Quantifying the determinants of climate change adaptation strategies and farmers' access to credit in South Africa

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1. Introduction

Climate change is critically evolving as a growing global development issue threatening the sustainability of many sectors in the world, particularly the agricultural sector (Comoé and Siegrist, 2015; Iglesias & Garrote, 2015). A continued rise in greenhouse emissions has resulted into an increased climate change impacts on the agricultural sector, with the impacts either positive or negative depending on geographical location among other characteristics (Tripathi and Mishra, 2017). Thus, global change may consequentially lead to high agricultural losses and endanger global food security, however, adoption of climate change adaptation strategies as a way to cope with the risks is gaining increased attention (Hijioka et al., 2014; Thornton and Comberti, 2017; Schneider and Asch, 2020).

Adaptations to climate change are strategies designed to eliminate the adverse effect of climate-related risks on agricultural activities (Jiang et al., 2017; Dang et al., 2019). Extreme weather and climatic events such as drought affect agricultural productivity in terms of yields and income generated and hampers food production (Trinh et al., 2018; Gomez-Zavaglia et al., 2020). The consequences of climate change on agriculture is huge, as the sector plays an important role in the economy through the creation of employment opportunities, foreign exchange earnings as well as poverty alleviation. Thus, most countries in the world, particularly South Africa which is characterized as a semi-arid (water-scarce) country, have swiftly considered the adoption of several adaptation strategies to ensure improved farm productivity, ensure food security and enhance the livelihood of smallholder farmers (Kibue et al., 2015; Adetoro et al., 2020).

In South Africa, agricultural sector remains vulnerable to climate change variability especially the smallholder farmers as they mostly practice rain-fed farming (Hosu et al., 2016). Climate change causes rainfall variability which may lead to drought and drought may cause reductions in crop yields and livestock productivity (Mare at al., 2018). According to reports from the International Disaster Database (EM-DAT 2017), the drought occurrence in South Africa in 2015 resulted in a high economic loss (about US$250 million) and affected the livelihood of many South Africans (around 2.7 million people). Among the people that were excessively affected were the smallholder farmers in South Africa due to their financial inability to adequately cope with the climate change risks. Future climate-related risks events may further deteriorate the sustainability of the agricultural sector in providing food for the growing population. Given the contribution of smallholder farmers to the agricultural sector and the economy at large, in terms of the gross value of agricultural production, gross domestic product and job creation, stakeholders in the agricultural sector are interested in understanding the factors that influence smallholder farmers' decision to adopt climate change adaptation strategies to allow the provision of necessary support to deal with climate change risks (Jägermeyr et al., 2016; Paymard et al., 2019).

Existing empirical studies listed the most used adaptation strategies in African nations such as improved crop varieties, planting trees, soil conservation, changing planting dates and irrigation (Gwambene et al., 2015; Gebru et al., 2020). Several other studies (Bhatt et al. 2014; Chapagain et al. 2017; Devkota et al. 2017; Dhakal et al. 2016; Sujakhu et al. 2016) have reported that climate change is a threat to agricultural production and sustainability due to the projected variability in temperature and precipitation, and more recurrent droughts, and it is, hence, necessary to study the associated indicators and determinants of farmers choice of adaptation strategies. In spite of their importance in climate risk mitigation and food security (Kassie et al., 2013), the adoption of adaptation strategies remains too low (Holden & Shiferaw, 2001; Holden et al., 2003). Among many factors that limit investments in agriculture, credit constraints, credit market imperfections and stringent conditions for credit accessibility are strong contributors in making an investment in agriculture, particularly climate change adaptation strategies unattractive (Holden et al., 2003; Ojo and Baiyegunhi, 2020).

According to Ojo and Baiyegunhi (2020), the link between climate change and credit access confirms to the understanding that financial resources can assist poor smallholder farmers harness essential potential required for resilience against production risks. Ojo et al. (2019) suggested that the provision of agricultural credit makes additional capital available for improving the level of households' productive and physical capital. Among many factors that limit investments in agriculture, credit constraints, credit market imperfections and stringent conditions for credit accessibility are strong contributors in making an investment in agriculture, particularly climate change adaptation strategies unattractive (Holden et al., 2003; Ojo and Baiyegunhi, 2020).

While there have been several studies done in this field, there are limited studies that have investigated coordinated variable types (such as socio-economic, institutional-cultural factors, and production inputs) that affect smallholder farmers' adaptation to climate change concurrently. Besides, the scope of most recent studies on adaptation to climate change has confined to agriculture as a whole (such as Bojovic et al., 2015; Kibue et al., 2016; Alam et al., 2017; Trinh et al., 2018) and without focusing on the important units that serve as the backbone of the agricultural sector in South Africa, that is the smallholder farmers. While there have been considerable attempts made by the government to relief the smallholder farmers through the provision of water tanks, animal feeds, drilling of boreholes (Agri SA 2016; DAFF 2016), there has been limited research that has investigated whether smallholder farmers have sufficient access to credits and factors that may determine their access to financial institutions. Besides, there is presently limited knowledge of how the government aims to further support the smallholder farmers to mitigate the impact of climate change.

Financial resources can potentially form one of the key strategies to both expanding and strengthening risk mitigating strategies, particularly in the presence of an increasing threat of climate change. However, the direct role of access to credit in mitigating against climatic risks, and the nature of credit constraints and their differing impacts on specific climate change adaptation strategies have not been fully examined. Evidence on the specific links between credit access and choice of adaptation strategies are mostly mixed (Asfaw et al., 2017). An analysis of the impact of credit access on adaptation to climate change is pertinent. The overarching objective of the study was divided into two- to empirically analyse the determinants of choice of climate change adaptation strategies and concurrently estimate factors influencing smallholder farmers' access to credit and its impact on the adoption of climate change adaptation strategies using the full information maximum likelihood (FIML) approach (Lokshin and Sajaia 2011). The findings of this study will guide the policymakers in formulating policy interventions that will support the smallholder farmers against climate change risks and sustain the livelihoods of the smallholder farmers.

2. Research methodology

2.1 Data collection

The study employed both qualitative and quantitative methods for the collection of data on smallholder farmers' choice of adaptation strategies towards climate change. According to Tewksbury (2009), qualitative research was used to seek understanding on the decisions of the smallholder farmer's adaptation strategies towards climate change by looking at first-hand experience to provide data that is meaningful to the researcher. The quantitative research method mainly uses numerical analysis to reduce data into numbers or percentages unlike qualitative method (Crossman et al., 2013). This method uses close-ended questionnaire. In this study, the quantitative method was used to compare responses across the participants because all participants were asked identical questions in the same order to allow for significant comparison of responses across participants and study areas (Crossman, 2013).

The survey questionnaire was prepared in English and then translated to respective local languages (IsiZulu, Setswana, South Sotho and Tshivenda) so that the field workers get accurate information from the farmers since these languages are used by all of the residents/farming communities in these areas. A multistage stratified random sampling procedure where a combination of purposive and random sampling procedure were used to identify and select sample of the districts and smallholder farmers, respectively. Data was collected from 183 participants from nine (9) selected District Municipalities, namely; Lejweleputswa and Thabo-Mofutsanyane (Free State), eThekwini, uGu, iLembe and Amajuba (Kwa-Zulu Natal), Mopani and Vhembe (Limpopo) and Dr Kenneth Kaunda (North West) in South Africa. A purposive selection technique was based on the prevalence and susceptibility of the districts to climate related problems and also these districts were recently declared drought disaster areas. Then, a sample household was selected using simple random sampling (SRS) with probability proportional to size technique. A simplified formula provided by Cochran, (1977) was used to determine the required sample size at 95% confidence level, 5% degree of variability and 8% level of precision. Accordingly, 183 samples of households out of 200 were selected for inclusion in the analysis. The primary data used for the study was obtained from a cross sectional survey of the Land Reform Beneficiaries (LRB) (smallholder farmers) in four (4) Provinces, namely: Free State, Kwa-Zulu Natal, Limpopo and North West, which made up the study area.

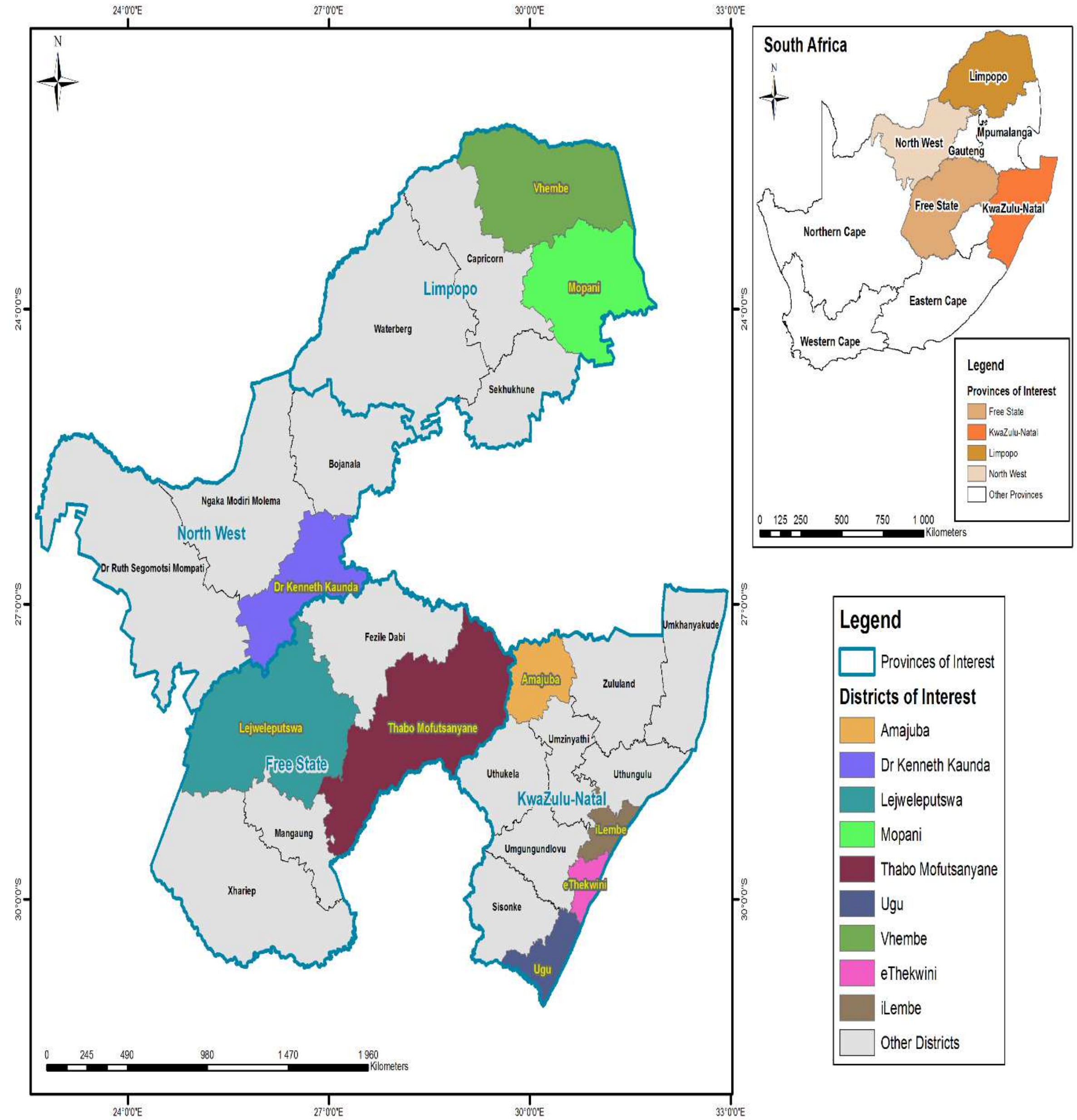

Figure 1. The map showing district municipalities for the study areas in South Africa

The field work for this study was carried out from November 2017 to June 2018. The initial field activity was the investigation survey of the study area to establish background information on agro ecological condition, livelihood activities, land use systems, natural resource base, and development activities being implemented in the context of climate change variations.

Interactions were carried out with government officials working in the districts and selected individuals having knowledge of their localities to enrich the investigation survey. In this exercise, issues related to climate change/ variability incidences, development interventions on agriculture and natural resources management/environmental protection activities designed to avert problems arising from climatic variability were points of concern. The overall activity in this regard helped the researcher to establish a good picture of the study areas and prepare relevant questions in each data collection tool such as questionnaire.

2.2 Conceptual framework

This study used the theory of utility satisfaction approach to conceptualise climate change adaptation strategies. Household utility is measured as a function of estimated costs and benefits in adopting a technology, as well as household preferences that are influenced by various factors. The advantage obtained from choosing a strategy might be the steadiness of productivity, with an implicit reduction in the impact of climate change. A utility is maximised by a risk-averse farmer when they select a strategy in which the benefits of adaptation minus the cost of adaption are more than the benefits realised without adaption. This study follows the method of Hazell and Norton (1986); the utility function of a farmer is shown in Equation 1:

$$\varphi_y = \Pi_y - \mu\theta_y \tag{1}$$

where φ_y is the assumed utility obtained from the choice of adaptation strategy y; Π_y represent the non-stochastic component; θ_y denote the disturbance term highlighting the differences in yields; and μ is the coefficient that captures the risk aversion of each farmer, affecting the degree of variation in yield θ_y.

Following Bechtold and Abdulai (2014) and Mulwa et al. (2017), the coefficient is defined as:

$$\mu = -\frac{\left(\partial\varphi / \partial\theta_y\right)}{\partial\varphi / \partial y} \tag{2}$$

where, at $\mu < 0$, the farmer is perceived to be risk averse and, therefore, more likely to adapt; a risk-neutral farmer is indicated by $\mu = 0$; while $\mu > 0$ indicates a farmer who is keen to take risks. The utility of effecting a climate change adaptation strategy $y\varphi_y$ is denoted by the incomes received through the adaptation strategy minus the variable costs acquired during the course of implementation. Given a set of adaptation strategies, a risk-averse farmer will choose a strategy, for example X strategy that yields a higher utility relative to the alternative (Y) as shown in Equation 3:

$$E(\varphi_x) - \rho_x > E(\varphi_y) - \rho_y \qquad (3)$$

where $E(\varphi_x)$ is the estimated utility of effecting strategy X and the associated costs ρ_x, while $E(\varphi_x)$ is the estimated utility of effecting strategy Y and acquired cost ρ_y. The assumptions associated to the relationship of disturbance terms of the adaptation equations (whether correlated or not) defines the category of qualitative choice model that is adopted in the analysis.

2.3 Empirical model for the determinants of climate change adaptation strategies

This study employed a multivariate probit (MVP) method for the empirical analysis. MVP models is equipped with the effect of a set of regressors for each of the adaptation strategies simultaneously, while allowing free correlation among the unobserved factors (Lin et al., 2005). The basis of correlation might be complementary, which signifies a positive association and substitutability, showing a negative correlation between the different adaptations strategies used in the model (Belderbos et al., 2004). When farmers experience production risk, they do not necessarily choose adaptation strategies to mitigate the risk, but choose a particular strategy to take advantage of complementarity or substitutability with alternative choices. Therefore, while adopting a particular adaptation strategy, a farmer might also consider other strategies.

The MVP model was formulated following Lin et al. (2005) specifications, using five dummy dependent variables representing the adaptation strategies used by farmers in the study area to mitigate the effect of climate change on their farms. MVP accounts for the correlation in the error terms by simultaneously modelling the effects of a set of covariates on each of the climate change adaptation strategies and estimating a set of binary probit models. According to Danso-Abbeam and Baiyegunhi (2017), MVP also creates the relationship between the adoption of adaptation strategies and accounting for potential correlations between unobserved disturbances. Since the utility could not be observed, it was represented as a function of observable components, as expressed in equation (4):

$$\gamma^*_{rf} = \alpha_f \mathrm{H}_{rf} + \beta_f V_{rf} + \varepsilon_f \qquad \text{where } (f=1,\ldots\ldots,m) \tag{4}$$

$$\gamma_{rf} = 1 \text{ if } \gamma^*_{rf} > 0 \text{ and 0 if otherwise}$$

Where γ^*_{rf} represent the latent variable that represent the unobserved characteristics, and it is associated with f^{th} which represent climate change adaptation strategies. The γ_{rf} denotes the binary dependent variable and the (f =1,…….,m) represent the several practices adopted by smallholder farmers in the study area. The smallholder farmer was assigned a value of 1 if any adaptation strategy was chosen and 0 if otherwise. H_{rf} is the vector of the explanatory variables in the model. Following Woolridge (2003), we represent climate change variables by V_{rf} to account for unobserved heterogeneity. α_f and β_f represent the conformable vectors that are estimated. The error term ε_f in the model have multivariate normal distributions, with zero means, unitary variance, and n × n correlation matrix (Mulwa et al., 2017), where $\varepsilon_f \approx MVN(0,\Pi)$. The covariance matrix is given in Equation 5:

$$\Pi = \begin{vmatrix} 1 & \eta_{12} & \eta_{13} & \cdots & \eta_{1m} \\ \eta_{21} & 1 & \eta_{23} & \cdots & \eta_{2m} \\ \eta_{31} & \eta_{32} & 1 & \cdots & \eta_{3m} \\ \vdots & \vdots & \vdots & 1 & \vdots \\ \eta_{m1} & \eta_{m2} & \eta_{m3} & \cdots & 1 \end{vmatrix} \tag{5}$$

where η represent the unobserved correlation between the stochastic components of the error terms in the model. As described by Teklewold et al. (2013), the elements at the off-diagonal denote the correlation between the stochastic error terms of the different adaptation strategies (η_{12}, η_{21}, η_{31}, η_{13}) in the covariance matrix. The hypothesis of the unobserved correlation between the stochastic component of the f^{th} and m^{th} choice of adaptation strategies indicates that equation (4) provides an MVP model that represents decisions to jointly adopt a particular adaptation strategy.

2.4

2.1 Access to credit

Following Ojo et al. (2019), benefitting from credit access is modelled in a random utility framework. Let Cr_i^* denote the difference between the utility derived from benefitting from credit access Cr_{1i}^* and that derived from choosing the non-beneficiary (Cr_{0i}^*), such that a household i will benefit from credit access, if $Cr_i^* = Cr_{1i}^* - Cr_{0i}^* > 0$. However, this difference is unobservable, but can be expressed by a latent variable model as follows:

$$Cr_i^* = \omega M_i + \varepsilon_i > 0 \text{ with } Cr_i = 1 \text{ if } Cr_i^* > 0, \quad (6)$$

Where Cr_i=1 if a smallholder farmer had access to credit and Cr_i=0 otherwise, M_i refers to a vector of variables (e.g. age, sex, farm size, household size and off-farm work participation) that may influence credit access; ω is a vector of parameters to be estimated; and ε_i is an error term, which is assumed to be normally distributed with zero mean.

Estimating the impact of credit access on adoption climate change adaptation strategies by simple regression would lead to bias, because households' credit market participation decisions are likely to be non-random if those who have access to credit have systematically different characteristics from those who are credit-constrained. For example, households with more collateral resources, or those who possess better individual skills, ability and motivation may have better access to credit, while those with fewer resources and weak networks are more likely to be credit-constrained. Such factors may influence both access to credit and adoption of adaptation strategies, resulting in inconsistent estimates of the effect of credit constraints on the adaptation activity. In such instances, an appropriate model of analysis requires accounting for possible selection bias. Given our interest of exploring the impact of credit access on adoption of climate change adaptation strategies while controlling for other factors that may influence farmers' decisions to adopt, we express farmers' adaptation strategies adoption decisions as a latent variable function:

$$G_i^* = \beta W_i + \lambda Cr_i + \varphi_i \text{ with } G_i = 1 \text{ if } G_i^* > 0 \quad (7)$$

where G_i^* is a latent variable that represents the propensity to adopt CCAS for household i, which gives the value of 1, if the farmer adopts CCAS and 0 otherwise; X_i is a vector of observable characteristics (e.g. age, education, household size and off-farm work participation) that are assumed to influence CCAS adoption; Cr_i is an indicator representing the farmer's binary choice of credit access; β_1 and λ are parameters to be estimated; and φ_i is a random error.

Modelling the impact of credit access on adoption of climate change

The study employed the endogenous switching probit regression which consists of two stages. In the first stage, factors determining access to credit among smallholder farmers was modelled. In the second stage, a probit model was employed to estimate the correlation between the adoption of climate change variable and a set of explanatory variables conditional on the farmers' access to credit. The two outcome equations can be expressed as follows:

$$G_{1i}^{*} = \beta_1 W_{1i} + \chi_{1i} \text{ with } G_{1i} = \begin{cases} 1 & \text{if } G_{1i}^{*} > 0 \text{, } G_{1i}^{*} \le 0 \text{ and } C_i = 1 \text{.} \\ 0 \end{cases} \quad (8a)$$

$$G_{0i}^{*} = \beta_0 W_{0i} + \chi_{0i} \text{ with } G_{0i} = \begin{cases} 1 & \text{if } G_{0i}^{*} > 0 \text{, } G_{0i}^{*} \le 0 \text{ and } C_i = 0 \text{.} \\ 0 \end{cases} \quad (8b)$$

Where G_{1i}^{*} and G_{0i}^{*} are two climate change strategy adoption variables for beneficiaries and non-beneficiaries of credit, respectively; G_{1i} and G_{0i} are observed adoption choices, which take the value of 1 if beneficiaries and non- beneficiaries of credit adopt the climate change adaptation strategies, and 0 if otherwise; W_i is a vector of observable covariates (age, household size, educations) that influence the decision to adopt the climate change strategies; β_1 and β_0 are the parameters to be estimated; χ_{1i} and χ_{0i} are two error terms that denote unobservable factors associated to climate change strategy adoption for beneficiaries and non- beneficiaries of credit, respectively. The full information maximum likelihood (FIML) approach estimates the selection Equation (6) and outcome Equations (8a) and (8b) simultaneously (Ayuya et al., 2015; Lokshin and Sajaia, 2011).

3. Results and discussion

3.1 The descriptive statistics of the smallholder farmers in the study area

This section reports the description of both dependent and the explanatory variables included in the model estimations. The dependent variables are the adoption and intensity of adaptation strategies employed by smallholder farmers. This study pulls its empirical specification from the studies of determinants of adoption of climate change adaptation strategies (Abdulai and Huffman 2014; Kibue et al. 2016; Mulwa et al., 2017; Ojo and Baiyegunhi 2020a). The description of the explanatory variables and their respective means are presented in Table 1. The socioeconomic characteristics such as gender, age, educational attainment, household size, and number of years in crop farming were included in the model to control for household heterogeneity. These variables have been hypothesized to potentially influence the adoption and intensity of adoption of adaptation strategies. Out of the 183 responses, about 61% were males, while 39% were females. The average age of the sampled farmers was 43 years, suggesting that the majority of our farmers in the sample were in the productive age bracket. The majority (about 60%) of the respondent had attained at least primary level of education. About 32% of the smallholder farmers are beneficiaries of the land reforms

Table 1: Definitions and summary statistics of variables used in the model

Variables	Description of Variables	Mean	Std. Dev.
Dependent variables			
CC perception	1 = Perceived CC, 0 = did not perceive CC	68	
Adoption of CCAS	1 = adopter, 0 = non-adopter of CC AS	90	
Number of CCAS	Numbers of CC AS adopted by farmers	5.95	4.20
Explanatory variables			
Age	Age of HH head (years)	43.83	12.68
Gender	1 if HH head is male, 0 if female	0.61	
Educational level	Years of education of HH head	59.96	52.55
Farming experience	Years of household experience in farming	10.54	4.71
Access to extension	1 if HH has access to extension, 0 if otherwise	0.33	
Non-farm income	1 = if HH engages in any off-farm activity	0.38	
Credit	1 if HH has access to credit, 0 if otherwise	0.45	
Land reform	1 = beneficiary, 0 = non- beneficiary of Land reform	0.32	
Access to training	1 if HH has access to agric. training, 0 if otherwise	0.48	

ICT_Radio	1 if HH has access to information through Radio, 0 if otherwise	0.48
ICT_Mobile phone	1 if HH has access to information through mobile phone, 0 if otherwise	0.36
ICT_Television	1 if HH has access to information through Television, 0 if otherwise	0.25
ICT_Neighbour	1 if HH has access to information through Neighbour, 0 if otherwise	0.50
ICT_Family members	1 if HH has access to information from family members, 0 if otherwise	0.36
Access to irrigation	1 if HH has access to irrigation, 0 if otherwise	0.57

3.2 Correlation matrix of the adaptation strategies from the MVP model

The correlation matrix from the MVP model of the adaptation strategies used by the farmers are presented in Table 2.

Table 2: Correlation matrix of the adaptation strategies from the MVP model

Variables	Changing Planting date	Reducing Livestock	Irrigation	Early maturing cro
Changing Planting date				
Reducing Livestock	0.141(0.097)*			
Irrigation	0.781(0.085)*	0.101(0.048)**		
Early maturing crops	0.090(0.091)*	0.088(0.042)**	0.120(0.070)*	
Likelihood ratio test (Chi^2)		Chi2(6) = 45.3969		
P-value		0.0000		
Joint probability (success)		0.546		
Joint probability (failure)		0.149		
Linear predictions:				
Changing Planting date		0.496		
Reducing Livestock		0.509		
Irrigation		0.583		
Early maturing crops		0.475		

*** and * represent the significance level at 5% and 10%, respectively.*

The likelihood ratio test (Chi^2 (6) = 45.396; P > 0.000) of the independence of the error terms in the different adaptation equations was rejected (Table 2). Therefore, the study accepted an alternative hypothesis of interdependence among the different adaptation strategies. The results, therefore, justified the use of the MVP model. All the pair-wise coefficients were positively correlated, demonstrating complementarity among the adaptation strategies. The results show that the joint probability of using adaptation strategies was 54%, while that of not using adaptation strategies was 15%. The linear predictions of the results show that the likelihood of adopting changing planting dates and reducing livestock sales was 50% and 51%, respectively. The linear predictions for irrigation and early maturing crops were 58%, and 48%, respectively.

3.3 Parameter estimates of the multivariate probit (MVP) model of the determinants for climate change adaptation strategies

The results in Table 3 presents the multivariate probit (MVP) estimation of the determining factors that influence farmers' choices of adaptation strategies in the Northwest, Free state and Limpopo provinces, South Africa. The adaptation measures adopted to limit or cope with the negative impact of climate change at the study sites include the early maturing crops, reduced livestock numbers, irrigation and change in crop variety. The four different strategies were discussed based on their respective significant variables to achieve a clear flow and provide a better organization of the empirical findings.

Table 3: MVP estimates for the determinants of climate change adaptation strategies

	EARLYMATCRO		REDUCELIVNO		IRRIGATION		CHNGCRPVARTY	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Location_NW	-0.141	0.438	0.396	0.409	-1.525	**0.570*** **	-0.814	**0.434***
Location_FS	-0.267	0.402	-0.194	0.445	-0.363	0.421	-0.707	**0.397***
Location_LIMP	-0.294	0.332	0.205	0.356	-0.503	0.367	-0.386	0.311
Marital status	0.154	0.269	0.199	0.273	3.164	**0.410*****	2.252	**0.270*****
Access to extension	1.164	**0.443*****	1.996	**0.453*****	1.002	**0.514***	0.424	0.386
Non-farm income	0.095	0.366	-1.338	**0.427*****	-0.418	0.388	-0.359	0.338
Farm based-organisation	0.152	0.271	-0.160	0.277	0.431	0.292	0.417	0.261
Education of House head	-0.092	0.086	0.010	0.086	0.005	0.096	0.075	0.085
Farming Experience	-0.045	**0.027***	-0.068	**0.029****	-0.047	0.033	0.011	0.028
Crop and livestock production	1.891	**0.449*****	1.488	**0.474*****	0.154	0.421	0.717	**0.366****
Age of the respondent	-0.016	0.012	0.002	0.011	0.012	0.011	0.004	0.010
GenderN	-0.124	0.261	-0.191	0.279	0.039	0.295	0.113	0.256
Susceptibility	0.694	**0.291****	-0.590	**0.319*****	-0.099	0.343	-0.290	0.312
Agricultural Training	-1.202	**0.406*****	-0.150	0.352	-1.146	**0.478****	-0.394	0.375
Access to credit	0.829	**0.380****	1.265	**0.328*****	0.297	0.435	0.129	0.396
Constant	0.424	0.750	-0.192	0.751	-0.563	0.822	-1.451	**0.709****
/atrho21	-0.466	0.168	0.006					
/atrho31	0.253	0.168	0.133					
/atrho41	-0.032	0.164	0.847					
/atrho32	0.103	0.167	0.539					
/atrho42	0.256	0.148	0.084					
/atrho43	1.410	0.368	0.000					
rho21	-0.435	0.136	0.001					
rho31	0.248	0.158	0.117					
rho41	-0.032	0.164	0.847					
rho32	0.102	0.166	0.537					
rho42	0.250	0.139	0.072					
rho43	0.887	0.078	0.000					
Log likelihood	-228.644							
Wald chi2(60)	235.86							
P-value	0.0000							

****,** and * represent significance level at 1%, 5% and 10%, respectively.*

Location of farmers play a significant role in determining the type of climate change adaptation strategy that is considered by farmers since weather varies with geographical location. The irrigation and changing crop variety adaptation strategy showed a significant but negative association with the Northwest location, while the Free State location was negatively signed and significant in influencing the adoption of the changing crop variety adaptation strategy. The negative sign could be ascribed to the variability in the climate, with no issue of drought since the last occurrence in the 2015 production period. Several studies (Below et al., 2012; Berman et al., 2015) have found the importance of location in determining the adoption of climate change adaptation strategies. For instance, some regions such as the Eastern Cape in South Africa experience more variability in rainfall and possible extreme drought events compared to other regions (Mahlalela et al., 2020), hence, location determines adoption of climate adaptation strategies by farmers.

For irrigation and changing crop variety adaptation strategy, the marital status shows a positive and significant relationship indicating that the status of farmers increases the likelihood of adopting the irrigation and changing crop variety strategy. According to Van and Holvoet (2016), unmarried or divorced women were found to irrigate and generally participate in climate change adaptation strategies relative to married women in Tanzania. In other words, farmers with a single marital status are generally a vital factor in determining the adoption of the irrigation and changing crop adaptation strategies.

Farmers' access to extension services is positive and significantly associated with the early maturing crop, reduce livestock number and irrigation adaptation strategies (at 1%). This indicates the importance of access to relevant information and other resources provided to farmers through extension service, thus enhancing farmers' tendency for adopting the listed climate-risk mitigating strategies (Ojo and Baiyegunhi, 2020; Thinda et al., 2020). Climate information such as updated weather forecast is one of the services provided by the extension services to the farmers as it significantly contributes to farmers' likelihood for adopting the listed adaption strategies at the study areas. The findings of this study comply with that of Belay et al. (2017) who affirms that access to up-to-date weather information as well as better irrigation schedules enables farmers to make an informed decision on early, late planting dates and increase water use efficiency. Also, decreasing the herd size of livestock has been reported as a considerable strategy for overcoming the adverse effects of climate change (Zhang et al., 2017). To achieve this, the result suggests that farmers who have regular contact with the extension agents or services are more likely to adopt the strategy of reducing the size of livestock on the farm. According to Abegunde et al. (2020), extension access could contribute significantly towards enhancing the productivity and income of farmers, thus represent a critical determinant of adopting the reducing livestock number strategy in South Africa. Similarly, these results also corroborate with the findings of Aryal et al. (2018) that farmers who receive extension services are more likely to adopt the reducing livestock number adaptation strategy, thus policies that could provide real-time extension services are needed to improve the understanding of farmers on the benefits of limiting the size of herds in South Africa.

Farmers who earn income from other businesses or investments aside the farming were found to have less probability of adopting reducing livestock number strategy, with results showing a negative and significant relationship with off-farm income variable. This implies that as farmers get more involved in off-farm businesses and earn income from such businesses, they are more likely to show little interest in the proposed adaptation strategies such as that of reducing livestock number. Moreover, engaging in off-farm activities that are not vulnerable to climate change impacts have been reported by Bryceson (2019) as a prominent adaptation strategy where farmers generate income to improve household livelihoods.

Unlike the prior expectations, the years of farming of experience of farmers is statistically significant with a negative coefficient for the early maturing crops and reduce livestock number strategies. This indicates that an increase in farmers' farming experience could lead to a decrease in farmers' likelihood to adopt the climate change adaptation strategy. The reason for the negative sign could be linked to the age of the farmers with high experienced (Ado et al., 2019), with previous studies suggesting that older farmers with high experience are less likely to adopt the mentioned strategies relative to the younger farmers who are desperate to gain experience. The findings of this study correspond with that of Denkyirah et al. (2016), who found a negative association between age and the adoption of adaptation strategy (like pesticides), amongst the smallholder farmers. As opined by Maddison (2006), as well as Ishaya and Abaje (2008), the age of farmers is often associated with the experience of farmers which plays a significant role in the likelihood of farmers to adopt a particular adaptation strategy.

Farmers who specialize in crop and livestock production are expected to be more interested in adopting the early maturing crop, reduce livestock number and change crop variety adaptation strategy. The crop and livestock production variable is positively and significantly associated with the three listed adaptation strategies. These strategies directly play a significant role in ensuring the effects of climate change are minimized as well as to ensure crop and livestock sustainability. An increase in crop and livestock production could translate to an increase in the adoption of the listed adaptation strategies since crops and livestock could be seriously affected by extreme weather conditions such as drought and disease outbreak, respectively (Komba and Muchapondwa, 2012; Saqib et al., 2016). The findings agree with the study of Deressa et al. (2011), who emphasized that possessing livestock and engaging in crop production significantly and positively influence the decision to adopt a specific strategy by farmers. Similarly, the findings of this study are supported by the study of Ojo and Baiyegunhi (2020a) who showed that crop and livestock production which could also be regarded as a mixed-production represent a significant determinant of adaptation strategy. Given that livestock production in South Africa has experienced a decline in the recent years, with the beef industry and dairy industry mostly affected (Zwane, 2019), the farmers in the industry would be willing to adopt relevant adaptation strategies that could improve the industry productivity and sustainability.

The susceptibility variable was found to be statistically significant as well as have a positive relationship with the likelihood of the farmers to adopt the early maturing crop adaptation strategy. On the other hand, susceptibility shows a significant and negative relationship with the reduce livestock number adaptation strategy. This implies that, farmers who produce crops and livestock at the Free State, Northwest and Limpopo provinces could be highly susceptible to climate change effects, for instance through droughts, thus increasing the farmers' probability to adopt the adaptation strategies (Thinda et al., 2020). Given that the agricultural sector is most vulnerable to drought caused by climate change-related hazards (Addisu et al., 2016), the adoption of early mature crop and reduce livestock number adaptation strategy could be the farmers' alternative means for increasing yields and increase farm incomes.

Agricultural training received by farmers was found to be negatively and significantly associated with the adoption of early maturing crop and irrigation adaptation strategy. Interestingly, based on prior expectation, these findings contradict expectations since an increase in demonstration training provides farmers with more information regarding climate change and adaptation strategies. Previous studies such as Ndamani and Watanabe (2016) have found agricultural training that educates farmers' increases farmers' likelihood adopt climate change strategies. On the contrary, the findings of Uddin et al. (2014) slightly correlates with our results, as agricultural training received by farmers was insignificant to the adoption of climate change adaptation strategies. A possible reason for obtaining a negative significant variable for training received by farmers could be linked to farmers who are engaged in off-farm activities and earn income, therefore showing negative consequences towards increasing their potentials of adopting the two significant adaptation strategies. Thus, the indication of a negative significance on such "developmental variable" highlights the need for rural development policy that would promote the magnitude of climate adaptation strategies among farmers in the study areas.

As expected, the result shows that access to credit positively and significantly related to the early maturing crop and reduce livestock number adaptation strategy. Productions on the farm are capital-intensive and therefore farmers with reliable access to credit facility would equip farmers with the financial power to invest in new technologies and new crops that mature earlier than other crops. According to Ojo and Baiyegunhi (2020a), farmers' decision to adopt adaptation strategies is heavily influenced by the financial support that is readily accessible. Similar to the findings of this study, Sani et al., (2016) and Marie et al. (2020) found that access to credit provides farmers with the financial ability to cope with transaction costs associated with various adaption options.

3.4. Full information maximum likelihood (FIML) estimates of the endogenous switching probit model (ESPM)

This study used an ESPM as the impact model because it was able to control for all possible biases that could confound the results. The correlation coefficients rho_1 and rho_0 in the ESPM were both positive, and statistically significant for the correlation between the adopters and adoption of climate change adaptation strategies. Thus, self-selection occurred in the adoption of climate change adaptation strategies, but might not have the same effect on non-adopters, should they choose to adopt. This finding corroborated that of Lokshin and Sajaia (2004), Abdulai and Huffman (2014), and Khanal et al. (2018). The statistical significance of the likelihood ratio test at 1% for joint independence of the three equations implied that they should not be estimated separately.

Table 4 presents the results of the full information maximum likelihood (FIML) estimates of the endogenous switching probit model. The discussion of results focuses on providing insights into the important variables that influence the adopters, non-adopters of climate change adaptation strategy and farmers with access to credit.

Table 4: Full information maximum likelihood (FIML) estimates of the endogenous switching probit model (ESPM)

	ADOPTERS OF CCAS			NON-ADOPTERS OF CCAS			ACCESS TO CREDIT		
	Coef.	Std. Err.	P-value	Coef.	Std. Err.	P-value	Coef.	Std. Err.	P-value
Location_NW	0.212	0.871	0.808	-0.504	0.407	0.215	-1.568	0.455	**0.001*** **
Location_FS	0.748	0.922	0.417	-1.270	0.556	**0.022** **	-0.915	0.414	**0.027** **
Location_LIMP	0.727	0.833	0.383	-0.699	0.440	0.112	-0.965	0.377	**0.010** **
Age of the respondent	-0.002	0.019	0.919	-0.047	0.017	**0.005*** **	0.017	0.013	0.182
Marital status	-0.119	0.329	0.717	-0.642	0.348	**0.065***	0.271	0.458	0.553
Non-farm income	0.799	0.448	**0.074***	0.322	0.424	0.448	-0.174	0.333	0.601
Gender	-0.115	0.377	0.759	-1.025	0.479	**0.032** **	-0.079	0.254	0.755
Education of House head	0.103	0.144	0.474	-0.294	0.124	**0.018** **	0.192	0.090	**0.032** **
Susceptibility	0.771	0.379	**0.042** **	2.082	0.546	**0.000*** **	0.006	0.297	0.984
Experienced drought	-0.765	0.758	0.313	-0.993	0.685	0.147	-1.037	0.517	**0.045** **
Access to Extension	1.100	0.508	**0.030** **	0.717	0.201	**0.001*** **	1.788	0.427	**0.000*** **
Agricultural Incentives	1.464	0.441	**0.001*** **	1.550	0.378	**0.000*** **			
Improved crop variety	-1.086	0.516	**0.035** **	1.333	0.664	**0.045** **			
Agricultural Training							1.515	0.248	**0.000*** **
Land Tenure							-0.364	0.442	0.411
Land Rights							-0.436	0.296	0.142
Constants	-1.172	1.557	0.452	4.114	1.511	0.006			
/athrho1	13.616	511.462	-988.830	1016.063					
/athrho0	-15.181	1200.817	-2368.739	2338.377					
rho1	1	0.000	-1	1					
rho0	-1	0.000	-1	1					
Prob > chi2	0.0000								
Wald chi2(16)	74.66								
LR test of indep. eqns.	14.06								

****, ** and * represent significance level at 1%, 5% and 10%, respectively.*

In the Northwest, Limpopo and Free State province, the location of farmers shows a significant and negative association with access to credit. This implies that farmers who are engaged in farming production in the listed locations could experience difficulty in obtaining credits from the financial institutions, possibly due to the higher tendency of experiencing droughts and as result, produce a reduced farm yield. A reduction in farm productivity would generally affect farmers' repayment capability and therefore influences their credibility or eligibility to secure access to credits. Similarly, to the location variables, the Free State location was significant at 5% and negatively influence the possibility of farmers' decision to adopt climate change adaptation strategies. The negative sign for the location variable could be attributed to the extent of farmers' exposure to climate change hazards and the level of fertility of the soil used for farming in the listed location. The results of this study are supported by that of Sharma et al. (2011) and Zakaria et al. (2020) who found a negative significance between farmers' location and their intensity to adopt climate change strategies. According to Rakgase and Norris (2015), the location was found to contribute to farmers' choice for perceiving drought-related climate issues, which also plays a part in farmers' choice and intensity of adoption of climate change adaptation strategies. Thus, the location of a farm is an important factor in decision making regarding adaptation strategies.

The age of farmers is significant and negatively signed, as results imply that farmers' age is an important variable that contributes to farmers' decision not to adopt climate change adaptation strategies. The negative indication of the age variable could be ascribed to the hypothesis that older farmers are less likely to adopt climate change adaptation strategies as they may not be willing to take the risks, that is, risk-averse. Besides, the older farmers may have limited knowledge (in terms of education level) on the available various adaption strategies such as different drought-tolerant crop varieties. The younger farmers are risk-averse relative to the older farmers, explaining that the older the farmers, the less likely they would adopt the climate change adaptation strategies. The result shows that relative to the younger farmers, the age of respondents which aligns with the level of knowledge about adaptation strategies contributes to the decision to adopt climate change adaptation strategies. The findings of this study are supported by Arslan et al. (2014) and Zakaria et al. (2020) who found a significant and negative effect of age variable on the adoption of adaptation strategy in Zambia. Also, in Ethiopia, the age of farmers was found to be significant and negatively influence decisions relating to climate change strategies adoption (Gebru et al., 2020).

Marital status of respondents was found to be statistically significant and negatively influence the likelihood of adopting the adaptation strategies for climate change. This implies that respondents' marital status, whether married, divorced, widowed or single affects the decision for not adopting the adaptation strategies of climate change. The negative sign for this variable could be ascribed to the low household income and large family size, majorly for the married households, whereby income is used for consumption. Given that the cost of adaptation could be expensive (Chambwera, et al., 2014), households with low income could find it difficult to cope with the financial commitments related to climate change adaptation strategies. This finding is in accordance with the study of Ojo and Baiyegunhi (2020a) who found a significant and negative association between marital status and climate change adaptation strategies.

The result shows a significant and positive association between off-farm income and adoption of climate change adaptation strategies. This implies that farmers who earn income from engaging in a non-farm activity could possess a substantial financial power to manage cost related to adopting adaptation strategies. In line with the study of Gberu et al. (2020) who found that non-farm income influences farmers adaptation to climate change and also serves as an enterprise diversification which helps farmers to improve livelihood and increase their income. Therefore, a lack of off-farm income may contribute negatively to the likelihood of farmers to adopt climate change adaptation strategies (Jiri et al., 2015).

The gender variable negatively influences the non-adaptation of climate change strategy and statistically significant at 5%. This indicates that gender distribution presents different adaptive capacity, with the females showing higher adaptive potentials compared to the male farmers (Alhassan et al., 2019). The negative effects on climate change adaptation strategies could therefore be attributed to the dominance of male farmers in the study areas compared to the female farmers. The higher adaptive capability of the households dominated by females compared to that of the male-headed households could be linked to the higher vulnerability to climate change as a result of females' low formal education, inadequate off-farm engagements and poor social network (Djoudi et al., 2016; Adzawla and Baumüller, 2020).

The results show that education of the household head is statistically significant and negatively influenced the choice of farmers to become non-adopters of climate change adaptation strategies. An increase in the training of household held would create awareness of climate change, knowledge about agricultural innovations, enhance interests in the strategies for coping with climate-related risk. Therefore, increasing the investments in educating farmers and providing a policy mechanism is essential for reducing the non-adopters of climate change coping strategies and reducing the vulnerability of farm households in the study areas. Previous studies have also reported the significance of education to increase the awareness of farmers towards climate change coping strategies (Abid et al., 2015; Tiyumtaba, 2016; Ali and Erenstein, 2017; Ojo and Baiyegunhi, 2020b).

The endogenous switching probit estimates revealed that the education of household heads positively and significantly affect access to credit in the study areas. This implies that farmers who are highly educated can motivate the financial institutions for the provision of credits that can be used to finance climate change adaptation strategies and subsequently improve farm productivities. This finding is supported by Abdul-Jalil (2015) and Pal and Laha (2015) who found that the educational level of farmers positively influences the worthiness for accessing credits and also provides the guarantee for credit repayments. The results of Kumar et al. (2017) similarly reveal that access to formal, institutional credit is significantly influenced by the educational attainment of respondents.

The susceptibility variable shows a positive and significant association with adopters and non-adopters of climate change adaptation strategies. The results suggest that more susceptible farmers are more likely to adapt to climate change-related risks and also, farmers who are not susceptible are less likely to adopt climate change adaptation strategies. Farmers who are closer to a drought-prone location could be categorized as susceptible, which indicates that high probability of farmers to adopt climate change coping strategies. On the other hand, farmers who are located where rainfall frequently and experience no drought could be less interested in adopting measures for coping with climate-related risk.

According to the results in Table 4, the drought experience of the farmers in the study areas was one of the statistically significant explanatory variables that have a negative coefficient. The negative sign indicates that it has a negative influence on obtaining credits from the financial institutions. The impacts of drought could lead to impacts can lead to a decrease in revenues from crop and livestock sales (Kuwayama et al., 2019), particularly in South Africa where there has been a temporal variability in drought events. Farmers who tend to experience drought creates strong indications for becoming incapable to repay loads which translates to low confidence and worthiness. In other words, credit managers are preferably interested in farmers with no drought experience, therefore, drought experience of farmers represents a key determining factor for credit access. The results related to the effect of drought found in this study is supported by the report of Kingwell and Xayavong (2017) who found that the financial performance of farmers heavily depends on the extent of drought experience of farmers.

Access to extension had a significant positive effect on the probability of farmers becoming adopters and non-adopters of climate change adaptation strategies, as well as access to credit. The extension agents provide farmers with information on the coping strategies necessary for managing climate risks and the information could translate to enhancing the interests of farmers whether to adopt or not to adapt, depending on other determining factors such as the experience of drought. Also, farmers who experience difficulties in accessing extension services could have low probability to adopt. Although the non-adopters may have access to extension, the ease of access could be a contributing factor as farmers whose farms are located far from home and nearby market are hard to reach by extension agents. Consequently, these contribute to the reduced adoption of improved production technologies. This result is consistent with Aryal et al. (2018) regarding farmers' adoption of multiple climate-smart agricultural practices in India.

Moreover, farmers' access to extension service increases their probability of obtaining credit, as result shows a positive and significant influence on farmers' access to credit. Extension services provided to farmers generally enable farmers to improve farm production and management skills through up-to-date information and subsequently increases farms productivity. Upon receiving training from the extension agents, farmers often require financial backing from financial institutions in terms of credit provision, to optimally use the adaptation information. The findings of this study correspond with results of Oyedele and Akintola (2012), and Dzadze (2012) who found that extension service access significantly and positively determines farmers' access to credit.

Empirical findings have shown that agricultural incentives are one of the important determining factors for adopters and non-adopters of climate change adaptation strategies. The coefficients of agricultural incentives for both the adopters and non-adopters are positive and statistically significant. The provision of incentives facilitates the transformation of the crop and livestock structure, and remain a key factor which may influence the farmers' decision to adopt climate change adaptation measures as they increase agricultural production. Similar to our findings, a study such as Nguyen et al. (2019) found that incentives contribute positively to farmers' decision-making to adopt climate change adaptation strategies. While agricultural incentives could increase the adaptation of climate change strategies, it could also increase the probability of farmers not to adopt the coping strategies to climate change. The reason for a potential increase in the non-adopters of climate change adaptation strategies could be ascribed to other contributing factors such as farm structure, recent farmers' experience related to adverse climate impacts and so on. According to Buelow and Cradock-Henry (2018), incentives do not inevitably drive adaptive response by farmers but instead, the effect of incentives on socio-cognitive processes in farmers rely solely on farming contexts such as recent farming experience on climate risks. The study concluded that incentives provided to farmers such as financial support alone are inadequate for catalyzing adaptation from intention to action.

The coefficient of improved crop variety showed a significant and negative effect for adopters of climate change adaptation strategies while it had a positive and significant effect on non-adopters of climate change adaptation strategies. Farmers who are already practising improved crop variety are hypothesized to cope with climate risks as such practice prevents vulnerability to climate change, hence result suggests that farmers in the adopters' category are less likely to adopt other climate change strategies. On the other hand, the non-adopter farmers are more likely to increase the chances of not adopting climate change strategies if they already focused on the use of improved crop varieties. This result indicates that the use of improved crop variety on its own may be sufficient for coping with climate risks. These findings are in line with previous work Abid et al. (2015); Fadina and Barjolle (2018) who found a positive and significant relationship between crop variety and the adoption of climate change adaptation strategies.

Agricultural training shows a positive and significant relationship with farmers' access to credit. This implies that farmers who are trained possess more credibility for securing credit from financial institutions. Education on investments and credit management enable farmers to improve farm productivity, increase income and reduce poverty. Loads obtained from the financial institutions are great financial empowerment offered to farmers to increase food production and enhance food security in South Africa. Thus, the increase in the likelihood of farmers to gain access to credit is a significant factor that also determines farmers' decision to either adopt or not to adopt climate change adaptation strategies in the study areas. In line with the findings of this study, Asante-Addo et al. (2017) also found that agricultural training programs set up to educate farmers about credit and farm business management provides farmers with an edge for obtaining credit. The findings from this study suggest that policy strategies that allow the training of farmers is important for improving farmers' access to credit services.

3.5 Estimated impact of credit access on climate change adaptation strategies

The primary focus of our study is to examine the impact of access to credit on farmers' adoption of climate change adaptation strategies. Three approaches were folowed in achieving this objective. Firstly, the study employed a multivariate probit model to estimate the determinants of adoption of choice of climate change adaption strategies. The second approach analysed impact of credit access on adoption of climate change adaption strategies with aid of endogenous switching probit model. The results show a positive and significant effect of credit access on adaptation strategies. A simple considerable difference in the average number of adaptation strategies between beneficiaries and non- beneficiaries of credit access in impact evaluation studies could be misleading as they usually fail to control for potential differences in the characteristics between the two groups. The estimate from the endogenous switching probit regression model can also be inadequate even if not misleading though it accounts for endogeneity. This is because direct coefficients from the model cannot be considered as ATT since the issue of missing data (counterfactual scenario) has not been accounted for.

The study, therefore, turned to the results of the causal effects of the access to credit on farmers' adaptation strategies using ATE and ATT, where the endogenous switching probit with tretment treatment was used and then complemented with IPWRA as a robustness check. Hence, the estimates from the swiching probit are discussed first. ATE and ATT were estimated after fitting the switching probit regression with endogenous treatment effects.[1] As indicated in Table 5, the estimated potential outcome means (ATE) of access to credit on the adoption of adaptation strategies adopted by farm households is about 9.4 and statistically significant at 1 %. The ATE estimate suggests that an average farm household in the study area will employ about nine more strategies to mitigate the potential effects of climate change if has access to credit. Similarly, the conditional treatment effects which measure the ATT of benefitting from credit access on the adoption of adaptation techniques adopted is about 8.7 and also statistically significant at 1%. Thus, the average farm household in the non-beneficiary group would adopt about 8.7 more of climate change adaptation strategies than it would if it did not benefit from credit access.

Table 5: Treatment effects for the adoption of climate change adaptation strategies – Endogenous switching probit model

Treatment effects	***Coefficient***	***Std.***
Average treatment effect (ATE)	9.399***	5.235
Average treatment on the treated (ATT)	8.697***	4.766

Consistent with the switching probit regression, IPWRA produces significant gains in adoption of adaptation strategies resulting from benefitting from credit access. From Table 6, the ATE and POM are approximately seven (7) and four (4), respectively. Thus, the adoption of adaptation strategies employed if all of the sampled farmers were to benefit from credit access would be seven times more the average of 4 that would occur if none of the farmers had benefitted from credit access. Likewise, the beneficiary treated group employed 7.245 more than they would have if they did not benefit from credit access.

Table 6: Treatment effects for the adoption of climate change adaptation strategies – Inverse-probability-weighted regression adjustment

Treatment effects	***Coefficient***	***Std.***
Average treatment effect (ATE)	7.103***	0.276
Average treatment on the treated (ATT)	7.245***	0.289
Potential-outcome mean (POM)	4.057***	0.179

Note: The bootstrap replications were changed from 100 – 1,000 but no significant change occurred, hence 500 replications were used to bootstrap the standard errors.

[1] ATE and ATT were estimated as a post-estimation after fitting the Stata command *switch_probit* for switching probit regression with endogenous treatment. The ATE estimated after *switch_probit* is the potential outcome means

The results from the two estimation techniques indicate that credit access significantly increases the adoption of strategies farmers employ to mitigate the adverse effects of climate change. The positive impact of credit access on climate change adaptation strategies agrees with the studies of Sallawu et al. (2016) and Derresa et al. (2009, 2011) in Nigeria and Ethiopia, respectively. The results suggest that the accessibility of farm households to credit may free them from financial burdens and credit constraint conditions, inducing to invest in productivity-enhancing farm inputs and other adaptation strategies to minimize production risk. Ojo and Baiyegunhi (2020) reported that access to credit enhances the chance of changing planting and harvesting dates, and planting trees, as mitigation strategies.

4. Conclusion

This study examined determining factors influencing the adoption of climate change adaptation strategies among smallholder farmer, using the descriptive statistics, the multivariate probit (MVP) model and endogenous switching regression model (ESRM). The empirical results of the multivariate probit model showed that location, access to extension, non-farm income, farming experience, crop and livestock production, susceptibility, agricultural training and access to credit variables influenced the smallholder decision to adopt climate change adaptation strategies. On the other hand, the ESRM showed that location, age, marital status, gender among others, influenced the decision to adopt climate change adaptation strategies. The variables such as location, education, drought experience affected the smallholder farmers' access to credit. Thus, to improve the adaptive capacity of farmers, it is therefore recommended that policies that would improve the decisions of smallholder farmers to adopt climate change adaptation strategies are put in place. These policies and investment strategies of the government should be formulated and targeted at providing education, credit facilities and climate change adaptation strategy information. In addition, the stakeholders and government must cooperate and collaborate to improve the conditions under which farmers can gain access to climate change information and suitable agricultural credit as well as policy incentives to ensure overall sustainability of the agricultural sector.

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while ATT is the conditional treatment effect.

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