Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.14, No.12, 2023

Financial Vulnerability and Climate Change Adaptation Practices of Smallholder Farmers: An Example of Southwest Nigeria

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Abstract
In many developing countries, smallholder farmers face several challenges in raising productivity, especially in the face of climate change risks, while access to requisite financing has continued to be challenging. This study estimated the financial vulnerability of smallholder farmers in the study area to assess their exposure as well as their ability to undertake climate-resilient practices in the face of possible climate change hazards. Cross-sectional data were obtained from 300 plantain farmers in Southwest Nigeria and collected data were analysed using the Stochastic frontier function and the Harold-Dorma equation to first determine their productivity and financing gap while Foster Geer-Thorbecke (FGT) equation was used to determine their financial vulnerability. Findings showed that farm size, herbicides, plantain suckers, and capital were positively significant to plantain production in the study area while the mean technical efficiency was 0.53. The mean financing gap of the farmers was \$310 and the Vulnerability index was \$409.6. More than two-thirds (84%) of the farmers were financially vulnerable, with 36% being severely incapacitated financially. Factors determining climate change adaptation strategies were examined using a Multivariate Probit Regression and findings showed that age, farming experience, credit access, farm size, market distance, extension contact, off-farm income, and land ownership all significantly impacted climate change adaptation strategies adopted by the farmers. However, credit access and Off-farm income determined the use of more adaptation strategies than other variables. Measures addressing improved access to finance are therefore imperative to increase the adaptive capacity of smallholder farmers for sustainable production.
Keywords: Vulnerability, Financing Gap, Adaptation, Smallholder, Credit Access, Climate change
DOI: 10.7176/JESD/14-12-03
Publication date: June 30th 2023

1. Introduction

Smallholder agriculture is used more generally to describe rural producers, predominantly in developing countries, who farm using mainly family labour and for whom the farm provides the principal source of income (Harvey et al, 2014). Therefore, because they typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income, and well-being (Hertel and Rosch, 2010; McDowell and Hess, 2012). They face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others (Morton, 2007; Harvey et al., 2014). While smallholder farmers face several challenges in raising productivity in the face of an ever-changing climate, access to requisite financing is however seen to be a critical challenge in many developing countries (Anang, et al., 2015). Globally, an estimated 475 million smallholder farmers are cultivating less than 2 ha of land (Lowder et al, 2016,) many of whom are poor, experience food insecurity, and live in highly precarious conditions (Morton, 2007; Cohn et al, 2017). In Nigeria, more than 80 percent of the total farmers, including medium and large ones, are smallholder farmers, and over 90% of agricultural production is rain-fed ((Akinsuyi, 2011; Nwajiuba, 2013). Thus, they are highly vulnerable to climate change because most depend on rain-fed agriculture, cultivate marginal areas, and lack access to technical or financial support that could help them invest in more climate-resilient agriculture (Holland et al, 2017; Donatti et al.,2018).

According to the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN, 2011), vulnerability is the inability to withstand the adverse impact of exposure to stresses or shocks associated with environmental and social change, and the absence of the capacity to adapt to the impact. In other words, the vulnerability of a given system or society is a function of its physical exposure to hazards and its ability to adapt to these conditions. While vulnerability may be defined on a case-by-case basis, studies have shown that poorer individuals and communities are especially vulnerable largely due to their limited access to financial resources. For instance, Sub-Saharan Africa has been identified as one of the regions that are most vulnerable to the negative impacts of climate change compared to other regions (Esham and Garforth, 2013). This is because of their low level of adaptation capacity and poverty (Bagamba et al., 2016). The adverse effect of climate change and variability has become an environmental and socio-economic problem increasingly causing climate-driven hazards to people worldwide (Scholze et al., 2006). Climate change poses a significant threat to smallholder farmers and threatens to undermine global progress toward poverty alleviation, food security, and sustainable development (Vermeluen et al, 2012; Lipper et al, 2014). Its impacts on farm-based livelihoods are manifested through shifts in cropping seasons and a loss in agricultural productivity (IPCC 2014). This translates into the loss of income and exacerbates food insecurity among the rural population. Especially vulnerable are those households that are engaged in subsistence farming (Qaisrani et al., 2018). According to the Intergovernmental Panel on Climate Change (IPCC), human adaptation is the process of adjusting to actual or expected climate variability and its effects to moderate harm or exploit beneficial opportunities" (Field et al, 2012). Barriers however are the factors and conditions that may hinder or prevent this adjustment to climate change and its effects and are categorized into financial, technical, sociocultural, and political-economic (Jain et al., 2009; Biesbroek et al., 2013).

In many developing countries, like Nigeria, smallholder farmers possess limited resources to mobilize coping strategies to introduce longer-term adaptation mechanisms (Adger et al.,2003). One of the key barriers to climate change adaptation that have been noted in the climate change literature is the lack of financial resources to implement appropriate adaptation strategies (Antwi-Agyei et al., 2014; Atube et al, 2021). For instance, Bryan et al. (2009) noted that financial barriers due to a lack of credit facilities are one of the most important obstacles hindering the implementation of climate adaptation strategies by farmers in Ethiopia. This study, therefore, estimated the financial vulnerability of smallholder farmers in the study area as a pointer to their exposure and capacity to undertake climate-resilient practices in the face of possible climate change hazards. The study also examined factors determining climate change adaptation strategies among farmers in the study area.

2. Literature Review

2.1 Vulnerability

The Intergovernmental Panel on Climate Change defines vulnerability as "the propensity or predisposition to be adversely affected", and describes exposure and vulnerability as the determinants of risk (IPCC, 2012). This thus provides a useful typology, suggesting that vulnerability may be characterized as a function of three components: adaptive capacity, sensitivity, and exposure (Schneider et al., 2007). Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses or to cope with the consequences. It is considered ''a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities'' (McCarthy et al., 2001). Sensitivity refers to the degree to which a system will respond to a change in climate, either positively or negatively while exposure relates to the degree of climate stress upon a particular unit of analysis; it may be represented as either long-term changes in climate conditions or by changes in climate variability, including the magnitude and frequency of extreme events. Kelly and Adger (2000) differentiate between the 'end-point' and 'start-point' features of climate change vulnerability. End-point studies define vulnerability in terms of net impacts and inevitably frame adaptive options in terms of ''fixes'', often technological in nature, which will minimize particular impacts that have been projected. The 'starting-point' approach defines vulnerability as a pre-existing state that may affect the adaptive capacity and hence increase exposure to climate risks. The consideration of financial vulnerability in this study thus fits into the 'starting-point' approach as it looks at the pre-existing state of the farmers in the study area to provide information on the extent of their adaptive ability in the face of any hazards, particularly those related to climate change.

Different methods and approaches have been developed and applied to quantitatively assess vulnerability on different scales (Fussel, 2007; Zurovec et al., 2017). As seen from the literature, vulnerability assessment in terms of climate change can be categorised into groups, such as the "Livelihood Vulnerability Index" (Belay et al., 2016; Adu et al., 2018), Multidimensional livelihood index (Gerlitz et al., 2017; Asmamaw et al., 2020), "Social Vulnerability to Climate Change" (Adger et al., 2006; Madu, 2012), "Climate Vulnerability Index" (Pandey and Jha, 2012; Khajuria and Ravindranath, 2012; Zurovec et al., 2017), and "Household Vulnerability to Climate Change" (Fernandez et al., 2016; Antwi-Agyei et al., 2012; Okafor et al., 2017). Few scientists (Antwi-Agyei et al., 2012) have utilised the term "Sustainable Livelihood Framework (SLF)" in order to measure household vulnerability considering the five assets of the social, human, financial, natural and physical, and livelihood diversification aspects. However, the "Livelihood Vulnerability Index" appears to be more common probably because it considers a wide range of parameters (Hahn et al., 2009; Piya et al., 2012; Gerlitz et al., 2017). While findings from the aforementioned vulnerability measurements have contributed to developing effective adaptations for communities and regions (Mudasser et al., 2020), they, however, failed to capture the extent or the degree to which individual farmers are vulnerable financially relative to their productivity, because finance is one of the most important obstacles hindering the choice of adaptive strategies that can improve productivity thus making farming households more vulnerable to risks posed by climate change.

3. Methodology

This study was carried out among plantain farmers in South-West Nigeria and a multi-stage sampling procedure was used to obtain plantain farmers in 3 states to give a total of 300 respondents. Cross-sectional data collected were analysed using Stochastic Frontier Analysis (SFA), Harold-Dorma Growth Equation, Foster GeerThorbecke (FGT) equation, and Multi-variate Probit regression model. Plantain was selected for this study because it serves as a useful crop for smallholder farmers and co-exists easily with established farming systems (Edeoghon and OkoedoOkojie, 2011).

3.1 Estimating the Financing Gap of the Farmers

The financing gap approach as employed in this study enables the degree of financial vulnerability of individual farmers to be ascertained. Following Ojo and Ayanwale (2019), the technical efficiency of each farmer is first determined and the finance required to produce at target efficiency is estimated using the Harrod-Domar (HD) growth Equation. The difference between the finance required to produce at the target technical efficiency and the finance available to the farmer at his current technical efficiency gives the financing gap of the farmer. This financing gap is thereafter used to estimate the farmer's financial vulnerability using Greer-Thorbecke (FGT) equation. According to Ojo and Ayanwale (2019), sustainable provision of credit and rational use of other inputs in the right proportions and at the right time are crucial to increasing output and productivity. Unlike other approaches such as the Livelihood vulnerability index or the Multidimensional vulnerability index which considers other indicators in determining vulnerability, this approach provides a quick first-line assessment in determining the extent to which individual farmers might be vulnerable to possible climatic hazards as a result of their financial status relative to their production efficiency.

3.1.1 Stochastic Frontier Model(SFM)

The functional form adopted by this study is the Cobb-Douglas production function as proposed by Battese and Coelli (1995). The equation is specified as follows:

$$InZ_i = \beta_0 + \sum_{j=1}^{5} \beta_j InX_{ji} + V_i - U_i \quad (1)$$

Where Z_i represents the quantity of plantain output for the i^{th} farmer, X_{ji}, is the vector of j^{th} inputs associated with the i^{th} farmer β_j is a vector of the unknown parameter to be estimated. V_i is the random error assumed to be independently and identically distributed as N $(0,\sigma^2)$, U_i is the non-negative ($U_i \geq 0$) inefficiency error term.

The condition that U_i is non-negative ensures that all observations lie on or below the stochastic production frontier (Coelli *et al*., 2005; Onumah *et al*., 2010). An estimated value of T.E. for each observation is calculated using an equation expressed as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i,\beta)\exp V_i - U_i}{f(X_i,\beta)\exp V_i} = \exp(-U_i) = e^{-U_i}. \quad (2)$$

The computation of T.E. in the econometrics literature is based on either input-oriented or output-oriented analysis (Martey *et al*., 2015). The output maximization measure is used in the estimation of the T.E. in this study as the focus is on increasing productivity through access to basic inputs facilitated by finance. To estimate the output of the farmers at the target efficiency level, the current technical efficiency (T.E) and plantain output of the farmers are first determined and then a higher T.E, which in this study is set as the target efficiency level desired for the farmers. Following Ojo and Ayanwale (2019), the plantain output expected to be produced by each farmer when his T.E increases to the target efficiency level (due to access to finance), is then estimated as seen in equations 3 and 4:

The quantity of plantain produced at target technical efficiency (QPPTTE) is determined as:

$$QPPTTE\ (Kg) = \frac{Target\ T.E\ X\ plantain\ quantity\ produced\ at\ current\ T.E\ (kg)}{Farmer's\ current\ T.E} \quad (3)$$

Increase in output = Output at target T.E – Output at current T.E (4)

3.1.2 Harrod-Domar (HD) Growth Equation

Following Ojo and Ayanwale (2019), the change in output due to available credit financing (from equation 4), was introduced into the HD equation and set as Q. Therefore,

Increase in plantain output (kg) = $Q_i = \frac{1}{c} * L_i$ (5)

The credit amount required by the i^{th} farmer to produce at the target efficiency is set as L_i while

$$c = \frac{\textit{Annual investment in plantain production}}{\textit{Annual increase in quantity of plantain produced}} \quad (6)$$

From equation 5, the amount (L_i) required to produce at the target efficiency and increase output is estimated and the difference between the estimated amount (L_i) and the farmer's savings or amount currently available to the farmer for production, gives the financing gap. The farmer's savings here represents all the finance available for his plantain production either directly from his farm or off-farm income. This financing gap represents the external funds required by the farmer to improve his production efficiency and possibly increase his adaptive capacity. This study considered the HD model appropriate as the model presents a fixed linear relationship between growth and investment in the short run with the ICOR measuring the marginal amount of investment capital necessary for an entity to generate the next unit of production. Hence, the model supports the positive relationship of increased productivity resulting from credit (investment) in the short run. The assumptions here are that any external finance received by each farmer is invested directly into plantain production and that such amount (L_i) is proportional to improvement in the farmer's technical efficiency (production growth) by a constant (c) known as the Incremental Capital Output Ratio (ICOR).

3.2 Vulnerability Assessment

3.2.1 Greer-Thorbecke (FGT) equation

To determine the financial vulnerability index of the farmers, the estimated financing gap is first normalised by dividing it by the farm size of each farmer so that the financing gap per farmer per hectare is obtained. This is then used to obtain the financial vulnerability index for the study area, adapting the poverty line index equation as used by Omonona *et al* (2007):

$$F_i = \frac{\textit{Financing gap per ha by ith farmer}}{\frac{2}{3}\textit{ of the mean financing gap per ha by the farmers in the study area}} \quad (7)$$

Where F_1= Vulnerability line or index

Vulnerability incidence, depth, and severity experienced by the farmers are determined through the Foster Greer-Thorbecke (FGT) equation. It is recognized that poverty is directly related to vulnerability (Fankhauser and Tol, 1997; Rayner and Malone, 1998). Although poverty should not be considered synonymous with vulnerability, it is "a rough indicator of the ability to cope" (Dow, 1992). The financial vulnerability of the farmers gives a measure of how the farmers can cope in the event of possible climatic hazards. According to Kates (2000), whether it is expressed as economic assets, capital resources, financial means, wealth, or poverty, the economic condition of nations and groups is a determinant of adaptive capacity. The FGT equation is thus used here to measure the incidence, depth, and severity of the financial vulnerability of each farmer and is given as:

$$V_\alpha = \frac{1}{n}\left[\sum_{i-1}^{n} G_i\right] = \frac{1}{n}\left[\sum_{i=1}^{n} \frac{Y_i - Z}{Z}\right]^\alpha \quad (8)$$

Where V_a= degree of vulnerability; Z= vulnerability index (vulnerability line); n = the number of financially vulnerable farmers; G = the vulnerability gap experienced by the i^{th} farmer per hectare; Y_i= the financing gap experienced by the i^{th} farmer for production per hectare and; α = measures the outfall from the defined financial vulnerability line. Taking values of 0, 1, and 2 for vulnerability incidence, depth and severity respectively. These three vulnerability measures are calculated based on three values of α:

Vulnerability incidence (VG0) where α = 0

$$VG_0 = \frac{1}{N}\sum_{i=1}^{N} I(y_i > z) \quad (9)$$

Here, I $(y_i > z)$ is an indicator function that takes on a value of 1 if the bracketed expression is true, and 0 otherwise. So, if the financing gap (y) is greater than the vulnerability line (z), then I $(y_i > z)$ equals 1 and the farmer would be counted as being vulnerable to climate change risks. Unlike in poverty estimation where it is expected that those above the poverty line are not poor, the reverse is taken here for vulnerability. This is so because those whose financing gaps are above the vulnerability line threshold are considered to have high financing gaps or needs which makes them less capable to respond to possible hazards and unable to carry out required adaptive measures compared to those below the line. Thus, VG_0 gives a count of financially vulnerable farmers. It however does not capture the extent to which the financing gap of each farmer exceeds the vulnerability index line, given that the larger the financing gap, the more likely vulnerable the farmer is. Hence a second measure, the vulnerability depth index (VG_1) is considered below.

Vulnerability depth (VG_1) where α = 1:

The Vulnerability depth adds up the extent to which the financing gap of the farmers exceeds the vulnerability line and expresses it as a percentage of the vulnerability line. More specifically, it defines the vulnerability depth (G) as the financing gap (y) less the vulnerability line (z) for the vulnerable individuals. The gap is considered to be zero for everyone else. Using the index function, we have:

$$G_1 = (y_i - z) \times \text{I}\ (y_i > z) \quad (10)$$

The vulnerability depth is thus calculated as:

$$VG_1 \frac{1}{N} = \sum_{i=1}^{n} \left[\frac{y_i - z}{z}\right] \quad (11)$$

VG_1 captures the acuteness of vulnerability since it measures the total gap of the farmers' financing gaps from the vulnerability line, thus giving a measure of the depth of vulnerability. In other words, it measures the total amount of finance required to remove the vulnerability of the farmer:

Vulnerability severity (VG_2) where α = 2

$$VG_2 \frac{1}{N} = \sum_{i=1}^{n} [\frac{y_1 - z}{z}]^2 \quad (12)$$

This measures the severity of vulnerability even more accurately as it gives an indication when multiplied by 100, of the percentage by which a farmer's financing gap needs to be reduced relative to the vulnerability line to move out of financial vulnerability.

3.3 Climate Change Adaptation Strategies

3.3.1 Utility maximization function

Adaptation strategies are a form of protection measure that reduce the farmers' risk exposure by reducing the marginal effect of climate change on productivity (Fisher-Vanden and Wing, 2011). This study adopts a utility maximization function to conceptualise adaptation decisions in the face of climate change risk. In this case, the utility to a farmer need not be defined by higher yields. In the context of adaptation, the utility derived from adopting a practice could yield stability and the implied reduction in downside risk (Mulwa et al., 2017). A risk-averse farmer maximizes utility by choosing an adaptation strategy if the benefits of adaptation (risk reduction) minus the cost of adaptation are higher than the benefits realised without adaption. Following Hazell and Norton (1986), we define the utility function as follows:

$$U_y = E_y - \alpha\omega_y \quad (13)$$

where U_y is the perceived utility from choosing adaptation strategy y, E_y is the non-stochastic component and ω_y is the disturbance term indicating variation in yields. The coefficient (α) captures individual farmers' risk aversion which would affect the degree of variability in the yields ω_y. Following Finger and Schmid (2007), we define this coefficient as:

$$\alpha = -(\partial U/\partial \omega_y)/(\partial U/\partial y) \quad (14)$$

where if a < 0, the farmer is risk-averse and thus more likely to adapt; α= 0 indicates a risk-neutral farmer and a > 0 indicates a risk-loving one. The utility of implementing a strategy (Y(U_y) is given by the revenues generated by the strategy less the variable costs incurred in implementation. Given an array of adaptation strategies, a risk-averse farmer will choose the strategy, say X, that yields higher expected utility than the alternatives, say Y, i.e.

$$E(U_x) - M_x > E(U_y) - M_y \quad (15)$$

where the first term is the expected utility of implementing strategy X and the associated costs Mx, while the second term is the expected utility of implementing strategy Y and associated cost M_y. Assumptions about the relationship of disturbance terms of the adaptation equations, i.e. whether correlated or not, determine the type of quantitative choice model to use in analysis.

3.3.2 Multi-Variate Probit (MVP) Regression Model

Many studies on farm adaptation strategies have used various empirical methods in analysing determinants of adaptation to climate change and the choice of adaptation strategies. Such studies range from discrete choice regression models (Fosu-Mensah et al 2010), multinomial probit or logit (Deressa et al 2008) to principal component analysis (Mandleni and Anim, 2011) and the Ricardian model (Kurukulasuriya and Mendelson,2006). However, farmers, most of the time do adopt a mix of adaptation strategies to deal with climate issues rather than a single strategy or method (Mulwa 2017). Given this reality, this study employed the Multivariate probit (MVP) model to investigate the factors influencing farmers' choice of adaptation methods. MVP simultaneously models the influence of the set of explanatory variables on each of the different adaptation strategies while also allowing for the potential correlation between unobserved disturbances, as well as the relationship between the strategies of different practices (Kassie et al., 2009). The results on correlation coefficients of the error terms indicate that there is complementarity (positive correlation) and substitutability (negative correlation) between different adaptation options being used by farmers. Failure to capture unobserved factors and interrelationships among adaptation strategies will lead to bias and inefficient estimates (Greene, 2012). Although the multinomial probit can be used to measure the set of adaptation choices being used by farmers, it is however limited in making interpretations for the simultaneous influences of explanatory variables on each dependent variable (the endogeneity problem cannot be addressed using multinomial probit). This is because the local adaptive choices practiced by the farmers are either substitutive or supplementary to one another (Feleke et al., 2016). Following Lin et al. (2005), the MVP model for this study is characterized by a set of m binary dependent variables Y_{hj} such that:

$$Y^*_{hj} = X^1_{hj}B_j + u_{hj} \quad \text{and} \tag{16}$$

$$Y_{hj} = \begin{cases} 1 \text{ if } Y^*_{hj} > 0 \\ 0 \text{ if otherwise} \end{cases} \tag{17}$$

Where $j = 1, 2 \ldots m$ denotes the type of adaptation strategy available; X is a vector of explanatory variables, ßj denotes the vector of the parameter to be estimated, and u are random error terms distributed as a multivariate normal distribution with zero mean and unitary variance. It is assumed that a rational h^{th} farmer has a latent variable, Y_{hj} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation strategy. The dependent variables included in the analysis are the adaptation strategies adopted by farmers in the study area which include: Soil conservation practices (σ_1), Crop diversification (σ_2), Adjusted planting time (σ_3), Irrigation (σ_4), improved variety (σ_5) (Ahmed, 2016). The independent variables included in the model are socioeconomic variables such as Age, Plantain farming experience, Education, household size, farm size, Off-farm income, Credit access, Extension services, and Land ownership.

4.0 Results and Discussion

4.1 Stochastic production function of plantain production

Both the Cobb-Douglas and Translog analysis were carried out for the stochastic frontier analysis, however, the Cobb-Douglas analysis provided better estimates and the results are presented in Table 1. The table showed that farm size, use of herbicides, plantain suckers, and capital were positively significant to plantain output, while labor was negatively significant. Findings from Okoruwa et al. (2014) support the positive relationship between farm size and the use of herbicides to plantain output. Interestingly however field observations showed that many of the farmers could not use herbicides due to financial constraints, thus they resorted to manual weeding. According to Ekunwe and Ajayi (2010), herbicides are either too expensive for farmers or are not easily available when needed. While the result showed that plantain sucker was positively significant in increasing plantain output, Faturoti et al. (2002) noted that scarcity of healthy planting materials hampers large-scale production of plantain. The positive relationship between capital and plantain output shows the importance of capital on productivity. According to Anang et al. (2015), improving access to credit can facilitate optimal input use leading to a positive impact on productivity. Also, Nouman et al. (2013) stated that agricultural credit creates and maintains the adequate flow of inputs thus increasing efficiency in farm production. Although labour has been described as an important factor in plantain production (Ekunwe and Ajayi, 2010; Baruwa et al., 2011; Olumba, 2014), results showed that more labour reduces plantain output. This agrees with the assertion by Sharrock and Frison (1998) and Kayode et al. (2013) that plantain production requires less labour compared to other crops like cassava, maize, rice, and yam.

Table 1: Cobb-Douglas stochastic production function for plantain production

Half Normal Output	Coefficient	Std. Error	Z
Farm size	0.45***	0.07	6.12
Herbicides	0.77***	0.29	2.58
Labour	-0.37**	0.19	-1.91
Fertilizer	-0.06	0.08	-0.72
Suckers	0.27**	0.14	1.91
Capital	0.34***	0.07	4.88
Constant	3.64	1.62	2.25
Sigma v	1.02	0.06	
Sigma u	0.03	1.36	
Lambda	0.03	1.38	

*significance at 10% **significance at 5%***significance t 1%
Source: Data Analysis (2022)

4.2 Technical Efficiency and Financing gap of the Farmers

Table 2 gives the range of the current efficiency level, the estimated financing gap and the percentage distribution for each class range. The mean technical efficiency of the farmers was 0.53, with the majority (74%) of the farmers producing at an efficiency of not more than 0.6. The mean financing gap was $310, suggesting that with an average amount of $310, the efficiency of many of the farmers can be improved towards producing at the frontier technical efficiency. According to Oruonye and Musa (2012), credit is often seen as an important factor in improving agricultural productivity and strengthening the rural economy in most developing countries. This is so since farmers facing binding capital constraints tend to use lower levels of inputs in their production activities compared to those not constrained (Petrick, 2004; Anang et al., 2015). The financing gap arising from credit constraint is seen to have a direct effect on the purchasing power of producers to procure farm inputs and finance operating expenses in the short run and to make farm-related investments in the long run, while indirectly, it can affect the risk behavior of producers, which can also affect technology choice and adoption by farmers (Guirkinger and Boucher, 2005).

Table 2: Financing Gap of Plantain Farmers

Current Efficiency	Financing gap ($)	Percent
0.14-0.30	70 -1550	5.67
0.31-.40	42 -1331	12.00
0.41-0.50	22 - 832	17.67
0.51-0.60	26 - 973	39.00
0.61-0.70	22 -1272	19.33
0.71-0.79	20 -1126	6.33
Mean–0.53	**Mean - 310**	
Std.Dev.– 0.13	**Std. Dev- 279**	

Source: Data Analysis (2022)

4.3 Extent of Vulnerability

Table 3 gives the estimated value of the Vulnerability index of the farmers in the study area as $409.6 with Vulnerability incidence (VG0) showing that 84% of the farmers were financially vulnerable. This indicates that more than two-thirds of the farmers have the "capacity to be wounded" in the face of any hazard, especially climatic hazards. The vulnerability depth (VG1) shows that relative to the vulnerability line, the total vulnerability gap of the farmers was 55%. This measures the mean proportionate vulnerability gap of the farmers in the study area (where the non-vulnerable have zero vulnerability gap) implying that an amount not less than $225.28 (55% of the vulnerability line $409.60) is required to reduce the farmers' vulnerability down to the vulnerability line or below it. The severity of vulnerability (VG2) indicates that 36% of the farmers are severely vulnerable financially, implying that about a third of the farmers are severely incapacitated financially to protect themselves in the face of any hazard whatsoever. According to Banuri (1998) and Munasinghe (2000), there is ample evidence that poorer nations and disadvantaged groups within nations are especially vulnerable to disasters. Mulwa et al. (2017) also noted that access to credit is a major determinant of the decisions to adapt to climate change. With resource limitations, therefore, farmers may fail to meet the costs of adaptation and at times cannot make beneficial use of available information (Kandli and Risbey, 2000).

Table 3: FGT Result of Financial Vulnerability of Plantain Farmers

Degree of vulnerability	Estimated Value	Standard Error	Vulnerability Line	Confidence level
Incidence ($\alpha = 0$)	0.84	0.14	409.6	95
Depth ($\alpha = 1$)	0.55	0.09	409.6	95
Severity ($\alpha = 2$)	.36	0.07	409.6	95

Source: Data Analysis (2022)

4.4 Factors Determining Adoption of Adaptation Strategies

The results of the MVP show that the adaptation decisions of farmers to different strategies were distinct and the factors governing the adaptation decision of each of them are also different, indicating the heterogeneity in the adaptation strategies. While farmers adopt a combination of strategies to reduce the impact of climate change, there would be several factors that can influence their decision to choose a particular strategy (Ahmed, 2016). Table 4 shows that the square age of the household head was found to have an inverse relationship with soil conservation strategy. knowledge and skills of farmers are likely to increase as their age increases. However, physical capability tends to decrease after a certain age level. Older farmers may be more interested in following traditional methods that are familiar to them rather than adapting new practices (Acquah,2011; 2012; Ahmed, 2016). However, the number of years of farming plantain was found to have a positive and significant relationship with the adoption of soil conservation practices and adjusted planting time.

Access to credit had a positive and significant impact on the likelihood of the farmers adopting soil conservation practices, adjusted planting time and use of improved variety. According to Mulwa et al (2017), access to credit is a major determinant of the decisions to adapt to climate change, noting that adaptation strategies can be expensive with some requiring the purchase of new adaptive seeds while others are resource intensive. Credit-constrained farmers are less likely to adopt expensive strategies such as irrigation and improved variety strategies. However, with more financial resources at their disposal, farmers can change their management practices in response to changing climatic conditions. Thus in the absence of micro-credit, farmers may still find it difficult to adapt even when provided with information on climate change because they are unable to purchase the requisite inputs (Mulwa et al., 2017). This finding is in line with that of Deressa et al. (2011), Di Falco et al. (2011), Fosu-Mensah et al. (2012), Temesgen et al. (2014) and Zuluaga et al. (2015). The result also showed that Off-farm income was positively significant in relation to the adoption of soil conservation practices, adjusted planting time, irrigation, and improved variety strategies. Depending on the proportion of total household income emanating from non-farm income, and the prevailing non-farm wages and therefore the opportunity costs of farm labour, farmers with access to non-farm incomes may be less exposed to production risks because their reliance on agricultural income and their food production is lower than that of the average rural household (Mulwa et al., 2017).

Farm size had a positive and significant relationship with the adoption of adjusted planting time and improved variety strategies. It is expected that farmers with bigger farm sizes are most likely to adopt measures that will ensure that their risk and exposure to climate change is minimized as they may stand to lose more considering the investment they have made on their farmland. Thus, the bigger the farm size, the more likely the adoption of adjusted planting time and improved variety strategies. Interestingly, farm size had no significant relationship with the adoption of soil conservation practices, crop diversification and irrigation strategies. Market distance was positively associated with the adoption of soil conservation practices and irrigation. This is interesting as the closer the farm is to the market, the easier it is for the farmers to get market information and be willing to adopt strategies such as irrigation that will ensure year-round production. When farmers are far from the market, the transaction cost for acquiring inputs will be high, and this will, in turn, reduce the relative advantage of adopting new technologies or strategies (Tazeze et al, 2012).

Access to government extension increases the probability of adaptation, thus, farmers with more access to information and technical assistance on agricultural activities have more awareness about the consequence of climate change (Di Falco et al., 2011; Fosu-Mensah et al., 2012; Zuluaga et al., 2015 and Ahmed, 2016). Farmers who owned their farmland were more likely to adopt an improved variety strategy as shown by the positively significant relationship between land ownership and improved variety strategy. According to Mulwa et al., (2017), land ownership does not seem to explain adaptation much as in this case where it only increased the likelihood of adopting improved variety while having no significant effect on the adoption of other strategies. It is believed that having a large land area gives farmers the room to try out different crops as a hedge against adverse outcomes. While Goh (2012) asserts that access to land is a major barrier to climate change adaptation among smallholder farmers, Harvey et al (2018) found that smallholder farmers with insecure land tenure were less likely to implement adaptation strategies than those farmers who owned their land because they are unwilling to make long-term investments in practices that yield long-term benefits.

Table 4: Multivariate Probit Regression Results for Climate Change Adaptation Decisions

Variables	**Soil conservation**	**Crop Diversification**	**Adjusted planting time**	**Irrigation**	**Improved variety**
Age	0.00018**	-0.00024	-0.00011	-0.00003	0.00013
	(0.00011)	(0.00022)	(0.00017)	(0.00011)	(0.00014)
Plantain farming Experience	-0.01469*	0.02251	0.03863***	0.01327	-0.00553
	(.01081)	(0.02136)	(0.01619)	(0.01093)	(0.01289)
Education	-0.01306	-0.03759	0.01697	-0.00329	-0.01268
	(0.01723)	(0.04745)	(0.02766)	(0.01701)	(0.02181)
Family size	-0.00829	-0.07402	0.01301	-0.02424	-0.01276
	(0.02499)	(0.05987)	(0.0428)	(0.02491)	(0.03059)
Credit Access	0.35011**	-0.25038	0.39288*	0.17942	0.26624 *
	(0.15986)	(0.37983)	(0.27262)	(0.16171)	(0.19951)
Farm size	0.02020	-0.10530	0.76589 ***	-0.19539	0.35630**
	(0.16597)	(0.41139)	(0.32885)	(0.17523)	(0.21670)
Market distance	-0.08743**	2.49492	3.97174	-0.08279**	2.08984
	(0.04331)	(537.097)	(253.933)	(0.04399)	(136.169)
Extension	0.63576*	-0.16744	0.02578	0.92873*	0.10703
	(0.20504)	(0.50154)	(0.35759)	(0.18767)	(0.26126)
Off-farm income	0.29291**	-0.21895	0.59836**	0.24463***	-0.41835*
	(0.15740)	(0.37951)	(0.27112)	(0.15820)	(0.18635)
Land ownership	-0.11601	0.52000	-0.26040	0.13987	0.36936**
	(0.16497)	(0.54374)	(0.25363)	(0.16763)	(0.21068)

Wald chi2(50) = 95.27
Log likelihood = -499.64986
Prob > chi2 = 0.0001

***, ** and * indicate significance at 1%, 5% and 10%, respectively
Note: Standard deviation in parenthesis

4.5 Correlation Matrix of Adaptation Strategies

Table 5 gives the correlation coefficients of the adaptation strategies used by the plantain farmers. The simulated Maximum Likelihood estimation of the MVP results suggests that there is positive and significant interdependence between farmers who adopted crop diversification strategy and soil conservation practices while farmers who adjusted their planting time also adopted soil conservation practices simultaneously in their plantain production. Farmers who adopted irrigation in their production adopted soil conservation practices, crop diversification, and adjusted planting time simultaneously while those who adopted improved variety also simultaneously used crop diversification, adjusted planting time, and irrigation strategies.

Table 5: Correlation coefficients of the climate change adaptation strategies (from the multivariate probit estimation).

Climate Change Adaptation Strategies	Correlation coefficient	Standard deviation
Crop Diversification and Soil conservation practices	0.46206*	0.18564
Adjusted planting time and soil conservation	0.01613	0.13353
Adjusted planting time and crop diversification	0.29575**	0.17482
Irrigation and soil conservation practices	0.75442*	0.05572
Irrigation and crop diversification	0.58826*	0.14122
Irrigation and adjusted planting time	0.26853**	0.13476
Improved variety and soil conservation	0.35192	0.09639
Improved variety and crop diversification	0.46492*	0.12595
Improved variety and adjusted planting time	0.52087*	0.11573
Improved variety and irrigation	0.63639*	0.08694

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho5> 2 = rho43 = rho53 = rho54 = 0: chi2(10) = 129.277 Prob > chi2 = 0.0000
Note that ***, **, and * indicate significance at 1%, 5% and 10%, respectively.

Conclusion

This study assessed the financial vulnerability of smallholder farmers using productivity to estimate the financing gap currently experienced by the farmers in their plantain production to indicate the extent to which they can be hurt or protected from hazards. The study also examined factors affecting climate change adaptation strategies among farmers in the study area. From the findings, it is clear that the majority of the farmers operate at low technical efficiencies and are experiencing financial constraints in their production as more than two-thirds (84%) are financially vulnerable and are likely to be unable to take measures that can improve their adaptive capacity. This result is very important for credit policy formulation as smallholder farmers typically depend directly on agriculture for their livelihoods and any agricultural productivity reductions can significantly impact their food security. Smallholder farmers produce the bulk of food in most developing countries, however, since their production is largely rain-fed, holistic credit financing programmes must be specifically designed and tailored to bridge the financing gap experienced by these farmers for sustainable food production. The need to foster credit markets for easy accessibility and affordability by smallholder farmers is not only necessary but imperative. A key finding from the MVP model showed that access to credit and having Off-farm income determined the use of more adaptation strategies than any other independent variable in the model. This further buttresses the importance of finance for smallholder farmers' adaptive capacity to climate change. The role played by credit in the adoption model also suggests the need for policies that support making credit available to farmers to enhance their ability to adopt improved practices needed to make them less vulnerable to climatic hazards. The fact that off-farm income was significant in the adoption of adaptation strategies suggests that policy measures to help income diversification of smallholder farmers would enhance their adaptive capacity. A well-structured and coordinated extension services programme for smallholders would help provide the information and technical know-how required by the farmers to aid adaptation. Greater extension contacts would not only help improve the farmer's productivity but their adaptive capacity as well. The complementarities observed among the different adaption practices further suggest that farmer education through extension services should be tailored to encourage farmers towards adopting optimal combinations of strategies in reducing their vulnerability to climate change risks. This study provided a first-hand approach to vulnerability assessment, considering the pivotal role that finance plays in the productive activities and livelihood of smallholder farmers in general. Future studies may consider incorporating the financing gap approach with weather elements to further explore possible interactions and outcomes.

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