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Factors Influencing Climate Adaptation: Evidence from Smallholder Farmers Mbhashe Local Municipality, South Africa

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ABSTRACT Climate change and variability are major challenges in agricultural productivity as farming is climate sensitive. Most African farmers rely on rain-fed agriculture, and most of these farmers are found in rural areas. This study explores the adaptation strategies adopted by crop-producing smallholder farmers to mitigate the effects of climate variability. This study was conducted in Mbhashe local municipality, where 207 farmers were interviewed using semi-structured questionnaires. The study used a multi-stage sampling procedure. According to the findings, 89.86 percent of farmers reported adapting to climate variability. The probit model results showed that farmers' choice of adoption is influenced by several socio-economic factorslike a farmer's age, marital status, household income, education level, and access to extension. According to the study, extension services should be available to all types of farmers, including those who farm alone, because they are critical for adapting to climate variability, educating farmers about climate change, and providing them with information on expected climatic variations.

INTRODUCTION

Agriculture is considered the backbone of the economy in Africa (Taruvinga et al. 2016). This is also supported by the fact that this sector hires approximately sixty-five percent of Africa's labour force (Mdoda 2015). However, the agricultural sector has been unable to meet the demand for the main food items consumed domestically since 2000 (Greyling 2012). Climate change has been an additional major challenge to the agricultural sector, as farmers produce less than they used to due to changes in climatic conditions and/or shifts in seasonal norms (Nadiruzzaman et al. 2021). Risi et al. (2020) stated that climate change is an inevitable process that exhibits itself in a variety of ways around the world, including temperature rises, sea-level rises, droughts, floods, hurricanes, and landslides. According to Chete (2019), recent predictions suggest that extreme climatic conditions will intensify as a result of greenhouse emissions. Thinda et al. (2020) stated that numerous climate models have indicated median temperature rises of between 3 °C and 4 °C in Africa by the end of the 21st century, roughly 1.5 times the global mean response. Climate change and variability have a momentous impact on developing countries, partially because many of them rely largely on agriculture as a source of income, which is especially susceptible to climate variability (Hossain et al. 2020). According to Asmare et al. (2019), climate change and variabilities are some of the most critical problems facing South African agriculture. In the Eastern Cape, a severe decline in rainfall, as well as increasing temperature levels in the form of climate variability, were observed (Ndhleve et al. 2017).

Crops are sensitive to climate change, which includes climate variability such as temperature and precipitation changes, as well as an increase in atmospheric CO_2 (Rosenzweig et al. 2014). According to Zhao et al. (2017), increased temperature has a more likely impact on crop yield. There is great uncertainty about the future effects of climate change on crop production (Olabanji et al. 2020). Smallholder farmers focusing on crop production are dependent on rainfed agriculture (Bozzola et al. 2016; Amare and Simane 2017). This is an indication that rainfall is the most important climate factor in crop production by smallholder farmers. Therefore, that makes smallholder farmers most vulnerable to the adverse impact of climate variability as rainfall is one of the key climate elements affected by a highly changing climate.A highly changing climate causes rainfall and temperature variability and negatively affects smallholder farmers' crop production. Many smallholder farmers in the Eastern Cape are also vulnerable to climate variability due to their low adap-

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tive capacity brought on by limited socio-economic and institutional capacity (Ndhleve et al. 2017). Although smallholder farmers have a low adaptive capacity as they are resource-poor farmers, they have employed several adaptation strategies in an attempt to survive the adverse impact of climate variability. Adaptation to climate variability is the process by which stakeholders (including farmers) make adjustments aimed at reducing the actual and expected adverse effects of the climate on their livelihoods. Adaptation is therefore not new to smallholder farmers, with many instances where adaptations have been employed in response to changes in the climate. However, insufficient rainfall and a rise in temperatures in the form of climate variability add a new dimension and urgency to the adaptation challenge. This, therefore, gives intensification to the need to explore the adaptation strategies currently adopted by rural smallholder farmers to cope with the adverse impacts of climate variability and the drivers behind the adaptation strategies.

The study, therefore, aims to assess the factors influencing the adaptation to climate change and variability by crop-producing smallholder farmers. The specific objectives are to assess the farmer's awareness of climate change and variability, to assess the current adaptation strategies adopted by smallholder farmers in the study area, and to investigate the factors influencing the adoption of climate change adaptation strategies by smallholder farmers in Mbhashe local municipality. The findings of this study are intended to answer the objectives and add to the growing literature in order to identify appropriate policy interventions for reducing livelihood vulnerability as well as make a recommendation on appropriate adaptation strategies based on the current state of climate (rainfall variability and increased temperature).

Objectives

The specific objectives of this study are:

- To assess current adaptation strategies adopted by crop-producing smallholder farmers to mitigate climate variability in the study area.
- To estimate the factors influencing the choice of adopted adaptation strategies to climate variability by rural small-holder farmers in Mbhashe local municipality.

METHODOLOGY

Study Area

The research study was conducted in Mbhashe local municipality. The municipality is one of the municipalities in South Africa that is challenged by poverty (Malusi 2017). The HDI human development index of 0.506 compared to 0.551 for Amathole and 0.596 for the Eastern Cape HDI. It is recorded as the worst HDI for Mbhashe when compared to South Africa as a whole (Malusi 2017). The percentage of people living in poverty is estimated to be 72.9 percent, which was the highest in Amathole in 2016. However, seventeen percent of the households in the Amathole District Municipality are strictly involved in agriculture and approximately forty percent of the households are from Mbhashe Local Municipality (Mbhashe Local Municipality 2012) (see Fig. 1).

The Mbhashe Municipality is located in the Eastern Cape, South Africa. It was established under the Municipal Structures Act. Elliot-dale, Willow-vale, and Dutywa were once part of the Elliot-dale, Willow-vale, and Dutywa subdivisions. It is found in the northern section of the Amathole District Municipality, on the southeast side of the Eastern Cape, and is bound by the coastline, flowing from the Mncwasa River in the north to the Qhora River in the south along the Indian Ocean (Mbhashe Local Municipality 2012). The municipality has a population of 2,54,909 people, 99.0 percent of whom are black, 0.1 percent are colored, 0.1 percent are Indian or Asian, and 0.2 percent are white. This shows that there is low diversity in the municipality. Its coordinates are 32°102 S and 28°352 E and covers an area of 3.169 square kilometres, or 1224 square miles. The municipality has 31 wards (Mbhashe Local Municipality 2012).

Sampling Procedure

The sample size of the study was 358 respondents, and it was made known to them the objectives and confidentiality of the study. The study followed a multi-stage procedure. Mbhashe municipality was purposely selected because seventeen percent of the households in the Amathole District Municipality are strictly involved in agriculture and approximately forty percent of the

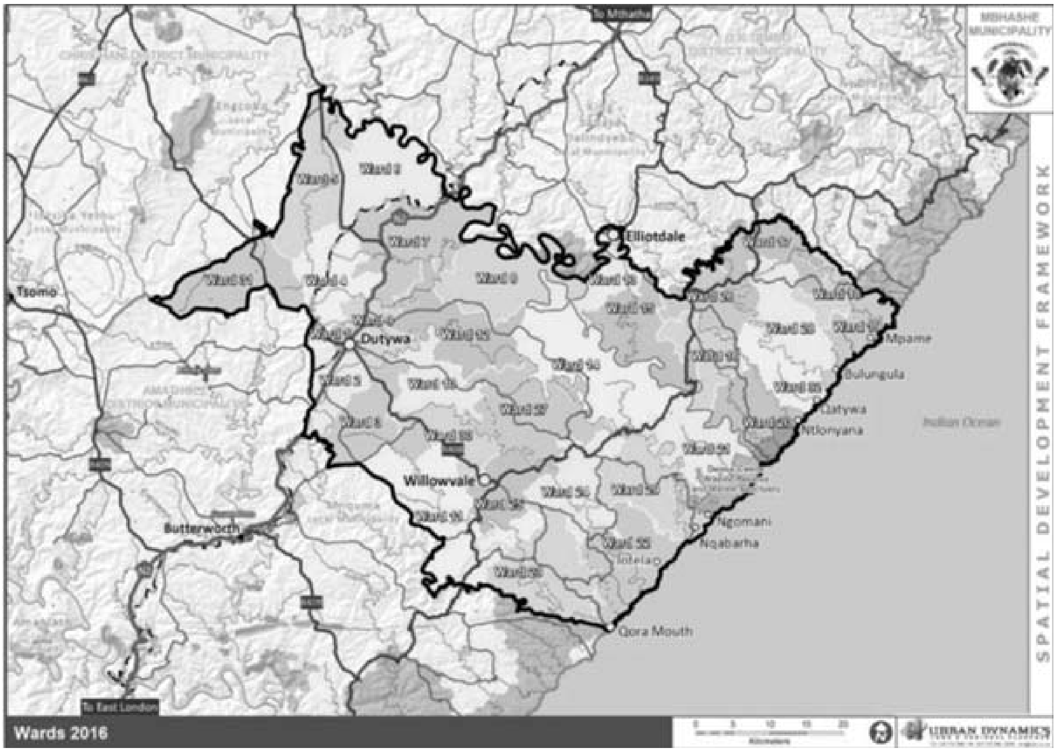

Fig.1. Mbhashe local municipality

households are from Mbhashe Local Municipality (Mbhashe 2012). It was chosen because it is an extremely rural settlement and has low density, with the second-highest population of households engaged in agricultural activities. The villages of Nqadu, Bholotwa and Sinqumeni were the ones where the study took place.

Data Analysis

The data collected was encoded and recorded in Microsoft Excel. Microsoft Excel was used to analyse variables such as age, gender, marital status, household size, monthly income, school years, and educational level of the respondents, and the results were presented in frequencies and percentages. The econometrics model of multivariate probit model was used to answer the factors influencing adaptation by smallholder farmers. A multivariate probit model was used using IBM SPSS version 21 to identify factors influencing the choice of adaptation strategies by sample households to climate change.

Multivariate Probit (MVP)Model

Several models have been used to analyse the factors influencing farmers' adaptation to climate variability and their choice of adaptation strategies. Studies by Taruvinga et al. (2016) made use of multinomial regression and linear regression. However, the authors propose that frequently, farmers do adopt a mix of adaptation strategies to mitigate the effects of climate change rather than going with one strategy. With that, this study employed the Multivariate Probit (MVP) model to investigate the factors influencing farmers' choice of adaptation methods. MVP investigates the trade-offs and complementarities that exist amongst farmer-adopted adaption techniques.

The MVP models the influence of the set of explanatory variables on each of the different adaptation strategies while also allowing for the potential correlation between unobserved disturbances, as well as the relationship between the strategies of different practices. The results on correlation coefficients of the error terms indicate whether there is complementarity (positive correlation) and substitutability (negative correlation) between different adaptation options being used by farmers."Failure to capture unobserved factors and interrelationships among adaptation strategies will lead to bias and inefficient estimates" (Ekemini et al. 2019). Although the multinomial probit can be used to measure the set of adaptation choices used by farmers, the MNL regression assumptions,homogeneous mutually exclusive categories, may be difficult to satisfy in an adaptation study where farmers choose a particular strategy to take advantage of complementarity or substitutability with alternative choices, meaning, a farmer may also choose other strategies while adopting a particular adaptation strategy.

The study followed the Ekemini et al. (2019), MVP model, which was characterised by a set of M binary dependent variables Yhj wherein j = 1, 2,...m denotes the type of adaptation strategy available, Xhj is a vector of explanatory variables, âj denotes the vector of a parameter to be estimated, and uhj are random error terms distributed as a multivariate normal distribution with zero mean and unitary variance. It is assumed that a rational hth farmer has a latent variable, Yhj, which captures the unobserved preferences or demand associated with the jth choice of adaptation strategy.

Dependent Variables

The dependent variables of this study were the adaptation strategies to climate variability, listed as conservation agriculture, drought-resistant crops, irrigation, water harvest, shifting planting season, use of fertilisation, crop diversification, use of indigenous vegetables, use of indigenous fruit, not adapting, seeking off-farming employment, mixed farming, and buying insurance.

Independent Variables

The independent variables were the socioeconomic factors such as farming experience, age, gender, household size, marital status, and level of education and included the following independent variables as well, that is, access to credit, access to climate information, access to extension service, and land size.

RESULTS

Crops Grown in the Area

The results in Figure 2 reveals that out of one hundred percent of the farmers, a proportion of 72.97 percent produce maize, 55.0 percent produce cabbage, 36.71 percent produce beans, and 26.64 percent produce spinach. Pumpkin is grown by 24.64 percent of the population, followed by potatoes at 14.01 percent. Onions (12.08%), beetroot (5.80%), fruits (2.42%), and herbs (1.45%) are among the other crops grown. These results in Figure 2 illustrate that smallholder farmers grow staple crops like maize, beans, pumpkin, cabbage, potatoes, and spinach, which account for the majority of their food crops. Maize, as depicted by the results, is the major crop farmed in the area. Maize, in some areas, is used as food for both livestock and human consumption.

Farmers' Access to Climate Variability Information

It is important for smallholder farmers to have access to climate information. As important as access to climate change information is, 65.7 percent of farmers, or the majority of farmers, did not have access to it. Only 34.0 percent of farmers have access to climatic knowledge. Farmers get their farming information from a variety of sources, with the majority (83.57% out of 100%) getting it from a family member and 36.71 percent getting it from extension officials. This means more farmers do not have access to government agricultural extension services.

Sixty-two percent of the farmers responded that they have made no changes due to extension services, while thirty-eight percent of the farmers said they have made changes because of extension services. The respondents who responded yes (37.68%) were then asked about how extension services changed their farming operations. Eighty-six percent responded that this brought about positive change, while twelve percent responded that this brought no change. Approximately two percent of these farmers opt

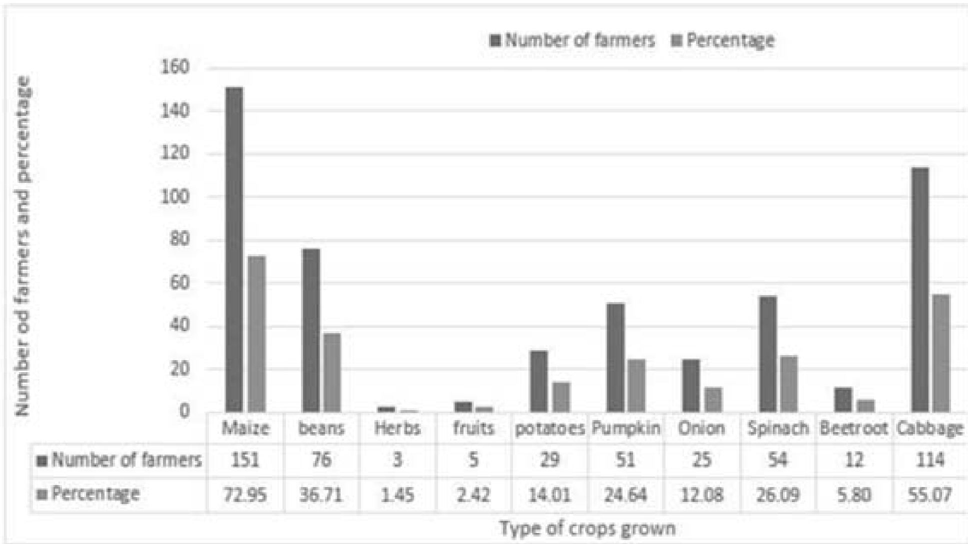

Fig. 2. Crops produced in Mbhashe local municipality

for other changes. They were then asked if they received any technical support, and only thirty percent of the farmers reported receiving technical support in their efforts to reduce the impact of climate change and variability in their farming system, and seventy percent responded that they had never received any kind of technical support. Respondents were asked what issues these farmers have with agricultural extension. Sixty percent said they never visit, while thirty-seven percent said extension service is slow and they seldom visit. A percentage of 29.47 percent gets their knowledge from farmers' groups, and lastly, 8.69 percent from the media (mainly radio). Some farmers complained of a clear radio broadcast on farming innovations.

Adaptation to Climate Change and Variability

Despite the fact that the majority (88%) of respondents in Mbhashe local municipality have adopted one or two climate change adaptation strategies, there is still a long way to go as farmers are yet to learn about climate change adaptation strategies suitable for their crops and the climate variability presented at the time. Drought-resistant crops are the most commonly used adaptation measure among these small-holder farmers, accounting for forty-six percent (mostly in maize), followed by shifting planting season (38%), fertiliser use (38%), mixed farming (21%), crop diversification (16%), irrigation (13%), use of indigenous vegetables (12%), use of indigenous fruit (10%), conservation agriculture (4%), and seeking despite the challenge of adaptation to climate change and variability.The results demonstrate the constraints to climate variability faced by farmers in the study area. Ninety-two percent of farmers reported that finance is an adaptation challenge. Nine-one percent pointed to access to credit as the challenge, and sixty-two percent reported a lack of climate information. While sixty-two percent of those polled said they had access to credit, forty-three percent said they had access to extension services.

Factors Influencing Adaptation by Smallholder Farmers

The study used a multivariate probit model. Eleven dependent variables were analysed, wherein 6 out of 11 showed statistical significance against the independent variables with different correlation coefficients. Wald's test for the hypothesis that all coefficients in each equation are jointly equal to zero is rejected, suggesting that

Table 1: Multivariate model results

Variables	*Conservational agricultural*			*Drought tolerant crop*			*Irrigation*			*Shifting of planting season*		
	B	*Std error*	*Sig*	*B*	*Std error*	*Sig*	*B*	*Std error*	*Sig*	*B*	*Std error*	*Sig*
Age	.392	.432	.364	.001	.126	.992	.472	.203	.020**	.401	.254	.115
Gender	1.482	1.157	.200	-.077	.320	.809	-.004	.496	.993	.471	.661	.477
Marital status	-.096	.535	.857	.242	.174	.165	-.598	.314	.057	-1.432	.583	.014**
Household size	-.985	.892	.270	-.056	.295	.849	.366	.415	.378	-.443	.626	.479
Employment status	1.612	1.063	.129	.256	.374	.495	.845	.473	.074	.431	.670	.519
Educational level	3.674	1.147	.001**	.317	.226	.160	1.067	.347	.002**	.186	.487	.703
Income level	2.102	.931	.024**	-.915	.285	.001**	.769	.429	.073	.524	.599	.382
Access to climate information	.324	1.058	.760	-.370	.312	.235	-.168	.477	.724	.595	.600	.322
Access to extension services	2.254	1.033	.029**	.830	.295	.005**	1.172	.418	.005**	.732	.511	.152
Constant	-14.957	4.631	.001	-.137	.868	.874	-5.949	1.464	.000	-5.059	1.836	.006

Significance <0.05**
Source: Data analysis 2021

Table 1: Contd...

Variables	*Use of fertilizer*			*Mixed farming*		
	B	*Std error*	*Sig*	*B*	*Std error*	*Sig*
Gender	.430	.314	.171	-.485	.374	.194
Marital status	-.232	.173	.180	.059	.201	.769
Household size	.140	.287	.626	-.096	.341	.779
Employment status	.028	.374	.941	-.844	.515	.101
Educational level	-.161	.222	.470	.140	.258	.588
Income level	.511	.284	.072	.647	.326	.047**
Access to climate information	-.134	.308	.662	.549	.358	.125
Access to extension services	.618	.278	.026**	-.112	.332	.736
Constant	-.977	.858	.255	-.898	1.019	.378

Significance <0.05
***Source:* Data analysis 2021

the variables included in the model explain significant portions of the variations in the dependent variables to determine if the association between the two elements is "statistically significant.

In conservation agriculture, the farmer's educational level had a positive coefficient of 3.674 and was statistically significant with a p-value of 0.001. The odds ratio is 39.399, which is greater than 1. This means the chance of farmers adopting conservation agriculture rises with an increase in farmers' education level.

The income level had a positive coefficient of 2.102 and a p-value of 0.0024, proving to be statistically significant for the adaptation of conservation agriculture by small-holder farmers. The odds ratio was 8.181 and it is greater than 1, indicating that an increase in household income increases farmers' chances of adopting conservation agriculture as an adaptation strategy to climate variability. Access to extension services also proved to be significant to the adaptation of conservation agriculture by small-holder farmers, with a p-value of 0.0029 and a positive coefficient of 2.102. The odds ratio is 9.522. Choosing to adopt a drought-resistant crop is proven to be influenced by access to extension services with a positive coefficient of 0.830 and a p-value of 0.005, and the odds ratio is 2.295, and house income, which had a negative coefficient of -0.915 and a p-value of 0.001 and an odds ratio of 0.400. This means that the likelihood of a farmer adopting a drought-resistant crop as a result of increased household income is lower than it was at the originalInstrumental variableVI. Choice of irrigation is statistically influenced by the age of a farmer with a p-value of 0,020 and a positive coefficient of 0.472, odds ratio = 1.603, the farmer's educational level with a p-value of 0.002, odds ratio = 2.907, and a positive coefficient of 1.067, access to extension with a p-value of 0.005, positive coefficient of 1.172 and odds ratio = 3.228. For the shifting planting season, marital status is statically proven to influence the farmer's decision on the adaptation of the planting season with a p-value of 0.014, a negative coefficient of -1.432, and an odds ratio of 0.239. The use of fertiliser adoption is statistically influenced by access to agricultural extension by a p-value of 0.026, a positive coefficient of 0.618, and an odds ratio of 1.854. Adaptation to mixed farming is statistically influenced by the farmer's level of income with a p-value of 0.047, a positive coefficient of 0.326, and an odds ratio of 1.909.

DISCUSSION

Smallholder farmers are directly affected by climate change and variabilities, according to Olabanji et al. (2021), but this does not halt them from farming. At Mbhashe local municipality, smallholder farmers grow staple crops like maize, beans, pumpkin, cabbage, potato, and spinach, which account for the majority of their food crops. These crops and vegetables expand the availability of fresh produce straight from the fields. As a result of the great yield, food security can be enhanced. According to Giller et al. (2021), farmers' crops are vital in providing food and income to households. By engaging in agricultural activities, the food produced from grown crops helps to alleviate the overwhelming problem of hunger. According to Santpoort (2020), corn seems to be one of the main crops grown in the area. However, according to Santpoort (2020), corn has become the main staple crop in several areas. Birchall and Bonnett (2021) stated that maize production, which contributes to around seventy percent of South Africa's total grain production, is predicted to fall by up to twenty percent over the next 50 years because of the hotter and drier conditions, even as a growing population increases food demand. Diseases and pests that threaten the maize crop are likely to be a greater problem as the temperature rises.

Climate change and fluctuation have been significant variables influencing smallholder farmer's production. According to Taruvinga et al. (2016), farmers have already taken adaptation measures to climate change, and also Belay et al. (2017) and Harvey et al. (2018) stated that farmers have already perceived climate variability and have made attempts to adapt using practices. This is true for the study area, where several adaptation strategies have been adopted to mitigate the effects of climate change and variability. Drought has hit Mbhashe local municipality, prompting many farmers to adopt drought-resistant crops. The adoption of drought-resistant crops by maize-producing farmers has been high due to the drought experienced in the past decades. Mdungela et al. (2017) reported that dry periods and drought remain the major meteorological factors that have devastating impacts on the livelihoods of the most rural people in South Africa. Borehole drilling for irrigation has been one of the most widely used measures in the local municipality's south side. Farmers have also implemented a variety of adaptation measures, but they are still a long way from achieving high agricultural yields in the face of climate change. Adaptation to climate change and variability has been faced with a number of challenges. Farmers in the area have (91%) pointed to access to credit as a challenge. A study by Assan et al. (2018) also reported that smallholder farmers have difficulties accessing credit. Female heads of farm households relied mainly on borrowed money from village savings and loans groups with ferociously high interest rates as a coping measure, and male heads of farm households depended primarily on sales of livestock. Access to climate information was shown to be one of the major challenges facing adaptation to climate change and variability in the area (62%) reported lack of access to climate information. Piggott-McKellar et al. (2019) also reported access to appropriate and relevant climate information as the major barrier to adaptation to community-based adaptation to climate change and variability. Access to extension services (43%) seemed to be another challenge, despite its importance. Agricultural extension services are important because they may influence and aid farmers in making decisions about farming and which adaptation strategies to apply in response to climate change and variability (Mdoda 2015). When asked how extension services affected their farming operations, 37.68 percent of the farmers in the area responded positively. Eighty-six percent responded that this brought about positive change, while twelve percent responded that this brought no change. They were then asked if they received any technical support, and only thirty percent of the farmers reported receiving technical support in their efforts to reduce the impact of climate change and variability in their farming system, and seventy percent responded that they had never received any kind of technical support. Respondents were asked what issues these farmers have with agricultural extension, wherein sixty-three percent said they never visit, while thirty-seven percent alleged that the extension service is slow and they seldom visit. They reported they felt neglected since some of them are not in government projects or they do not farm collectively.

A variety of factors influence climate change adaptation by smallholder farmers in the area. These include educational level, household income, access to extension services, farmer age, and marital status. Conservation agriculture is becoming more popular with a rise in farmers' educational levels, income levels, and access to agricultural extension services improving. Farmers' use of drought-resistant crops is influenced by farmer income and increasing access to agricultural extension. Irrigation method adaptation is influenced by a farmer's age, level of education, and access to agricultural extension, whereas fertiliser use is influenced by increased access to agricultural extension. Access to agricultural extension appears to be a crucial element impacting climate change adaptation, although most smallholder farmers reported having little or limited access to agricultural extension. This is supported by Poopola et al. (2019), who reported that many farmers did not have access to government agricultural extension services on climate change in Mbhashe local municipality and the majority felt left out from government climate change support services as they were farming individually or not part of government/ordinary projects. Farmers' level of education also proved to be one of the essential socio-economic factors influencing adaptation to climate change and variability. This is supported by Paltasingh and Goyari (2018), who reported that education improves the farming skills and productive capabilities of the farmer. The farmer's ability to interpret relevant information and influence the adoption of innovations is referred to as a major component of education. According to Oduro-Ofori (2014), with improved educational levels, output increases with secondary school education having a positive impact on agricultural productivity. Education is critical in increasing agricultural productivity because formal education opens farmers' minds to knowledge, while informal education provides farmers with hands-on training and improved farming methods, and informal education keeps farmers up to date on innovations and ideas while also allowing them to share their experiences (Rousell and Cutter-Mackenzie-Knowles 2020).

CONCLUSION

Mbhashe local municipality shows a great deal of agricultural potential. The growth of studies on climate change adaptation has revealed numerous and complex perspectives regarding the social dimensions of adaptation. This study sought to assess the adaptation strategies used by rural small-holder farmers and estimate the factors influencing the choice of adaptation to climate variability with a 358-sample size and only 207 farmers interviewed due to the availability of respondents. The descriptive statistics revealed that drought, high temperature, and off-season are the major climate variabilities faced by smallholder farmers in the study area, while floods seem to be affecting farmers mostly located in the south region of Mbhashe. The above phenomenon has resulted in a decline in crop production and a shortage of food, which has contributed to food insecurity.

Farmers are aware of climate variabilities, which lead to adaptation to climate variabilities. Drought-tolerant crops, shifting planting season, fertiliser use, mixed farming, crop diversification, and irrigation are the most adaptable climate variability adaptation strategies in Mbhashe local municipality. Age, marital status, household income, farmer's education level, and access to extension services are the major drivers behind adaptation to climate variability in the area. Access to agricultural extension is most important for adaptation to climate variability in Mbhashe local municipality.

RECOMMENDATIONS

This study recommends to educate farmers about climate change and provide them with information about anticipated climatic changes, early natural disaster warnings to farmers through radio programs, television programs, and on information days through extension agents, highlighting changes in temperature, rainfall patterns, drought, and floods in smallholder farmers' understandable method of communication. Extension services should be accessible to all kinds of farmers, even those farming individually, as its most crucial to adaptation to climate variability. The government should consider the recruitment of more agricultural extension agents, as most farmers reported they had limited access to advisor services. Also, extension personnel experience a quite high ratio of farmers, which leads to ineffectiveness.

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