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Full Length Research Paper

Water storage for dry season vegetable farming as an adaptation to climate change in the upper east region of Ghana

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The climate is changing in Ghana and farmers in the upper east region are adapting to the situation. The study analyzed determinants of farmers' adaptive capacity in dry season vegetable farming using an Ordered Logit Model. The effects of adaptive capacities on farm income were also analyzed using log-linear production function. The empirical results reveal that sex, access to land near a reservoir site, engaging in off-farm business activity, access to credit and number of years of formal education determines farmers' decision to venture into dry season vegetable farming. Besides, about 31.3% of farmers are of low adaptive capacity, 26.0% are of moderate adaptive capacity and 42.7% being high adaptive capacity. Further, adaptive capacity is explained by sex of respondent, number of years of formal education, household size, off-farm business activity and access to credit. Finally, the study also indicates that high adaptive capacity increases income from vegetable farming, and the results have implications for dry season food crop farming in developing countries.

Key words: Dry season vegetable farming, climate change, adaptive capacity, ordered logit model, Ghana.

INTRODUCTION

Climate change is defined as a significant shift in the average weather condition of an area especially in temperature and precipitation (MacIver, 1998). Changing climatic conditions has been the focus of environmental economists for the past decade, especially its effect on agriculture, water resources and economic development (Ariaster et al., 2008; Mendelsohn et al., 2000, 2006; Tol, 2005). These researchers tried to predict and quantify the effects of climate change on water resources and agriculture in an attempt to explain its effects on economic development. Seo et al. (2005) for example, explained that knowledge of climate change is relevant for predicting the behavior of agricultural commodity markets in developing economies.

Fairhead and Leach (2000) attributed the changing climatic conditions to fossil fuel combustion and deforestation. Their research explained that fossil material combustion and deforestation increase the concentration of greenhouse gases in the atmosphere and cause global temperatures to rise significantly. Mendelsohn et al. (2006) explained that higher temperatures hamper agricultural crop productivity in the tropics and therefore worsen incomes of farmers. Climate change has profound negative impact on water resources and agriculture. The study by Masters and Macmillan (2000) concludes that, changing climatic conditions has higher possibility of worsening farm incomes in the tropics than in the temperate regions. Seo et al. (2005) in their studies on the impact of climate change on Sri Lankan agricultural sector using a Ricardian valuation model quantified the effects of climate change on agriculture. Their results suggest that increase in temperature will reduce output by about 11 to 20%.

In the case of water resources, changing climatic conditions affectt both water quality and availability for

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agricultural crop production. For example, warmer, drier conditions promote mineralization of deleterious heavy metals (Murdoch et al., 2000) and thus increase their supply to surface and groundwater bodies, therefore making it unsafe for crop production. Surface water bodies such as dams, reservoirs and dugouts are vulnerable to climate change. With increasing temperatures and evaporation, reservoirs dry up in the tropics making water unavailable for crop production. Nonetheless, the extent of impact imposed by climate change on water resources can be managed by effective adaptation. MacIver (1998) indicates that adaptation is crucial and forms a key component of an integrated and balanced response to climate variability. Adaptation to climate change with respect to water resources implies adjusting or living in equilibrium with the scarce water resources. Adaptation can be done by expanding infrastructure for water storage, changing planting dates to adjust for droughts, or regulating water prices for efficient utilization on farms. Adapting to scarce water condition among farmers in sub-Saharan Africa involves a plethora of mechanisms. One of such is to expand water storage facilities to harvest rainwater for utilization in the dry season.

The climate is changing in Northern Ghana and has affected farming systems that require farmer adaptations. Uchendu and Antony (1969) indicated that the period of cropping in Northern Ghana had not changed much between 1930s and 1960s due to the stable and reliable patterns of rainfall. During this period, farmers used to plant millet, sorghum, cowpea and other cereals except rice in the first week of April to coincide with first heavy rains which mostly occurred in the first week of April in the region. Tona (1993) and Mensah-Bonsu (2003) indicated that planting period for crops in Northern Ghana has changed from early April in 1960s to late April or early May in recent years due to the unpredictable nature of rains and the changing environmental conditions especially rainfall amounts and distribution. Compound land which was mainly used for animal rearing became another farmland for farmers in the region as a result of reduction in soil fertility owning to the loss of forest cover in the face of the changing climatic conditions (Wills, 1962), and also, livestock which were traditionally reared by farmers for social occasions became the source of income for purchasing food in times of crop failure resulting from unfavourable climatic conditions (Agyepong et al., 1999). Planting of indigenous trees was not practiced by farmers before 1984 (Gana, 1995). When the area under forest cover in the Upper East Region reduced from 44% in 1964 to 21% in 1984 due to changes in the climatic conditions and bad agricultural practices such as slash and burn and indiscriminate felling of trees for fire woods, farmers resorted to the planting of indigenous trees such as *neem* and mango (Gana, 1995).

Organic matter from these indigenous plants served as materials for mulching which is an adaptation strategy for conserving moisture in the soil for crop growth. Dry season farming in Ghana largely draws on stored water. In this system, rainwater is harvested in reservoirs and dugouts (that is, trench/hollow) for the production of tomato, onions, sweet potato vines and leafy vegetables in the dry season. Irrigation dams, dugouts and shallow wells are the predominant forms of water storage systems used for dry season farming in the Upper East Region. According to the Irrigation Development Authority (2007), about 70% of the dugouts in Ghana are located in the Upper East Region, and dugouts constitute over 80% of the water storage systems in the Region. Dugouts therefore form the most widely used water storage structures among farmers in the Region. By using adaptive capacity to dugout as a proxy for adaptive capacity to climate change, the study sets to determine how effective dry season farmers use dugouts as a strategy in adapting to the changing climatic conditions in the Upper East Region.[1] The objectives of the study are in threefold: (a) to quantify the adaptive capacities of farmers to dugouts; (b) to determine the factors that affect farmers' adaptive capacities to dugouts as a strategy for minimizing the effects of climate change; (c) to determine the effects of farmers adaptive capacities on dry season vegetable farm income.

Future changes in water availability due to climate change are important for food security of the rural poor in sub-Saharan Africa. Water shortage followed by devastating floods in the Sahel reflected some of the climate change predictions which are becoming more certain. Hence, investments in agricultural water storage could reduce the vulnerability of the rural poor by creating buffers against uncertainties in water availability. Studies on water in Ghana considered different aspects of water including impact of small scale reservoirs on rural livelihood (Ikilulu, 2006), access to water, management and constraints to utilization of natural resources for sustainable development (Ahenkora et al., 1998). In all these, knowledge about water storage for dry season farming as an adaptation to climate change is limited. Since this study considers water storage for dry season farming as an adaptation to climate change, it is important. Northern Ghana is much more vulnerable to climate change than the southern Ghana. Vulnerability to climate change also means that their main economic activity (agriculture) is volatile. Hence, in times of favorable weather conditions, crop yields are better and vice versa. To stabilize crop yields against weather vagaries and climate change, it is important to analyze the factors that affect farmers' adaptive capacities to water storage (dugouts) and recommend augmenting measures. Adapting to climate change is aimed at reducing the risk of losing farm income due to variability of climate. This study also seeks to analyze the effects of adaptive capacities on vegetable farm incomes and

[1] Adaptive capacity is defined as the ability/effectiveness of dry season farmers' use of dugout as a strategy to mitigate the changing climatic conditions.

Table 1. Score levels of farmers' achievement of attributes.

Knowledge	Use	Availability	Accessibility	Consultation
Very well 1.00	Several 1.00	Very well 1.00	Easily accessible 1.00	Several 1.00
Well 0.75	Twice 0.75	Regular 0.75	Accessible 0.75	Twice 0.75
Fairly well 0.50	Once 0.50	Occasional 0.50	Not easily accessible 0.50	Once 0.50
Not well 0.25	Never 0.25	Never 0.25	Not accessible 0.25	Never 0.25

Source: Asante and Egyir (2006).

hence contribute to existing literature on water studies.

MATERIALS AND METHODS

Description of site

The study was conducted in the Upper East Region. The Upper East Region is located in the Sudan Savannah vegetation zone that lies between latitudes 8° 00'N to 10° 12' N and longitudes 0° to 1° 32' W with an area of about 8,842 km². The estimates based on the 2010 Ghana's population census indicate that Upper East Region has a population of 1,001,926.

The Region also has gentle sloping topography with silty textured soils which make it possible for the construction of shallow wells, dugouts and reservoirs (Asante and Egyir, 2006). The major agricultural crops include millet, sorghum, groundnut and vegetables such as tomatoes and onions. Upper East Region is characterized by poor rainfall pattern with a unimodal rainfall system and an average rainfall per annum of about 800 mm. As a result, there are water conservation technologies such as rain harvest in dugouts, wells and irrigation dams to mitigate droughts and also keep farmers in business during the dry season (Asante and Egyir, 2006).

The data was collected in the Kassena-Nankana and Bolgatanga districts in the Upper East Region. In an interaction with the manager of the Irrigation Company of the Upper Region, there are 86 and 178 dugouts representing 33% and 67% in Kassena–Nankana and Bolgatanga districts, respectively used for growing vegetables in the dry season. Tomatoes, garden eggs, onions and leafy vegetables are grown at the banks of the dugouts and water is drawn from them for the irrigation of these crops.

Primary data was used for analysis. The data was collected by administering questionnaires to farmers in 15 communities in the Kassena-Nankana and Bolgatanga districts in the Upper East Region of Ghana in 2008. 8 out of the 25 vegetable growing communities in the Kasenna–Nankana District were included whiles 7 out of 23 communities were selected from Bolgatanga District. According to Irrigation Company of Upper Region Limited (ICOUR) Ghana (2007), Kassena-Nankana and Bolgatanga districts produce over 80% of vegetables in the Upper East Region during the dry period. In selecting the sites, a numbered list of communities in each district were obtained from the Ministry of Food and Agriculture's (MoFA) office and then the 15 communities were selected at random.

In selecting farmers in each community, the names of dry season vegetable farmers were obtained from the extension officer for each community. Ten (10) dry season vegetable farmers were randomly selected in each community making up a total of 150 vegetable farmers. Following the study of Asante and Egyir (2006) in which they computed farmers adaptive capacities to dryland farming technologies, this study deployed their framework to compute farmers adaptive capacities to dugouts based on the following attributes:

Knowledge

Farmers were asked to score the level of their knowledge about dugout use in dry season vegetable farming. This was a qualitative assessment for which figures ranging from 0.25 to 1 were used as shown in Table 1. A higher number indicates a relatively better knowledge about dugout use.

Use

This represents how often a farmer has used the dugout. A higher number indicates that the farmer has relatively used dugout more often for vegetable production.

Accessibility

Accessibility indicates the level to which the farmer considers dugouts to be accessible to him or her. A higher number indicates a relatively better level of access to dugouts.

Availability

Availability indicates the farmer's assessment of the availability of dugouts in his or her view even though they might not be accessible. A higher number indicates a higher level of dugout availability to the farmer.

Consultation

This represents the number of times the farmer has made consultations about the facility. A higher number indicates a farmer has made relatively more consultations about dugout use for vegetable farming. Table 1 is a summary of the framework used to calculate adaptive capacities of farmers.

The Adaptive Capacity (AC) is obtained by dividing the total score of attributes for the i^{th} farmer by the number of attributes as shown in Equation (1):

$$AC_i = \Sigma(K_i, U_i, V_i, A_i, C_i)/T \quad (1)$$

Where AC_i represents the i^{th} farmer's Adaptive Capacity; K, the knowledge of the farmer in water storage (dugout); U, the level of usage of water (dugout); V, availability of dugout innovations to the farmer; A, accessibility of stored water (dugout); C, number of consultation made by or to the farmer on water storage (dugout) and T is the number of attributes which is 5 for this study. Asante and Egyir (2006) categorized adaptive capacities into three main divisions: low, medium and high adaptive capacities. Computing adaptive capacity for each farmer using the five indicators as in equation (1) result in indices within the following ranges:

Table 2. Variables, definitions and measurements used in the ordered logit model.

Variable	Definition and Measurement
AGE	Age of farmer (in years)
MAR	Married =1, 0 Otherwise
SEX	Male =1, Female = 0
HEDUC	Number of years of formal education
HHS	Household size
OFFARM	Off farm activity = 1, 0 otherwise
LANDAC	Access to land near dug out =1, 0 otherwise
CREDIT	Access to credit = 1, 0 otherwise

1. Low adaptive capacity includes farmers with adaptive capacity index lower or equal to 0.33, (that is, AC < 0.33).
2. Moderate adaptive capacity includes farmers with adaptive capacity index greater than 0.33 but less than 0.66, that is, 0.33 ≤ AC < 0.66).
3. High adaptive capacity includes farmers with adaptive capacity index greater than 0.66 but less than or equal to 1, (that is, 0.66 ≤ AC ≤ 1).

Following Asante and Egyir (2006) classification, farmers are categorized into low, moderate and high adapters of dugouts. The three alternative dependent variable (low, moderate and high) obviates the applicability of a binary choice model and allows for Ordered Logit Model estimation. Hence, representing farmers' adaptive capacity as *AC*, and predicting the probability that a farmer will have a particular adaptive capacity given his characteristics:

$$\Pr ob(AC_{ij}) = Z_{ij}\theta' + \tau_{ij} \quad (2)$$

Where *AC* = low, moderate, high adaptive capacity which represent assigned values of 0, 1 and 2, respectively in Equation (2). τ is the error term with a logistic distribution, Z is vector of explanatory variables and θ' is a vector of regression coefficients. The marginal effect of adaptive capacity to dugout is derived as:

$$\frac{\partial AC_{ij}}{\partial Z_i} = AC_{ij}(\theta_{jk} - \sum_{m=1}^{j-1} \theta_{im} AC_{mk}) \quad (3)$$

And variance (Var) of the error term of adaptive capacity to dugout is:

$$Var(\tau_{ij}) = \frac{\pi^2}{6} \text{ (Green, 2003)} \quad (4)$$

Now, the determinants of adaptive capacity were analyzed using ordered logit model and estimated with LIMDEP Software. The socio-economic factors in the model include age of farmer, marital status, sex, education, household size, off-farm business, access to irrigable land, access to credit and income. The parameters were estimated using maximum likelihood estimation procedure. The relationship between adaptive capacity and its determinants is specified as:

$$AC = \theta_0 + \theta_1 AGE + \theta_2 MAR + \theta_3 SEX + \theta_4 HHS + \theta_5 WIC + \theta_6 OFFARM + \theta_7 HEDUC + \theta_8 CREDIT + \theta_9 LANDAC + \tau \quad (5)$$

The definitions of the variables and their measurement in the Ordered Logit Model are presented in Table 2. Next, the log-linear production function was used to analyze the effects of adaptive capacities on dry season vegetable farm income (Y). It was assumed that farmers adapt to dugouts in order to minimize the effects of adverse climatic conditions on their production. In the production process, a dry season vegetable farmer combines inputs (X_i) to produce output (Y). Yilmaz and Ozkan (2004) expressed this technical relationship between output and inputs as:

$$Y = f(X_i) \quad (6)$$

Where X_i is vector of inputs (rent of land, volume of water, fertilizer applied and labour). For a log-linear function:

$$Y = \ell^{f(X_i)} \quad (7)$$

Taking a log-linear transformation of Equation (7) and expressing the variables we obtain Equations (8 and 9) below:

$$\ln Y = f(X_i) \quad (8)$$

$$\ln Y = A + \alpha VLand + \beta VLab + \delta CFert + \gamma VWater + \varphi \quad (9)$$

Where *VLand*, *VLab*, *VFert*, *VWater* and φ are value of land, value of labour, value of organic fertilizer applied, value of water and the error term, respectively. Yilmaz and Ozkan (2006) added dummy variables to a log-linear production function to analyze structural comparisons. Following Yilmaz and Ozkan (2006), low (Low) and high (High) adapters were included in the model as dummy variables is use to analyze their effects on farm income. In this aspect, Equation (9) is re-specified to yield the empirical model in Equation (10) as follows:

$$\ln Y = A + \alpha VLand + \beta VLab + \delta VFert + \gamma VWater + \sigma Low + \rho High + \varphi \quad (10)$$

The value of land and water were measured as the amount of money (in Ghana cedi) paid for land and water use, respectively in one productive season. The value of labour is a continuous variable measured as a product of number of labour days worked on farm and cost of labour per day. Organic fertilizer in the form of poultry droppings are bought and applied on vegetables farms. Due to absence of standards in measuring organic fertilizer, the value of organic fertilizer used was measured as the total amount of money that the farmer paid for organic fertilizer.

Table 3. Variables, definitions and measurements used in the log-linear regression.

Variable	Definition and measurement
VLAB	Value of labour employed (in GHS)
VWATER	Value of water used (GHS)
VRENT	Price of land (GHS)
VFERT	Value of organic fertilizer applied(GHS)
LOW	Low adaptive capacity =1, 0 Otherwise
HIGH	High adaptive capacity =1, 0 Otherwise

Table 4. Demographic and socio-economic characteristics of respondents.

Age of vegetable farmers			Sex distribution of vegetable farmers			Marital status of vegetable farmers			Educational level of vegetable farmers			Access to credit by vegetable farmers		
Age	#	%	Sex	#	%	Marital status	#	%	Level	#	%	Status	#	%
Below 20	5	3.3	Male	100	66.7	Married	100	66.7	None	50	33.3	Yes	80	53.3
20 - 25	26	17.3	Female	50	33.3	Single	39	26.0	Primary	60	40.0	No	70	46.7
26 - 30	23	15.3				Widowed	10	6.7	JSS/Middle	19	12.8			
31 – 35	35	23.3				Divorced	1	0.6	Sec/voc/tech	11	7.3			
36 – 40	18	12.0							Post-sec	8	5.3			
Above 40	43	28.8							Tertiary	2	1.3			
Total	150	100	Total	150	100							Total	150	100

Low and high adaptive capacities were measured as dummy variables assuming the value of 1 for farmers with applicable adaptive capacity and 0 otherwise. Table 3 shows the definition of the variables and their measurement in the Log-linear regression.

RESULTS

This section presents the results of the study. It includes the demographic characteristics of farmers, farmers' adaptive capacities to dugouts, determinants of adaptive capacity and the effects of adaptive capacity on farm income.

Demographic characteristics

Demographic and socio-economic characteristics of respondents are presented in Table 4. The age distribution of the dry season vegetable farmers is grouped into six classes. Majority of the vegetable farmers (43) are above 40 years and constitute about 28.8% of the total dry season vegetable farmers. However, 5 farmers representing 3.3% of dry season vegetable farmers are below 20 years. Among the dry season vegetable farmers, the study included 100 male and 50 female who represent 66.7 and 33.3%, respectively. The results show that 100 dry season vegetable farmers constituting about 66.7% were married. However, whiles widows represent 6.7% of dry season vegetable farmers, 1 person was divorced. 50 respondents constituting 33.3% of the total respondents sampled did not receive any formal education. Besides, 62 of the respondents representing 40.0 and 1.3% had primary and tertiary education, respectively. However, the results show that 80 of the farmers had access to credit, representing 53.3%, whereas 70 (representing 46.7%) farmers do not have access to credit.

Table 5. Adaptive capacity of farmers to dug-outs.

Adaptive capacity (AC)	Range	#	%
Low	AC < 0.33	46	31.3
Moderate	0.33 ≤ AC < 0.66	39	26.0
High	0.66 ≤ AC ≤ 1.0	64	42.7
Total		150	100.0

Table 6. Ordered logit regression for determinants of adaptive capacities to dugouts.

Dependent variable: Adaptive capacity of farmers				
Included observations: 149				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Constant	-6.11935714	1.79213556	-3.415	0.0006
AGE	-0.00256895	0.02167037	-0.119	0.9056
MARR	-0.06195200	0.25552753	-0.242	0.8084
SEX	4.65453721	1.29421613	3.596	0.0003***
HEDUC	0.14926026	0.04838499	3.085	0.0020***
HHS	0.29575981	0.06324564	4.676	0.0000***
OFFARM	-1.89896367	0.69705673	-2.724	0.0064***
LANDAC	-0.23549478	0.77976905	-0.302	0.7626
CREDIT	3.43084226	0.60036065	5.715	0.0000***
Log likelihood function			-72.79383	
Restricted log likelihood			-160.4231	
Chi squared			175.2585	
Degrees of freedom			9	
Prob[ChiSqd> value]			0.0000000	

*, **, *** indicates significance at 10, 5 and 1%, respectively.

Adaptive capacity of farmers

The scale in the adaptive capacities of farmers interviewed is presented in the Table 5. Out of the 150 farmers interviewed, 47 of the respondents (31.3%) are of low adaptive capacity to dugouts (low adapters), whiles 39 respondents constituting 26.0% are of moderate adaptive capacity (moderate adapters) to dugouts. Majority of the respondents (64) constituting about 42.7% of the dry season vegetable farmers are of high adaptive capacity (high adapters) to dugouts and these are said to have adapted very well to dugout technology. The determinants of farmers adaptive capacity to dugout is estimated using an Ordered Logit Model and the results presented in Table 6.

The chi-square value is significant at 1% level thereby indicating the overall significance of the Ordered Logit Model in determining the factors that affect adaptive capacities of farmers to dugouts. The sex of respondent (SEX), number of years of formal education (HEDUC), household size (HHS) and credit (CREDIT) positively influence adaptive capacity whiles off-farm business (OFFARM), marital status (MARR), age of respondent (AGE) and access to land near a dugout (LANDAC) negatively influence probabilities of adaptive capacities. The sex of the respondent is significant at 1% and meets the a priori expectation implying that men are more likely to adapt better to dugouts than women. The education variable (a higher year of formal education) influenced the adaptive capacity positively as expected and significant at 1% level.

Thus, more educated farmers can easily upgrade their knowledge about a technology thereby increasing adaptive capacity. Engaging in off-farm business is significant at 1% level and meets the a priori expectation. As one engages in off-farm business, the time allocated to upgrading knowledge about dugouts and the number of times he or she uses the dugout declines thereby reducing adaptive capacity. Access to credit meets the a priori expectation and significant at 1% level. Some financial institutions monitor the activities of farmers to ensure that disbursed loans are used for the intended purposes. Consequently, farmers accessing loans for dry season vegetable farming are compelled to actually invest in vegetable farming thereby increasing the number of times a dugout is used and subsequently

Table 7. Marginal effects of significant variables for ordered logit model.

Variable	Low adapter	Moderate adapter	High adapter
SEX	- 0.8034	0.4707	0.3327
HEDUC	0.0121	- 0.0144	0.0265
HHS	- 0.0239	- 0.0285	0.0525
OFFARM	0.2672	- 0.0450	- 0.2222
CREDIT	- 0.4121	- 0.0898	0.5019

Source: Authors' computation from field data.

Table 8. Log-linear regression of the effects of adaptive capacity on dry season vegetable income.

Dependent variable: Natural logarithm of dry season Income				
Sample: 1 150				
Included observations: 149				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Constant	3.496855	0.095277	36.70209	0.0000
VLAB	0.008772	0.001270	6.904866	0.0000***
VWATER	0.006943	0.001448	4.795114	0.0000***
VRENT	0.001924	0.003470	0.554462	0.5801
VFERT	-1.12E-05	0.001208	-0.009296	0.9926
LOW	-0.845145	0.085803	-9.849860	0.0000***
HIGH	0.220821	0.100192	2.203969	0.0291**
R-squared	0.862408	Mean dependent var		4.026566
Adjusted R-squared	0.856553	S.D. dependent var		0.982344
S.E. of regression	0.372057	Akaike info criterion		0.906603
Sum squared resid	19.51813	Schwarz criterion		1.048363
Log likelihood	-60.08863	F-statistic		147.2947
Durbin-Watson stat	1.658419	Prob (F-statistic)		0.000000

*, **, *** represent 10, 5 and 1%, respectively.

enhancing adaptive capacity. Access to credit confirms the findings of Asante and Egyir (2006) of the effects of financial services on adaptive capacity to dry land farming. The size of the household does not meet the priori expectation but significant at 1% level. Table 7 indicates the marginal effects of significant variables for the Ordered Logit Model. A year increase in formal education increases probability of low and high adaptive capacity adapters by 0.0121 and 0.0265, respectively whiles decreasing the probability of moderate adapters by 0.0144. An increase in household size decreases the adaptive capacities of low and moderate adapters by 0.0293 and 0.0285, respectively, whiles increasing the adaptive capacities of high adapters by 0.0525. For off-farm business, an individual who is not engaged in off-farm business activity being replaced by one engaged the adaptive capacity of low adapters increase by 0.2672 and decreases by 0.045 and 0.2222 for moderate and high adapters, respectively. Whiles replacing a non-credit access farmer by one accessing credit, the probability of low and moderate adapter's adaptive capacity decreases by 0.4121 and 0.0898, respectively, and increase by 0.5019 for high adapters as shown in Table 7.

Adaptive capacity and dry season vegetable farming income

The log-linear regression model of the effects of adaptive capacity on dry season vegetable income is presented in Table 8. The F-statistic is significant at 1% level indicating the significance of the model. The R-square of 0.8624 indicates that the explanatory variables explain about 86.24% of the variation in the dry season vegetable income. The value of water used (VWATER), value of labour employed (VLAB), price of land (VRENT), value of organic fertilizer applied (VFERT) and high adaptive capacity (HIGH) positively influence dry season vegetable farm income. However, low adaptive capacity negatively influence dry season vegetable farm income and significant at 1%. The value of labour is significant at 1% and meets the a priori expectation. This implies that holding the wage rate of labour constant, employing more labour in the production of vegetables on farms results in increase in farm income. This is attributable to the fact that vegetables require more human labour to keep farmers in business. The value of water is significant at 1% and meets the a priori expectation in explaining the effects of water on dry season vegetable farming. The importance of water is explained by the fact that Upper East Region is in the Sudan Savannah zone characterized by high temperatures. Hence, to maintain the appropriate moisture content in the soil requires the application of more water. The empirical results in Table 8 show that low adaptive capacity meets the a priori expectation and significant at 1% level implying that low adapters earn lesser incomes from their farms. On the other hand, high adaptive capacity is significant at 5% level and meets the a priori expectation indicating that, high adapters earn high incomes from dry season vegetable farming.

DISCUSSION AND IMPLICATIONS

The results showed that sex, access to land near a reservoir site, engaging in off-farm business activity, access to credit and number of years of formal education determines farmers' decision to venture into dry season vegetable farming. Besides, about 31.3% of farmers are of low adaptive capacity, 26.0% are of moderate adaptive capacity and 42.7% being high adaptive capacity. Further, adaptive capacity is explained by sex of respondent, number of years of formal education, household size, off-farm business activity and access to credit. Finally, the study also indicates that high adaptive capacity increases farm vegetable income. As a farmer increases in age, the likelihood of producing vegetables in the dry season decreases. It can be concluded also that, sex play a significant role in dry season vegetable farming. Specifically, women farmers have lesser chance of producing vegetables in the dry season compared to their male counterparts. Moreover, farmers who own other businesses in addition to farming are not likely to produce vegetables in the dry season. However, access to credit and irrigable land increases the chances of vegetable production in the dry season.

From the categorization of adaptive capacities employed in this study, about 31.3% of the farmers have adapted poorly (low adapters), 26.0% adapted moderately and 42.7% have adapted highly to dugouts. Further, the results show that men adapt better to dugouts than women but adaptive capacity of men decreases among low adapters whiles increasing across moderate and high adapters. Increasing the number of years in formal education generally improves adaptive capacity. Thus, being educated increase the chances of low and high adapters to increase their adaptive capacity while narrowing that of moderate adapters. Household size has an overall positive effect on adaptive capacity. However, one member increase in a household size decrease the probabilities of low and moderate adapters to improve upon their adaptive capacity while increasing the chances of high adapters to improve upon their adaptive capacity. Engaging in off-farm business activity has an overall negative effect on adaptive capacity. For moderate and high adapters, when a farmer who did not engage in off-farm business activity now engages, the probability of adaptive capacity decreases while increasing across low adapters. The study also shows that, access to credit increases the ability to adapt to dugouts. However, access to credit by a dry season vegetable farmer results in the adaptive capacities of low and moderate adapters decreasing, while increasing the adaptive capacities of high adapters.

Finally, while low adaptive capacity negatively affects dry season farm income, high adaptive capacity positively affect vegetable income. This study confirms that climate change damages could be large in more vulnerable areas of the tropical developing countries. Following the findings in this study, it is recommended that, community opinion members should assist women in accessing land to undertake dry season vegetable farming. Secondly, government should support both aged and the youth to venture into vegetable farming in the dry season. Financial institutions should deepen credit provision to farmers since credit influence farmers' adaptive capacity to dugout and enhances their dry season vegetable production and their income. Training programs should be initiated to enhance the adaptive capacity of farmers as a strategy to improve upon their dry season vegetable income. This study is limited to only dugouts and vegetable farmers in Upper East Region. Future research should focus on undertaking a comparative analysis of farmers' adaptive capacities to dugouts, tube wells and irrigation dams across the region.

REFERENCES

Agyepong GT, Gyasi EA, Nabila JS, Kufogbe SK (1999). Population Land-Use and The Environment in a West African Savannah Ecosystem: An Approach to Sustainable Land-Use on Community Lands in Northern Ghana, In People and their Planet: Searching for Balance. Baudot, B. S. and Moomaw, W. R. (eds.), Macmillan Press Ltd., pp. 251-271.

Ahenkorah Y, Dowouna GNN, Amatekpor JK (1998). Soil and water resources:conservation, management, and constraints to utilization for sustainable development in Ghana. Africa's Natural resources conservation and management surveys, Summary proceedings of the UNU/INRA, Regional workshop Accra, Ghana, March 1998.

Ariaster B, Filho DA, Holanda MC, Carlo F (2008). Forecasting the impact of climate variability: lessons from the rain fed corn market in Ceara, Brazil. Environ. Dev. Econ., 13(2): 201-227.

Asante FA, Egyir IS (2006). Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming-A baseline Survey. A report Prepared by the Strategic Innovations in Dryland Farming Project (PN 6) for the Challenge Program for Food and Water.

Fairhead J, Leach M (2000). Reforming Deforestation: global analysis and local realities. Studies in West Africa, Global Environmental Change Series. Reviewed by James K. A. Benhim. Environ. Dev. Econ., 5(3): 338-340.

Gana BK (1995). Evaluatin Soil Degradation Trends North-Eastern Ghana Using GIS an Image Analysis, M.Sc. Dissertation, Department of Soil Science, University of Saskathewan.
Irrigation Company of Upper Region Limited (ICOUR) Ghana (2007). Annual performance report, unpublished.
Ikilulu M (2006). Impacts of small reservoirs on rural livelihoods in Northern Ghana._M.Phil dissertation submitted to the Department of Agricultural Economics and Agribusiness, University of Ghana, Legon.
MacIver DC (1998). Adaptation to Climate Variability and Change. IPCC Workshop Summary, San Jose, Costa Rica, 29 March - 1 April 1998. Atmospheric Environment Service Environment Canada, Downs View, Ontario, Canada, p. 55.
Masters WA, Macmillan SS (2000). Climate and Scale in Economic Growth. *Centre for the study of African Economies*, WPS/2000-13, June, University of Oxford, UK.
Mensah-Bonsu A (2003). Migration and Environmental Pressure in Northern Ghana, Vrije Univesity, Amsterdam.
Menselsohn R, Dinar A, Williams L (2006). The distributional impact of climate change on rich and poor countries. Environ. Dev. Econ., 11(2): 159-178.
Mendelsohn R, Dinar A, Sanghi A (2001). The effect of development on the climate sensitivity of Agriculture. Environ. Dev. Econ., 6(1): 85-101.
Murdoch PS, Baron JS, Miller TL (2000). Potential effects of climate change on surface water quality in North America. JAWRA, 36: 347–366.
Seo SN, Mendelsohn R, Munasinghe M (2005). Climate change and agriculture in Sri Lanka: A Ricardian valuation. Environ. Dev. Econ., 10(5): 58-596.
Tol SJR (2005). Emission abatement cost of carbon-sink projects in developing countries. Environ. Dev. Econ., 10(5): 581-596.
Tonah S (1969). The Development of Agropastoral Households in Northern Ghana: Policy Analysis, Project Appraisal and Future Perspectives, Breitenbal.
Uchendu VC, Anthony KRM (1969). Economic, Cultural and Technical Determinants of agricultural Change in Tropical Africa: Field Study of Agricultural Change: Bawku District, Ghana, preliminary Report No. 7, Food Research Institute, Stanford University.
Wills JB (1962), Agriculture and Land Use in Ghana, Oxford University Press.
Yilmaz I, Ozkan B (2004). Econometric Analysis of Land Tenure Systems in Cotton Production in Turkey. Int. J. Agric. Biol., 6(6): 1023-1025.