# ADAPTIVE CAPACITIES OF FARMERS TO CLIMATE CHANGE ADAPTATION STRATEGIES AND THEIR EFFECTS ON RICE PRODUCTION IN THE NORTHERN REGION OF GHANA

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Received October 24, 2012

## ABSTRACT

*This study estimated the adaptive capacities of farmers to climate change adaptation strategies and their effects on rice production in the Northern Region of Ghana. The adaptive capacities of rice farmers were estimated quantitatively and categorized into high, moderate and low adaptive capacities. Double logarithmic regression model of Cobb-Douglas production function was used to quantity the effects of adaptive capacities of farmers on rice production. On the average, the farmers interviewed are moderately adaptive to climate change. Also, high adaptive farmers obtain nine more bags of 50 kg bag of paddy rice than farmers with low adaptive capacities. Therefore, the more a farmer has the ability to adjust to climate change, the more the number of bags of rice he or she obtains. Rice farmers should be empowered through better extension services in order to attain high adaptive capacity status so as to help them obtain more rice output.*

## KEY WORDS

*Adaptive capacities; Adaptation strategies; Climate change; Cobb-Douglas; Production function; Ghana; Northern Region; Rice.*

The lives of the entire global community are increasingly threatened by the effects of the current climatic conditions. The activities of man are gradually destroying the environment thereby affecting its suitability for habitation for natural creatures. IPCC (1998) defined climate change as a significant shift in the average weather condition especially average temperature and precipitation of an area. The Fourth Assessment Report of the IPCC (2007) emphasized that most land areas will have warmer and fewer cold days and nights. Globally, the earth has over the years observed a significant increase in temperature but decreased precipitation (Fancherean et al., 2003). Climate change has raised a lot of concerns by scientists and world authorities of both developed and developing countries. Many researchers have shown that agriculture in Africa is negatively affected by climate change (Deressa et al., 2008; Kurukulasuriya and Mendelsohn, 2006). The changing climatic conditions are affecting soil moisture which may affects crop production adversely especially rice in Northern Ghana.

The importance of rice in Ghanaians' staple diet cannot be overemphasized and its availability throughout the year is of great concern. Cereals such as maize, rice, millet and sorghum are staple crops grown for food as well as income for both the rural and urban households in Ghana. According to Bozza (1994), the importance of rice came to light in 1960 when Northern Region expanded the area of cultivation and became the major rice production area. Shortage of water, high cost of inputs, unsuitable varieties and over dependent on unreliable rainfall are major factors affecting rice production in the country (Kranjac-Berisavljevic et al., 2003). Rice is very sensitive to climatic, environmental and soil conditions. Unfavorable changes in climatic factors (temperature, precipitation, relative humidity and bright sunshine duration) are expected to affect rice yield adversely and farmers need to adapt effectively to climate change.

The effects of climate change on agriculture have called for the need to adopt certain adaptation technologies to cope with its harmful effects. Adaptation to climate change in agriculture production is the adjustment of farming activities or methods to suit the changes in climatic conditions in order to lessen the potential damage that are caused. Many definitions and characteristics for adaptation are documented by researchers both in developing and developed countries (Burton et al., 2005; Carter et al., 1994). IPCC (2001) defined adaptation to climate change as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm so as to take advantage of opportunities'. Farmers can achieve food security, high income and livelihood security objectives if they adapt effectively to climate change (Hassan and Nhemachena, 2008). To adapt effectively means to have the capacity to adopt an adaptation strategy in minimizing the effects of climate change on agricultural production. Generally, the common adaptation strategies to climate change in crop production which are documented by literature are crop diversification, irrigation, changing planting dates, using draught tolerant varieties, using early maturing varieties etc. Soil conservation, tree planting, early and late planting are additional adaptations strategies to climate change that are practiced across African countries (Deressa, 2008). The adaptation technologies that a farmer adopt depends mostly on the type of crop cultivated (Dixon et al, 2001). A vulnerability assessment study conducted by Dazé (2007) for land resource in Ghana revealed the following coping strategies for climate change: mixed farming, drought tolerant crops or varieties, control of soil erosion, planting and conservation of trees, planting of early or late maturing varieties, chemical fertilizer usage, land use intensification, agricultural diversification, extension of farming into marginal lands, cropping in moist valley bottoms, integration of trees in crops, rearing of goats more than sheep and cattle, as goats are easier to feed, changing diet and emigration of people.

According to Nyong (2005), farmers in Sub-Saharan African countries are vulnerable to climate change because they lack the capacity to adapt. The technologies for adapting to climate change are limited. The ability of a farmer to adopt an adaption strategy so as to reduce the adverse effects of climate change on agricultural production is called adaptive capacity. The degree of farmers' adaptive capacities to adaptation strategies in coping with climate change in rice production in the study area is unknown. Also, it is not known how effectively farmers have adapted to the adaptation strategies in coping with climate change. What is the degree (categorization) of farmers' adaptive capacities to adaptation strategies in minimizing the effects of climate change? Is higher adaptive capacity equivalent to higher rice output and lower adaptive capacity equivalent to lower rice output? How effectively farmers have adapted to the available adaptation strategies will be of much importance to policy makers and technocrats. This is because it will help technocrats and policy makers design technical and evidence base policies to facilitate the ability of farmers in attaining the highest degree of adaptive capacities.

## METHODOLOGY

**Measurement of Farmers' Adaptive Capacities to Adaptation Strategies.** According to Klein (2002), adaptive capacity to climate change is the ability of a system or an individual to adjust to climate change or climate variability so as to minimize the potential damages or cope with the consequences. Therefore, adaptive capacity is the ability to plan and use adaptation measures to moderate the effect of climate change. Adaptive capacity varies from farmer to farmer based on certain factors that are peculiar to each farmer. It is assumed that farmers are rational and as such they adapt to climate change in order to reduce its consequences. Some farmers have higher ability to adjust to climate change than others. This objective will be achieved by determining the adaptive capacities of each farmer in the study area using qualitative and quantitative indicators described below.

*Empirical determination of the degree of adaptive capacities.* Asante et al. (2009) and Nakuja et al. (2012) measured adaptive capacities of farmers by considering five attributes such as knowledge, use, availability, accessibility and consultation. The adaptation strategies considered in this research are the use of; formal irrigation facilities (drip, furrow, sprinkler), dugouts, chemical and organic fertilizers, mulch, early maturing and drought tolerant rice varieties. Changing planting dates, construction of fire belts, building of embankments and integration of trees in rice farms were other adaptation strategies considered. Other adaptation strategies were identified from farmers.

Adaptive capacities of farmers depend on certain factors or attributes such as their knowledge on and number of times they use a particular adaptation strategy. Other factors are the availability and accessibility of the adaptation strategy. Also, the number of consultations that a farmer makes on a particular adaptation strategy affect whether the farmer will be lowly or moderately or highly adaptive to climate change. In measuring the adaptive capacities quantitatively, farmers were asked to indicate their degree of attainment of each attribute. The highest degree of attainment of each of the attributes or factors affecting adaptive capacities was scored 1 whereas the lowest degree was given a score of 0.25. The score level for a farmer with higher degree of attainment of each attribute is 0.75. Lastly, the score level for high degree of achievement is 0.50. Therefore, the degree of each farmer's knowledge on each adaptation strategy was sought. In terms of knowledge, the higher the degree, the better knowledge the farmer has on a particular adaptation strategy. Table 1 summarizes how each attribute was measured.

Table 1 – Score Levels of Farmers' Achievement of Attributes

| Degree | Scores | Knowledge | Use | Availability | Accessibility | Consultation |
|---|---|---|---|---|---|---|
| Highest degree | 1.00 | Very well | Several | Very regular | Easily accessible | Several |
| Higher degree | 0.75 | Well | Twice | Regular | Accessible | Twice |
| High degree | 0.50 | Fairly well | Once | Occasionally | Not easily accessible | Once |
| Low degree | 0.25 | Not well | Never | Never | Not accessible | Never |

*Source: Modified from Nakuja et al. (2012)*

The adaptive capacity (AdapCap) of an ith farmer to jth adaptation strategy is calculated as shown in equation (1) below:

$$AdapCap_{ij} = \frac{K_{ij} + U_{ij} + V_{ij} + A_{ij} + C_{ij}}{N_A} \qquad (1)$$

where $AdapCap_{ij}$ denotes the adaptive capacity of an $i$th farmer to a $j$th adaptation strategy; $K_{ij}$, the knowledge of the $i$th farmer on $j$th adaptation strategy; $U_{ij,,}$ the level of usage of $j$th adaptation strategy by $i$th farmer; $V_{ij}$; the availability of innovations on $j$th adaptation strategy to $i$th farmer; $A_{ij}$, accessibility of innovations on $j$th adaptation strategy to $i$th farmer; $C_{ij}$, level of consultation on $j$th adaptation strategy by $i$th farmer; $N_A$, the sum of applicable attributes.

The average adaptive capacity of farmers to $j$th adaptation strategy, $AveAdapCap_j$ is calculated using the equation (2) below.

$$AveAdapCap_j = \frac{\sum AdapCap_{ij}}{N} \qquad (2)$$

where $N$ is the number of observations.

Table 2 – Degree of Adaptive Capacities of Farmers

| Degree of adaptive capacities | Ranges of indices for $AdapCap_{ij}$ | Ranges of indices for $AveAdapCap_j$ |
|---|---|---|
| Low adaptive capacity | $0 < AdapCap_{ij} < 0.33$ | $0 < AveAdapCap_j < 0.33$ |
| Moderate adaptive capacity | $0.33 \leq AdapCap_{ij} <0.66$ | $0.33 \leq AveAdapCap_j < 0.66$ |
| High adaptive capacity | $0.66 \leq AdapCap_{ij} \leq 1.00$ | $0.66 \leq AveAdapCap_j \leq 1.00$ |

*Source: Modified from Nakuja et al. (2012)*

Based on the adaptive capacities of the attributes, three indices were established. Table 2 shows the categories of adaptive capacities (low, moderate and high) to which each farmer falls within. It also shows the categories of average adaptive capacities (low, moderate and high) of each adaptation technology. Farmer $i$ is lowly adaptive to adaptation strategy $j$ if the adaptive capacity calculated falls in the range of $0 < AdapCap_{ij} < 0.33$. The range for moderate and high adaptive capacities are $0.33 \leq AdapCap_{ij} < 0.66$ and $0.66 \leq AdapCap_{ij} \leq 1.00$ respectively.

**Effects of Adaptive Capacities on Rice Output.** The yield of a crop depends on the inputs used in production, the characteristics of the farmer and the adaptation strategies employed by the farmer to moderate the damages caused by climate change indicators (temperature, relative humidity, sunshine duration and rainfall). The assumption here is that the degree of adaptive capacities to adaptation strategies affect rice yield *ceteris paribus*. According to Koutsoyiannis (2003), there exist a technical relationship between the endogenous inputs and output called a production function. The production function represents the technology of the farmer which transforms inputs into outputs at any particular time. An augmented Cobb-Douglas production function shows the relationship between rice output and inputs including adaptive capacities.

*Empirical model for quantifying the effects of adaptive capacities on rice output.* A Cobb-Douglas production function which shows a technical relationship between inputs and output can be specified as:

$$Q_i = \beta_0 K_i^{\beta_1} L_i^{\beta_2} e^{\mu_i} \qquad (3)$$

where $Q_i$ is the total output of rice for *i*th farmer, $\beta_0$ is the constant, $K_i$ is the capital input for ith farmer, $L_i$ is the labour input for ith farmer, $\mu_i$ is the error term for *i*th farmer and $\beta_1$ and $\beta_2$ are the slope coefficients for capital and labour respectively. The unit of measurement for rice output, capital and labour are kilogrammes (Kg), Ghana Cedis (Gh¢) and man-days respectively. An augmented Cobb-Douglass production is then specified as shown in equation (4) by including dummy variables such as extension contact (*Ext*), access to education (*Edu*), gender (*Gen*), adaptive capacity indicators and continuous endogenous variable inputs such as quantity of fertilizer (*Fert*), farm size (*FmS*) and age of the farmer (*Age*). Extension contact was dummied 1 for farmers who have access to extension contact and 0 otherwise. A farmer with at least primary education was dummied 1 and 0 otherwise. A male farmer was given a score of 1 whereas a female 0. $LA_i$ and $HA_i$ represent low and high adaptive capacities respectively. A farmer with low adaptive capacity was dummied 1 and 0 otherwise. On the other hand, high adapters were given a score of 1 and 0 otherwise. Quantity of fertilizer, farm size and age were measured in kilogrammes (kg), hectares (ha) and years respectively.

According to Onumah *et al.* (2010), the Cobb-Douglas production function restricts the return to scale to one. Eventhough, this is a limitation, Cobb-Douglas production function has been used by Battese (1997) for its simplicity. For the purpose of this study, an augmented Cobb-Douglas production function is specified as:

$$Q_i = \beta_0 K_i^{\beta_1} L_i^{\beta_2} Fert_i^{\beta_3} FmS_i^{\beta_4} Age_i^{\beta_5} (Age_i^2)^{\beta_6} e^{\beta_7 Ext_i} e^{\beta_8 Gen_i} e^{\beta_9 Edu_i} e^{\beta_{10} LA_i} e^{\beta_7 HA_i} e^{\mu_i} \qquad (4)$$

Taking the natural log of equation (4) above gives the double log equation shown below.

$$ln\,(Q_i) = \beta_0 + \beta_1 ln(K_i) + \beta_2 ln(L_i) + \beta_3 ln(Fert_i) + \beta_4 ln(FmS_i) + \beta_5 ln(Age_i) + \beta_6 ln(Age_i^2) + \beta_7 Ext_i + \beta_8 Gen_i + \beta_9 Edu_i + \beta_{10} LA_i + \beta_{11} HA_i + \mu_i \qquad (5)$$

*Statement of hypothesis*

**I** $H_0$: Low adaptive capacity has no effect on rice output. $H_1$: Low adaptive capacity has negative effect on rice output. Similar hypotheses are stated for old age.

**II.** $H_0$: High adaptive capacity has no effect on rice output. $H_1$: High adaptive capacity has positive effect on rice output. Similar hypotheses are stated for access to education, access to extension contact, gender, quantity of fertilizer used, farm size, capital, and amount of labour employed and age (youthfulness).

The a priori expectations are shown in table 3 below.

Table 3 – A priori Expectations of the Variables

| **Variables** | **Parameters** | ***Apriori* Expectations** |
|---|---|---|
| Capital | $\beta_1$ | Positive |
| Labour | $\beta_2$ | Positive |
| Fertilizer | $\beta_3$ | Positive |
| Farm size | $\beta_4$ | Positive |
| Age | $\beta_5$ | Positive |
| Age square | $\beta_6$ | Negative |
| Extension contact | $\beta_7$ | Positive |
| Gender | $\beta_8$ | Positive |
| Access to education | $\beta_9$ | Positive |
| Low adaptive capacity | $\beta_{10}$ | Negative |
| High adaptive capacity | $\beta_{11}$ | Positive |

**Data Collection and Sampling Techniques.** Primary data was collected by administering structured questionnaires to rice farmers in Tolon-Kumbungu and Savelugu-Nanton Districts of the Northern Region. This data is on 2011 farming season. The districts were purposively selected based on the fact that they produce the largest quantity of rice in the region. Meanwhile, the communities where rice farmers were interviewed were randomly selected. Rice farmers were purposively selected since they were the target group. Simple random sampling technique was then employed for collecting data from 150 rice farmers comprising 80 and 70 rice farmers from Tolon-Kumbungu District (TKD) and Savelugu-Nanton District (SND) respectively. Simple random sampling procedure was used due to the homogeneity of farmers. Broadly, all the farmers face approximately the same weather, market and soil conditions. They also have similar socioeconomic characteristics (Ikililu, 2007). This sample size was chosen based on the fact that there was no exact number of rice farmers in each of the districts. Meanwhile, larger number of farmers was chosen from TKD because the district produces more rice than Savelugu-Nanton District. Also, TKD is where Savannah Agricultural Research Institute (SARI) is located and there is a high probability that farmers will get knowledge from researchers to improve upon their adaptive capacities.

## RESULTS AND DISCUSSION

**Degree of Adaptive Capacities of Farmers to Adaptation Strategies.** The degree of adaptive capacities of rice farmers to the various adaptation strategies is presented in table 4. The respondents interviewed were highly adaptive to the use of chemical or organic fertilizers, mulch, farming on fallowed land, formal irrigation, farming near water bodies and the use of early maturing rice varieties. This is because their adaptive capacities are within the range of $0.66 \leq AdCap_j \leq 1.00$. Among these adaptation strategies with high adaptive capacities, the use of chemical or organic fertilizers and early maturing rice varieties recorded the highest and the lowest adaptive capacities of 0.83 and 0.68 respectively. The adaptive capacities calculated for formal irrigation and farming near water bodies are equal in value (0.71).

Table 4 – Degree of Adaptive Capacities of Farmers

| Adaptation strategies | Adaptive capacities ($Adap_j$) | Rank | Degree of adaptive capacities |
|---|---|---|---|
| Use of chemical/organic fertilizers | 0.83 | 1 | High adaptive capacity |
| Mulching | 0.81 | 2 | High adaptive capacity |
| Farming on fallowed land | 0.76 | 3 | High adaptive capacity |
| Formal irrigation | 0.71 | 4 | High adaptive capacity |
| Farming near water bodies | 0.71 | 4 | High adaptive capacity |
| Early maturing rice varieties | 0.68 | 5 | High adaptive capacity |
| Drought tolerant rice varieties | 0.63 | 6 | Moderate adaptive capacity |
| Mixed cropping | 0.59 | 7 | Moderate adaptive capacity |
| Mono-cropping | 0.59 | 7 | Moderate adaptive capacity |
| Construction of fire belts | 0.36 | 8 | Moderate adaptive capacity |
| Changing planting dates | 0.34 | 9 | Moderate adaptive capacity |
| Use of dugouts | 0.33 | 10 | Moderate adaptive capacity |
| Building of embankments | 0.32 | 11 | Low adaptive capacity |
| Integration of trees in rice farms | 0.30 | 12 | Low adaptive capacity |
| Crop rotation | 0.30 | 12 | Low adaptive capacity |
| **Average** | **0.55** | – | **Moderate adaptive capacity** |

*Source: Computation from field data (2012)*

The adaptation strategies with moderate adaptive capacities are the use of drought tolerant rice varieties, mixed cropping, mono-cropping, construction of fire belts, changing planting dates and the use of dugouts. Out of the 15 adaptation strategies used, farmers are moderately adaptive to 6 of them. Among adaptation strategies which farmers are moderately adaptive, the use of drought tolerant rice varieties had the highest adaptive capacity value of 0.63 whiles the use of dugout recorded the lowest of 0.33. The adaptive capacities calculated for mixed cropping, mono-cropping are equal with the value of 0.59. Farmers need to be empowered to increase their adaptive capacity status for these adaptation strategies with moderate adaptive capacity values.

The respondents in the area have low adaptive capacity to the building of embankments, the integration of trees in rice farms and crop rotation. Building of embankments to keep water on the rice field has the adaptive capacity value of 0.32. The adaptive capacity value quantified for integration of trees in rice farms and crop rotation is equal with a value of 0.30.

Generally, the average adaptive capacity of the respondents is 0.55. This implies that farmers in the study area are moderate adapters to climate change.

*Percentages of the degree of adaptive capacities of respondents.* Generally, table 5 indicates that 38.0% out of 150 farmers interviewed are high adapters to the climate change adaptation strategies. Also, 35.5% of the respondents are moderate adapters. On the other hand, 26.6% of the respondents interviewed are low adapters. Though, majority (38.0%) of rice farmers are high adapters to climate change; on the average, the farmers interviewed are moderate adapters. This is because, the mean adaptive capacity calculated is 0.54 which falls within the range of moderate adapters ($0.33 \leq AdCap < 0.66$). This implies, averagely the farmers in the area do not have all the necessary resources to aid them adapt highly and effectively to climate change.

Table 5 – Percentages of the Degree of Adaptive Capacities of Respondents

| Adaptive Capacity | Mean Adaptive Capacity | Frequency | Percentage |
|---|---|---|---|
| High Adapters | 0.76 | 57 | 38.0 |
| Moderate Adapters | 0.54 | 53 | 35.3 |
| Low Adapters | 0.32 | 40 | 26.7 |
| **Average** | **0.54** | **150** | **100.0** |

Source: Computation from field data (2012)

**Effects of Adaptive Capacities of Farmers on Rice Output.** Table 6 presents the Ordinary Least Square (OLS) regression results on the effects of adaptive capacities on rice output. These results were obtained by estimating the double logarithmic augmented Cobb-Douglas production function specified in equation (4). The coefficient of determination ($R^2$) value is 81%. This value implies that the variations in labour, fertilizer, farm size, age, extension contacts, gender, education and adaptive capacities explained about 81% of the variations in rice output. The F-statistic indicates that the overall regression is significant at 1% meaning that the independent variables jointly affect rice output. The Durbin-Watson statistic value of 1.73 implies that autocorrelation is absent. Also, since, the computed chi-square value of 28.689 is significant at 5%, the White test indicates that the variance of the error term is constant justifying the absent of heteroskedasticity. The log-log model was used because it gave better coefficient estimates and better goodness of fit than other models. Note that the rice used in this study is paddy rice.

From table 6, the amount of labour employed in mandays (L), the quantity of fertilizer (Fert) applied in kilograms and farm size (FmS) in hectares are consistent with the a priori expectation. The amount of labour employed is significant at 10%. This implies that labour significantly affects the quantity of rice produced. Since double logarithmic Cobb-Douglas production function is used, the coefficients are elasticities. So, 1% increase in the amount of labour employed will result in an increase in the quantity of rice produced by 0.19%. Also, the quantity of fertilizer applied is significant at 1%. Therefore quantity of fertilizer significantly affects rice output in the study area. As such, an increase in the quantity of fertilizer applied by 1% increases rice output by 0.18%. The number of hectares of land cultivated is significant at 1% implying that farm size affects rice output. Hence, an increase in farm size by 1% increases the quantity of rice output by 0.77%. Rice output is more responsive to area expansion than other input variables because farm size has the highest elasticity value. $Age^2$, capital (K), gender (Gen) and education (Edu) are not significant eventhough $Age^2$ and education meets the a priori expectations. Capital and gender are not consistent with the a priori expectations. Age was eliminated from the model because it was highly correlated with $Age^2$. Including $Age^2$ gave a better fitness of the model than Age.

The marginal effects of each of the significant variables (labour, fertilizer, farm size, extension contact, low adaptive capacity and high adaptive capacity on rice output) are depicted in column 6 of table 6. The marginal effect of labour is 6.99. This value implies that an increase in man-days of labour employed by 1unit will results in an increase in the quantity of rice produced by 6.99 kg. Also, if the quantity of fertilizer applied increases by 1kg, the quantity of rice produced will increase by 1.60 kg. It is expected that an increase in farm size by one hectare will lead to an increase in the quantity of rice output by 603.09 kg or 12 bags. Furthermore, a farmer with extension contact will obtain 182.58 kg (3.65 bags) of rice more that of a farmer without extension contact. Note that one bag of paddy rice in this study is equivalent to 50 kg of paddy rice.

Table 6 – OLS Regression Results: Adaptive Capacities as Determinants of Rice Output*

| **Variable** | **Coefficient** | **Std. Error** | **t-Statistic** | **Prob.** | **Marginal effects** |
|---|---|---|---|---|---|
| *ln(K)* | -0.0057 | 0.0436 | -0.1317 | 0.8955 | – |
| ***ln(L)*** | **0.1882** | **0.1049** | **1.7939** | **0.0754*** | 6.99 |
| ***ln(Fert)*** | **0.1790** | **0.0568** | **3.1543** | **0.0020****** | 1.60 |
| ***ln(FmS)*** | **0.7736** | **0.1027** | **7.5295** | **0.0000****** | 603.09 |
| *ln($Age^2$)* | -0.0211 | 0.0144 | -1.4707 | 0.1440 | – |
| ***Ext*** | **0.0977** | **0.0578** | **1.6892** | **0.0938*** | 182.58 |
| *Gen* | -0.0940 | 0.0570 | -1.6498 | 0.1016 | – |
| *Edu* | 0.0293 | 0.0532 | 0.5515 | 0.5823 | – |
| ***LA*** | **-0.1856** | **0.0717** | **-2.5891** | **0.0108**** | -347.02 |
| ***HA*** | **0.2436** | **0.0568** | **4.2931** | **0.0000****** | 455.36 |
| **R-squared** | | **0.818322** | Mean dependent var | | 7.421050 |
| **Durbin-Watson stat** | | **1.7310** | **Prob(F-statistic)** | | **0.000000****** |
| Log likelihood | | -4.2386 | F-statistic | | 53.6005 |
| **White Heteroskedasticity Test** | | | | | |
| Chi-square | | 28.68904 | Prob. Chi-Square(15) | | **0.01763**** |

*Dependent Variable: Natural logarithm of rice output; Dependent Variable: *ln(Q);* Method: Least Squares.

More importantly, farmers with high adaptive capacities obtained 455.36 kg (9 bags of 50 kg bag) of paddy rice more than moderate and low adaptive farmers. This implies that a farmer who attains a higher adaptive capacity status in adapting to climate change in rice production can obtain 9 more bags of paddy rice than a farmer who has low adaptive capacity. Therefore, adaptive capacities affect rice production in the study area. This suggests that high adaptive farmers learn and use modern techniques in their farming activities which minimise the detrimental effects of climate change on rice production. In every spheres of rice production (land preparation to harvesting), highly adaptive farmers adopt innovations to reduce the risk pose by climate change. While high adaptive capacity positively affects rice production, low adaptive capacity negatively affects rice production.

**Policy Recommendations.** Based on the findings that farmers with higher adaptive capacities get higher rice output, rice farmers should be empowered in order to attain high adaptive capacity status. Policy makers should design policies to train farmers on the use of the adaptation strategies to help them adapt well to the changing climatic conditions in the study area. This could be done through effective extension education on adaptation strategies available for use by rice farmers. If this is done, farmers would be able to attain high adaptive capacity status which will help them get higher rice output.

## SUMMARY AND CONCLUSIONS

The study determined the adaptive capacities as well as the degree of adaptive capacities of rice farmers to each climate change adaptation strategy. This was done by asking farmers to indicate the degree of achieving each of the following attributes: knowledge, use, accessibility, availability and consultations. The adaptive capacities of farmers estimated were categorized into high, moderate and low adaptive capacities. The effects of adaptive capacities to climate change adaptation strategies on rice output were analyzed by introducing high and low adaptive capacities as dummy variables into a double logarithmic Cobb-Douglas production function.

1. The results of this study revealed that farmers are highly adaptive to the use of chemical or organic fertilizers, mulch, fallow farming, formal irrigation, farming near water bodies and using early maturing rice varieties.

2. It was discovered that farmers are moderately adaptive to the use of drought tolerant rice varieties, mixed cropping, mono-cropping, construction of fire belts, changing planting dates and using dugout wells.

3. They are lowly adaptive to building of embankments, integration of trees in rice farms and crop rotation.

4. Generally, farmers are moderately adaptive to climate change adaptation strategies as this was justified by the average adaptive capacity value of 0.55.

5. Also, farmers with high adaptive capacities get more rice output whereas farmers with low adaptive capacities get less rice output.

6. It can be concluded that rice production is significantly affected by the degree of adaptive capacities, amount of labour employed, the quantity of fertilizer applied, the number of hectares of land cropped and extension contact.

7. This study considered only rice farmers and hence future research should consider the effects of adaptive capacities of farmers to climate change on the production of other food crops (maize, groundnut, sorghum etc.) which are major staples produced in the region.

## REFERENCES


Asante, F.A., Egyir, I.S., Jatoe, J.B.D. and Boakye, A.A. (2009). Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming – An Impact Assessment. A report Prepared by the Strategic innovations in Dryland Farming Project (PN 6) for the Challenge Program for Food and Water, Ghana.

Battese, G.E. (1997). A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. Journal of Agricultural Economics 48 (2): 250-252.

Bozza, J. (1994). Development of rice production in Northern Ghana, unpublished. Savannah Agricultural Research Institute SARI, Tamale, Ghana, pp. 8-26.

Burton, I., Malone, E.L. and Huq, S. (2005). Adaptation Policy Frameworks for Climate Change. Developing Strategies, Policies and Measures. Cambridge University Press, Cambridge.

Carter, T.R., Parry, M.L., Harasawa, H and Nishioka, S. (1994). IPCC Technical Guideline for Assessing Climate Change Imparts and Adaptations. University College, London, UK, and Centre for Global Environmental Research, Tsukuba, Japan.

Dazé, A. (2007). Climate Change and Poverty in Ghana. CARE International, Accra, Ghana.

Deressa, T. (2008). Analysis of Perception and Adaptation to Climate Change in the Nile Basin of Ethiopia. Centre for Environmental Economics and Policy for Africa (CEEPA), University of Pretoria.

Deressa, T., Hassan, R.M., Alemu, T., Yesuf, M. and Ringler, C. (2008). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI Discussion Paper 00798. Environment and Production Technology Division, Ethiopia.

Dixon, J., Gulliver, A. and Gibbon, D. (2001). Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. FAO (Food and Agriculture Organization), Rome, and World Bank, Washington, DC.

Fancherean, N., Trzaska. M., Rouault, M. and Richard, Y. (2003). "Rainfall Variability and Changes in Southern Africa During the 20th Century in the Global Warming Context", Natural Hazards 29, pp. 139–154.

Hassan, R. and Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. Centre for Environmental Economics and Policy in Africa (CEEPA), University of Pretoria AfJARE Vol 2 No 1. pp. 83-104.

Ikililu, A.M. (2007). Impact of Small Reservoir Irrigation on Livelihoods in Northern Region of Ghana. MPhil. Thesis in Agricultural Economics. Department of Agricultural Economics and Agribusiness, Universty of Ghana, Legon.

IPCC. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. (2001). Climate Change 2001 – The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, X., Maskell, K. and Johnson, C. A. (eds.)], Cambridge University Press, Cambridge, UK.

IPCC. (1998). The Regional Impacts of Climate Change: An Assessment of Vulnerability. A Special Report of IPCC Working Group II [Watson, R.T., Zinyowera, M. C. and Moss, R.H. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 517.

Klein, R.J.T. (2002). Climate Change, Adaptive Capacity and Sustainable Development. OECD Informal Expert Meeting on Development and Climate Change - Paris, France, 13–14 March 2002.

Koutsoyiannis, A. (2003). Modern Microeconomics. Third Edition, Macmillan Press Ltd., London, pp. 34-78.

Kranjac-Berisavljevic, G., Blench, R.M. and Chapman, R. (2003). Rice Production and Livelihoods in Ghana: Multi-Agency Partnerships (MAPs) for Technical Change in West African Agriculture. ODI. Ghana.

Kurukulasuriya, P. and Mendelsohn, R. (2006). Modeling Endogenous Irrigation: The Impact of Climate Change on Farmers in Africa. Center for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 8. Special Series on Climate Change and Agriculture in Africa.

Nakuja, T., Sarpong, D.B., Kuwornu, J.K.M. and Ashante F.A. (2012). Water storage for dry season vegetable farming as an adaptation to climate change in the upper east region of Ghana. African Journal of Agricultural Research, Vol. 7(2), pp. 298-306.

Nyong, A. (2005). Technologies for adapting to climate change: water resources and agriculture. UNFCCC Seminar on the Development and Transfer of Environmentally Sound Technologies for Adaptation to Climate Change, 14-16 June 2005, Tobago, Trinidad and Tobago.

Onumah, E.E., Br¨ummer, B. and Gabriele H.S. (2010). Elements Which Delimitate

Technical Efficiency of Fish Farms in Ghana. Journal of the World Aquaculture Society. Vol. 41, No. 4. P. 511 (506-518).