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SMALLHOLDER FARMERS' ADAPTATION TO RAINFALL VARIABILITY IN NORTHERN GHANA

Salisu Mustapha
University for Development Studies, Department of Agricultural and Resource Economics, Nyankpala Campus, Tamale, Ghana
mustaphasalis@hotmail.com

Tijani Inusah Iddrisu
University for Development Studies, Department of Environment and Resource Studies, Wa Campus, Ghana
ahmedyelisumah@gmail.com

William Adzawla
University for Development Studies, Department of Agricultural and Resource Economics, Nyankpala Campus, Tamale, Ghana
adzawlawilliam@gmail.com

Abstract

Irregular rainfall pattern pose challenges to smallholder farmers in Ghana, especially, those in the Northern Region, who risk losing their major source of livelihood as a result of the devastating impacts of climate change. To ensure food and livelihood security, smallholder farmers adopt indigenous and modern soil and water conservation strategies. This study therefore examined the influencing factors of adaptation to irregular rainfall pattern and the challenges therein. A cross sectional data of 140 households from five (5) randomly selected districts in the Northern region of Ghana was used. Results of a Negative Binomial Regression showed that access to extension services and credit positively influenced the number of adaptation strategies to irregular rainfall pattern. Also, quantity harvested, gender and age negatively influenced the number of adaptation strategies adopted by a farmer. Consistently, lack of credit was the first major constraint to climate adaptation among the farmers. The *study recommends that extension services, credit facilities as well as education of smallholder farmers should be intensified to promote adaptation to the rainfall patterns in the region. Also, government's effort is needed in developing irrigation facilities to aid smallholder farmers to offset the potential effects of climate change. Overall, this study provides suggestions to policy makers on how to improve climate adaptation in the region. Future studies should examine forms and effectiveness of climate change communication, since effective communication is imperative to the adoption of modern agricultural practices.*

Keywords

Climate Change, Adaptation, Rainfall Variability, Negative Binomial Regression Model

1. Introduction

Concerns on how smallholder farmers are adapting to the impacts of climate change have already taken centre stage in global climate discourse. The predicted impact of climate change on the livelihoods of smallholder farmers is expected to be more intense largely due to low capacity to adapt (IPCC, 2012). The phenomenon is expected to worsen climate related risks with severe shortfalls and disparities in rainfall distribution (IPCC, 2014). The high dependence on rainfall for agricultural production in most developing countries is much more pronounced among smallholder farmers (Kreft, 2015; Wijaya, 2015).

Globally, while some areas in the temperate regions will benefit from increased intensity of rain, areas around the tropics including the northern and southern latitudes are predicted to be negatively affected by reduction in rainfall intensity (Nhemachena & Hassan, 2007). As climate change is expected to get worse in the coming years, water supply, pests and diseases, food production and food security would be worsened (Alessandro, Demirag, & Akiko, 2012).

There is no shrewd of doubt about the role of adaptation in reducing adverse impacts of climate change (IPCC, 2007; 2012; 2014; Adger, Agrawala, Mirza, & Conde, 2007; Smit & Wandel, 2006; Williamsa, Crespoa, & Mumuni, 2019). In recent times however, challenges such as access to finance, information, education and technology have limited the adaptive capacities of smallholder farmers (UNEP, 2014). These barriers have worsened the plight of smallholder farmers, and also present a new set of risks, thereby, heightening their vulnerability.

Just as the impacts of climate change are not evenly distributed, the adaptive capacities to climate change are also different with respect to locations and class. It is widely acknowledged in literature that, Africa's contribution to climate change on smallholder farmers is minimal while the region will be hardest hit in terms of the adverse impacts (Kyei-Mensah, Kyerematen, & Adu-

Acheampong, 2019). The safest way to deal with the negative impacts of climate change is adaptation (Deepak, James, Graham, & Paul, 2015).

In sub-Saharan Africa, comprehensive baseline for adaptation strategies to rainfall variability is still a major challenge. (Tessema & Simane, 2019). The lack of reliable data in sub-Saharan Africa makes it difficult to build resilience (FAO, 2012). Although a wide range of policies have been focused on adaptation to rainfall variability, erratic rainfall pattern has rendered these efforts non-productive (Asfaw, 2014). It is estimated that two-thirds of the majority of the 80% of farmers who rely directly on rainfall are located in sub-Saharan Africa (Dumenu & Obeng, 2016).

Even though agricultural gains in Ghana has dwindled in the last few years largely due to rainfall variability, its potential for contributing enormously to the growth of the country still abound (GSS, 2017; Kyei-Mensah , Kyerematen , & Adu-Acheampong, 2019). This trend is more likely to persist since over 90% of agricultural lands are in the hands of the smallholder farmers who rely heavily on only rainfall for cultivation (IFAD, 2012; Sova, Nelson, Chaudhury, & Nutsukpo, 2014).

The phenomenon has negative impact in the northern belt than any part of the country (Yaro, 2010; Alessandro, Demirag, & Akiko, 2012). As noted by Yaro (2013) some of these difficulties are as a result of the geography of the region which is particularly exposed to the vagaries of the weather in the mist of other socioeconomic and political struggles that have bedevilled the region (Yaro, 2013; Samuel, Shem, & Danie, 2017). Rainfall variability in recent times is particularly eroding past and present efforts in making the region the food hub of Ghana. The region's vulnerability to erratic rainfall stems more from its single rainfall season which is increasingly becoming more erratic in the face of high (Akudugu & Ditoh, 2012).

Recent analyses of rainfall variability in Northern region of Ghana have revealed three dimensions of rainfall pattern, namely, reduction in intensity; irregular pattern; and late onset as well as early cessation. Various studies have been conducted on how smallholder farmers in northern Ghana have been adapting to climate variability (Amikuzuno, 2013; Kuwornu, Al-Hassan, Etwire, & Osei-Owusu, 2013; Mabe, Sienso, & Donko, 2014). However, the issue of adaptation to climate variability, especially rainfall variability has not been given the due attention in recent empirical studies. Considering the negative implications of erratic rainfall and the essential role adaptation plays in mitigating the effects of rainfall variability (Weber, 2010). This study provides grounds for policies that can enhance climate change adaptation in the region. In doing this, the study addressed three main objectives; firstly, the study assessed the adaptation strategies in the municipality. Secondly, the study explored the determinants of the number of adaptation strategies and lastly examined the challenges of adaptation to irregular rainfall pattern.

2. Literature Review

2.1 Rainfall Variability and Global Adaptation Experience

The concept of adaptation to climate variability has undergone a lot of development and scrutiny in the 21st Century. This is mainly due to the unprecedented adverse impacts predicted on human and natural systems (IPCC, 2012; Williamsa, Crespoa, & Mumuni, 2019). Adaptation in climate literature is traceable to the natural sciences in evolutionary studies. It describes the development of features and mechanisms by human and natural systems to cope with stress pose by environmental and climate variability (Smit & Wandel, 2006). All over the world, people and societies have adjusted to climate variations and extremes with varied levels of achievements; with some very beneficial whilst others have failed leading to irreparable consequences on human and the environment (IPCC, 2014). Smit and Wandel (2006) conclude that adaptation in any human system is connected with and mirrors the adaptive capacity as well as vulnerability of the people. Nonetheless, as the adverse impacts of climate variability keeps increasing; adaptation alone is not expected to offset all the negative impacts associated with climate variability (IPCC, 2007; Samuel, Shem, & Danie, 2017).

Recent studies (UNFCCC, 2013; Hiwasaki, Emmanuel, Syamsidik, & Rajib, 2014) on climate and rainfall variability have highlighted the mainstreaming of indigenous adaptation strategies. This advocacy dwells on the diverse nature of impacts and socio-cultural factors that are contingent on some adaptation process. Hiwasaki et al. (2014) noted that, indigenous people have a long standing adaptation experience to climate variability and are therefore, very close to the natural biophysical system; and have accumulated knowledge and practices that play a major role in reducing associated risks (IUCN, 2008). Other studies (Fechter, 2009; Fekadu, 2014) contend that, the risks associated with rainfall variability will require context specific strategies of adaptation rooted in indigenous knowledge.

2.2 Barriers to Adaptation

The role adaptation plays in reducing the adverse impacts of climate and rainfall variability cannot be over emphasised (IPCC, 2007; 2012; 2014; Adger et al., 2007). In recent times however, a gap exist between the actual existing climatic impacts and the on-going adaptation process due to the barriers to adaptation (UNEP, 2014).

Existing literature identifies the barriers to adaptation which can broadly be classified as: physical and ecological; technological; financial; information and knowledge; and social and cultural barriers to adaptation (UNEP, 2014; Burton, Diringer, & Smith, 2006).

2.2.1 Physical and Ecological Barriers

Various ecological studies have predicted that the magnitude and rate of climate variability will alter ecological systems considerably. Those physical and ecological systems will likely exceed their thresholds and therefore alter the normal functioning of the system (IPCC, 2007). Persistence of climate variability is projected to also alter the physical conditions of key environmental systems in certain regions and this has the potential to limit the adaptation possibilities (Yamba , Appiah, & Siaw, 2019).

2.2.2 Technological Barriers

Technology has greatly improved humanity in general and is expected to impact greatly on climate adaptation. Innovations in technologies for climate adaptation have provided adaptation needs and benefits of people through proper dissemination channels. Technologies that will enhance adaptation could be developed and transferred across nations especially to the developing world where adaptation needs are very high (Adger et al., 2007). However, technologies in itself has become a barrier to adaptation in climate change due to its reliance on internet and gadgets that are not readily deployable to areas where climate change effects are devastating (Mutunga, Ndungu , & Muendo, 2017).

2.2.3 Financial Barriers

The IPCC (2014) estimated that the global cost of adaptation will reach between $70 billion to $100 billion by 2050 (Nelson, 2009; IPCC, 2014). However, estimates from the World Bank indicate a total of $10 billion to $40 billion for the same estimated period (UNEP, 2014). This varies from country to country. Irrespective of the figure, adaptation to climate variability is limited financially especially in developing countries where smallholder farmers struggle to meet adaptation needs. The high incidence of poverty, inadequate financial resources for simple farm implements and difficulty in obtaining inputs limits smallholder farmers' adaptive capacity.

2.2.4 Information and Knowledge Barriers

The United Nations Environmental Program (UNEP), identified knowledge limitation in three phases, that is missing or incomplete knowledge, inadequate linkage between different bodies of knowledge and limited diffusion and translation of knowledge to decision makers. This could be described explicitly as gap in the production of knowledge in adaptation, integration and transfer (UNEP, 2014). The uncertainty which clouds climate variability together with individualised perception of risk associated with these variations influences adaptation decisions at both the local and national level.

2.2.5 Social and Cultural Barriers

Social and cultural beliefs and practices of people, as manifested in their varied interpretations, experience and response to issues, also influence adaptation to climate change (Yaro, 2013). These social and cultural diversities breed varied and diverse understanding of adaptation across the several groups of people (Umar , Man , Shuaibu, & Saleh, 2018).

3. Methodology

3.1 Study Area and Data Collection

The study was conducted in the Northern region where the rainfall pattern is affected by climate change. The region covers an area of about 70,383 square kilometres and bordered by the Upper East and Upper West regions to the north, Brong Ahafo and Volta regions to the south, and two neighbouring countries (the Republic of Togo to the east and Côte d'Ivoire to the west). The soil types are savannah-ochrosols, which develop under rainfall averages between 800 mm and 1,500 mm. There are predominantly medium sandy loams in the upland and valley (GSS, 2017).

Data for this study was obtained using multiple sampling techniques, where five districts (Yendi Municipal, Savelugu Municipal, Nanton District, Mion District and Tolon District) were randomly selected from the region. From each selected district, two communities were randomly selected. In the last stage, fourteen farming households were randomly selected from each community, giving a total of 140 households. The data was collected using a semi-structured questionnaire. The data was analysed using Stata and Statistical Package for Social Sciences (SPSS v.20).

3.2. Data Analysis

3.2.1 Negative Binomial Regression Model

Negative binomial Regression Model (NBRM) is used in analysing data with count dependent variables. Count dependent variables if treated as continuous dependent variable as in linear regression model can result in inefficient, inconsistent and biased estimates. The commonly applied count model is the Poisson Regression Model (PRM). The PRM assumes that the probability of a count is determined by a Poisson distribution, where the mean of the distribution is a function of the Instrumental Variables (IVs). The conditional mean of the outcome is also assumed to be equal to the conditional variance. In practice, however, the conditional variance often exceeds the conditional mean. The Negative Binomial

Regression Model (NBRM) deals with this problem by allowing the variance to exceed the mean. However, both the PRM and NBRM are based on the Poisson distribution:

NBR models the number of occurrences (counts) of an event when the event has extra-Poisson variation, that is, when it has over dispersion. The NBRM is given as;

$$y_i \approx Poisson(\mu_j) \tag{1}$$

$$Where \qquad \mu_j = \exp(X_j \beta + offset_j) \tag{2}$$

For observed counts y_i with covariates X_i for the j_{th} observation. One derivation of the negative binomial mean-dispersion model is that individual units follow a PRM, but there is an omitted variable V_j, such that e^{vj} follows a gamma distribution with mean 1 and variance α:

$$y_i \approx Poisson(\mu_j^*) \tag{3}$$

$$Where \qquad \mu_j^* = \exp(X_j \beta + offset_j + \mathrm{V_j}) \tag{4}$$

$$and \qquad e^{vi} \approx Gamma(1/\alpha, \alpha) \tag{5}$$

With this parameterisation, a Gamma (a; b) distribution will have expectation *ab* and variance *ab*^{2}.

We refer to α as the over dispersion parameter. The larger α is, the greater the over dispersion.

The Poisson model corresponds to $\alpha = 0$. The negative binomial model parameterises α as $\ln \alpha$ and fits two different parameterisations of the NBRM. The default, described above and also given by the mean dispersion, has dispersion for the j_{th} observation equal to

$\mu_j^* = \exp(X_j \beta + offset_j + \mathrm{V_j})$. This is seen by noting that the above implies that

$\mu_j^* \approx Gamma(1/\alpha, \alpha\mu_j)$

$$\textit{and}\ \text{thus} \qquad \begin{aligned} Var(y_i) &= E\{Var(y_i / \mu_j^*)\} + Var\{E(y_i / \mu_j^*)\} \\ &= E(\mu_j^*) + Var(\mu_j^*) \\ &= \mu_j(1 + \alpha\mu_j) \end{aligned}$$

The empirical model is stated as

$$y = \beta_0 + \sum_{i=1}^{10} X_i \beta + \mu \qquad \text{...(6)}$$

The variables are defined in Table 1.

Table 1: *Variables and their Measurement*

Variable	Measurement
Sex	Dummy: 1=Male, 0=Female
Credit	Dummy: 1=Accessed credit, 0=otherwise
Age	Total number of years
Household size	Number of people leaving and sharing same household resources
Education	Dummy: 1=Have formal education, 0=otherwise
Extension	Dummy: 1=Have extension contact, 0=otherwise
Land ownership	Dummy: 1=Self owned, 0=otherwise
Farm size	Total number of acres cultivated by farmer
Maize output	Total kilogram of maize harvested by farmer
Income	Ghana Cedis

Source: Author, 2019

3.2.2. Kendall's Coefficient of Concordance

According to Legendre (2005), the Kendall's coefficient of concordance *(W)* is given by the relation

$$w = \frac{12s}{P^2\left(n^3 - n\ \right)} - p^t \tag{7}$$

Where: W represents the Kendall's coefficient of concordance; P denotes the number of respondents ranking the challenges, n denotes the number of quality perceptions and t denotes correction factor for tied ranks, while s denotes the sum of squares statistics over the row sum of ranks (Ri). The sum of square statistics (*S)* is given as:

$$S = \sum_{i-1}^{n} \left(R_i - R\right)^2 \tag{8}$$

Where R_i is row sums of rank and R is the mean of R_i. The correction factor for tied ranks (T) is also given as:

$$\text{T=} \sum_{k-1}^{m} \left(t^3 - t_k\right) \tag{9}$$

Where t^3 is the number of ranks in each of *m* group of ties

The test of significance of the Kendall's coefficient of concordance was done using the chi-square statistics which is computed using:

$$X^2 = P(n-1)W \tag{10}$$

The null hypothesis for the Kendall's is that, there is no agreement among respondents on the challenges limiting adaptation. If the calculated chi-square is greater than the critical chi-square, then the null hypothesis is rejected in favour of an alternative hypothesis that there is agreement among the ranking of the constraints by the respondents.

4. Results and Discussions

4.1 Socio-Characteristics

Table 2 presents the descriptive statistics of the variables used in the model. The result shows that 58% of the respondents were males and the remaining 42% were females. This is in line with the sex distribution of farmers in Ghana, where male farmers dominate due to the fact that women are usually relegated to the kitchen and home. Access to credit is low (33%) among the respondents as the majority of the respondents (67%) do not have access to credit to facilitate their farm activities. The results further reveal that on average, a farmer from the sample is 49 years old.

The average household size of the respondents was 8 persons, with a minimum household consisting of two (2) persons and the maximum household of thirty (30) persons. The level of education among the respondents is very low since only 33% of the respondents had some level of formal education, even though this is consistent with the low level of education among farmers in Northern Ghana. Access to extension services is also below average (45%), indicating that high percentage of the farmers do not have access to extension services. This is likely to affect the level of adaptation to the irregular rainfall pattern especially the modern strategies that farmers need more education and training from experts. The average farm size of the respondents is 1.87 acres. However, the minimum farm owned is 1 acre and the maximum is 3 acres giving an indication that the sampled farmers are smallholder farmers. The average quantity harvested by an average farmer is 225 Kg, with a minimum of 100 Kg and a maximum of 400 Kg. Farmers earn an average income of GH₵162.00, with a minimum income of GH₵70.00 and a maximum of GH₵420.00.

Table 2: *Descriptive Statistics of Respondents*

Variable	Mean	Min	Max
Sex	0.58	0	1
Credit	0.33	0	1
Age	42.85	30	75
Household size	8.06	2	30

Education	0.33	0	1
Extension	0.45	0	1
Land ownership	0.56	0	1
Farm size	1.87	1	3
Maize output	225	100	400
Income	162.00	70	420

Source: Authors' computation, 2019

4.2. Adaptation Strategies to Irregular Rainfall

Table 3 presents the various adaptation strategies to the irregular rainfall pattern. The results indicate that high percentage of the respondents (98.6%) practice at least one adaptation strategy to irregular rainfall pattern in Northern Ghana whilst a few of the farmers (1.4%) do not. The results further show that the most common adaptation strategy used is changing planting dates (98.6%), followed respectively by ridging (86.4%), mixed cropping (70.7%) and mulching (57.9%). On the other hand, the least practiced adaptation strategies were weather insurance (1.4%), irrigation use (8.6%), improved weather forecast (10.7%) and use of early maturing seeds (55.7%). It can be observed that most of the strategies commonly used are the indigenous adaptation strategies whilst the modern strategies are rarely used. This situation may be as a result of the cost and the difficulty in comprehending these modern strategies.

Table 3: *Irregular Rainfall Adaptation Strategies*

Adaptation Strategy	Mean (proportion)	Std. Dev.	Min	Max
Changing planting dates	0.986	0.119	0	1
Ridging	0.864	0.344	0	1
Early maturing seeds	0.557	0.499	0	1
Weather insurance	0.014	0.119	0	1
Mulching	0.579	0.46	0	1
Irrigation	0.086	0.281	0	1
Improved weather forecast	0.107	0.310	0	1
Mixed Cropping	0.707	0.457	0	1

(Source: Authors' computation, 2019)

4.3. Factors Influencing Farmers' Adaptation to Erratic Rainfall

The determining factors that stimulate adaptation to irregular rainfall patterns are presented in Table 4. The significance of the chi-square statistic (32.92) summary statistics of the NBRM revealed that at least one of the regression coefficients in the model is not equal to zero, hence, the negative binomial regression model is appropriate in measuring the influencing factors on adaptation strategies.

The results of the NBRM show that access to credit, education, extension service, and income have positive influence on adaptation to irregular rainfall pattern. On the other hand, gender, age and output harvested negatively affect adaptation in a significant manner.

The estimated positive coefficient of extension means that farmers with access to extension officers adopt 0.376 units more of adaptation strategies than those without access to extension services, holding all other variables in the model constant. The Incidence Rate Ratio (IRR) for extension indicates that compared to those without access to extension, farmers with extension are expected to have a rate of 1.457 times greater for the number of adaptation strategies, holding other variables in the model constant. Also, educated farmers and farmers with access to credit have 0.551 and 0.526 logs higher than the farmers who are not educated and those without credit, respectively. Moreover, income represents the negative binomial regression estimate and this suggests that for a GH₵1.00 increase in the income of farmers, the adoption of adaptation strategies increase, holding other variables in the model constant. The IRR for income shows that with an increase in income by one GH₵1, rate for number of adaptations would be expected to increase by a factor of 1.005, holding all other variables in the model constant.

Gender of the farmer had a negative effect of the number of adaptation strategies adopted by the farmer. This means that the female farmers adopt more strategies than male farmers. The IRR for Gender indicates that compared to males, females are expected to have a rate of 0.502 times less for adaptation.

Age and quantity harvested are negatively related with the number of adaptation strategies. The coefficient of age is 0.016 indicating that a year increase in the age of a farmer is expected to decrease the number of adaptation strategies marginally by a factor 0.016. This gives an indication that the number of adaptation strategies decreases as a farmer gets older. Also, an increase in output by one Kg will decrease the number of adaptation strategies by a factor of 0.463, holding other factors in the model constant. This is contrary to the expectation that large producers are likely to combine more strategies to adapt to the irregular rainfall pattern in the northern region.

Table 4: *Smallholder Adaptation to Irregular Rainfall Pattern*

Variables	Coef.	IRR	Std. Err.	P>z
Sex	-0.689[a]	0.502[a]	0.186	0.000
Age	-0.016[c]	0.984[c]	0.009	0.079
Household size	0.023	1.023	0.019	0.222
Extension	0.376[b]	1.457[b]	0.183	0.039
Land ownership	-0.112	0.894	0.184	0.541
Education	0.551[a]	1.734[a]	0.193	0.004
Credit	0.526[a]	1.692[a]	0.183	0.004
Farm Size	0.041	1.042	0.055	0.460
Maize output	-0.463[a]	0.629[a]	0.168	0.006
Income	0.005[b]	1.005[b]	0.002	0.013
Constant	1.085[b]	2.958[b]	0.523	0.038
Lnalpha	-0.908		0.276	
Alpha	0.403		0.111	
Number of obs		**140**		
LR chi2(10)		**32.92**		
Dispersion		**Mean**		
Prob > chi2		**0.0003**		
Log likelihood		**-266.08918**		
Pseudo R square		**0.0583**		
Likelihood-ratio test of alpha=0: chibar2(01) = 39.05 Prob>=chibar2 = 0.000				
Where a, b and c represents significance at 1%, 5% and 10% levels				

(Source: Authors' computation, 2019)

4.4. Challenges to Climate Change Adaptation

Result of the Kendall's coefficient of concordance is presented in Table 5. The result indicates that there is about 40% level of agreement amongst the respondents at 99% level of confidence. From the ranking, the lower the mean estimate the severe the challenge, and vice versa. The results reveal that out of the eight challenges identified, lack of access to finance or credit is the main constraint that affects adapting to irregular rainfall patterns in Northern region. This was followed by inadequate irrigation facility which has a mean rank of 3.30 and then lack of access to information on appropriate adaptation strategies which has a mean rank of 4.17. The educational level as a challenge to adapting to the rainfall pattern has the highest mean rank of 5.87 indicating that it is the least ranked challenge among the set of challenges presented to the respondents. This could be attributed to the fact that most of the farmers use the indigenous adaptation as against the modern strategies. They are more comfortable and conversant with those indigenous strategies. They learn more from informal sources than from the formal ways. Unreliable weather forecast had a mean rank of 5.47 and ranked as the 7th most important challenge. Although the farmers complained of the scarcity of timely information on weather forecast, this does not have much effect on their adaptation decisions since they are able to rely on their personal and traditional weather predictions.

Table 5: *Kendall's Coefficient Estimation of the Factors Inhibiting the Adaptation to Irregular Rainfall Pattern*

Challenges	Mean Rank	Rank
Rank of Finance/Credit	1.30	1st
Rank on inadequate irrigation facilities	3.30	2nd
Rank of negative response from strategies adopted	4.17	3rd
Rank on cost of adoption	4.87	4th
Rank on access to information on appropriate adoption strategies	5.28	5th
Rank on access to extension	5.47	6th
Rank on unreliable weather forecast	5.74	7th
Rank of Educational background	5.87	8th
N	**140**	
Kendall's W[a]	**0.403**	
Chi-Square	**936.424**	
Df	**7**	
Asymp. Sig.	**0.000**	
a. Kendall's Coefficient of Concordance		

(Source: Authors' computation, 2019)

5. Conclusion and Recommendations

This study examined how smallholder farmers in Northern Ghana adapt to irregular rainfall pattern resulting from climate change. The study analysed cross sectional data from 140 farmers using Negative Binomial Regression Model (NBRM). The result of the study indicates that most farmers change planting dates and practice mixed cropping to neutralise the expectant effects of irregular rainfall pattern. On the other hand, the least practiced adaptation strategy is weather insurance, irrigation use and improved weather forecast. This therefore reveals limited adoption of modern agricultural practices in combating the devastating effects of climate change.

The results of the NBRM reveal that access to extension services and credit influences the number of adaptation strategies to the rainfall pattern positively whilst quantity of output harvested, gender and age negatively influence the number of adaptation strategies adopted. In addition, the Kendall's analysis of the constraints to adaptation indicates inadequate agricultural credit, inadequate irrigation facilities, and negative response from strategies adopted as the top three ranked challenges.

Based on the findings, the study recommends that the Ministry of Food and Agriculture (MoFA) increases extension services and advocacy to promote the adoption of modern farming practices such as rainfall insurance and reliance on weather forecast. Also, government's effort is needed in developing irrigation facilities and providing agricultural credit to enable smallholder farmers offset the devastating effects of climate change.

The forms and effectiveness of climate change communication is as important as the climate change mitigation strategies. Therefore, future studies on smallholder adaptation should examine this important aspect. This is because a high percentage of smallholder farmers are illiterates and hence, the effectiveness of the communication will enhance acceptability of modern adaptation practices.

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