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Socioeconomic determinants of modern climate change adaptation of small-scale vegetable farmers in Bohlabela District, Mpumalanga Province

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Climate change significantly impacts small-scale agriculture, with limited adaptation capabilities due to lack of access to advanced science and technology. Traditional methods are ideal, but modern adaptations require significant financial investment, affecting the smallholder under-resourced agricultural sector's economic activities. The study analyzed climate change adaptation drivers among small-scale vegetable farmers, using a representative sample of 244 farmers from four villages through face-to-face interviews and semi-structured questionnaires. Using the Logistic regression model, the results showed resources (extension services), institutional (association membership) and societal influence (farm produce theft, and animal trespassing in the farming plots) to be associated with the use of modern climate change adaptation measures in the study area. The study recommends expanding extension services, strengthening community policing, creating community grazing guidelines, and training farmers on climate change causes, social cohesion, and mitigation strategies to address farm produce theft and animal trespassing. The study contributes new knowledge to the discourse of climate change adaptation by providing empirical evidence pointing out the need to consider critical non-climate factors for farmers when making climate change adaptations interventions in the smallholder farming sector.

KEYWORDS

small-scale, modern climate change adaptation, Mpumalanga Province, South Africa, Bohlabela District

1 Introduction

Climate change is a major global threat to all economic industries; however, the agricultural industry is the most vulnerable as it directly depends on rainfall and temperature. Climate change negative effect on agriculture has been widely reported globally (Ahsan et al., 2020; Abbas and Mayo, 2021; Ait-El-Mokhtar et al., 2022). Food supply and food security are immensely threatened by climate change (Van Etten et al., 2019; Pawlak and Kołodziejczak, 2020). The biggest challenge at hand is that small-scale farmers are highly under-resourced and yet play a pivotal role in food security. Baptista et al. (2020) reported the

critical role played by small-scale farmers across Africa cementing that their relevance cannot be underestimated. With the anticipated increase in population growth mostly concentrated in Africa, food demand is expected to increase (Sadigov, 2022). On the bright side, the population forecasts show that small-scale farmers will have more opportunities to sell their produce since increased demand for food is anticipated in the future (Maiwashe-Tagwi, 2023), however, the demand for food production is expected to bypass the supply due to rapid population growth and urbanization (Balogun et al., 2022). The unavailability of conducive farming opportunities in rural areas will further exacerbate the situation as the active labor force will migrate to urban areas for better economic opportunities, this will ultimately decrease the number of small-scale farmers, and negatively affect food security across Africa. Climate change is widely caused by fossil fuel energy use currently dominating the world. The future food demand will put a strain on natural resources, especially energy sources (Tagwi, 2022), further making food security a challenge. Considering that most rural households depend on agriculture for livelihood across Africa, this will put immense pressure on the agricultural sector.

The inability of small-scale farmers in South Africa to successfully safeguard themselves against extreme weather occurrences that endanger agricultural productivity is one of the key challenges (Dinesh et al., 2015). Amongst others, climate change causes droughts, pest infestation and low yield. To reduce the impact, small-scale farmers use traditional adaptation strategies. However, formal markets require large volumes of produce, consistent supply and quality. Small-scale farmers often struggle to enter formal markets, however, they need access to these markets to reduce poverty (Maiwashe, 2012; Hao et al., 2018; Hlatshwayo et al., 2021; Maiwashe-Tagwi, 2023). Due to a lack of market access most small-scale farmers resort to cooperative membership to secure markets (Chagwiza et al., 2016; Maiwashe, 2017; Ma et al., 2022). The formal markets present many economic benefits to small-scale farmers and as such once they secure these markets, they cherish them. The reality at hand is that focusing on traditional climate change adaptation might not be enough when targeting these formal markets although it is a less capital-intensive strategy compared to the modern adaptation measures. Modern adaptation techniques refer to access to improved seeds, irrigation, current knowledge of adaptation technologies, and access to information (Ishaya and Abaje, 2008). In this study, modern climate adaptation will refer to the use of inorganic fertilizer, drought-resistance seeds, pesticides, herbicides, and the use of irrigation. Dibakoane et al. (2022) study found that most female farmers do not use modern agricultural coping strategies in Mpumalanga due to a lack of financial resources. The use of modern climate change adaptation becomes crucial when targeting formal markets, however, this requires financing. Moreover, the socioeconomic background of small-scale farmers makes it difficult to access climate change funding. In South Africa, the agricultural sector is earmarked as one of the pillars of poverty and inequality reduction. However, access to resources plays a major role in a person's ability to reduce poverty (Sargani et al., 2022) and the majority of small-scale farmers lack this. Improving the incomes of farmers is one solution to reduce the impacts of climate change (Javadi et al., 2023). Studies have reported poverty, a lack of funding, high input costs and operating costs in farming as major obstacles to climate change adaptation (García de Jalón et al., 2015; Masud et al., 2017; Ochieng et al., 2017; Khan et al., 2020; Musafiri et al., 2022).

Various climate change adaptation studies have captured the perceptions of farmers on climate change, the adaptation measures used by the farmers and the driving factors of adaptation measures. While adaptation is a locally specific issue, approaches used may differ significantly not only from one location to another but also from one farmer to another. In Mpumalanga province, studies on small-scale farmers' climate change adaptation are few. In literature, few authors reported on climate change perceptions by farmers (Ajala, 2017; Elum et al., 2017; Boluwatife, 2019; Nesamvuni et al., 2022), adaption strategies used by farmers (Ubisi et al., 2020; Sithole and Agholor, 2021). Despite the paucity of research on adaptation perception and adaptation strategies used for climate change, there is no literature on the drivers of climate change in general and modern climate change adaptation methods in Mpumalanga Province. The determinants of climate change adaptation measures highlight the significance of adjusting climate change policies to small-scale farmers' dynamics to improve adaptation. Understanding behavioral factors in farmers' adaptation can shape adaptation policies (García de Jalón et al., 2015). Climate change adaptation behavior drivers include various socio-economic factors such as socio-demographic factors (i.e., *age, gender, education, marital status, land size, labor affordability*), resources factors (i.e., *extension services, market, credit, information*), institutional and political factors (i.e., *government support, collective organization membership*), societal and traditional influences (i.e., *common values, empathies and shared resources and social capital)* and perceptive and psychological factors (i.e., *beliefs, faith, refutation, perceived costs and benefits*) (Aryal and Marenya, 2021; Nor Diana et al., 2022).

Considering the current gap of lack of literature on the drivers of modern climate change adaptation use and the economic social standing of small-scale farmers across the country, it is of interest to investigate how socioeconomic factors influence the use of modern climate change adaptation strategies in Mpumalanga Province. The study's objective was to assess the determinants of modern climate change adaptation strategies amongst small-scale vegetable farmers in the Mpumalanga province. The remainder of the paper is organized as follows. The second section covers a literature review, while the methodology is discussed in Section Research methodology. Results are presented in Section Results and discussion, and in Section Conclusion and policy implications the study's conclusions, recommendations, study limitations and suggestions for future studies are presented.

2 Literature review

2.1 The theoretical background of adaptation strategies

Literature has widely covered the need for climate adaptation and mitigation as a solution to climate change. Adaptation (mostly focused on local solutions) and mitigation (mostly focused on policy solutions) are measures taken to solve environmental problems at the local and national levels, respectively. Of

importance, Biesbroek et al. (2009) indicated that adaptive strategies should not only focus on climate scientists' views but must consider other climate-sensitive policy areas together with non-climatic drivers for sustainable development. Adaptation as a concept is broad however, the common thread of adaptation is increasing the ability of communities, individuals, private organizations, and natural systems to withstand the effects of climate change (Noble et al., 2015; Tompkins et al., 2018; Vincent and Cundill, 2022). Climate change adaptation is an evolving phenomenon and very complex. With regards to who is adapting to what and how, the definition of adaptation is highly context- and scale-dependent (Preston et al., 2015). Without human insights, data and the hard sciences will not be able to address the challenges of the future since adaptation is an inherently human endeavor (Shah, 2020). In addition, adaptation is determined by socioeconomic context and location (Bhatta et al., 2015) and as such, small-scale farmers' understanding of climate change is necessary for effective adaptation strategies (Karienye and Macharia, 2021). Without understanding, coping strategies and social safety nets are put under increased strain (Thornton et al., 2014). Small-scale farmers have increasingly become vulnerable in their agricultural systems as a result of climate change's inadequate capacity to plan, cope, and recover from climate, non-climate shocks, and water stress (Pereira, 2017). Africa suffers the most as a result of climate change variability. Due to a lack of income, education, health care, infrastructure, and market access, small-scale farmers struggle to adapt to climate change, with changing and degraded ecosystems being the most significant contributing factors (Ubisi, 2016). Climate change as a concept is not a new phenomenon, since time immemorial, the environment has always been changing and indigenous societies have traditional coping mechanisms and adaptation skills that have been passed down from one generation to the next. Traditional or indigenous knowledge is the collective body of knowledge held by indigenous peoples of interaction with nature and adaptation to shifting ecological and social contexts, which include seasonal forecasting and timing of suitable farming activities (Adger et al., 2014; UNESCO, 2017; Makondo and Thomas, 2018; Radeny et al., 2019; Asmamaw et al., 2020; Leal Filho et al., 2022). The majority of smallholder farmers utilize traditional climate indicators to predict the weather and make crucial short-term decisions about their farming activities and adaptation measures (Rankoana, 2016; Ubisi et al., 2017). This form of adaptation usually does not require farmers to spend. Ubisi et al. (2020) reported that the most common traditional weather and climatic indicators used by farmers for adaptation can be categorized as animal and plant behavior indicators, atmospheric indicators, and human ailments. However, with more produce quantity destined for the market, the pressure to use modern adaptation strategies increases, requiring farmers to allocate substantial budgets toward modern mitigation measures. Moreover, unprecedented climate change frequently renders traditional climate techniques ineffective (Roncoli et al., 2001).

These modern climate change measures include the use of inorganic fertilizer, drought-resistance seeds, pesticides, herbicides, and irrigation. Zeleke et al. (2022) study found small-scale farmers' usage of irrigation as an adaptation strategy to be hampered by financial capital. Priorities of investment in modern adaptation strategies will vary according to the scale of the farming business and market target. The majority of small-scale farmers target local retail markets which come with high expectations of farm produce without pest infestation and of good quality. In South Africa, the situation demands the adoption of various adaptations due to variations in climate change effects in various parts of the country. However, this requires funding for intervention, which is usually unavailable to small-scale farmers. Commercial farmers can cushion themselves through insurance services and access to funding, a luxury for small-scale farmers. However, this problem is not unique to South Africa but also to the African continent. The absence of a climate change policy in place exacerbates the problems even further (Mogomotsi et al., 2020).

Aryal and Marenya (2021) reported that common climate change adaptation strategies were crop diversification, farm diversification, improved crop varieties, agroforestry, soil conservation practices, water conservation practices and use of fertilizer. Farmers have found cost-effective ways of mitigating climate change problems by resorting to growing drought-tolerant crops, burning charcoal and collecting rainwater. Changing the timing of planting and introducing short-duration crop types in response to climate change have been used by most farmers (Ahmed et al., 2021). Acevedo et al. (2020) found the use of drought tolerance and water-use efficiency methods to be the most used adaptation methods in low-and middle-income countries. Farmers also mitigate climate change by using irrigation, improved drought-resistant crops, soil and water conservation, income source diversification, and mixed cropping in Kenya and Ethiopia (Agesa et al., 2019; Marie et al., 2020). Other traditional adaptation methods used by the indigenous people of the Andean highlands in Bolivia included planting trees and poking plots with fire, a traditional practice intended to ward off frost or hail by dissipating the clouds with smoke (Meldrum et al., 2018). Most farmers are now embracing the idea of agricultural produce diversification broadly. Seo (2010) reported that farmers who were engaged in a mixed farming adaptation strategy were likely to lose less value of their land. Fadina and Barjolle (2018) reported that although farmers use a variety of adaptation methods, agroforestry and crop diversification were the most promising strategies in Benin. Although crop diversification is a good idea, it destroys economies of scale to some extent as farmers are forced to focus on multiple crops planted in small plots, further increasing the cost of production.

2.2 Determinants of climate change adaptation strategies

Climate change adaptation is a social construct and does not take place in isolation. The level of various climate change adaptation techniques was found to depend on the gender and human capital (education, awareness, and training) of the farmer (Mburu et al., 2015; Trinh et al., 2018). Although women farmers are mostly affected by climate change, they are more innovative in climate change adaptation measures when given empowering decision roles in farming (Shahbaz et al., 2022).

Human capital factors are key to farmers' ability to comprehend crop diversification patterns, and planning and implementation of climate change adaptation methods (Labeyrie et al., 2021). In other studies, literacy level, the use of credit services, extension services, and water availability were also found to be determinants of climate adaptation techniques (Sertse et al., 2021). Access to knowledge on climate change, the input and output markets, extension services, and social capital, were found to be associated with climate change adaptation techniques (Balew et al., 2014). Recent studies have also shown that gender, farm size, and knowledge of changes in temperature and rainfall patterns have a substantial impact on farmers' judgments on how to adapt to climate change (Kom et al., 2020). These resources have a bearing on the extent to which farmers can adopt adaptation measures. Contrarily, in other studies access to credit had no impact at all on climate change adaptation (Vo et al., 2021). Social cohesion is a critical component in the climate change discourse as the depletion of natural resources (i.e., water, grazing land, and residential space) due to climate change causes clashes between animals and people and within various communities. The creation of harmony in communities creates strong social capital and resilience. Apart from the common operational factors, the influence of peers and neighbors, attitudes and subjective standards were found to play a role in climate change adaptation, an indication that social capital is a critical element that policymakers should take into account in climate change adaptation (Arunrat et al., 2017). Small-scale farmers also face other challenges that impede the extent to which they can adopt available adaptation techniques. Wilk et al. (2013) reported some of these challenges as, insufficient government support, farm produce theft and affordability of improved seed types and implements.

From the farmers' point of view, the major drawback of climate change is livelihood, as this negatively affects productivity. The outcome is stunted growth, poor quality or damaged produce, directly affecting the price that the farmer can get at the market. Other issues include pests and diseases, altered weed species and distribution, degraded soils, and water stress (Azadi et al., 2019). Fagariba et al. (2018) also reported that the availability of weather information highly influenced farmers' ability to adapt to climate change. In India, farmers reported a lack of financial resources, and limited information on weather, lack of access to input markets, inadequate farm labor as constraints to adaptation (Singh et al., 2018). In general, farmers are showing a developed perception of climate change, this shows an improvement in understanding of the concept. Climate change's negative effects are experienced everywhere, it is crucial to recognize an area's climatic peculiarities when advocating for adaptation methods (Malhi et al., 2020). However, the most common challenge facing farmers as a result of climate change is water shortages. Farmers' success in farming anchors on water resources, without it, the produce quality gets affected consequently affecting the farmers' income (Bjornlund et al., 2018). Irrigation is able to sustain farming, but for most small-scale farmers the challenge is affordability. Mango et al. (2018) reported access to irrigation equipment as one of the determinants of climate change adaptation. In South Africa, small-scale farmers not only face a lack of access to irrigation equipment but also a steady increase in electricity costs (Numbi and Malinga, 2017) to run the irrigation system. The situation is exacerbated by electricity load-shedding affecting productivity negatively. To circumvent the situation, commercial farmers have started to include renewable energy in their energy mix. However, this requires funding, which is inaccessible to small-scale farmers. Although small-scale farmers have the potential to meaningfully participate in producing renewable energy through bioenergy, the lack of green energy investment in the small-scale agricultural sector hampers this opportunity (Tagwi, 2022, 2023; Tagwi and Chipfupa, 2022). Most small-scale farmers in Limpopo province in cooperatives reported an inability to cope with electricity costs due to 3-phase transformers installed in the farming plots by ESKOM which attracts higher rates (Maiwashe, 2017). Energy has become an important factor of progress in South Africa in all sectors. Kabir et al. (2017) assert that different communities experience varying degrees of vulnerability, which are related to their potential for adaptation, physiographic characteristics, and socioeconomic and cultural limitations. Such experiences should be investigated on their merit.

3 Research methodology

3.1 Study area

Mpumalanga Province is a summer rainfall area, which is divided into two escarpments of the Highveld region and the Lowveld region. The research study was conducted in the Lowveld region in Bohlabela district under Bushbuckridge municipality (Figure 1) covering an area of 10.249 93 km^2. The area is adjacent to Hazyview/Kruger National Park's main gate. The rainfall pattern in Bushbuckridge Municipality starts between September and March or late May. The average annual rainfall is 913 mm while the average temperature is 18.30 degrees Celsius. Citrus fruit (oranges, grapefruit, lemons), subtropical fruit (mangoes, avocados, litchis, papayas, granadillas, guavas, nuts), and vegetables (summer vegetables and winter vegetable crops) are abundant in Mpumalanga. Farmers of citrus and subtropical fruits export to the following markets: Europe, the United State of America, China, Japan, Thailand, and Korea. They also sell to the local markets and some of the fruits they send to juice factories. The main economic activity in Bushbuckridge Municipality is small-scale farming mainly growing vegetables and fruits (Nkuna, 2017).

3.2 Sampling and data collection

The research study was conducted in the 2021/2022 season. A semi-structured questionnaire was used to collect data from 244 small-scale farmers in Botlabela District, Mpumalanga Province using face-to-face interviews. The approach allows open conversations with farmers, providing essential information to the researchers about the unobserved parameters in the study (Alotaibi et al., 2021). The population size of vegetable farmers in the study area was 670. To determine a representative sample, Krejcie and

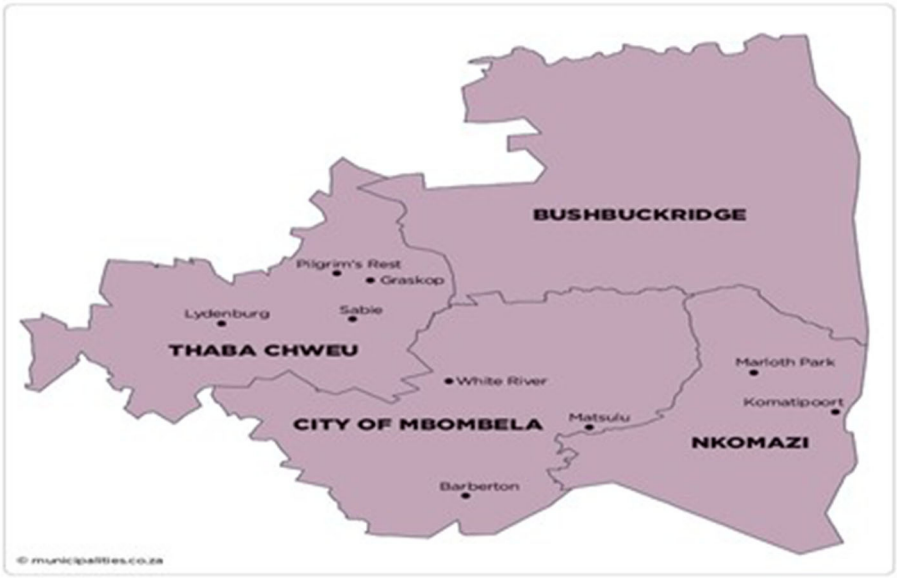

FIGURE 1
Study area map. Source: Local Economic Development Strategy of Bushbuckridge Local Municipality, 2010–2014.

TABLE 1 Population and sample distribution per area based on stratification.

Location/ area	Number	Representative proportion	Sample per village
Mkhuhlu	70	70/670 * 244 = 25	25
Marite	150	150/670 * 244 = 53	55
Jim Brown	150	150/670 * 244 = 53	55
Cork	300	300/670 * 244 = 105	109
Total	**670**		**244**

Source: Author (2022). *represents 10%, **represents 5%, ***represents 1%.

Morgan (1970) sample formula was used. Using the formula below, a representative sample of 244 was randomly selected. The table below shows the distribution of the population size of 670 farmers. The stratified random sampling technique was used to afford each farmer from each stratum an equal opportunity to participate in the study. Table 1 shows the 4 strata (4 villages) used in the study. Stage 1 of the sampling was to determine the appropriate sample size (244) given the total population (670) of small-scale vegetable farmers in the study area using Krejcie and Morgan's formula. Stage 2 of the sampling involved calculating the representative portions from each stratum that should constitute the final sample size (Table 1). Permission to conduct the study was granted by the local Department of Agriculture and consent from farmers was acquired. Ethical clearance was issued by UNISA ethical committee.

Formula:

$$n = \frac{x^2 Np(1-p)}{e^2(N-1) + x^2 p(1-p)}$$

n = sample size
N = population
e = acceptable sampling error
x^2 = Chi-square of degrees of freedom,1 and confidence level of 95% = 3.841
p = proportion of the population (if unknown, 0.5).

3.3 Analytical framework

3.3.1 Binary logistic model

The study used binary logistic regression to determine the association between farmers' modern adaptation strategies to climate change and several anticipated explanatory variables. This is because of the nature of the dependent variable (modern climate change adaptation (1-adaptation, 0-traditional adaptation) which was binary. The logistic regression model was chosen due to its simplicity of interpretation.

Empirical and specified model

$$Logit(P_i) = ln(P_i/1 - -P_i) = \alpha + \beta_1 X_1 + \ldots + \beta_n X_n + U_t$$

Where:
$ln\ (P_i/1 - P_i)$ = logit for modern climate change adaptation
P_i = modern adaptation (1)
1-P_i = traditional adaptation (0)
β = coefficient
X = covariates (variables stipulated in Table 2)
U_t = error term
$Logit$ (modern climate change adaptation) $= \alpha + \beta_1 AGE_1 + \beta_2 GEN_2 + \beta_3 EDUL_3 + \beta_4 MART_4 + \beta_5 FARM\_ASS_5 + \beta_6 LANS_6$

TABLE 2 Parameter estimates of logistic regression on modern climate change adaptation.

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
Age (AGE)	0.008	0.019	0.201	1	0.654	1.009
Gender (GEN)	−0.828	0.522	2.514	1	0.113	0.437
Education level (EDUL)	0.043	0.068	0.402	1	0.526	1.044
Marital status (MART)	−0.041	0.159	0.067	1	0.796	0.960
Farm association (FARM_ASS)	−1.874	0.461	16.527	1	0.000***	0.154
Land size (ha) (LANS)	0.021	0.053	0.152	1	0.697	1.021
Extension services access (EXTEN)	−0.600	0.225	7.090	1	0.008**	0.549
Labor (LABR)	0.866	0.482	3.231	1	0.072	2.378
Farm produce Theft (THEFT)	2.528	0.466	29.423	1	0.000***	12.525
Animal trespassing (ANI_TRES)	−0.332	0.166	4.011	1	0.045**	0.717
Electricity cost (ELECT)	0.382	0.454	0.708	1	0.400	1.465
Constant	1.301	1.638	0.630	1	0.427	3.672
Hosmer and Lemeshow Test						
Chi-square	6.418					
P-value	0.600					

Source: Authors (2022). *represents 10%, **represents 5%, ***represents 1%.

$+ \beta_7 EXTEN_7 + \beta_8 LABR_8 + \beta_9 THEFT_9 + \beta_{10} ANI\_TRES_{10} + \beta_{11} ELECT_{11} + \beta_n X_n + U_t.$

3.3.2 Dependant variable

The dependent variable was adaptation (1-modern adaptation, 0-traditional adaptation), and the dependent variable was measuring the use of modern adaptation strategies to climate change. Traditional adaptation referred to traditional practices observed by farmers over the years, which included seasonal forecasting and identification of suitable plowing seasons. Modern climate change adaptation strategies in the study referred to adaptation measures that involved money such as the use of inorganic fertilizer, drought resistance seeds, pesticides, herbicides and irrigation. These adaptation strategies required the farmer to spend more money. Farmers who were using modern methods were given a value of 1- Yes, and the farmers using traditional mitigation strategies were given a value of 0-No.

3.3.3 Independent variables

Table 3 below shows the independent variables which were used in the study. The variables were based on the 5 categorized behavioral determinants of climate change adaptation from literature (i.e., socio-demographic factors, resources, institutional and political factors, societal and traditional influences and perceptive and psychological factors). The socio-demographical characteristics of the farmers in the study area were represented by age (AGE), gender (GEN), educational level (EDUL) and marital status (MART). LANS represented land size, this was important to include in the model, primarily because the size of the land could be a good indication of the extent of resources that a farmer needs to operate with. The implications in this context are, the bigger land size could be demanding for a farmer leading to inadequate climate change adaptation methods as a result of higher costs related to acquiring modern climate change adaptation resources. Alternatively, farmers with bigger land sizes could benefit from economies of scale with secured markets consequently having enough farm revenue to purchase modern climate change adaptation resources. LABR represented hired labor, the variable was included to measure the extent to which paid labor affects modern climate change adaptation. These variables were of interest as studies have shown that these socio-demographic factors are associated with climate change adaptation (Mburu et al., 2015; Singh et al., 2018; Trinh et al., 2018; Kom et al., 2020; Labeyrie et al., 2021; Ojo et al., 2021).

Resource factors included extension services, EXTEN represented access to extension services by small-scale farmers in the study area. The variable was key as studies show the importance of extension in climate change adaptation decisions (Sertse et al., 2021). Institutional factors were represented by government support structures and interaction structures such as affiliation membership to other farming structures, FARM_ASS represented farm associations membership, this was important in the model as farmers are able to access and share knowledge on climate change adaptation easily and cheaply, especially in the absence of public extension services (Ojo and Baiyegunhi, 2020). Government structure support was measured by electricity costs burden. Government is a monopoly of electricity supply (ESKOM) and as such small-scale farmers have been reporting high costs of

TABLE 3 Description of independent variables included in the model.

Variable	Description	Mean	Standard deviation	%	Expected sign (+/−)
AGE	Age of the farmer	60,1	14.69	-	+ (9)
GENDER	1-Female. 0-Other	-	-	71.3	+ (1)
EDUCATION (GRADE)	Education grade	3.87	4.44	-	+ (2 and 3)
MARITAL STATUS	Marital status. 1-Yes, 0-Other	-	-	40.2	+ (9)
FARM_ASSOSSIATION MEMBERSHIP	Farm association. 1-Yes, 0-Other	-	-	29	+ (10)
LAND SIZE (HA)	Land size (ha)	4.08	3.10	-	+ (5)
EXTENTION SERVICES	Access to extension service. 1- Yes, 0-Other	-	-	54.5	+ (4)
LABOR	Hired Labor. 1-Yes, 0-Other	-	-	73.4	+ (8)
FARM PRODUCE THEFT	The challenge of farm produce theft. 1-Yes, 0-Other	-	-	60.7	+ (6 and 12)
ANIMAL_TRESSPASSING	Animal tress passing. 1-Yes,0-Other	-	-	79.1	+ (7)
ELECTRICITY COST CHALLENGE	Electricity challenge. 1-Yes, 0-Other	-	=	69.3	+ (11)

Source: Survey Data (2022).
1. Mburu et al., 2015, 2. Trinh et al., 2018, 3. Labeyrie et al., 2021, 4. Sertse et al., 2021, 5. Kom et al., 2020, 6. Wilk et al., 2013, 7. Arunrat et al., 2017, 8. Singh et al., 2018, 9. Ojo et al., 2021, 10. Ojo and Baiyegunhi, 2020, 11. Numbi and Malinga, 2017, 12. Laukkonen et al., 2009. *represents 10%, **represents 5%, ***represents 1%.

electricity (ELECT) in farming plots in rural areas. Considering that irrigation is one of the modern climate change adaptation strategies, which uses electricity, it was of interest to assess possible association with modern climate change adaptation (Numbi and Malinga, 2017). In addition, farmers are not only affected by the high costs but also the electricity load-shedding. The negative impacts of load-shedding directly affect farmers' productivity (Chiluwe, 2020).

Societal and traditional influences were represented by community activities such as farm crime and animal control in the villages. THEFT was key, especially with the current spate of crime reported in farming areas in South Africa. It was of interest to assess the connection of theft with adaptation. ANI_TRES represented animal trespassing in the study area. This variable was of great interest as farmers in rural areas always wage wars over animal trespassing in farming plots. A great discomfort was expressed during focus group discussions in the study area about the loss incurred as a result of animal trespassing. It was of interest in this study to assess the societal activities' influence on modern climate adaptation. It is generally acknowledged that the poorest communities are the most susceptible to climate change because they cannot access even the most basic urban services, which puts them at a disadvantage and limits their capacity to cope with climate change (Laukkonen et al., 2009; Wilk et al., 2013; Arunrat et al., 2017). The extent to which basic services are supplied in the community will affect climate change adaptation.

4 Results and discussion

4.1 Descriptive results

The average age of small-scale farmers was 60 years old, which means the study was dominated by aging farmers. The findings in this study were consistent with the findings in Uganda, where the majority of farmers were 55 years and older and with primary education (Tiyo et al., 2015). The problem of aging farmers is common across the African continent. The results in Table 3 show that the majority (71.3%) of the farmers were female. The finding is consistent with other studies showing that women dominate small-scale farming. Amenyah and Puplampu (2013) report that 50% of agriculture in Sub-Saharan Africa, was led by women farmers with males mostly focusing on cash crop cultivation (Cadger et al., 2016). Studies have shown that paying attention to gender is not only important in addressing equity in climate change adaptation programmes but also key in enabling efficiency and effectiveness (Bryan et al., 2018; Shahbaz et al., 2022). Results showed that the average education grade in the study area was three, an indication of a high level of low education. Education level is crucial in farming and some studies have also established that there is a connection between empowerment and education (Sell and Minot, 2018). About 40% of farmers were married in the study area, however, when compared to other marital status proportions, there was a dominance of married participants in the study which is consistent with literature findings from other studies (Ajala, 2017). A similar finding was observed in the study in the Eastern Cape of South Africa where most of the small-scale farmers were married (Richard, 2014). Farm association membership was expected to have a positive influence on modern climate change adaptation, primarily because memberships in such organizations reduce the costs of information and peer influence also plays a positive role. Only 29% of small-scale farmers had farm association membership. According to several studies farmers association membership was found to be associated with climate change adaptation measures (Gbetibouo et al., 2010; Iheke and Agodike, 2016; Amare and Simane, 2017; Diallo et al., 2020). The mean land size was 4 hectares in the study. The findings were expected as small-scale farmers usually have small plots of land just below 3 hectares, this was also observed in other parts of Nigeria (Osei, 2017).

The size of the farming plot was expected to have an impact on climate change adaptation. Research shows that access to extension services positively affects climate change adaptation amongst small-scale farmers.

Access to extension services was 54.5%, an indication that almost half of the farmers do not get access to extension services. Piya et al. (2013) reported that the transition from traditional to modern climate change adaptation anchors on the availability of extension services. The problem of lack of public extension services for small-scale farmers is wide in the African continent (Atube et al., 2021). The majority (73.4%) of small-scale farmers could afford to hire labor. The variable measured the availability of labor or manpower and could therefore have an impact on the modern climate change adaptation of the farmer. Although hired labor is increasingly becoming expensive, small-scale farmers are generally keen on hiring labor as family labor reduces due to urban migration.

The South African community has a major problem with security at the household level, and over the years farmers have been badly affected by farm crimes, some even resulting in the death of farmers. Interestingly, variable theft was expected to both negatively and positively affect the adaptation of the farmers in the sense that stealing could reduce the financial resources of the farmer and thereby influencing the farmer not to invest in modern climate change adaptation methods. While the positive impact expectation could be a result of financial loss pressure, inevitably forcing the farmer to adapt to modern climate change methods in an effort to reduce losses. The study findings show that the majority (60%) of small-scale farmers had a challenge of theft from their farms.

Animal trespassing was included as one of the variables. Although this variable is not a direct household theft, it is a reducing agent for a farmer, and considering the lack of infrastructure and spatial planning of the communities and farming plots in rural areas, it was expected that this variable would positively or negatively affect the modern climate change adaptation of the farmer. This is because crop production in rural areas is not only vulnerable to climate change but also to animal trespassing. Most (79.1%) farmers reported having been badly affected by animal trespassing in the study area. Irrigation is more reliable for production for small-scale farmers, however, electricity costs in irrigation constitute the major costs in production in South Africa. This is largely due to the 3-phase transformers installed in the farming plots which carry higher tariffs and therefore introduce higher inefficiencies for small-scale farmers. In addition, South Africa has an energy insecurity problem becoming a risk for farmers. For a farmer who is faced with climate change issues, irrigating crops becomes one of the important components of production. The results show that most (69.3%) farmers had a challenge with high electricity costs.

4.2 Empirical model results

4.2.1 Factors affecting modern climate change adaptation

The logit regression model was used to analyse the determinants of modern climate change adaptation. The farm association was found to be significant at a 1% level of significance (*P*-value 0.000). The estimate/coefficient was negative (−1,874). This implies that the likelihood of switching to modern climate change adaptation methods was less likely by 1.874 times. Farmers who joined associations were supposed to have more resources, such as information, and so be more willing to try new things. According to a study conducted in Ghana, farmers' associations' membership had a positive impact on climate change adaptation (Wongnaa and Babu, 2020). Small-scale farmers with farm associations meet as groups and organize farm activities together. Communication is easy and meetings become easier for information sharing. During data collection, it was also easy to meet farmers because the message was conveyed easily. Farm associations make farmers do things collectively, seek information, and share ideas as a group about farming activities. In general farmer's organization membership provides technical efficiency benefits to farmers (Bartova and Fandel, 2020). A priori, the expectation was that farmers belonging to farm associations would be more likely to use modern climate adaptation measures. However, on contrary, results suggest that the programmes of these farming associations in the study area could be lacking in terms of climate change adaptation issues coverage, considering that rural areas are largely under-resourced.

The extension services access variable was statistically significant at the 1% level. (*P*-value 0.008) with a negative estimate of **−0.600**. The result shows that extension services access was associated with modern climate change adaptation, however, farmers who received extension services were 0.600 times less likely to switch to using modern climate change adaptations. A priori, farmers who got extension services would be more likely to employ various adaptation strategies simply because they had access to more knowledge as a result of receiving extension services. Contrary, a Pakistani study by Akhtar et al. (2018) found that extension services had a favorable impact on farmers' climate change adaptability. The findings in this study were different. Extension services are critical in helping farmers transition from traditional to modern climate change adaptation methods. In addition to the numerous difficulties that smallholder farmers encounter, the main obstacle to their sustainability is the lack of access to extension services (Mapiye et al., 2021). The plausible explanation could also be the fact that small-scale farmers in the study area had limited visits from the extension officers due to government financial austerity measures (1 to 2 visits a year). Perhaps the outcome of the study results could also be explained by the fact that farmers who had received extension services did not necessarily receive information that had a huge impact on climate change adaptation.

At a 1% level of significance, the **farm produce theft** variable showed statistical significance (*P*-value 0.000). The variable had a positive estimate (2,528). This implies that it was more likely for farmers experiencing produce theft in the farming plots to implement modern climate change adaptations by 2.528 times. This means that theft had a positive influence on modern climate change adaptation in the study area. The findings suggest that as theft takes place, more pressure for efficiency and productivity to counteract the loss becomes high for a farmer. The same association between theft and climate change adaptation was observed in other studies.

A study in the Mkuranga district, coast region (Tanzania) also reported theft as a problem among small-scale farmers (Rukwaya, 2016). In the study, small-scale farmers complained about the theft of crops during the harvest period. A recent study in the eastern cape in South Africa also reported produce theft as a challenge for farmers (Fanadzo et al., 2022). Another major challenge for small-scale farmers was the lack of fences on their farms, a common challenge in South Africa seen as an enabler for theft (Wilk et al., 2013; Acha, 2015).

Animals' trespassing variable was peculiar in the study and statistically significant at a 5% level (*P*-value 0.045), and the coefficient estimate was negative (−0.322), this implied that although the variable had an influence, it was less likely for farmers experiencing animal trespassing to switch to climate change adaptation methods by 0.322 times. Ordinarily, a farmer should focus on issues directly affecting farming activities, however, other social cohesion issues involving household traits, community and country affairs play a role. In this case, the free movement of livestock in the area will harm the farming activities of the farmers. The problem of not having a fence in the plot exacerbates the loss as animals have been reported to be damaging the crops. This has also stirred tensions amongst the farmers as some own livestock. This is largely due to the fact that climate change has drastically reduced grazing areas for livestock and as a result, animal trespassing looking for grazing in the farming plots has been normalized. Animals had caused overgrazing, especially in dryland in Africa. In addition, grazing areas are currently disappearing in Sub-Saharan Africa at an alarming rate as a result of land degradation, conversion to crop and urban land, and other factors (Milne et al., 2016). A recent study has shown that across the continent, there is a loss in land appropriate for livestock production (Nidumolu et al., 2022).

Modern adaptation to climate change was expected to be influenced by several factors. However, in the study, these variables were statistically non-significant. Variables which were found to be non-significant were age (*P*-value 0.654), gender (*P*-value 0.113), completed educational level (*P*-value 0.526), married status (*P*-value 0.796), hectares of agricultural arable land (*P*-value 0.697), unskilled labor (*P*-value 0.072), and electricity challenge (*P*-value 0.400). Positive and negative coefficients were found in some of the variables.

5 Conclusion and policy implications

The purpose of this study was to assess factors associated with small-scale vegetable farmers' modern adaptation to climate change in the study area. The study results indicated that factors associated with modern climate change adaptation were farm association membership, access to extension services, farm produce theft, and animal trespassing in farming plots. The study recommended that government must encourage farmers to participate in farming associations. The affiliation might expose farmers to more information about climate change, further increasing farmers' resilience. Associations are likely to offer farmers services that ordinarily have to be paid for at zero cost or a discounted rate. Although results showed less likelihood of associations predicting modern climate change adaptation, it was still associated with adaptation. The less likelihood could be due to a lack of tailor-made information on climate change offered by associations. Therefore, there is a need for the associations to deliberately provide tailor-made climate change information. The study recommends that training be made available to expose farmers to the causes of climate change in general. The training must also focus on the available resources that farmers in the study area can use in climate change adaptation.

It is recommended that the extension services budget must be increased to ensure that each farmer can at least access an extension officer once or twice a year. Research has shown that government extension officers are overstretched and unable to service all farmers within a year. Unfortunately, for small-scale farmers, this is all they have. The government must find alternative ways of reaching out to all farmers. The easiest way is to conduct climate change workshops, in that way, an extension officer can help many farmers at the same time. Farmers in the study area strongly complained about the lack of availability of extension services. The extension officials indicated that their lack of availability was hampered by the current austerity measures in budgets by the government. The lack of sufficient budget meant that extension officers allocated kilometers could only cover traveling to fewer farmers in a month and year. A unique challenge of theft and animal trespassing on the produce in the study area was highlighted as a common problem for farmers. The study results also indicated that theft played a role in modern climate change adaptation in the study area. The study recommended that the government must strengthen community policing forums in rural farming areas to address theft. This approach has some benefits as community members can work hand in hand with the police by providing tip-offs in a safer environment. In this way, mob vigilantism can be avoided, a growing trend in communities that cost innocent lives. This is because most of the time, the perpetrators are also community members who later sell the same stolen produce to the community. Farmers felt that the contributing factor to theft was the lack of allocation of policing resources in rural areas and as such perpetrators took advantage of the situation.

The study recommends that the problem of animal trespassing be resolved by the traditional leadership in the rural area by creating guidelines for livestock owners and agreeing on consequence management. Farmers indicated a growing competition for grazing, farming and residential land. The biggest challenge is that, in the past, community livestock freely grazed the land and in recent years the grazing allocation has reduced leading to the current conflicts. Farmers recommended that alternatively the government can expand the disaster management budget for farmers affected by these damages as most farmers had reported having experienced disasters but with no financial help extended. Ultimately these damages take money out of the farmers' pockets, further reducing resources available for modern climate adaptation.

The study points out the need for stakeholders to take cognisant of the weight that social activities have on the ability of a small-scale farmer to use modern climate change adaptation and what is most challenging, is that these are factors beyond the farmer's control. The small-scale farmer usually does not have a choice not to use

modern climate change adaptation if destined for a formal market, precisely because of the supply demands obligations (volume, quality, and consistency) this is usually difficult to meet with rain-fed agriculture. There should be a certain social ecosystem set for farmers to use modern climate change adaptation. Although there is an emerging market for organic farming, which enables the farmer to focus on natural and mostly traditional climate change adaptations, the market growth is sluggish, especially in low-income areas and ultimately food security precludes the production process. On the high-end market, consumers appreciate the use of minimal modern production technologies and are willing to pay more for farm produce produced in an environmentally friendly manner. However, for a small-scale farmer, what is important is income security. There is a need for stakeholders to create a conducive environment for the commercialization of organic food grown in rural areas to position farmers in the existing high-end lucrative market. This will allow both farmers (modern and traditional based production orientated) to have a space in the market. Farmers concede that the use of traditional climate change adaptation methods is the way to go for the environment. However, the rate at which climate change is affecting production makes it a luxury they cannot afford. This is also consistent with Shahbaz et al. (2021) who reported excessive use of nitrogen fertilizer by farmers to counteract the climate change negative impacts. And using modern climate change seems to be their lifeline, however, they cannot afford it without climate change finance.

6 Study limitations

There are limitations to this study, considering that adaptation is a context and location-based phenomenon, more studies are certainly required to examine region-specific adaptation options and diverse adaptation techniques that would be appropriate in several places given the geographic and resource base variations across the different ecological regions of Mpumalanga province. And therefore, the generalization of the outcomes is limited to the municipality. Furthermore, the sole basis for this study was to assess the socioeconomic drivers of modern climate change adaptation. Future studies can also measure technical efficiency for both modern and traditional use of climate change adaptation to see if there is an association. This will inform future policy for government input programmes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the UNISA-CAES Research Ethics Committee reference 2019/CAES-HREC/121 authorized the study questionnaire and method, and the respondents gave their informed consent. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AM and KK contributed to the conception and design of the study and organized the database and performed the statistical analysis. KK collected the field data and wrote the first draft of the manuscript. AM wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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