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Determinants Of Climate Change Adaptation Measures Among Small Scale Crop Farmers In Limpopo Province Of South Africa.

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Abstract
Agriculture remains the primary source of livelihood and food security for smallholder crop farmers in South Africa's Limpopo Province. However, this sector is increasingly threatened by climate change, prompting farmers to adopt various adaptation strategies. This study investigates the socioeconomic factors influencing climate adaptation strategies among small-scale tomato and avocado farmers across three districts: Capricorn, Vhembe, and Mopani. Using a multistage sampling technique, data were collected from 156 respondents through structured questionnaires and interviews. Descriptive statistics and binary logistic regression analysis were employed to examine patterns and determinants of adaptation behavior. The demographic analysis revealed that the majority of farmers were between 46 and 55 years old (29%) and predominantly male (68%). Most participants (73.7%) identified farming as their main occupation, and 56.4% reported access to climate change information. Notably, 50.6% of respondents observed an increase in drought frequency. Common adaptation strategies included crop rotation (48.7%), altered planting dates (41.7%), soil conservation (41%), irrigation (40.4%), and multi-cropping (37.8%). Regression results identified significant relationships between farmers' adaptation decisions and their income source, education level, and occupation. These variables influenced their ability to implement climate-responsive practices. The study recommends that key adaptation strategies such as irrigation and soil conservation be subsidized to improve adoption rates. Additionally, enhancing farmers' access to accurate climate information and strengthening extension services are vital for building resilience and sustaining agricultural productivity in the region.

Keywords: *Climate change, adaptation strategies, binary logistic regression model, avocado and tomato, crop farmers,*

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I. Introduction

Scientific evidence across the world indicates that the earth's climate is changing and this is due to the effects of the increase in greenhouse gas emission to the atmosphere (Belay et al., 2017). This increased greenhouse gas effects have led to alterations in the temperature and rainfall distribution across the globe. Africa is one of the most vulnerable Continent to the impacts of climate change and its variabilities. Because most Sub-Saharan African countries depend mostly on Agriculture, which is the most exposed sector to climate change effects, these countries are being perceived to be the most susceptible to these climate variability changes (Gebru et al., 2020).

Evidence are been provided to show that extreme events such as droughts and floods are incidences that has occurred across developing countries who depend solely on rain-fed agriculture for their livelihoods, this has affected the small-scale farmers a great deal. Climate change has affected both the social and natural systems in Africa and to control or limit the damages been done to the system has been of great challenge to communities across the globe, this has made both mitigation and adaptation measures to be very crucial to the African community and the world at large. Because most smallholder farmers in developing countries rely solely on rain-fed agriculture for livelihood, Adaptation is of utmost importance to the agricultural sector (Niang et al., 2014). It is therefore important to help the farmers identify ways by which these adaptation capacity measures can be strengthened in the local communities to help cope with climate change and its variabilities. Several studies have shown that not one adaptation measure fits all as there are different adaptation measures that works for different farmers depending on the type of crops grown and time of planting. Because of this, understanding the ways by which small-scale farmers perceive climate change is important and the adaptation strategies they practiced to cope with this menace is required to be known for policy making and develop programs aimed at improving adaptation measures in the agricultural sector.

Different factors are known to influence farmers' perception about climate variability and change and their decisions to adapt or not to climate change (Deresa et al., 2009). Farmers in developing countries are developing resilience to climate change through practicing different adaptation strategies and this includes irrigation system, diverse agricultural practices, planting different crop varieties to mention a few. According to (Belay et al., 2017), Ethiopia small-holder farmers practiced different adaptation strategies to cope with climate change impacts but the most commonly used especially in the lowland were change in planting dates and crop varieties, crop diversification and moving to the highland area for some time in cases of extreme drought was also practiced. Also, according to (Williams et al., 2019), it explained that farmers in Ghana are experiencing temperature increase and rainfall decline over the past two decades which has affected their productivity in the negative ways. It further described the different adaptation measures that was taken by these farmers to help reduce their vulnerability and cope with climate change impact which includes soil, water and crop conservation techniques, farm management practices such as fertilization, supplementary irrigation, crop rotation, intercropping and mixed farming.

South Africa is seen to be highly vulnerable to climate change impact and its variabilities (Republic of South Africa (RSA), 2011). A study conducted by Zulum et al., (2017) explained that there has been an increase in temperature and a decrease in the average rainfall in the Limpopo province of South Africa between 1985-2014. It is therefore important for proper structure and improved policies to be put in place to encourage the adoption of adaptation measures amongst farmers. This will help them to understand better the effects of climate change on their productivity considering the fact that the Agricultural sector is a major employer of labor force in the country and how they can identify the effective adaptation measures to be adopted. A better understanding of farmers' climate change adaptation measures and their determinants is important for future successful policy planning, especially in the agricultural sector. This paper therefore aims at highlighting current small-scale farmers' adaptation options in the Limpopo province of South Africa and their determinant factors. The specific objectives of this study are: (a) to examine farmers' perception of climate change, (b) identify the effective adaptation strategies that the farmers (tomato and avocado farmers) have adopted to help cope with the effects of climate change and (c) Identifying the determinant factors that influences the farmers' choice of adaptation strategies. Few studies have been published to date that investigated the determinants of adaptation options in Southern Africa. Therefore, understanding the household choice of adaptation options can provide insights into policies that can be taken into consideration in identifying the adaptation measures that can be used to help cope with climate change impacts. Nhemachena et al., (2014) reported that female-headed households are more likely to adapt to climate change impacts than male-headed households. This is so because referencing to their report, it was explained that most agricultural activities in the local communities of South African region are carried out mostly by women as the men often migrate to towns and urban areas in search for greener pastures to help cope with their livelihood. This in turn can help the policy of paying more attention to women groups and associations in the local communities to educate them more on climate change and its impacts and the possible adaptation measures that they can adopt to help improve their productivity. They further explained that farmers' experience is another determinant for farmers to adapt to climate change impacts. Highly experienced farmers are more likely to have more information and knowledge on changes in climatic conditions hence take up more adaptation options than those who are not experienced.

II. Literature Review

Climate Change and Agricultural Vulnerability in Africa

Climate change poses a major threat to food security in sub-Saharan Africa, particularly for smallholder farmers who depend on rain-fed agriculture. Rising temperatures, shifting rainfall patterns, and extreme weather events reduce crop productivity and increase vulnerability to pests and diseases (Niang et al., 2014; FAO, 2015). South Africa's Limpopo Province, one of the country's top agricultural zones, has been identified as highly vulnerable to these changes, given its semi-arid climate and reliance on small-scale farming (Zulum et al., 2017).

Adaptation Strategies Among Farmers

Farmers across Africa have developed a range of adaptation strategies in response to climate stressors. These include crop diversification, soil conservation, irrigation, use of drought-tolerant seed varieties, mulching, and altered planting dates (Debela et al., 2015; Fosu-Mensah et al., 2012; Belay et al., 2017). In Ghana, mixed cropping and conservation agriculture are common, while Ethiopian farmers often resort to crop substitution and relocation (Deressa et al., 2009; Gebru et al., 2020).

Socioeconomic Determinants of Adaptation

Adaptation strategies are influenced by socioeconomic and institutional variables such as education, household income, land tenure, access to credit, and extension services. Trinh et al. (2018) found that higher

educational levels are associated with a greater likelihood of adopting climate-smart practices. Similarly, access to weather information and agricultural extension services significantly improves the adoption of adaptation measures (Assan et al., 2018; Ojo & Baiyegunhi, 2018).

Youth Participation and Demographic Dynamics

The aging farming population in many African regions is a cause for concern. Agyapong and Mensah (2021) argue that limited economic returns and lack of incentives discourage youth from engaging in agriculture.

In Limpopo, the majority of farmers are above 36 years old, indicating a generational gap. Introducing digital agriculture tools and vocational training could help reverse this trend and bring youth into the agricultural workforce (Osei-Assibey & Adu-Gyamfi, 2022).

Gender Dynamics in Agricultural Adaptation

Gender plays a pivotal role in the adoption of adaptation strategies. Studies show that female-headed households often face limited access to land, credit, and information, which affects their adaptive capacity (Olaniran & Iwuagwu, 2022; Tsikata, 2019). However, women tend to be more proactive in implementing adaptation measures when resources are made available (Assan et al., 2018). Interventions must therefore consider gender-specific barriers to foster inclusive climate resilience.

Role of Information and Technology

Access to timely and reliable climate information shapes farmer decision-making. Farm Radio International (2023) reports that over 60 percent of rural farmers rely on radio programs for agricultural advice. Integration of mobile applications with traditional communication methods has also proven effective in bridging the information gap (Osei-Assibey & Adu-Gyamfi, 2022). In Limpopo, media remains the dominant source of climate information, followed by extension agents and personal observation.

Policy Relevance and Knowledge Gaps

Despite growing interest in climate adaptation, few studies focus specifically on the tomato and avocado farming communities in Limpopo. These crops are economically vital in the region yet under research. Addressing this knowledge gap will support the design of targeted adaptation strategies that reflect local needs and crop-specific challenges (Maponya & Mpandeli, 2012; Musetha, 2016). Localized research and community-driven policy frameworks are crucial for strengthening resilience.

III. Methodology

For the purpose of this study, the research was conducted in the Limpopo Province of South Africa. Limpopo is located in the northern part of the Country. This province was named after a river (Limpopo River) that flows through it and the name "Limpopo" originated from the Sepedi word "diphororo tsa meetse" meaning strong gushing waterfalls. The capital of Limpopo is Polokwane and was formerly called "Pietersburg". Limpopo province was created from Transvaal province in 1994 which is the northern part of the country and was named "Northern Transvaal" which was later changed the following year to "Northern province". The name was changed in the year 2003 to "Limpopo province" (Wikipedia, 2016).

Poverty is seen to be increasing in South Africa with Limpopo province having the highest percentage rate of 78.9%, people living in poverty in the province live below the national poverty index (www.polokwanecity.co.za). It is said to have five municipal districts (Capricorn, Mopani, Sekhukhune, Vhembe and Waterberg) which is subdivided into 22 local municipalities. STAT, SA (2019) described population to be approximately 5.4million and they are identified by their culture, language and race, 97.3% of the population are black, 2.4% are white, 0.2% are coloured, 0.1% are Indian/Asia.

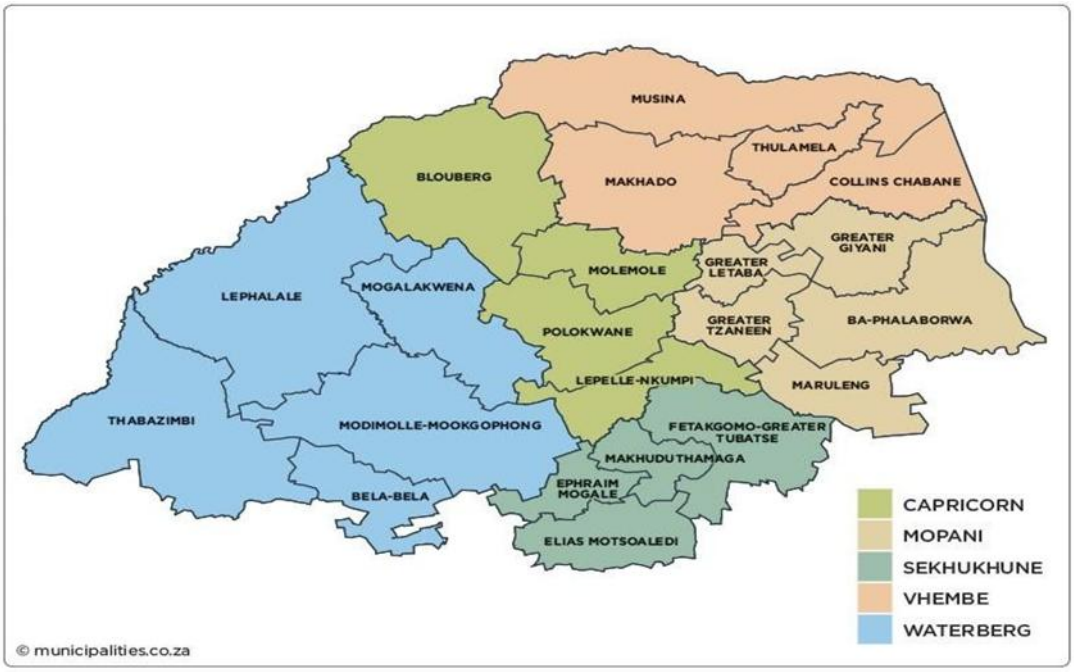


Figure 1: Map showing the five districts which comprises of Limpopo Province of South Africa
Source: Limpopo municipality (2019)

Sample size and sampling procedure

For the purpose of this research study, two crops were considered (avocado and tomato). These crops were chosen because there has not been a lot of research findings that was carried out on how climate change has affected avocado and tomato farming and its productivity particularly in Limpopo Province. A multistage sampling technique was used for this study. The criteria for participation of the farmers were based on their cultivation of the crops in at least two farming seasons. The two-stage sampling technique was used because at different stages of sampling, different sampling methods were adopted. Firstly, three districts (Vhembe, Capricorn and Mopani) were purposively selected out of five districts in Limpopo Province, this was due to the prevalence of production of the selected crops in the districts. Sample frame, containing the list of farmers who cultivated at least one of the targeted crops (avocados and tomatoes) was obtained from each selected district. In line with outcome of the equation 1, a total number of 376 farmers were targeted for this study. Therefore, the second stage involved a total of 376 farmers, which were randomly selected from each selected district. Out of the 376 targeted farmers, only 156 randomly selected farmers participated and managed to complete the questionnaires for the study. This shows that156 respondents comprised of 69 farmers from Capricorn, 37 farmers from Mopani and 50 farmers from Vhembe. Information such as socioeconomic characteristic (including income, sex, age, land ownership, farm size and farming experience) of the farmers and dichotomous variable on farmers' awareness of climate change were gathered from the respondents. The 376 farmers were selected following a sample size formula, which was expressed as.

$$ss = \frac{z - score^2 p(1-q)}{margin\ error^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots equation\ 1$$

Where: e is the desired level of precision (margin of error) which is at 5%. The symbol p is 0.5 derived as the proportion of targeted crops to be participant of the studies., farmers would be participant if he/she produced at least one of the two targeted crops. The symbol qi 1- P. z- value is found in a z-table. This formula is used at 95% confidence level which gives a 1.96 z- value.

Data collection

Data for this study were collected from the small-scale farmers from different municipalities across the three selected districts in Limpopo Province of South Africa. A partially structured questionnaire was provided to collect primary data. This questionnaire contained both open and close ended questions which targets small

scale crop farmers. The sections in the questionnaire were focused on the socio-demographic characteristics of the respondents (farmers), land characteristics, information on changes in climate and awareness, observations on climate change and farmers' adaptation measures. Prior to administering the questionnaire, permission to collect data was sorted from the Department of Agriculture and Rural Development, Limpopo Province and subsequently in the districts and local municipalities. Interviews were conducted face-to-face and information were gathered from the respondents using a structured questionnaire written in English. With the help of a translator, the questionnaire was translated to the local languages (Tshivenda, Sesotho, Xitsonga) before been administered to the farmers. The survey was carried out between September and December 2019. Five questionnaires were pre-tested and administered to five respondents before the actual data collection. The respondents used for pre-test did not participate in the main interview. Amendments were made and a final questionnaire was developed, the pre-testing was done to test the reliability and validity of the study.

Data Analysis

To satisfy the aims and objectives of this study, the following analytical procedure were used; descriptive analysis and inferential methods. Data was cleaned, coded and entered on Microsoft Excel and STATA version 14 for the descriptive and inferential measures respectively. The descriptive analysis includes frequency distribution, percentages and mean and most of the data was categorical data so descriptive statistics were used to present the main findings that address the objectives of the study. This is used to analyse the socio-economic parameters such as age of the farmers, education level of farmers, gender of farmers, access to extension officers and farm size. The inferential method involves the use of binary logistic regression model (BLRM) to determine the factors that influence crop farmer's decision to adapt or not to climate change. The binary logistic regression model was used to determine the factors that influence farmer's decision to adapt or not to climate change. The binary dependent variable was a dummy for undertaking any adaptation at all where Yi has only two possible values, 1 or 0 for either adapting or not to climate change. The independent variables took the form of both categorical and continuous. Therefore, this model considers the relationship between a binary dependent variable and a set of independent variables. The binary dependent variable is a dummy for undertaking any adaptation at all which takes the value 1 and 0 if otherwise. A farmer will be considered to have adapted to climate change if he or she employs at least one of the adaptation strategies that will be listed in the questionnaire.

The binary logit regression is presented as follows;

$$PY_i = 1 - \frac{expexp\ [X^i\beta^i]}{expexp\ [X^i\beta]} \quad \text{(1)}$$

$$P(Y_i = 0) = 1\text{-}P = 1 - \left(\frac{\exp(X^i\beta}{1+expexp\ (X^i\beta)}\right) = \frac{1}{1+expexp\ (X^i\beta} \quad \text{..... (2)}$$

Where: P(Y=0) represents the probability of a farmer not adapting to climate change

P(Y=1) represents the probability of a farmer adapting to climate change

X^i represents the sets of all the independent variables that determine the farmers' probability to adapt to climate change

β coefficient represents the explanatory power of the independent variable.

The binary logit equation in its explicit form will be expressed thus;

$$Adapt^* = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots\cdots \beta nXn \quad \text{(3)}$$

$$\text{Adapt} = \beta_0 + \beta 1sex + \beta 2age + \beta 3educ + \beta 4landowner + \mu i \quad \text{(4)}$$

Where adapt * is unobservable and adapt is observable which is the different adaptation measures employed by the farmer.

μ_i is the error term, this is a standard logistic distribution.

β_0 is constant term

β_1 is vector of coefficients

X_1 is vector of the explanatory variable

The logit model could be written in terms of odds and log of odds ratio to enable comprehension of the interpretation of the coefficient. This odd ratio is a linear function of the independent variables. From equation 1and 2, the odd ratio for a logit model can be written as

$$adapt = \begin{cases} 1 \; if \; adapt^* > 0 \\ 0 \; if \; adapt^* \leq 0 \end{cases}$$

The model (4) used for this study is specific below. Table 1 below provides a description of the variables.

$$Adapt = \beta_0 + \beta 1 sex + \beta 2 age + \beta 3 educ + \beta 4 landowner + \beta 5 mainoccu + \beta 6 farmsize + \beta 7 income + \beta 8 experience$$

Table 1: Definition of Variables

Variable	Definition	Measurement
Sex	Farmer's gender	Male= 0 Female= 1
Age	Age of the farmer	< 35 years=0 36-45 years=1 46-55 years = 2 >55 years=3
Educ.	Highest education level of the farmer	Tertiary = 0 Secondary level=1 Primary level=2 No education=3
Land ownership	Land tenure system of the land the farmer is using	Privately own =0 Communal =1 Other = 2
Main occupation	The respondent's main occupation	Farming = 0 Employed =1 Self-employed=2 Other =3
Farm size	The size of the farm	< 2 hectares(ha) = 0 1-5ha=1 6-10 ha= 2 >10ha

Income	If farming is the main source of income	Yes = 0, No =1
Experience	Years of farming experience	< than 2 years = 0 2-5 years =1 6-10 years = 2 > 10 years
Marital status	The farmer's marital status	Single = 0, Married =1, Other = 2
Awareness	If the farmer received information on climate change awareness	Yes = 0, No =1
HH size	Number of members in the household	< 4 members =0 4-5 members =1 6-7 members =2 > 7 members = 3

Source: Data Survey (2019)

IV. Results And Discussion

Data obtained from the household survey on the demographic and socio-economic characteristics of small- scale farmers in the study area are presented in Table 2. The results indicates that 68% of the farm households were headed by men, 32% headed by women while 29.1% of the farmers were between the age of 46-55 years. It was also revealed that 21.9% of the respondents were between the age of 36-45 years, over 55 years were 27.7% and less than 36 years was 21.3% respectively. Majority of the small-scale farmers had limited education with 38.5% having achieved secondary education, 30% had gone through tertiary education, 26.9% had primary level education while 3.8% had no education at all. Furthermore, the study reveals that the farming household size who have between 4-5 members were 47.4%, 6-7 members are 21.8% of the respondents, those who have less than 4 members were 17.3% while those that were more than 7 members were 13.5%. This study also indicated that majority of the farmers in the study area see farming as their major occupation holding to 73.7%, 14.1% are employed doing other jobs, 7.7% are self-employed, 0.6% are business owners while 3.9% are pensioneers. Majority of these farm households in the study area also practice farming and this serves as their major source of income resulting to 75.6% of the respondents while 24.4% accounts for those who does off-farm jobs to support themselves. The findings of this study also suggested that majority of the small-scale farmers were producing basically for their own personal consumption (45.5%), a few of them (33%) still have enough after consumption to sell off at the market while 21.5% were producing for commercial purposes only. From the findings, it is evident that the system was controlled mostly by communal land system with 79.5%. 10.3 percent of the farmland was occupied by the respondents through permission to own or occupy, 8.9% of the land were personally owned by the farmers while the remaining 1.3% were occupied through other means either by renting/ leasing or through land reform programs. This study shows that most farmers occupy their farmland through communal land tenure system which means that the lands are either owned collectively by an extended family, clan, community or even ancestral related people but allows them to cultivate the land in exchange for a levy. This implies that the farms are well managed and proper adoption process are executed in contrast to other types of farm land so as to generate enough produce to sell in order to

meet the family's needs to maintain a livelihood and be able to pay the levy on the farm at the appropriate time. Statistics South Africa (2016) also revealed that 4.5% of the agricultural activities in the Limpopo province of South Africa are done on communal land. Most farms were individually managed at 52.6%, 26.3% of the farms were managed by families, 8.3% are managed by farmer's group, 7.7% managed by companies while 5.1% are farms that are managed by trust. This implies that Individual will manage their farms well by ensuring that they make use of the required and important resources required for the farming season, this in turn makes adoption of adaptation strategies, adoption of new technological changes and changes in the style of livelihood easier. Maponya (2021) however supported these findings by reporting in his research that most farms in Limpopo province of South Africa are owned and managed by independent farmers. This survey also shows that most farms are owned by family members with 54.5%, individual owner 14.1%, farmer's group owns 18.6%, 9.6% is owned by companies while 3.2% is trust owned. This implies that the respondents (farmers) prefer to own their farms as family and not as a group or individual. The family nominates a certain member or members of the family to possess the land in order to take full management of the farm. This enables them to pay more attention to climate changes and how they can cope with it so as to improve their yield. From this survey, a great number of the farmers cultivates on the farm size lesser than one hectare with a 33.3% while those cultivating on the farm size between 1-5 hectares is 30.1%. Nine percent cultivated on farm size between 6-10 hectares, 8.3% between 11-15 hectares, 7.1% between 16-20 hectares while 12.2% were owned by farmers who cultivated on the farm size that is above 20 hectares.

A total of 7.8% of the respondents had been farming for less than two years in the study area, 11.6% had been farming between 2-5 years, 14.0% between 6-10 years, 55.1% between 11-15 years while 11.6% accounted for those who had been farming for over 15 years. This shows that most of the respondents has enough years of experience in crop farming who had been farming for about 11-15 years. Also, there is urban migration which has showed enough evidence that the house-hold members migrate from the rural areas to urban settlements in search of better source of livelihood thus leading to a decreased number of years of farming in the study area. The respondents have substantial years of experience in crop farming, this will in turn give them enough knowledge about climate change and be able to participate in various adaptation strategies that will be of help to them on the farm. This was reiterated by Maddison (2007) that farmers who are more experienced have enough knowledge and information about the changes in climate and its variabilities and can employ proper adaptation measures in response to these challenges. The findings of this study also identified how they got to know about the climate change despite claiming that climate change awareness is very poor. The results therefore identified how important information on climate change has contributed to their knowledge about it. It was disclosed that 26.3% of the farmers knew about climate change through formal schooling, 81.2% explained it was through their own personal observation they got to know that the climate is changing. 88.9% which shows majority of the respondents acknowledged that it was through media they knew about this phenomenon. They indicated broadcasting media such as radio and television and print media such as newspapers as a major tool in getting and distributing ideas on climate change. This has however been a major contributor to their understanding on climate change. 70.2% knew about climate change through extension services either by those provided by the government or by private companies. This has also aid in their knowledge about climate change. 68.3% explained they get information on climate change through other people either from other farmers, farmers' groups or their families. From the interpretation of this finding, it is obvious that most of the respondents have more than one source at which they get information about climate change. Some farmers showed that they get their information through extension services and also through broadcasting media while some can receive their information through personal observation and still receive more information from other people.

Table 2: The demographic and socio-economic characteristics of small scale farmers in the study area (n=156).

CHARACTERISTICS	CATEGORY	FREQUENCY	PERCENTAGE
Age group	Under 36 years 36-45 years 46-55 years Over 55 years	33 34 46 43	21.3 21.9 29.1 27.7
Gender	Male Female	106 50	68.0 32.0
Marital Status	Single Married Divorced Widow	38 93 12 13	24.4 59.6 7.7 8.3
Educational Level	Primary Secondary Tertiary No education	42 60 48 6	26.9 38.5 30.0 3.8
Household Size	< 4 members 4-5 members 6-7 members >7 members	27 74 34 21	17.3 47.4 21.8 13.5
Major Occupation	Farming Employed Self employed Business Pensioner	115 22 12 1 6	73.7 14.1 7.7 0.6 3.9
Farming as major source of Income	Yes No	118 38	75.6 24.4
Reason for cultivating	Personal consumption Surplus sold Commercial/ industrial purpose	93 40 23	45.5 33.0 21.5
Farm management	Individual Family Farmers' group Company owned Trust owned	82 41 13 12 8	52.6 26.3 8.3 7.7 5.1

Farm ownership	Individual	22	14.1
	Family	85	54.5
	Farmer's group	29	18.6
	Company-owned	15	9.6
	Trust-owned	5	3.2
Farm size	< 1 hectare	52	33
	1-5 hectares	47	30
	6-10 hectares	14	9
	11-15 hectares	13	8.3
	16-20 hectares	11	7.1
	>20 hectares	19	12.2
farming experience	<2 years	10	7.8
	2-5 years	15	9.1
	6-10 years	18	12.0
	11-15 years	71	55.1
	>15 years	42	16.0
Crop planted	Avocadoes	10	6.4
	Tomatoes	37	23.7
	Both	109	69.9

Source: Data Survey (2019)

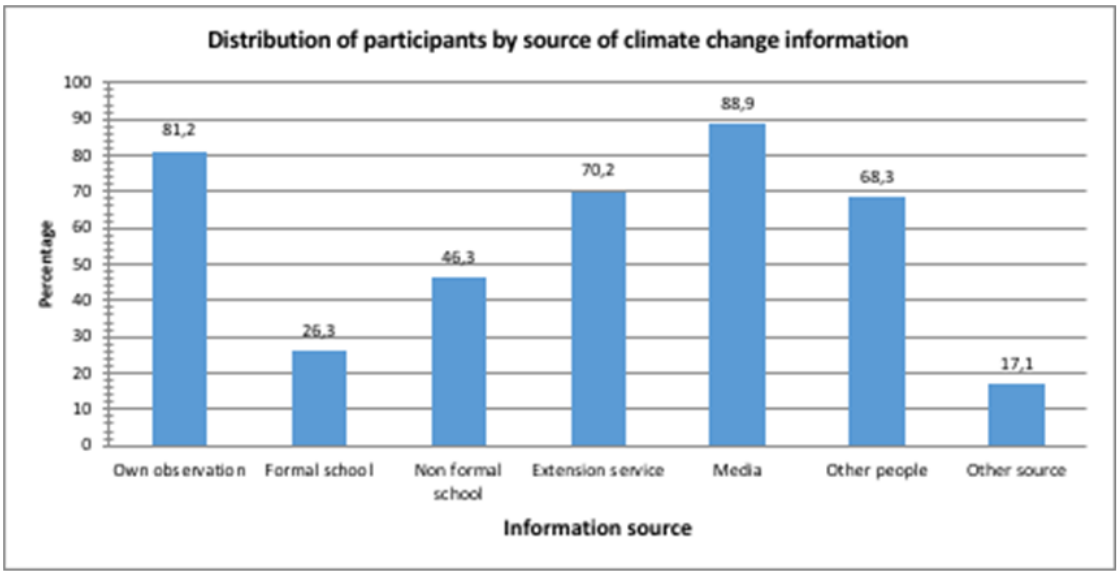


Figure 2: Distribution of participants by source of climate change information

Source: Data Survey (2019)

Farmers' Perception and Adaptation To Climate Change

According to Oxford dictionary, "Perception" is defined as the way one notices things, especially with the senses, and be able to understand the true nature of it. A lot of studies on farmers' perception have identified certain limitations in their understanding of climate variability and change (FAO, 2015). However, it is important for farmers to have a deep understanding of climate variabilities so as to be able to cope with it. This

can be done in different ways at grass-root levels such as organizing trainings for them to enlighten them about climate variabilities, making them understand the importance of getting information from registered weather and climate information stations, and coming together to understand different crop varieties which can be planted at different planting seasons. Debela et al. (2015) explained in their findings that farmers in South Ethiopia perceived changes in climate and its adverse impacts on their productivity and regard these changes as a risk to their future livelihood and economic development. They further explained some factors which obviously affected the perception of the farmers about climate change and these includes: age, level of education of the farmers, number of livestock owned by the farmer, access to information on climate change and extension services. Several researches have accessed the perception and level of awareness of small-scale crop farmers on the impacts and effects of climate variability and change on their production.

Musetha (2016) also explained in his research that farmers in the Limpopo province of South Africa perceive climate change in different ways and how they can adapt differently. They believed that temperature in the province is getting higher thereby making it hotter leading to shortage of water in the province. He also further explained that some farmers believe prayers can make the impacts of climate change to go away, some believe that by planting different crops on the farm can assist to adapt with climate change while some believes that crop diversification will also help them to cope with climate change impacts. In addition, Trinh et al., (2018) stated that certain determinant factors such as the age of the head of the household, information on climate change, wealth, social capital and agroecological settings are directly related to farmers' perception on climate change and these in turn helps them to make proper decisions on the mitigating and adaptation measures they can use to cope with changes in climate. Information about weather, poverty and lack of knowledge on adaptation strategies has been seen to be the major factors that can affect farmers' decision making about climate change (Fosu- Mensah et al. 2012). Farmers particularly small-scale farmers are aware of changes in climate but do not have enough knowledge on how to tackle these problems. This is due to the fact that they do not have access to enough information either through different media forms or through extension services, this will in turn have a negative effect on their decision-making process.

Awareness of the effects of climate change is very important as this is the first step of adopting adaptation strategies to offset the negative impacts of climate change on agricultural productivity. The findings from this study shows the results of the farmers' perceptions of the effects of climate change on their productivity. This is represented in Table 3. Results showed that 67.9% of the respondents indicated that climate change impact has affected/ reduced the fertility of their farmlands while 32.1% indicated that its impacts has actually increased the fertility of their lands in one way or the other. 65.4% of them explained that climate change impacts have also led to an increase in crop diseases on their farms while 50% showed that their livestock production has drastically reduce due to the impact of climate change on their livestock. 62.2 percent also indicated among the crop farmers that there has been a decrease in their crop yield due to its impacts on their productivity. This implies that there has been decrease in crop yield in the study area over time due to reduced land fertility and increase in crop diseases which has affected the production. This might mean that food security is been threatened in the study area as there is not enough production due to climate change impacts. This is supported by a study conducted by Kumar et al. (2013) in India that climate change impact on agricultural productivity is evident of food grain and non-food grain productivity which in turn affects food security especially small-holder farming households. Masters et al. (2010) also explained in his study that by 2080 crop yields could decrease by 15%, agricultural production output could decrease by 20% in underdeveloped countries due to the effects of changes in climate while yield output is expected to decrease by 6% in developed countries.

Participants gave explanations on how changes in climate have affected their food security, This is indicated in Table 4. 58.3 percent indicated that climate change impact has led to increase in food prices while 60.9% showed that it has led to scarcity of food. 87.8 percent indicated that climate change impact has led to lack of local market to sell their products while 12.2% stated that it has led to an increase in the availability of local markets for their produce. Most of the respondents 74.4% indicated that it has also led to decrease in employment rate. This finding suggests that climate change effects can lead to production problems in the long-run and seasonal low crop yields hence resulting to food insecurity in the study area. FAO (2008) report stated that climate change impacts will have an impact on human health, livelihood assets, food production and food security. Ahmad et al. (2011) also stated that changes in climate variables can affect the ability of a country to feed its people, this is because food security is dependent on the impacts of changes in climate.

Table 3: Distribution of climate change impact on agricultural production

Agricultural production variable	Frequency (n=156)			
	Increase	(%)	Decrease	(%)
Land fertility	50	32.1	106	67.9
Crop yield	59	37.8	97	62.2
Crop disease	102	65.4	54	34.6
Livestock production	78	50.0	78	50.0

Source: Data from Survey (2019)

Table 4: Impact of climate change on food security (n=156)

Variable	Increase	Decrease
Food prices	58,3%	41,7%
Employment	25,6%	74,4%
Income	49,6%	50,6%
Food availability	39,1%	60,9%
Local market	12,2%	87,8%

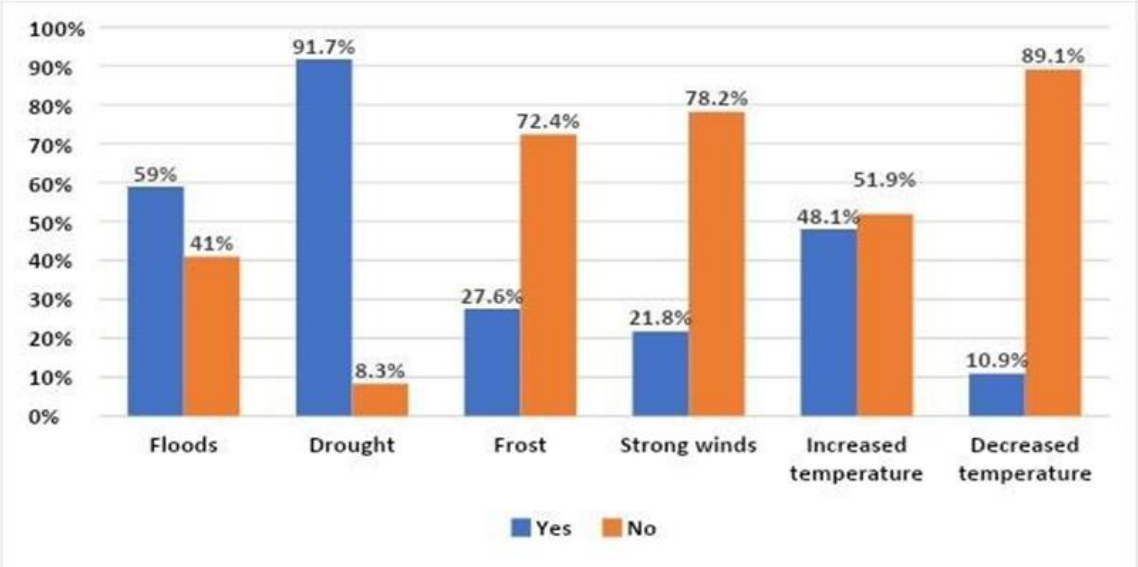
Source: Data from Survey (2019)

Farmers' perception of problems attributed to climate change

Figure 3 shows how the farmers responded to questions on their experience with changing climatic variables in the study area. About 59% of the farmers indicated that there has been flood occurrence in their area. 91.7% indicated that there has been an increase in the occurrence of drought in the study area while 48.1% explained that there has been an increase in temperature in their locality. About 21.8% indicated that they have experienced strong wind while 27.6% indicated that frost has occurred on occasional cases in the area.

53.2 percent talked about other climatic variables such as hailstorm has also been experienced in their locality. This implies that an average of the respondents has witnessed flooding on some occasions and almost all the respondents has also witnessed droughts. This means that when there is too much rainfall, this leads to flooding and erosion which then washes off the surface of the soil leading to surface run-off and loss of soil nutrients thereby leading to increased pests and diseases incidents loss in crop yield and low productivity. However, in times when there is low rainfall, temperature increases and leads to increase in the rate of evaporation in the soil thereby leading to drought, loss of nutrients in the soil and reduced crop yield. This is evident that drought is the most identified climatic variable that is changing and occurring in the study area. This result is in agreement with other studies carried out by Shewmake (2018), reported in detail that change in climate is expected to increase the occurrence of adverse weather events such as droughts and floods especially in the Sub-Saharan Africa due to changes in rainfall pattern in the long run and changes in temperate regions. It also reported that a cross-sectional data survey was used in 2005 to detect that Limpopo Province has the highest occurrence of droughts in that year which has led to a negative impact on agricultural production. Low yield, poor crop performance, poor germination, ease of spread of diseases and ineffectiveness of agricultural chemicals due to delayed rainfall has amongst other factors been attributed to climate changes (Ayanwuyi et al. 2010).

Figure 3: Farmers' experience with adverse climatic problems

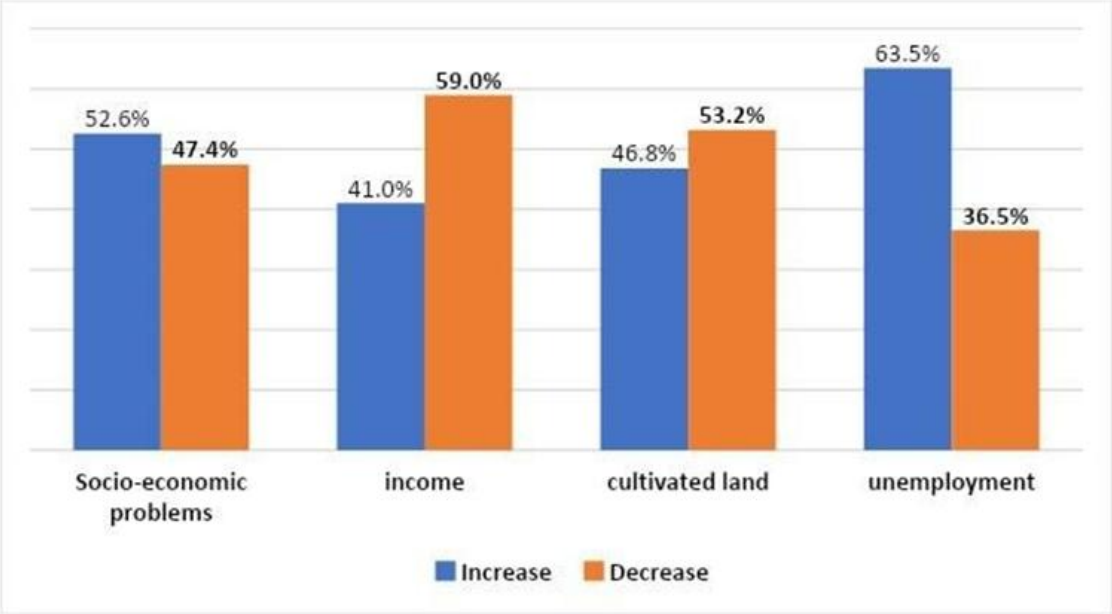


Source: Data from survey (2019)

Farmers' perception of climate change effects on their livelihood

From Figure 4, 52.6% in the study area indicated that climate change impact has led to a significant increase in the socio-economic problems in their community while 47.4% explained that their socio-economic problems have not increased owing to climate change. Unemployment has also increased in response to climate change as indicated by 63.5% of the respondents while 53.2% indicated that land under cultivation will decrease. The impact of climate change on employment and area under cultivation cannot be overemphasized. Studies have proved how climate changes are detrimental to production and thereby affecting employment especially in rural communities who wholly depends on agriculture (Ayanwuyi et al. 2010). Consequently, reduction of employment results in reduced income at household level. Fifty-nine percent of the respondents indicated that climate change has attributed to reduced income. The results are in line with the findings of Nhemachena et al. (2014) which alluded that climate changes have adverse effects on livelihoods. Invariably, with reduced income, land under cultivation and increased unemployment, food insecurity is inevitable as most household will struggle to access food owing to lack of income (Assan 2018).

Figure 4: Impact of climate on farmers' livelihood (n=156)



Source: Data from survey (2019)

3.4 Adaptation strategies used by small-scale farmers to cope with climate variabilities

The specific climate change adaptation strategies that the farmers in the study area adopted were also captured. Table 5 shows the proportion of the respondents according to the adaptation strategies they adopted to cope with climate change impacts. About 14% of the respondents indicated that they practiced crop diversification to adapt to climate change while 37.8% stated that they practiced multi-cropping, 41.7% used different planting dates, 48.7% practiced crop rotation while 28.9% planted different varieties of crops to cope with climate change on their farms. Forty one percent used soil conservation techniques while 18.6% practiced integrated farming system. Approximately 19% stated they practiced crop-livestock shift whilst 12.8% changed the area of land they used to farm, 40.4% indicated they practiced increased use of irrigation system, 15.4% used increased water conservation techniques. Only 4.5% find off-farm jobs to support themselves while 23.1% planted seeds that are drought-resistant so as to cope with climate change. About 31%, indicated that they change the type of fertilizers and pesticides they used on their various farms to cope with climate change whilst 18.6% have crop insurance to save themselves from the menace of climate change impacts. Some of the farmers 19.2% changed their farmland totally and moved to another so that the old one can rest and regain back its nutrients, 14.1% made use of agricultural subsidies while 9.0% indicated there was no perceived adaptation strategy, they followed in coping with climate change. This shows that almost average of the farmers practiced crop rotation, change of different planting dates, soil conservation and irrigation system on their farms to cope with climate change impact. This suggests that farmers in the study area still need to be sensitized on the different adaptation strategies that can be practiced to cope with climate change.

Table 5: Climate change adaptation strategies adopted by the farmers (n=156)

Climate change strategy	Percentage	Climate change strategy	Percentage
Crop diversification	14.1	Change the land area size	12.8
Multi-cropping	37.8	Increased use of irrigation system	40.4
Use of different planting dates	41.7	Increased water conservation	15.4
Practicing crop rotation	48.7	Finding off-farm jobs	4.5
Planting different crop Varieties	28.9	Use of drought tolerant varieties	23.1
Soil conservation techniques	41.0	Change of fertilizers and pesticides	30.8
Integrated farming system	18.6	Use of crop insurance	18.6
Crop-livestock shift	19.2	Changing farmland	19.2
Use of agricultural Subsidies	14.1	No adaptation strategies	9.0

Source: Data from survey (2019)

Factors determining the adoption of adaptation strategies used by small-scale farmers

The factors that influence the farmers' decision to adapt to climate change were empirically identified using a binary logistic regression model. The farmers were asked if they had adapted with climate change. The responses took values of 1 for the farmers who had adapted to climate change and 0 for farmers who had not adapted to climate change, thereby making the responses become the dependent variable. Most of the farmers indicated that they have adapted to climate changes while a few did not. Using the adaptation of farmers to climate change as a dependent variable, a binary logistic model was employed. The results of the binary model are presented below in Table 6.

Table 6: Factors affecting farmers' decision to adapt to climate change (n=156)

Variable	Coefficient	Std Error	P> z
Gender	-0,627461	0.5549164	0.258
Farming experience	0,1719967	0.34281	0.616
Access to information	0,227573	0.5363761	0.672
Land tenure system	-0,3946359	0.4771624	0.408
Source of income	-1,730177	0.7761248	0.026**
Education level	0,6390651	0.3544164	0.071*
Farm size	1,11794	0.2438736	0.000***
Main occupation	-1,634294	0.7806717	0.036**
Marital status	-0,4475633	0.3633004	0.218
Household size	-0,125006	0.2671302	0.640
Age	-0,4053699	0.4300395	0.346
Cons	-1,046681	1.08994	0.337

LR chi2(11) =83,76

Prob > chi2 = 0,0000

Pseudo R2=0,4112

Log Likelihood = -59,959072

* = significant p-value <0.01; ** = significant p-value <0.05; *** = significant p-value <0.1

From Table 6, there is a statistically significant relationship (p-value <0.05) between source of income and climate change adaptation. The coefficient for source of income (-1.730177) suggests that respondents whose main source of livelihood (income) is farming are likely to have low rate of adaptability to climate change impacts at ceteris paribus as compared to their counterparts whose main source of income is not farming. This implies that farmers who takes part in off-farm income activities are more likely to overcome their financial constraints hence have the capacity to purchase good irrigation system as a means to adapt to changes in climate than those who only take part farming activities to enhance their livelihood. Households that have access to off-farm income are likely to adapt to climate change. This is in correlation with the study by Ojo and Baiyegunhi (2018), who found a positive relationship between household income and adoption of management practices.

The estimate of the coefficient of education level (0.6390651) is positive. The coefficient suggests, any other level of education that the farmer has is expected to increase the chances and ideas of the farmer to adapt to climate change. Education level is also statistically significant associated to climate change adaptation at p-value <0.1 level of significance with all other variables at constant. Therefore, in comparison to the farmers who have obtained tertiary level education, farmers who have obtained any other lower level of education including those who have no formal education are also likely to adapt to climate change. Education comes with easy understanding and openness to change. Previous studies have indicated that there is a positive relationship between education level and decision to adapt to climate changes (Anunrat et al., 2017; Jianjun et al., 2015). There is a positive association between farm size and the adaptation to climate change adaptation as indicated by the coefficient, (1,11794). This implies that farmers who have larger farms are more likely to adapt to climate change. Farm size is also statistically significant at all level of significance holding other variables constant. Therefore, farmers whose farm size is more than 2 hectares are highly likely to adapt to climate change. The results of this study are in agreement with the results of a study by (Belay et al. 2017). Large farm size provides

an opportunity for crop diversification and livestock enterprises thereby assisting with distributing risks associated with unpredictable weather patterns. Therefore, large farm sizes are positively associated with climate change adaptation decisions (Belay et al. 2017).

At ceteris paribus, if the main occupation of the respondent is not farming, the less likely they are to adapt to climate changes as indicated by the coefficient (-1,634294). The association between main occupation and climate change adaptation is statistically significant at p-value <0.05. This therefore means that respondents who consider farming as their main occupation are more likely to adapt to climate changes than those who are part-time farmers.

There is a negative association between gender and climate change adaptation as indicated by the coefficient (-0,627461) ceteris paribus. This implies that female farmers are unlikely to take up adaptation measures compared to their male counterparts. However, the relationship is not statistically significant at any level of significance. A study conducted by Tibesigwa and Visser (2015) found that adaptation to climate changes is more in male-headed farm households than female-headed households. However, Ylipa et al., (2019) claim that females adapt more to climate changes than males as most men are based in cities while the women remain in the rural areas engaging in farming activities.

Farmers who have not had access to climate change information are also likely to adapt to climate changes unlike the farmers who had access to the information. This is as indicated by the positive coefficient (0,227573), at ceteris paribus. Although the association is in line with apriori expectations, the association is not statistically significant. It is expected that accessing information to climate change increases knowledge of the farmer about the implications of climate change thereby positively associated with climate change adaptation (Adesina et al. 1995; Luseno et al. 2003). There is a negative association (-0,4053699) between age and climate change adaptation at ceteris paribus. This suggests that farmers who are above the age of 35 years are less likely to adapt to climate changes. However, the association is not statistically significant. Studies have shown that older farmers grasp the concept of climate change faster as they are able to compare previous weather conditions with current ones hence being more open to change (Belay et al. 2017; Hisali et al. 2011).

V. Conclusions And Recommendations

Crop production is an important part of the agricultural sector and plays a huge role in the economy of South Africa. It particularly plays a big role in the Limpopo Province of South Africa as it provides various job opportunities to the communities especially in the rural area. Because majority of these rural communities depends on agricultural activities for livelihood, it is evident that they are mostly affected with the impacts of changes in climate and its variabilities, hence the need for proper knowledge of the adaptation strategies these farmers can adopt to help them cope with changes in climate. However, this study investigated the impacts of changes in climate and its variability at the farm level by indicating the determinant factors that affects the farmers' adaptation to climate change. Farmers' demographic characteristics were examined in order to investigate the factors that affect their decisions to adapt to the negative impact of climate change and to understand their perceptions towards climate change. It was discovered that farming is the major occupation with 73.7% of the participants in the study area and their major source of income is also farming (75.6%).

A binary logistic regression model was used to identify the factors that influence the farmers' decision to adapt to climate change. From the results, it was discovered that the source of income influenced climate change adaptation. Adaptation is an important measure(s) that must be taken into consideration by farmers to achieve their farming goals so as to improve their livelihood, food security and reduction in the negative impacts of changes in climate. Results identified that farmers whose main source of income is farming are likely not to adopt any adaption measures to climate change compared to others who has other source of income. The results also showed that the level of education of the farmers increased their chances to adapt to climate change. Farmers who have large farm size that is more than 2 hectares are also likely to adapt to the negative impacts of climate change. Also, farmers who choose farming as their major occupation are more likely to adapt to climate change than those who see farming as part time job. The study also identified the adaptation measures those farmers employed to adapt to the negative impacts of climate change in the study area. It was identified that most of them practiced crop rotation, irrigation system, use of different planting dates and the use of soil conversation techniques to cope with climate change impacts. Many studies have shown that climate change has been a major problem in South Africa and there are several discussions on how to deal with this problem. However, these problems cannot be solved when the people especially the farmers do not understand or perceive climate change and identify how it is affecting their productivity and society at large. This is why this study was conducted to identify how farmers have perceived climate change, the impacts it has on their crop production, examine the factors that affected their decisions to adapt or not to climate change, and also identify the adaptation strategies that they adopt to cope with or adapt to these changes.

Policy recommendations were suggested based on the research findings and can be put into consideration by the government in the province and other sectors involved in matters relating to climate change. These policies aim to improve the determinant factors for crop farmers in the study area and South Africa as a whole to make use of proper adaptation measures to changes in climate.

- Government needs to put in place policies that will support research and developments to give better technologies to farmers to help them adapt to the negative impacts of climate change and there should be proper information channel that can help results from researches carried out to reach the farmers.
- Proper education and training programs should be put in place to enhance for better information to the farmers to help them have a proper and better understanding of the phenomenon of climate change and the adaptation strategies they can employ to help cope with the negative impacts of climate change.
- Government as well as private institutions should help provide better ways of how farmers can gain access to improved climate information forecasting and provide adequate extension services to them. These will help them to know more about the changing climate and understand better the technical know-how of how to use the adaptation measures to help them cope with climate change impacts.
- Certain adaptation measures should be subsidized for farmers especially those employed at the farm-level such as irrigation systems, soil conservation techniques to mention a few as most small-scale farmers cannot afford these improved technology techniques to help them improve their adaptive capacity. More incentives should also be provided to them such as new and improved seedlings, pesticides and insecticides to help fight infestations on the farms and crop insurances.
- Proper climate change awareness programs should be put in place for farmers, this is to educate them about climate change because the study discovered that information on climate change and awareness was a major problem for farmers not to employ adaptation measures to cope with its impacts. Therefore, it is important for government especially at the provincial level in the study area to disseminate information about this menace to the farmers and how it can affect their productivity and livelihood if proper adaptation measures are not taken.
- Farmers should have an open-mind to new technologies, gather knowledge on climate change and tools that can be used in production, capacity building and management practices that can help them to cope with or mitigate the changes in climate.
- Farmers should also start documenting their yield results so they can have proper information on the changes in yield over the years, this will help them to be able to understand how changes in climate has affected their productivity and make proper decisions about adaptation or mitigation strategies.

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