Farmers’ choice of adaptation strategies towards weather variability: Empirical evidence from the three agro-ecological zones in Ghana

Isaac Dasmani1*, Kwabena Nkansah Darfor2 and Alhassan Abdul-Wakeel Karakara3

Abstract: This study analyzed factors that influence farmers’ choice of adaptation strategies toward weather variability and food crop production. The study used a cross-sectional data from 622 randomly selected farmers from 18 Villages across the three major agro-ecological zones using structured questionnaire. The study hypothesized that farm characteristics, climatic variables and extreme weather events had no significant influence on farmers’ choice of various adaptation strategies across the three agro-ecological zones. Employing Multinomial logit Model, the results indicated that irrigation farming, income-generating activities, crop diversification, tree planting and shifting planting dates are some of the adaptation strategies farmers used to adapt to changes in the weather and other related factors. The study thus recommends the intensification of the use of these strategies.
adaptation strategies through support from government and other stakeholders to help the farmers to cope very well with the vagaries of the weather and improve food crop production in Ghana.

**Subjects:** Agriculture & Environmental Sciences; Economics; Environmental Economics

**Keywords:** adaptation strategies; weather variability; food production; multinomial logit and agroclimatic zones

**JEL classification:** C12; C13; C25; Q12; Q54; Q57

1. Introduction

In the developing countries, there are general concerns about the effect of weather changes on food crop production, especially, in Sub Saharan Africa (SSA) where most of the farmers are peasant and only produce to support their households (Dang et al., 2019). Scholars have noted some changes in global climate to include the rise of land and ocean surface temperatures by 0.65 to 1.06 °C between 1880 and 2012, sea level rise, a decrease of the Arctic ice volume and the increase of warm days and nights (Stocker et al., 2013). Also, extreme weather events such as droughts, storms and floods have also been on the increase (United Nations Development Programme [UNDP], 2015). Climate change and variability are projected to affect different regions of the world in different ways (Antle, 2008; Rosegrant et al., 2008). Sub-Saharan Africa, are expected to be more adversely affected by climate change and variability due to overreliance on natural climatic conditions for agricultural production, lack of resources to adapt effectively, poor infrastructure and poor planning and policies (Kabubo-Mariara & Kabara, 2015; Ngaira, 2007).

The trend in food crop production globally has witnessed an increase from 850 million tons in 1960 to 2.35 billion tons in the years 2000s. Per capita food consumption has also increased from 2,803kcal/day, in the years 2000s, to approximately 2,940 kcal/day, in the last decade (Food and Agricultural Organization, 2015). Some reasons for such increase are: intensified food farming systems; appropriate research; technological development; functioning institutions; and good policy guidelines and this could also serve as barriers to farmers’ climate adaption-crop production synergies if they are lacking (Intergovernmental Panel on Climate Change [IPCC], 2007). However, in SSA, the story is different as the sub region has experienced deteriorating food production (IPCC, 2007) making it difficult for most of the countries to meet the United Nations Millennium Development Goals (MDGs) of reducing hunger by half by half by 2015 and these countries might not also meet the United Nations Sustainable Development Goals—SDGs (specifically goal one) if efforts and policy does not reorient in a way to understanding the lapses in agriculture.

Besides, weather variability has increased the rate of extreme events such as droughts and floods that have adversely affected the food security situation in SSA (Hassan & Nhema, 2008). Droughts and floods have prolonged and increased in frequency leading to crop failures and damages (UNDP, 2015). In addition, high population growth in the SSA region has worsened the impacts of climatic change (Kabubo-Mariara & Kabara, 2015). This has exerted pressure on land leading to land fragmentation and continuous cultivation without traditional fallows (Ajay et al., 2008). In Ghana, like most countries in SSA, weather variability has disrupted farming systems through crop failures and damages. This has resulted in shortfalls in food crop production, hunger and malnutrition (International Food Policy Research Institute [IFPRI], 2014). Droughts and floods impede poverty reduction efforts as stipulated in the Ghana Shared Growth and Development Agenda paper (GSGDA, 2010). Following the impacts of climate variability on farmers’ food production and food security, a number of interventions are encouraged to help farmers contain climatic and weather variability related impacts in the ecological zones.

Ghana, with an estimated population of about 25 million people and a gross domestic product of about US$5.8 billion, is one of the developing countries in SSA that is heavily dependent on
agriculture (International Monetary Fund, 2014). However, presently, food productivity does not meet the food demand due to, in part, high population growth and deteriorating soil productivity that has been exacerbated by weather variability (Alhassan et al., 2019; Amikuzuno et al., 2019). Unpredictable climatic indicators induce excessive soil erosion that has led to loss of soil fertility. In Ghana, improved food productivity is very critical to the country’s socioeconomic development. As such, the government has developed a number of programs to help farmers adapt to changes in climate/weather and other related factors (Adu et al., 2019; Armah et al., 2019; Sadiq et al., 2019). There is the need to understand how farmers adapt to weather variability for some reasons. First, weather variability affects crop yield and lack of knowledge on it could lead farmers to achieve crop failure, which affects their welfare, since smallholders depend much on their agricultural activities. Second, to achieve food sufficiency and security to enable a country achieve goal 1 (Eradicate Extreme Hunger and Poverty) target 1 C (Food security and hunger) of the Sustainable Development Goals—SDGs there is the need to concentrate on farmers (smallholders) and weather is a major factor that affect them. Thus, improving their knowledge on weather related and adaptive strategies could help in this direction. Gbetibouo (2009) noted that lack of information and knowledge on the part of farmers’ serves as a barrier to farmers’ adaptive strategies.

Generally, the impacts of weather or climate changes on farmers’ and the strategies farmers adapt to cope with that is widely recognized in the literature (Bate et al., 2017; Dong et al., 2019; Ragasa & Akriso, 2019; Ubisi et al., 2017). Ragasa and Akriso (2019) indicated that perceived severity of climate change, perceived susceptibility to climate change threat, perceived own ability to respond, response efficacy, and cost of practices predicted farmers’ motivation to practice climate change adaptation and mitigation strategies. While Ubisi et al. (2017) found that subsistence farmers perceived prolonged droughts as the main shock stressing crop production and strategies these farmers adapt to include; changing planting dates, engaged in crop variety and diversification and mixed cropping. The authors finally indicated that smallholder farmers tend to adapt better when they have access to extension officers. Also, Bate et al., (2019) summarized that farmers have adopted rainfall-related adaptation and resorted to temperature-related adaptation in Cameroon. They indicated that access to road, access to non-farm income source, and membership of farmers’ groups were significant determinants for the adoption of temperature-related adaptation options while access to improved seeds is significant determinant for the adoption of rainfall-related adaptation options.

Though there is extensive literature on the synthesis of weather variability on farmers’ yields but they mainly focus on farmers’ perceptions and adaptations (Gbetibouo, 2009; Juana et al., 2013; Patt & Schröter, 2008) rather than factors affecting farmers’ adaptation. Thus, there are limited studies (especially in SSA) about what factors influence farmers’ choice of adaptation strategies and what the impact of such adaptation strategies on farmer food production.. Furthermore, few or no studies have addressed the question of why farmers combine a number of strategies to adapt to climatic and weather variability effects. Also, there is no much study in relation to Ghana. Therefore, the objective of this paper is to analyze factors that influence farmers’ choice of adaptation strategies to weather variability across the different agro-ecological zones. What are the adaptive strategies farmers adopt towards climatic and weather variability in the three agro-ecological zones? Is there any difference in these strategies across the three ecological zones? Do these adaptive strategies have economic implications on food crop production? These are the specifics this study seeks to uncover. Aggarwal et al. (2010) observed that research on farmers’ adaptation strategies offers better policy options on how to integrate adaptation strategies in food security projects. Using data collected from 622 farmers, randomly selected across three ecological zones in Ghana, this study explores factors that influence farmers’ choice of adaptation strategies to inform decision makers on the better design or implementation of weather variability adaptation programmes. The study further highlights adaptation strategies’ economic impacts on food crop production. This information is important for the design of effective climatic and food security related projects across the agro-ecological zones in Ghana. The rest of the paper is organized as follows; Section 2 presents the theoretical and empirical literature used in the study and this is followed by modeling farmers’ choice of adaptation strategies.
towards weather variability in Section 3. Section 4 contains results and discussion on the estimations. Conclusion and policy implication of the study are captured in Section 5.

2. Review of theoretical and empirical literature

Theoretically, social-ecological systems analysis advocates that human action and social setting where the human finds him-self are importance social structure of nature (Adger, 2006). However, humans at certain periods may be threatened either resulting from their actions or inactions, leading to vulnerability. Vulnerability refers to the states of being susceptible to harm that can be attributed to environmental and social changes without adaptive capacity (Adger, 2006). Adaptation is the ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’ (IPCC, 2007, p. 869). Adaptation in agriculture was defined as how the perception of the farmers was translated into agricultural decision process. It also indicates a set of actions that the farmers need to take in order to maintain the capacity to cope with the climate change (Halsnaes & Traerup, 2009; Nelson et al., 2010).

There are some number of empirical studies on climate change and weather variability, adaptation, crop production and household food security across the globe (Afroz & Akhtar, 2017; Bate et al., 2019; Dang et al., 2019; FAO, 2007; Ragasa & Akirso, 2019; Tessema, 2019; Ubisi et al., 2017). However, most of these studies have concentrated on the impacts of climatic variability on food crop production and less on the factors that influence farmers’ choice of adaptation strategies (Aggarwal et al., 2010; Akpalu et al., 2008; Hassan & Nhemachena, 2008). Despite limited research on climatic and weather variability adaptation, most food crop production require information on how households would adapt to the effect of climatic and weather variability. Maddison (2006) applied a Heckman model to determine factors that influence adoption of adaptation strategies towards climatic and weather variability in Africa. The study revealed that education, gender, extension and experience significantly influenced households in adapting towards climatic change. It was found that education and gender increased the probability of adoption of adaptation strategies by 0.03% and 6%, respectively. The study recommended that education and extension should be emphasized to appropriately adapt towards changes in climate. Furthermore, lack of appropriate seeds, credit accessibility, security of tenure and market accessibility were some of the barriers to household adaptation.

In a similar study, Deressa (2006) also employed a Heckman model to assess the determinants of household adaptation to climate change in Ethiopia. The study found that household size and gender, availability of credit and temperature had positive influence on household adaptation to climate change. For instance, credit accessibility and climatic information increased household likelihood of adopting adaptation strategies by 48% and 37%, respectively. Favourable temperature and precipitation increased the probability of household adoption of adaptation strategies by 18% and 12%, respectively. It recommended mainstreaming of credit accessibility in household farming projects. Action Aid (2006) assessed farmers’ adaptation strategies towards climatic change and variability in the Southern part of Malawi. It was found that most households in Malawi do not have sufficient capacity to cope with challenges posed by climatic change and variability. However, the study did not estimate the impacts of adaptation strategies on household food production and food security. In another note, on Malawi, Pauw et al. (2011) used an economy-wide general equilibrium model to study the impacts of drought and floods on the Malawian economy. Empirical results showed that droughts and floods were associated with losses of 1.7% in GDP. It was recommended that adaptation have to be intensified in order to counteract the adverse impacts of droughts and floods.

Two separate studies, Nangoma (2007) and Environmental Affairs Department Environmental Affairs Department (2006) identified improved varieties, irrigation farming, shifting cropping dates and crop diversification as some of the household adaptation strategies to climatic and weather variability in the Southern Malawi. Langyintuo and Mekuria (2008) used a Tobit model to analyze the effects of household characteristics on adoption of improved varieties among...
Mozambican farmers. The study found a significant contribution of social networks to technology adoption. It was suggested that government should invest in farmers' associations to facilitate high technology adoption. On the other hand, Akpalu et al. (2008) investigated the impacts of climate change and weather variability on maize yield in the Limpopo Basin of South Africa using the Generalized Maximum Entropy Leuven Estimators. Their results showed that precipitation increased maize yield by 42% while temperature enhanced maize yield by 38%. In addition, irrigation improved maize yield by 32%. Similarly, Kato et al. (2011) studied the impacts of soil and water conservation on crop production using a Cobb-Douglas production function in the low and high rainfall areas of Ethiopia. The results showed a significant contribution of soil and water conservation on household food production. For instance, it was found that soil and water conservation technologies increased production by 4% and 25% between the low and high rainfall areas, respectively. Besides, it was reported that grass trip improved production by 32% and 15% between the low and high rainfall areas, respectively. Kato et al. (2009) also found that irrigation increased production by 4% among low rainfall areas and a 25% reduction in food production among high land households. These results suggest that soil and water technologies performed differently in different agro-ecological regions of Ethiopia. This underscored the importance of geographical targeting when promoting and scaling up soil and water conservation technologies.

Kurukulasuriya and Mendelsohn (2006) used a Structural Ricardian model using data from 11 SSA countries to study the impacts of climatic change on farm level net revenues. The study results showed that an increase in temperature was associated with losses of US$23 billion for dry land and US$16 billion for all African croplands. Also, increases in precipitation and irrigation were associated with a gain of $97 billion and $1 billion per year in most African croplands. Furthermore, Mendelsohn and Dinar (2009) employed a Ricardian model to assess the impact of adaptation on agricultural production in India and they found that adaptation strategies increased production by 15% to 23%. However, it was revealed that access to credit, extension and information on rainfall and temperature constrained household adaptation to climatic and weather variability.

Similarly, Molua and Mlambi (2008) applied a translog production function to assess the impact of climate change on crop farming activities in Cameroon. Empirical results revealed that a 2.5°C and 5°C increase in temperatures reduced farm level net revenues by $0.5 and $1.7 billion, respectively. It was also found that a 7% decrease in precipitation decreased net revenues by $1.96 billion. Net revenues were estimated to have risen by $2.9 billion in mild and wet climate from US$1 billion. The study concluded that precipitation and temperature remained the dominant determinants of cultivatable farming practices in Cameroon. Rowhani et al. (2010) studied the impacts of precipitation on household crop yield in Tanzania. The study findings indicated that a 20% increase in precipitation reduced agricultural yields by 3.6%, 8.9%, and 28.6% for maize, sorghum and rice, respectively. Benhin (2006) found similar results in South Africa where he assessed the economic impact of climatic change on crop farming. It was depicted that an increase in temperature reduced net revenue by US$2,637 and US$880 between irrigated and dry-land areas of South Africa, respectively. On the other hand, increase in precipitation improved net revenue of dryland areas by US$22 from US$10.

Most studies have proposed specific studies and technologies to address climatic change impacts and household adaptation in specific locations (Aggarwal et al., 2010; Deressa, 2006; Fatuase & Ajibefun, 2013; Kato et al., 2011; Shongwe & Manyatsi, 2014; Global Water Initiative, 2014; Uddin et al., 2014). This study employs a Multivariate Analysis to model factors that influence households' choice of adaptation strategies in low and highland areas of Chikhwawa district. Studies conducted in Malawi have mainly assessed the impacts of climatic change on food production and food security (Action Aid, 2006; Gomani et al., 2007). However, research on the existing adaptation measures practiced by the farmers' and the determinant factors that affects farmers’ choice of adaptation in different agro-climatic zone is very limited. Understanding the factors associated with adaptation would help policy makers for future
intervention to address the challenges of sustainable development to climate variability. Thus, the main purpose of this study was to identify the determinant factors that affect farmers’ choice of adaptation in the three-agro-climatic zones in Ghana. This study applied the multinomial logit model to examine the various adaptation strategies adopted by farmers in different agro-ecological zones.

3. Data and methodology

3.1. Data

A Multi-Stage Sampling Method was used to randomly select 622 households from the sample frame list. Sample frame list was collected from District Agricultural Office of the three randomly selected Districts from each agro-ecological zones. Firstly, districts within each of the agro ecological zones (coastal, forest and savannah) were identified based on the differences in topographical vulnerabilities. Secondly, District agricultural extension officers in each selected district were also identified. Thirdly, the study selected 46 villages from which it randomly sampled 622 farmers. Lastly, a probability proportional sampling method was applied for a representative sample size. From 622 farmers, the study collected data using a household questionnaire. A household survey is used mainly because in Ghana, mostly in the rural areas, farming/agricultural activities still a household affair. The impact of climate variability is felt at the household level and increases the risk faced by farmers in Ghana. Thus, household survey gives a better picture on smallholders’ decision on agricultural activities. The primary data included household characteristics, food production, food availability as well as climatic and weather variability. Description of the variables in the study is captured in Table 1.

3.2. Methodology

3.2.1. Farmers’ choice model of adaptation strategies

We developed a theoretical framework for this paper following a random utility theoretical structure. A random utility model describes a choice decision in which an individual has a set of alternative adaptation strategies from which to choose (McFadden, 1978). It is assumed that

| Variables               | Measurements                        | Variable                      | Measurements   |
|-------------------------|-------------------------------------|-------------------------------|----------------|
| Gender                  | 1 = Male; 0 = female                | Drought                       | 1 = Yes; 0 = No|
| Household size          | Number of people                    | Soil erosion                  | 1 = Yes; 0 = No|
| Education               | Years                               | Flood                         | 1 = Yes; 0 = No|
| Labour                  | Person-days                         | Extreme weather conditions    | 1 = Yes; 0 = No|
| Farm size               | Area Cultivated                     | Irrigation                    | 1 = Yes; 0 = No|
| Age                     | Years                               | Green Manure                  | 1 = Yes; 0 = No|
| Income                  | GHS                                 | Cropping Pattern              | 1 = mixed cropping; 0 = monocropping |
| Extension               | Number Visits                       | Variation in Planting Dates   | 1 = Yes; 0 = No|
| Rainfall                | 1 = increased; 0 = reduced          | Use of Improved Varieties     | Kg/acre        |
| Temperature             | 1 = increased; 0 = reduced          | Local seeds                   | Kg/acre        |
| Fertilizer              | Kg/Acre                             | Crop diversification          | 1 = Yes; 0 = No|
| Climate Information     | 1 = Yes; 0 = No                     | Yield                         | Kg/acre        |

Source: Authors’ fieldwork
each adaptation alternative has its attributes, which also influence the individual’s choice over another alternative. The random utility model helps us address how farmers make choices over alternative adaptation strategies. The model is based on the notion that an individual derives utility by choosing a number of alternatives. The utilities are latent variables, and the observable preference indicators manifest the underlying utilities. Based on theoretical framework, the empirical specification of the Multinomial Logit Model (MNL) has the following response probabilities:

\[
p(Y = j/X) = \frac{\exp(\beta_j^T X)}{\sum_{j=0}^{J} \exp(\beta_j^T X)}
\]

where \( \beta_j \) is a \( K \times 1 \) vector and \( j = 0, 1, 2, \ldots, J \). Equation (1) can only provide the direction of the effect of contextual background on choosing a particular adaptation strategy. The marginal effect is obtained by differentiating equation (1) with respect to independent variables of interest. The marginal probability for a typical independent variable is given as:

\[
\frac{\partial P(Y = j/X)}{\partial X_k} = P(Y = j/X) \left( \beta_{jk} - \sum_{j=0}^{J-1} P_j \beta_{jk} \right)
\]

The study examined factors that influenced farmers’ choice of various adaptation strategies at the farm level. Socioeconomic characteristics, climatic variables and extreme events are modelled to assess whether they have influence on farmer choice of adaptation strategies. The study assessed factors that influence choice of adaptation strategies in the three major agro ecological zones in Ghana—coastal, forest and savannah by employing a conditioned multinomial logit analysis. It considered adaptation strategies such as irrigation farming (IF), improved varieties (IV), income generating activities (IGA), shifting planting dates (SPD) and crop diversification (CD) as dependent variables. Application of information on climatic and weather variability is a base outcome of the study.

To ensure that results of the study are robust, we carried out the following tests to assess the presence of heteroskedasticity and multicollinearity. Through the Breusch Pagan, White and Cameron and Trivedi Decomposition tests, the study found varying variances (heteroskedasticities) over various dependent variables.

4. Results and discussion

4.1. Descriptive statistics

This paper explores the effect of household characteristics such as education; age, farm size, labour, income and gender of the farmer that influence the level of understanding and application of any agricultural technology (Edriss, 2003). Table 2 shows that females farmer are about 32%, 38% and 11% of the households in coastal, forest and savannah zones, respectively. Conversely, Table 2 shows that males 78%, 72% and 89% of the coastal, forest and savannah farms. The mean age of farmers are 38 within the coastal zone, 35 within the forest zone and 42 within the savannah agro zone. This is in conformity with NSO (2008) who found out that farmers in Malawi are in the economically active group of 25 to 49 years. Table 2 shows no substantial difference in the level of education of the farmers across the agro ecological zones. From the table, it can also be observed that most farmers had completed at least primary school. Again, in terms of household size, the average household size in the forest and savannah zones was five whereas that of the coastal zone was four. Furthermore, the results revealed that all the three zones (coastal, forest and savannah) have 4.2, 5.3 and 4.6 acres of farm size on the average respectively. The mean household income for coastal, forest, and savannah zones was GH¢476.35, GH¢420.45, and GH¢512.16 respectively.
4.2. Adaptation strategies

The study found that almost all households adopted at least one of the adaptation strategies to improve food production and meet their food security needs. In addition, the study found out that most strategies have been in practice for decades. We highlighted that the use of these strategies have been intensified in recent decades due to prolonged droughts and floods’ occurrences that have been exacerbated by variability in climate and weather. Households adopted strategies such as irrigation farming, crop diversification, income generation activities, shifting planting dates and improved varieties. In percentage terms, 84% of the farmers in the coastal zone, 69% of the farmers in the forest zone and 58% of the farmers in the savannah zone grow improved varieties. It is widely acknowledged that improved varieties had advantages over local varieties because some of them having the capacity to produce high yield in spite of droughts and floods.

As regards crop diversification, 77% of the farmers in the coastal zone, 64% in the forest zone and 56% in the savannah zone diversified their crops. Some of the reasons adduced for crop

| Table 2. Farmers’ Socio-economic Characteristics and Adaptation Strategies |
| --- |
| Variable | Coastal | Forest | Savannah |
| --- | --- | --- | --- |
| Age | 38.9 | 14.06 | 35.56 | 18.09 | 42.58 | 15.35 |
| Gender | | | | | | |
| Male | 78% | 0.65 | 62% | 0.56 | 89% | 0.73 |
| Female | 32% | 0.32 | 38% | 0.45 | 11% | 0.21 |
| HH_size | 4.35 | 2.14 | 5.92 | 2.58 | 5.23 | 3.24 |
| Education | 5.56 | 1.34 | 6.56 | 3.45 | 5.78 | 2.54 |
| Labour | 3.24 | 1.73 | 4.56 | 2.11 | 4.67 | 3.24 |
| Farm size | 4.23 | 2.11 | 5.35 | 3.42 | 4.56 | 2.34 |
| Income | 476.35 | 245.45 | 420.45 | 324.56 | 512.16 | 345.23 |
| Extension officer visit | 54% | 0.54 | 46% | 0.65 | 63% | 0.45 |
| Temperature | 78% | 0.45 | 92% | 0.35 | 83% | 0.65 |
| Rainfall | 86% | 0.46 | 89% | 0.30 | 85% | 0.46 |
| Fertilizer application | 3.5 | 1.34 | 2.76 | 0.45 | 4.4 | 1.53 |
| Climate information | 78% | 0.45 | 69% | 0.36 | 75% | 0.56 |
| Drought | 84% | 0.40 | 54% | 0.50 | 74% | 0.44 |
| Extreme conditions | 47% | 0.12 | 56% | 0.34 | 48% | 0.21 |
| Use of Irrigation | 35% | 0.65 | 42% | 0.23 | 38% | 0.36 |
| Variation in Planting Dates | 66% | 0.56 | 84% | 0.35 | 77% | 0.56 |
| Green Manure | 67% | 0.55 | 53% | 0.24 | 48% | 0.36 |
| Soil erosion | 58% | 0.32 | 74% | 0.35 | 81% | 0.11 |
| Use of Improved Varieties | 84% | 0.30 | 69% | 0.45 | 58% | 0.43 |
| Crop diversification | 77% | 0.67 | 64% | 0.50 | 56% | 0.44 |
| Flood | 55% | 0.32 | 43% | 0.60 | 63% | 0.45 |

Source: Authors’ survey data 2018. Note: Std. Dev. means standard deviation; HH_size is household size.
diversification were that farmers diversify their crops in order to spread the risks and challenges presented by climatic and weather viability. In addition, food crop farmers grow other crops such as sorghum, cassava, yam and millet, other than maize to avoid the risk of food shortages during the lean season. Similarly, 66% of the farmers in the coastal zone, 84% in the forest zone and 77% in the savannah zone shifted crop-planting dates due to erratic rainfall and unfavourable temperatures. This implies that crops that were grown late encountered abrupt stoppage of rainfall and high temperatures. This resulted into lack of adequate water for proper crop growth and maturity. Furthermore, a substantial disparity over irrigation farming is depicted. The study results depict that 35% of the farmers in the coastal zone, 42% in the forest zone and 38% in the savannah zone irrigate their farms by using any form of irrigation practices. The study indicated that, low irrigation farming among the food crop farmers was due to lack of reliable water sources. Also 84% of the farms in the coastal zone, 54% in the forest zone and 74% in the savannah zone have adapted to reduce the effects of droughts. On the other hand, 55% of the farms within the coastal zone, 43% in the forest zone and 63% in the savannah zone have adapted to reduce the effects of floods.

![Table 3. Multinomial logit Model Estimates. Dependent Variable: improved Varieties](https://doi.org/10.1080/23311886.2020.1751531)

| Variable                  | Coastal dy/dx | Forest dy/dx | Savannah dy/dx |
|---------------------------|---------------|--------------|----------------|
| Age                       | 0.321* (2.02) | −0.521* (−1.82) | 0.499 (1.44) |
| Education                 | 0.784** (2.83) | 0.563 (0.98) | 0.356* (1.99) |
| Gender                    | 0.453 (0.78) | 0.230 (0.95) | 0.189 (0.87) |
| Labour                    | 0.234* (1.69) | 0.345** (2.98) | 0.034 (1.45) |
| Farm size                 | 0.045 (1.32) | 0.005* (1.78) | 0.021* (2.22) |
| HH_size                   | 0.653 (0.67) | 0.643 (1.34) | 0.541 (0.99) |
| Income                    | 0.432* (1.76) | 0.567 (1.33) | 0.622*** (3.11) |
| Extension officer visit   | −0.721 (−0.67) | 0.780 (0.86) | 0.231* (1.75) |
| Fertilizer application    | 0.452* (2.02) | 0.543* (1.74) | 0.345* (1.98) |
| Temperature               | −0.325 (−0.97) | 0.532 (0.55) | −0.433* (−2.36) |
| Rainfall                  | 0.402 (0.34) | 0.331* (2.90) | 0.209* (1.77) |
| Drought                   | −0.341 (−1.45) | 0.061* (3.78) | 0.072 (0.98) |
| Flood                     | −0.533* (−1.65) | 0.510 (1.35) | 0.455 (0.33) |
| Green manure              | 0.411* (1.93) | 0.341** (2.67) | 0.298* (2.34) |
| Soil erosion              | −0.221** (−2.78) | −0.321 (−0.56) | −0.440 (1.34) |

**Source:** Authors’ survey data 2018. Note: HH_size is household size; standard errors are within brackets; *; **, *** indicates significance at 10%, 5% and 1% respectively.
4.3. Factors that influence farmers’ choices of adaptation strategies

On our main interest of the study, factors that influence farmers’ choice of adaptive strategies are explained in Tables 3–7. After estimating our multinomial model we run post estimation test to ensure our estimation is robust. Robust test of the results was done to ensure that our model is good. The following tests; Breusch Pagan, White and Cameron and Trivedi Decomposition tests, found varying variances (heteroskedasticities) over various dependent variables. The presence of heteroskedasticity is remedied by a multivariate analysis (i.e. multinomial logit model) (Greene, 2003). On the other hand, the study found no multicollinearity among independent variables included in the models. Results from the Multinomial logit are presented and discussed in Table 3–7. The Log likelihood χ² showed that the multinomial logit model had a strong goodness of fit on assessing farmers’ choice of adaptation strategies in the three-agro ecological zones.

Table 3 reports how socio-economic factors impact on farmers’ decision to choose improved varieties in their farming behaviour.

The study found that farm characteristics such as education and age have significant influence on farmers’ choice of growing improved varieties. Statistically, education increased the prospect of growing improved varieties by 78% in the coastal and 36% in the forest zone. Age (i.e. experience)
of the farmer increased the likelihood of growing improved varieties by 32% in coastal areas while reduced the chances of growing improved varieties in the forest areas. Discussions with farmers indicated that the more years a farmer adds, the more the level of experience on a kind of crop variety to grow. Furthermore, farmers in the coastal areas have noticed that local varieties do quite well in both circumstances of climatic and weather variability. Labour employed by the farmer had a positive influence on farmers’ choices over growing improved varieties. Droughts augmented the prospect of growing improved varieties by 6% in the forest zone. Floods had negative effect on influencing farmers’ choices to grow improved varieties. For instance, the logit results show that floods reduced chances of growing improved varieties by 53% in the forest zone. Furthermore, it is depicted that green manure substantially enhanced the chance of planting improved varieties by 41% in the coastal zone, 34% in the forest zone and 30% in the savannah zone and 16%.

A number of farmers’ characteristics at 5% and 10% significance level influence crop diversification. Statistically, age (i.e. experience) of the farmer increased household choice of diversifying their crops by 8% in the coastal zone. Education of the farmer enhances the prospect of diversifying crops by 54% in the coastal zone, 83% in in the forest zone and 52% in the savannah zone. Besides, the study found that rainfall improved farmers’ likelihood of diversifying food crop especially maize to other crops by 5% and 70% in coastal and savannah areas respectively. Drought also increased farmers’ probability

| Table 5. Multinomial logit Model Estimates. Dependent Variable: Irrigation Farming |
|----------------------------------------|------------------|------------------|------------------|
| Variable                             | Coastal          | Forest           | Savannah         |
| Age                                  | 0.265* (1.93)    | 0.323 (0.04)     | 0.278** (2.89)   |
| Education                            | 0.592* (2.01)    | 0.154* (1.69)    | 0.072* (1.82)    |
| Gender                               | 0.389 (0.09)     | 0.53 (0.81)      | 0.790 (0.07)     |
| Labour                               | 0.525* (2.30)    | 0.779 (0.78)     | 0.374* (1.90)    |
| Farm size                            | 0.506 (0.78)     | 0.168 (0.94)     | 0.537 (0.66)     |
| HH_size                              | 0.002* (2.42)    | 0.634 (1.34)     | 0.204* (1.94)    |
| Income                               | 0.437* (2.12)    | 0.42* (1.68)     | 0.689** (2.78)   |
| Extension officer visit              | 0.654 (0.71)     | 0.735 (0.09)     | 0.449 (0.54)     |
| Fertilizer application               | 0.109 (0.33)     | 0.012 (0.24)     | 0.002 (0.07)     |
| Temperature                          | 0.351 (0.88)     | 0.789** (3.32)   | 0.203* (2.31)    |
| Rainfall                             | 0.153 (0.56)     | 0.489 (0.76)     | 0.222 (0.64)     |
| Drought                              | -0.187** (-2.33) | -0.103 (-0.98)   | 0.725* (1.79)    |
| Flood                                | -0.462** (-2.55) | 0.992 (0.34)     | 0.037* (1.81)    |
| Green manure                         | 0.242* (1.99)    | 0.901* (2.45)    | 0.061* (2.03)    |
| Soil erosion                         | 0.539 (0.56)     | 0.665 (0.79)     | 0.713 (0.46)     |

Source: Authors’ survey data 2018. Note: HH_size is household size; standard errors are within brackets; *, **, *** indicates significance at 10%, 5% and 1% respectively.
of diversifying crops by 83% in the coastal zone. However, floods reduced the chance of diversifying ones crops by more than 25% in the savannah zone.

In this study, it is revealed that labour, age and rainfall have significant influence on farmers’ choice of irrigation farming at 10% significant level. Labour increased the prospect of engaging in irrigation farming by 53% in coastal zone and 37% in the savannah zone. Education of the farmer enhanced the likelihood of engaging in irrigation farming by 59% in the coastal zone, 15% in the forest zone and 7% in the savannah zone. Age allowed farmers accumulate more experience over weather behaviour. In this study, farmers experience positively influenced choices over irrigation because it supplemented water for crop growth and development during drought times in both coastal and savannah zones.

Green manure had a positive influence on adoption of irrigation in the study area. It augmented the probability of irrigating crops by 24% in coastal zone, 90% in forest zone and 6% in the savannah zone. Drought increased the chances of irrigating crop fields by 73% in savannah zone. Nonetheless, droughts negatively influenced farmer probability of irrigating crops by 19% in coastal zone. This was due to lack of water to irrigate crops during drought times. However,

| Table 6. Multinomial logit Model Estimates. Dependent Variable: Shifting Crop Planting Dates |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Coastal                                      | Forest                                       | Savannah                                     |
| dy/dx                                        | dy/dx                                        | dy/dx                                        |
| Age                                          | 0.375* (2.07)                                | 0.233* (1.68)                                | 0.251* (1.83)                                |
| Education                                    | 0.035* (1.92)                                | 0.588** (2.78)                               | 0.479** (2.91)                               |
| Gender                                       | 0.527 (0.78)                                 | 0.506 (0.56)                                 | 0.38 (0.23)                                  |
| Labour                                       | 0.862** (2.63)                               | 0.422 (0.02)                                 | 0.566* (1.74)                                |
| Farm size                                    | 0.005 (0.90)                                 | 0.002 (0.11)                                 | 0.111* (2.08)                                |
| HH_size                                      | 0.689 (0.86)                                 | 0.148 (0.78)                                 | 0.26 (0.03)                                  |
| Income                                       | 0.324 (0.31)                                 | 0.342 (0.56)                                 | 0.183 (0.62)                                 |
| Extension officer visit                      | 0.530* (2.33)                                | 0.04** (2.43)                                | 0.055** (1.99)                               |
| Fertilizer application                       | −0.208 (0.42)                                | 0.065 (0.56)                                 | 0.164 (0.79)                                 |
| Temperature                                  | −0.495* (−2.26)                              | −0.249** (3.02)                              | −0.724** (2.01)                              |
| Rainfall                                     | 0.436* (1.78)                                | 0.260** (2.75)                               | −0.016* (−2.00)                              |
| Drought                                      | −0.733* (1.66)                               | −0.173 (0.77)                                | 0.492* (1.89)                                |
| Flood                                        | 0.030* (2.43)                                | −0.291* (−1.87)                              | 0.035* (1.95)                                |
| Green manure                                 | 0.013 (0.98)                                 | 0.339 (0.66)                                 | 0.185* (1.67)                                |
| Soil erosion                                 | −0.001 (0.45)                                | 0.809 (0.78)                                 | 0.427* (1.66)                                |

Source: Authors’ survey data 2018. Note: HH_size is household size; standard errors are within brackets; *, **, *** indicates significance at 10%, 5% and 1% respectively.
Farmers in the savannah zone irrigated their crops during flood times by 4% due to presence of water. Farmers’ choice of shifting crop-planting dates is influenced by factors such as age, education, income, rainfall, droughts and floods at 1% and 5% significant levels. Education of farmer had a positive influence on farmers’ choice over shifting planting dates. For example, the results show that education improved the probability of changing planting dates by 4% in the coastal zone, 58% in the forest zone and 50% in the savannah zone. Extension services had significantly enhanced the prospect of shifting crop-planting dates by 53% in the coastal zone, 4% in the forest zone and 6% in the savannah zone. Rainfall increased the likelihood of shifting planting dates by 44% in the coastal zone and 26% in the forest zone while reduced the same likelihood by 2% in savannah zone. Droughts positively influenced household choices by 49% savannah zone and reduces the planting dates by 73% in the coastal zone. On the other hand, floods negatively influenced household choice over shifting planting dates by 29% in the forest areas and increased the planting dates by 4%. In other words, farmers were more likely to shift their planting dates when there were droughts than when there were floods. According to focus group discussions, this was due to lowland farmers grew other crops such as rice that favoured water.

Some income generating activities adopted in the study areas included off-farm income, transfers and farm income. The study found that farmers’ choice of income generating activities is influenced

| Table 7. Multinomial logit Model Estimates. Dependent Variable: Income Generating Activities |
|-----------------------------------|-----------------------------------|-----------------------------------|
|                                   | Coastal                          | Forest                           | Savannah |
| dy/dx                             | dy/dx                             | dy/dx                             |
| Age                               | 0.996*** (3.87)                   | 0.773** (2.56)                    | 0.682 (2.08) |
| Education                         | 0.674* (2.32)                     | 0.759* (1.98)                     | 0.383 (2.03) |
| Gender                            | 0.691 (0.73)                      | 0.006 (0.89)                      | 0.502 (0.45) |
| Labour                            | −0.881 (−0.97)                    | 0.473 (0.89)                      | 0.002 (0.06) |
| Farm size                         | 0.004 (0.03)                      | 0.059 (0.76)                      | 0.927* (1.74) |
| Household size                    | 0.411* (1.79)                     | −0.543* (−2.08)                   | 0.197* (1.66) |
| Extension officer visit           | 0.655 (0.45)                      | 0.652* (2.32)                     | 0.267 (2.04) |
| Fertilizer application            | 0.462 (0.76)                      | 0.369* (2.45)                     | 0.261* (2.22) |
| Temperature                       | −0.283* (−1.94)                   | 0.264 (2.03)                      | 0.251* (1.88) |
| Rainfall                          | 0.189* (2.33)                     | −0.104** (−2.67)                  | 0.482* (1.96) |
| Drought                           | 0.472 (0.43)                      | 0.443 (0.98)                      | 0.373 (0.76) |
| Flood                             | 0.537 (0.67)                      | 0.406 (0.69)                      | 0.329 (0.88) |
| Green manure                      | 0.141* (1.76)                     | 0.123 (0.55)                      | 0.502* (2.04) |
| Soil erosion                      | 0.076 (0.45)                      | −0.586 (−0.86)                    | 0.028 (0.75) |

Source: Authors’ survey data 2018. Note: HH_size is household size; standard errors are within brackets; *,**,*** indicates significance at 10%, 5% and 1% respectively.
by factors such as age, rainfall and temperature. Age of the farmer positively influenced choices of income generating activities. In this study, the more the number of years of farmer, the more likely the farmer is to engage in income generating activities. Education had a positive influence on engagement in income generating activities. It enhanced the prospect of engaging in income generating activities by 67% in the coastal zone and 76% in the forest zone. Farmers who have higher education is more likely to engage in income generating activities because it economically helped farmers in accessing food at the market during food shortage period. Temperature increased the likelihood of income generating activities by 25% savannah zone and reduced the likelihood of doing income-generating activities by 28% in highland areas. Rainfall reduced the prospect of engaging in off farm income-generating activities by 10% in forest zone while increased the prospect of indulging in income-generating activities by 19% in the coastal zone and 48% in the savannah zone. Both droughts and floods showed positive influence on farmers’ choices of engaging in income generating activities. This implies that, farmers engaged in income generating activities to earn income that was used to acquire food when the on farm harvest food finishes. In addition, it was reported off farm activities provided income that was used to purchase inputs such as fertilizer.

5. Conclusion and policy implications
This study analyzed factors that influenced farmers’ choice of various adaptation strategies in the three agro-ecological zones of Ghana. The study employed a multinomial logit function to analyze data on farmers collected from the zones. The study found that farmers adopt various adaptation strategies in order to cushion them against the negative effects of climatic/weather variability and extreme events such as drought and floods across the zones. The study found that factors such as gender, education and age of the farmer, rainfall and temperature, pest outbreak, floods as well as drought occurrence significantly affected farmers’ choice of adaptation strategies. Policy and decision makers would find these findings very important in making decision towards adaptation to changes in climate. The study results imply that climatic and weather variability projects should mainstream factors that affect farmer choice of adaptation strategies. The study elicited interesting innovations from farmers in the various agro-ecological zones. This stemmed from the use of indigenous knowledge in some of the adaptation mechanisms adopted by them, which seemed to serve them well. It is recommended that any adaption strategies should inculcate some of these indigenous knowledge about how to adapt to extreme weather events in order for farmers to buy into such strategies. It is also recommended that crop insurance products should be marketed more amongst the farmers at competitive rates in order for them to patronize them as one of the adaptation measures.

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Author details
Isaac Dasmani
E-mail: idasmani@ucc.edu.gh
Kwabena Nkansah Darfor
E-mail: kdarfor@ucc.edu.gh
Alhassan Abdul-Wakeel Karakara
E-mail: wakeel.kara@gmail.com

1 Department of Economic Studies School of Economics, University of Cape Coast, Cape Coast, Ghana.
2 Department of Applied Economics, School of Economics, University of Cape Coast, Cape Coast, Ghana.
3 Department of Economic Studies, School of Economics, University of Cape Coast, Cape Coast, Ghana.

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