hazards and human vulnerability or adaptive capacity" (Smit and Wandel, 2006, p. 1), and aimed at reducing the adverse impacts of climate change on populations. In order to minimise the effects of climate variability on farmer productivity and by extension livelihood, new technologies and innovations in crop cultivation practices aimed at enabling farmers to maximize and diversify their production to reduce risks associated with agricultural activity continue to be introduced. Some of the innovations introduced to communities in northern Ghana include the development of drought tolerant and early maturing crop varieties such as sorghum, cowpea and the introduction of cassava into the cropping system of the area which hitherto were not done due to low precipitation and other unfavourable soil conditions. Other innovations include water harvesting and effective water management practices, innovative small dam water reservoir construction and improvement, innovative ways of transplanting sorghum and millet, innovation on organic matter and composting as well as sustainable use of soil and land resources. These are intended to reduce water loss and make as much water as possible available for productive use. The success of these innovations depends on the adaptive capacities of beneficiaries (farmers) to such innovations and their exposure to adaptation mechanisms.

Smit and Wandel, (2006) indicate that a human communal system (household, community, group, sector, region, country) shows its ability to adapt as a result of adjustments or changes in its characteristics and/ or behavior and that this is necessary for the system to better manage, cope with, or adjust to some risk, stress, hazard, changing condition, or opportunity. Adaptive capacity reflects the resilience or coping ability of the system (Smit and Wandel, 2006; Valdivia, 2001) and the forces that influence this ability of the system to adapt or the determinants of adaptive capacity provide useful guides to adaptation strategies that are likely to be effective. Most climate change research on adaptation processes aim to address risks (and opportunities) associated with climate change in decision- making at some practical level (Smit and Wandel, 2006). This necessitates the development of some indicators of vulnerability and adaptive capacity aimed at a two-pronged effect. Firstly, to determine the robustness of response strategies over time and secondly, to better understand the underlying processes (Adger and Vincent, 2005).

The propensity or ability of a system to be influenced to adapt or a system’s priority towards adaptation measures have been given much attention in literature and have been based on the characteristics of the system. These characteristics have been called determinants of adaptation. The capacity to adapt to climate risks takes place in a dynamic social, economic, technological, biophysical and political context over time and location. The main features of an individual, community or system that determine their adaptive capacity include economic wealth, technology, information and skills, infrastructure and institutional framework (Smit and Pilifosova, 2003). These determinants of adaptive capacity are neither independent of each other, nor can permanently replace each other. This implies that adaptive capacity results from the combination of the determinants as well as variations between economic units and their location over a period of time. Livelihood strategies are created by access and control of human, natural, productive, financial, cultural and social infrastructure like markets, institutions (public and private) and the political environment (Bebbington, 1999; Valdivia and Gilles 2001; Ellis 1998). There are differences in livelihood strategies which are also influenced by linkages both agricultural and non-agricultural, as well as by socio-economic characteristics like age, education, and household size. The variance in the set of household activities is determined by these characteristics and also by the household's goals in risk management. The set of household activities geared towards adaptation is limited by the effect of the combination of assets, resources, and forms of capital that can be accessed (ibid). Adaptation options are also limited by the range of possible responses by individuals, community or a nation and this is so if there is limited or lack of technology available (Scheraga and Grambsch, 1998). Adaptive capacity is therefore likely to vary depending on availability and access to technology. Many of the adaptive strategies identified to be possible in the management of climate change and variability are directly or indirectly related to technology (Burton, 1996). These technologies include early warning systems, crop breeding (genetic engineering), water management practices and irrigation, and protective structures. The current level of technology and the ability to develop new ones are important determinants of adaptive capacity. Other requirements essential for strengthening adaptive capacity are exposure to the development and judicious use of new technologies for sustainably, and development of natural resources (Goklany, 1995). In the context of Asian agriculture for example, Iglesias and Rosenzweig (1996) noted that the development of heat-resistant rice cultivars will be crucial in the face of changing climate but systems with the ability to develop new technology have enhanced adaptive capacity.

Successful adaptation requires recognition of the necessity to adapt, knowledge about available options, the capacity to access them and the ability to use the most suitable ones (Fankhauser and Tol, 1997). Lack of trained and skilled personnel can limit the ability of a household, community or nation to implement adaptation options. In general, nations and regions with high levels of stores of human knowledge are considered to have greater adaptive capacity to climatic variations than developing ones in which education and skills development is comparatively low (Scheraga and Grambsch, 1998; Smith and Lenhart, 1996). Magalhães (1996) concluded that illiteracy and poverty are the major determinants of low adaptive capacity to climate change and variability. Again, adaptive capacity varies with social infrastructure and is regarded as a function of availability and accessibility of infrastructure to decision makers as well as vulnerable sub-sectors of a population (Kelly and Adger, 1999; Toman and Bierbaum, 1996). Information and communication infrastructure enhances fast and effective dissemination of technology. This increases adaptive capacity as it provides information to the farmer on the available options for adaptation. Institutions play the role of holding society together, giving it a sense and purpose and enabling it to adapt (O' Riordan and Jordan, 1999). The role of inadequate institutional support is frequently cited as a hindrance to adaptation. For example, Smith and Lenhart(1996) indicated that in general, societies with advanced social institutions are more likely to have greater adaptive capacity than those societies with less developed institutional arrangements. Besides the institutions for research and development required for developing, improving and disseminating technology, the social institutions, financial and political institutions to support the process are very vital. Arguments in support of adaptive capacity suggest that the probability that it (adaptive capacity) will be greater is linked to equitable distribution of the resources of a community or nation based on proper social institutions and arrangements that govern the allocation and access to these resources. (Ribot et al., 1996; Mustafa, 1998; Adger, 1999; Handmer et al., 1999). The extent to which communities are entitled to draw on resources influences their adaptive capacity and their ability to cope (Kelly and Adger, 1999).

1.1. Research question and objective of the study

According to (Smit and Wandel, 2006), very few studies on adaptation to climate change have focused on identifying the determinants of adaptive capacity. The major question that provides thrust for this study is "what influences the adaptive capacities of farmers to innovations introduced to them with the advent of climate variability'?

Therefore, the main objective for this study is the interest in estimating the determinants of adaptive capacity of farmers to various innovations that will provide the platform for lessons in future interventions by showing which adaptive strategies are effective. The uptake and diffusion of the strategic innovations is necessary for the attainment of household food security and sustainable income while conserving and regenerating the natural resource base in northern Ghana.

2. Methodology

2.1. Data sources and estimation of adaptive capacity

Primary data by way of a household survey conducted in the Northern and Upper East Regions of Ghana was largely employed in this study. Both purposive and random sampling methods were used in the information gathering process and a total of 353 household heads were interviewed. The study focused on three major innovations, namely construction/ improvement of dugouts, innovations in transplanting sorghum and millet (local and improved varieties), and mulch/ organic matter and compost use in sustainable agriculture. These innovations are expected to help farm households better cope with inadequate water resources for farming purposes, by making more effective and efficient use of available water. Farmers are assumed to be rational and as such when a "hazard" is identified, its potential adverse impacts are assessed and measures are taken to reduce the risk or adverse consequences. Mehta (2003) used the risk management approach to build a model of adaptive capacity based on a mathematical definition of risk.

$$\text{Risk} = \text{Probability} \times \text{Consequence}$$

This suggests that to reduce risk associated with climate variability, safeguards can be adopted to decrease the probability of an adverse event from occurring and /or reduce the impact with exposure to such conditions. Failure to adapt or to effectively adapt under certain climatic conditions increases risk and makes the individual and community more vulnerable.

2.2. Measuring adaptive capacity: theoretical framework

Adaptation as suggested by Valdivia (2001) does not occur instantaneously; a system requires time to realize its adaptive capacity before a meaningful adaptation. The assumption therefore is that for any system that undertakes adaptation, there is a threshold level of capacity that must be acquired. It therefore follows that a system or individual that have fully adapted to stimuli, have attained a high level of adaptive capacity above the threshold for adaptation. A system faced with extreme hazards will either adapt by using the adaptive options and strategies available to it or fail to adapt (Adapted Y = 1, Not adapted Y = 0). This presents a discrete outcome or choice situation of adaptation that can be described using the latent variable model or the threshold concept for discrete variables (Long, 1997). Any farmer or household therefore faced with options to mitigate climate stimuli has a reaction threshold or breaking point below which stimulus elicits no response (Jatoe, 2000). For an individual or system to adapt to a "hazard" making use of innovations, technologies and strategies at its disposal, some major attributes are very critical and these are used to assess whether the individual has adapted using the set of strategies under consideration or not. These include knowledge of the intervention strategy, the extent of use, accessibility, availability to the individual or system and number of consultations made. The probability of a positive outcome to be adapted assumes a value of one (1) and, zero (0) otherwise.

2.3. Empirical measurement of adaptive capacity

The capacity of farmers to adapt is more of qualitative assessment than quantitative. The degree of attainment of the attributes, knowledge, use, availability, accessibility and consultation of farmers on the various innovations and improved cultivation practices identified are scored qualitatively depending on the degree of the farm household's attainment in relation to each of the attributes. Table 1 shows the graduation scores in assessing the level of attainment of the attributes by farmers. A threshold of capacity is required to be able to adapt. High adaptive capacity will therefore enhance effective adaptation, making the probability for adaptation to be one (1) and zero (0) otherwise. Households considered to have fully adapted has a high adaptive capacity with the highest scores of these attributes with total score of one (1) while those with the minimal level have total scores approaching zero.

The Adaptive Capacity (AC) is obtained by dividing the total score of the attributes for the i^{th} respondent by the sum of most desirable score of all attributes, thereby reducing the adaptive capacity to a scale of $0 \leq AC \leq 1$.

$$AC_{ij} = \sum (K_j, U_j, V_j, A_j, C_j) \Big/ T \tag{1}$$

where: AC_i represents the i^{th} farmer's Adaptive Capacity to an innovation; K, the Knowledge of the farmer to the innovation; U, the level of usage of the innovation; V, availability of innovations to the farmer; A, accessibility of such innovation; C, level of consultation made by or to the farmer on the innovation and T the sum of most desirable scores for all attributes *(T= 5).*

Table 1. Score of level of farmer's achievement of attributes

Knowledge		Use		Availability		Accessibility		Consultation	
Very well	1	Several	1	Very regular	1	Easily accessible	1	Several	1
Well	0.75	Twice	0.75	Regular	0.75	Accessible	0.75	Twice	0.75
Fairly well	0.5	Once	0.5	Occasional	0.5	Not easily accessible	0.5	Once	0.5
Not well	0.25	Never	0.25	Never	0.25	Not accessible	0.25	Never	0.25

Source: Authors' estimations

Adaptive capacity of a system falls along a continuum ranging between zero and one, and is a function of several socio-economic, technological and institutional factors of the household, community and region (Mehta, 2003; Smit and Pilifosova, 2003). For the purposes of clearer analysis and establishment thresholds that will inform policy decisions about the adaptive capacity of the farmers, they were categorized into three, thus farmers with low adaptive capacity ($AC_i < 0.33$), moderate adaptive capacity ($0.33 \leq AC_i < 0.66$) and high adaptive capacity ($0.66 \leq AC_i \leq 1.0$).

2.4. Determinants of adaptive capacity

An inverse relationship exists between adaptive capacity and vulnerability among rural households especially in the third world where there is a heavy dependence on agriculture purely under the dictates of the unreliable climatic conditions. Enhancing the adaptive capacity of rural farmers will therefore greatly reduce their vulnerability. The first step in the effort at enhancing capacity is to identify the underlying factors that influence capacity of farmers to adapt using coping interventions available. There exist considerable understandings of factors that influence the adaptability of households which cut across socio economic, technological and institutional factors. These target variables include socio – economic factors of age, gender, education of the adaptor and household characteristics such as household size, income and land size accessible to the household (Smit & Pilifosova, 2003). Other variables include availability of technology, and the level of awareness of the available technology and adaptation options as well as social network or groups that enhance ability to adapt and access to financial services.

Adaptive capacity of an economic unit falls along a continuum in its dynamic nature and differences due to location, time and resource endowment. While some farmers may have a high capacity to adapt in order to escape adverse conditions unhurt, others may have a low capacity to adapt thereby increasing their vulnerability. Besides, there exists another category with moderate capacity or just adequate to be able to survive. This makes the determination of adaptive capacity a discrete variable case, which is better estimated using the discrete choice models as applied in the general framework of probability models:

Prob (event *j* occurs) = Prob ($Y = j$) = F [relevant effects: parameters] (2)

In this regard, the probit, logit and tobit models can be used based on whether the error distribution assumes a normal distribution or logistic distribution or if the dependent variable is censored. Discrete dependent variable models are classified based on whether the outcome is a choice between two or more alternatives (Greene, 2003). Binary choice models are used in estimating two outcome choices while multiple outcome decisions are estimated using polytomous models. The continuum span of adaptive capacity stretches the situation beyond ordinary binary choice models. Beside the multinomial nature of adaptive capacity, the qualitative measurement makes it more ordered than nominal. The appropriate formulation used in situations of ordinal (ordered) dependent variables as indicated by Hedeker (2002), is the ordered logistic regression.

The ordered logitistic analysis is based on the structural specification in equation 3 where X_i is the vector explanatory variables, β is a k×1 vector of unknown regression parameters to be estimated with the first element being the intercept and ε_i is the error effect.

$$y^* = \beta' X_i + \varepsilon_i \quad (3)$$

Considering a latent (unobserved) variable y* which maps to an ordered observed variable y,

$$y^* = m \ if \qquad \tau_{m-1} \leq y_i^* < \tau_m \quad \text{for } m = 1, 2 \ldots J \quad (3.1)$$

with τ 's as thresholds or cut points. If the continuous latent variable y* is related to the ordinal variable then the extreme categories are $\tau_0 = -\infty$ and $\tau_j = \infty$ (Long, 1997). For an ordinal dependent variable y_i with j categories,

$$y_i = \begin{cases} 0 & if \quad y \leq \tau_0 \\ 1 & if \quad \tau_0 < y \leq \tau_1 \\ 2 & if \quad \tau_1 \langle y \leq \tau_2 \\ . & \\ . & \\ . & \\ J & if \quad y \rangle \tau_{J-1} \end{cases} \quad (4)$$

The error term ε_i is logistically distributed with mean of 0, variance of $\pi^2/3$ and a probability density function (pdf) as well as cumulative density function (cdf) as shown in equations 5 and 6 respectively (ibid).

$$\lambda(\varepsilon) = \frac{\exp(\varepsilon)}{[1+\exp(\varepsilon)]^2} \tag{5}$$

$$\Lambda(\varepsilon) = \frac{\exp(\varepsilon)}{1+\exp(\varepsilon)} \tag{6}$$

Assuming a dependent variable Y with values 0, 1 and 2 for three ordinal responses, which in this case represent low, moderate and high levels of adaptive capacity respectively, the probability of obtaining an outcome are represented as P_1 = Pr (y=1), P_2 = Pr (y=2) and P_3 = Pr (y =3) for outcome of zero, one and two respectively. The parameter estimates are obtained using maximum likelihood estimation procedure. This study estimates the ordered logit for adaptive capacity to innovations with the household data using LIMDEP software.

2.5. Empirical model for determinants of adaptive capacity

This model enables the determination of the level of adaptive capacity of a farmer given his socio–economic, technological and institutional characteristics. From the estimations, the capacity of farmers were determined to be either high, moderate or low giving three ordered outcomes characterizing farmer's status in terms of capacity to adapt.

The ordered logistic regression model which expresses the relationships in the adaptive capacity and its determinants is empirically specified as follows.

$$\begin{aligned} ADCAP = {} & \beta_0 + \beta_1 INAGE + \beta_2 GENDR + \beta_3 EDUC + \beta_4 INHSIZE + \beta_5 INSLAND + \\ & \beta_6 GRUPM + \beta_7 INPINCOME + \beta_8 FINSEV + \beta_9 TECH + \beta_{10} AWARE + \\ & \beta_{11} INFRAST + \varepsilon \end{aligned} \tag{7}$$

where β_i are the parameter estimates including the constant and ε the error term. The other independent variables are defined in Table 2.

2.6. Choice of variables

The explanatory variables for the analysis of the objectives are chosen in conformity with literature and these selected regressors cover the relevant areas as far as the factors that determine adaptive capacity are concerned. These factors as indicated by Smit and Pilifosova (2003) include various social and economic characteristics of farmers, technological and institutional factors as well as information and infrastructural access that are likely to impact on the capacity of farmers to adapt.

Table 2. Definition of variables in the model

Variable	Definition
INAGE	Natural logarithm of age of household head in years
GENDR	Gender of the household head (1 = Male, 0=Female
EDUC	Highest level of education attained by the head of household (measured in terms of no education = 1, Basic education = 2, Secondary = 3 and Tertiary =4)
INHSIZE	Natural logarithm of household size
SLAND	Natural logarithm of total land under cultivation by the household (measured in acres)
GRUPM	Social capital into which household can tap with household head participation in decision making on water management being used as proxy (dummy 1 = participation of household head in water management decision making, 0 = otherwise)
INPINCOME	Natural logarithm of annual household income for 2008 in Ghana Cedis (Proxy for Financial capital or wealth)
FINSEV	Access to financial resources (dummy: 1 = household do not have difficulty with access to financial support for farming, 0 = otherwise)
TECH	Access to the innovations/technology (dummy: 1 = household have access to improved technology, 0 = otherwise)
AWARE	Awareness of innovations and adaptation options available for coping (measured by the awareness level or knowledge of innovations, 1 = no knowledge, 2 = fairly well knowledge, 3 = well and 4 = very well knowledge)
INFRAST	Access of household to infrastructure (1 = inaccessible, 2 = accessible, 3 = fairly accessible and 4 = very accessible)
ADCAP	Adaptive capacity of farmer to innovations (0 = Low, 1 = Moderate and 2 = High)

2.6.1. Socio–economic factors

The socio–economic factors included in the model are age, gender, level of education of household head as well as household size, total cultivated farm land of the household, the household per capita income and the level of awareness of strategic innovations. Agricultural activities are high risk ventures and experience is often considered relevant in minimizing risk. Besides, a longer planning horizon is expected to help in the decision of the farmer to adapt. Age, leadership status and gender may determine whether or not an individual takes decisions regarding the choice of technology use. Pannin (1988) noted that elders in traditional African societies are widely accepted as superior because experience and decisions relating to adoption of innovation are positively influenced by age factors. Age is therefore expected to have a positive impact on adaptive capacity. Farming enterprises in the study area are gender specific with specific crops being produced mainly by either males or females. Given the risks associated with farming especially in semi–arid regions, farmers are sceptical about new innovations. With education and experience come new knowledge and skills, and an associated increase in confidence as uncertainty is reduced (Jatoe, 2000). It has been argued that education enhances one's ability to receive, decode and understand information on an innovation or technology (ibid). This builds confidence in the farmer and dispels doubt, hence its choice as one of the factors. Education is expected to have a positive impact on adaptive capacity. Available farmland and labour are very critical for farming especially in poor areas such as northern Ghana where capital intensive production is not common. Many of the farmers in the area of study depend largely on family labour for their farm operations. Hence the availability of the two factors – cultivated farm land (in acres) and household size - are expected to positively affect adaptive capacity. Financial resource is also essential as it provides the means of acquiring the complementary inputs needed for adaptation. The annual household income in Ghana cedi was used as proxy for financial capital and is expected to have a positive impact on the capacity of farmers. Knowledge or the awareness of innovations and technology provides the farmer with an option to use in adapting to prevailing conditions. The level of awareness[1] about the innovation is expected to have a positive relationship with the capacity to adapt.

2.6.2. Technological and institutional factors

Different innovations have been introduced in the study area in order to provide them with options for adaptation. Under this, the availability of the innovations or technical knowledge in the environs of the farmer is considered. Availability of any of the dugout technology, sorghum/ millet transplanting technology or mulch or compost are considered for technology; dummied 1 for availability of improved technology and 0 otherwise. Similarly, the opportunity available to the household head to be involved in community water management and the influence of decisions taken concerning the management of this resource in order to help them adapt were explored. Head of household involvement in community water management decisions; dummy as 1 if yes and 0 otherwise. Easy access to financial resources (credit in the form of cash or inputs) in the farmer's community or a nearby community that renders service to the farmer is seen as access to financial resources and dummied 1, and 0 for otherwise.

2.6.3. Infrastructure

Access to infrastructure such as transport, market, education, communication and energy in the community in which the household is located or in other communities to which households can access was used for the infrastructure base. This is graded for the community depending on the combination of such facilities available and this is represented as follows: 1 = inaccessible; 2 = accessible; 3 = fairly accessible and 4 = very accessible.

3. Results

The estimated results from the ordered logit models of determinants of adaptive capacity to improved dugouts, sorghum/ millet transplanting, and mulching/composting innovations are shown in Tables 3, 4 and

[1] For this study, the level of awareness or knowledge of specified innovation is scored into four, as shown in Table 1, thus farmers with no knowledge, those with fairly well knowledge, well knowledge and very well knowledge.

5 respectively. The actual coefficients of ordered logit models do not give a very good idea about the effects of changes in the explanatory variables on the predicted probabilities of falling under one of the categories of the dependent variable (Greene, 2003). Such information is provided by the marginal effects of the explanatory variables, evaluated at the sample mean of the other variables. But in the case of dummy variables, the computed marginal effects are not truly marginal effects but reflect the effects of a change from zero to one. The marginal effects of significant variables in the ordered logit model are also presented in Tables 6, 7 and 8 for dugout, sorghum/millet transplant, and mulch/composting, respectively. In addition, the log likelihood functions as well as the chi square distribution statistics were presented for each of the ordered regression models indicating the goodness of fit and general significance of the models. The results of the estimated model for dugout construction or improvement indicate that only two of the explanatory variables, education and available technology were statistically significant in influencing farmer's adaptive capacity to the innovation on dugout construction and improvement (Table 3). The rest of the explanatory variables did not exert any significant effect on the adaptive capacity to dugout construction and improvement. Education had a negative but significant (at 5%) effect on the adaptive capacity of farmers to the dugout construction and improvement innovation, while technology positively influenced farmers adaptive capacity to dugout construction and improvement. Technology was significant at 1 % level of statistical significance.

Only three of the explanatory variables in the estimated model for the sorghum and millet transplant innovation were statistically significant in influencing farmer's adaptive capacity to the innovation (Table 4). Available technology (TECH), education (EDUC), and access to financial services (FINSEV) were statistically significant at 1, 5, and 10 %, respectively, in influencing the adaptive capacity of farmers to the sorghum and millet transplant innovation. The rest of the explanatory variables did not exert any statistically significant effect on the adaptive capacity of farmers to the innovation on sorghum and millet transplant although some were positively related while others were negatively related to the innovation.

The estimated ordered logit model for mulch organic matter use and composting show that Available technology (TECH), and education (EDUC) were statistically significant at 1 % (Appendix E). However, most of the explanatory variables, including age (INAGE), gender (GENDR), access to financial services (FINSEV), and cultivated land (INSLAND) were negatively related to the adaptive capacity of farmers to organic matter use and composting but were not statistically significant. Also, household size (INHSIZE), group membership (GRUPM), infrastructure (INFRAST), and household income (INPINCOME) were positively related to the adaptive capacity of farmers to organic matter use and composting but were not statistically significant.

3.1. Marginal effects of determinants of farmers adaptive capacity to strategic innovations

The impact of the independent variables on the adaptive capacity of farmers to dugout construction and improvement is measured by their marginal effects (Table 6). Each explanatory variable is assumed to have a linear relationship with adaptive capacity of farmers to dugout construction and improvement. Therefore, a marginal increase in the explanatory variable is expected to result in increases in the probability of adapting among high, moderate or low capacity. For example, a unit increase in the state of education increases the probability of attaining improved capacity to dugouts by 13.7 % among those with low adaptive capacity. However, the same change in educational status reduces the probability attaining improved capacity among those with moderate and low adaptive capacities by 12.5 % and 1 %, respectively. The results on the influence of education on the adaptive capacity of farmers to dugout construction and improvement suggest education will only make a difference for those with low adaptive capacity. Increases in access to/ availability of technology (TECH) by a unit causes increases in the probability of attaining improvement in adaptive capacity by 91.8 % among those with high adaptive capacity, but rather causes decreases by 6 % and 86 % respectively in the moderate and low capacity categories respectively. Technology appears to widen the gap between the different adaptive capacity categories.

Table 3. Results of ordered logit regression model of determinants of adaptive capacity to dugout

Variable	Coefficient	Std. Error	t - Value	P > |t|
CONSTANT	-1.414	2.482	-0.570	0.569
INAGE	0.000	0.500	0.000	1.000
GENDR	-0.353	1.040	-0.340	0.734
EDUC	-0.561*	0.293	-1.915	0.056
INHSIZE	0.375	0.313	1.197	0.232
INSLAND	-0.141	0.128	-1.107	0.268
GRUPM	0.089	0.345	0.260	0.795
FINSEV	-0.575	0.368	-1.565	0.118
TECH	8.331***	1.309	6.362	0.000
INFRAST	0.009	0.389	0.024	0.981
INPINCOME	0.087	0.162	0.538	0.590

****, **, and * represents 1%, 5%, and 10% levels of significance by the t -statistic*
Dependent variable is adaptive capacity, ranging from low capacity (0) to high capacity (2)

Number of Observations = 347 Chi-square = 346.9583***
Log likelihood = -139.6501 Prob. > Chi Square = 0. 000000
Restricted Log Likelihood = -313.1292

Table 4. Results of ordered logit regression model of determinants of capacity to sorghum – millet transplanting innovation

Variable	Coefficient	Std. Error	t – Value	P > |t|
CONSTANT	-0.297	1.342	-0.221	0.825
INAGE	-0.121	0.268	-0.450	0.653
GENDR	-0.235	0.573	-0.410	0.682
EDUC	-0.314**	0.157	-1.998	0.046
INHSIZE	0.200	0.165	1.211	0.226
INSLAND	-0.079	0.069	-1.147	0.252
GRUPM	0.074	0.185	0.403	0.687
FINSEV	-0.329*	0.194	-1.697	0.090
TECH	4.220***	0.550	7.667	0.000
AWARE	0.015	0.204	0.072	0.942
INFRAST	0.044	0.089	0.491	0.623
INPINCOME	-0.297	1.342	-0.221	0.825

****, **, and * represents 1%, 5%, and 10% levels of significance by the z (t) -statistic*
Dependent variable is adaptive capacity, ranging from low capacity (0) to high capacity (2)

Number of Observations = 347 Chi Square = 347.0657***
Log likelihood = -139.5964 Prob. > Chi Square = 0.000000
Restricted Log Likelihood = -313.1292

The results of marginal effects on sorghum and millet transplanting innovation suggest that all the significant variables in the model are non-linearly related to adaptive capacity since there is divergence in the direction of their individual effects across the three levels of adaptive capacity (Table 7). The effect of education and financial services are similar across the three levels of adaptive capacity, being negative at moderate and high adaptive capacities but positive at low adaptive capacities. An increase in the level of education by a unit will decrease the probability of adapting among those with high adaptive capacity by 2.7 % and moderate capacity by 9.8 %, whereas the same marginal change will increase the probability of adapting among those with low capacity by 12.5 %. This result may suggest that there is a threshold below which education or access to financial services exerts a positive influence on a farmer's adaptive capacity. Farmers with education or access to financial services above the threshold rather engage in other activities for income generation instead of the traditional subsistence growing of millet and sorghum by other farmers in the study area. On the other hand access to technology (TECH) exerts a positive influence on adaptive capacity at high capacity and a negative influence at moderate and low capacities. This result suggests that a unit increase in access to technology increases the probability of adapting among those with high adaptive capacity by about 92 % while decreasing the probability of adapting among those with moderate and low adaptive capacity by 7 and 85 %, respectively. Thus access to technology enhances the adaptive capacity of farmers with high adaptive capacity to the innovation on sorghum and millet transplant.

Table 5. Results of ordered logit regression model of determinants of capacity to mulch organic matter use and composting

Variable	Coefficient	Std. Error	t - Value	P > |t|
CONSTANT	-1.349	2.465	-0.547	0.584
INAGE	-0.022	0.494	-0.045	0.964
GENDR	-0.250	1.042	-0.240	0.810
EDUC	-0.569*	0.291	-1.955	0.051
INHSIZE	0.376	0.313	1.201	0.230
INSLAND	-0.145	0.128	-1.137	0.256
GRUPM	0.051	0.344	0.148	0.882
FINSEV	-0.482	0.370	-1.301	0.193
TECH	8.252***	1.308	6.307	0.000
INFRAST	0.029	0.391	0.074	0.941
INPINCOME	0.088	0.166	0.530	0.596

****, **, and * represents 1%, 5%, and 10% levels of significance by the z (t) -statistic*

Dependent variable is adaptive capacity, ranging from low capacity (0) to high capacity (2)

Number of Observations = 347 Chi Square = 347.7154***
Log likelihood = -139.2715 Prob. > Chi Square = 0.00000
Restricted Log Likelihood = -313.1292

With respect to organic matter use and composting innovation, two explanatory variables (the highest level of education attained by the household head and access to technology) were significant determinants of the adaptive capacity of farmers. Results from the estimation of the marginal effects suggest that a unit increase in access to technology increases the probability of adapting to organic matter use and composting by 91% among those with high adaptive capacity while decreasing the probability of adapting by 6% and 85% among those with moderate and low adaptive capacities, respectively (Table 8)

Table 6. Marginal effects of significant variables in the ordered logit model for improved dugout

Variable	High Capacity	Moderate Capacity	Low Capacity
EDUC	-0.0122	-0.1249	0.1371
TECH	0.9183	-0.0631	-0.8551

Table 7. Marginal effects of significant variables in the ordered logit model for sorghum – millet transplanting innovation

Variable	High Capacity	Moderate Capacity	Low Capacity
EDUC	-0.0270	-0.0983	0.1253
FINSEV	-0.0262	-0.1043	0.1306
TECH	0.9183	-0.0666	-0.8517

Table 8. Marginal effects of significant variables in the ordered logit model for mulch organic matter use and composting

Variable	High Capacity	Moderate Capacity	Low Capacity
EDUC	-0.0123	-0.1266	0.1390
TECH	0.9138	-0.0612	-0.8526

Education also has a nonlinear relationship with adaptive capacity of farmers to organic matter use and composting. Among those with low adaptive capacity, a unit increase in the highest level of education attained by the household head increases the probability of adapting to organic matter use and composting by 14 %. However, the same marginal change in the highest level of education attained by the household head decreases the probability of adapting by 1 and 13 % among those with high and moderate adaptive capacity respectively.

4. Discussion and Conclusion

The savannah area of Ghana of which the Northern and Upper East Regions are part, is characterized by unpredictable weather conditions that continue to exacerbate over the years in line with global trends in climate change and variability. The dependence on a single season of rain-fed agriculture often cannot guarantee the availability of grains which constitute the main staple in these areas throughout the year and in particular, during the long dry hunger periods. Poor rains in terms of amount and variability during the rainy season, the severe long dry season devoid of other income generating activities, dependence on small-sized household farms using unimproved agricultural technologies and implements and the deteriorating soil and environmental conditions together account for the deficit in food supply and the perpetual famine and poverty. In view of these prevailing circumstances, better adaptation to climatic conditions through efficient use of available water, improvement in crop varieties and cultivation practices that are well adapted for optimal benefit and new technology provides the avenue for ameliorating the impact of changing environment on farmers in the Guinea and Sahel savannah belt.

Results of the ordered logit regression analysis showed that farmer's adaptive capacity to the innovation on dugout construction and improvement is determined by educational level of the household head, and availability of technology. While education enhances the probability of adapting for those with low adaptive capacity, technology enhances the probability of adapting for those with high adaptive capacity. Determinants of a farmer's adaptive capacity to the sorghum/ millet transplanting innovation are availability of technology, educational level of the household head, and access to financial services. Education and access to financial services have similar effects on adaptive capacity being negative at moderate and high adaptive capacities but positive at low adaptive capacities. Two of the variables were significant determinants of the adaptive capacity of farmers to organic matter use and composting, the highest level of education attained by the household head and access to technology. The influence of technology and education on the adaptive capacity of farmers to organic matter use and composting were similar to those observed for the innovation on dugout construction and improvement.

The results on the influence of education on the adaptive capacity of farmers to dugout construction and improvement suggest education will only make a difference for those with low adaptive capacity. This result, which also holds for the innovation on organic matter and composting, suggests that there is a threshold below which education or access to financial services exerts a positive influence on a farmer's adaptive capacity. Farmers with education or access to financial services above the threshold rather engage in other activities for income generation instead of the traditional subsistence growing of millet and sorghum by other farmers in the study area. Therefore future interventions may target farmers with very low levels of education with non-formal education in order to improve their appreciation of the innovations. Access to technology enhances the adaptive capacity of farmers with high adaptive capacity thresholds to the innovation on sorghum and millet transplant. Thus, technology appears to widen the gap between the different adaptive capacity categories of farm households.

Knowing the impact of such trends on the livelihood of farmers, how farm households cope with the changing environment and climate, and more importantly what influences their capacity to adapt to strategic innovations or interventions will go a long way in policy formulation to address the long term threat posed by the severe and adverse climate events anticipated in climate change. Since access to innovations is critical to the adaptive capacity of farmers (and subsequent impacts on livelihood) efforts to improve their access to the strategic innovations must be intensified.

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