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Determinants of Livestock Smallholder Farmer's Choice of Adaptation Strategies to Climate Change in Raymond Mhlaba Local Municipality, Eastern Cape, South Africa

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ABSTRACT

Globally, climate change is a major challenge facing farmers. This phenomenon threatens the sustainability of smallholder farmers in rural communities who depend solely on agriculture. Farmers are known to take suitable steps to adapt when they observe change and adjust their farming practices to cope with climate change. However, livestock farmers' response to climate change is very low due to insufficient scientific and context-based evidence. Hence, this paper sought to investigate the determinants of livestock small-scale farmers' choices and adaptive strategies in response to the effects of climate change in Raymond Mhlaba Local Municipality. The study used a cross-sectional research design to collect data from 220 livestock farmers using a semi-structured questionnaire. The study used multinomial logistic regression to analyse the data. Empirical results reveal that access to weather forecasts and extension services, farmers' perception of climate change, level of education, age of the household head, distance to input markets, member of farm organisation, income from livestock sales, and livestock holding affect livestock farming decision for climate change adaptation. Therefore, the study recommends that the government improve farmers' access to accurate and timely agro-meteorological forecasts, capacity building, and technical support for income diversification through improved provision of agricultural extension services.

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1. INTRODUCTION

Globally, climate change is one of farmers' most significant challenges (Kom et al., 2020). Several climate change models predicted that South Africa would experience temperature increases ranging from 5°C to 8°C (Popoola et al., 2020). Such changes hit smallholder farmers hard since their livelihoods rely on climate-sensitive natural resources (Mdiya et al., 2023). Smallholder livestock farmers in South Africa are adversely affected by current changes in climatic conditions, and it is expected that long-lasting effects will be experienced on livestock production (Mukwena, 2017; Lottering et al., 2021; Maluleke & Bontsa et al., 2023). This can be attributed to communal livestock production being subjected to limited resources and inadequate access to climate change support materials (Ngarava, 2019; Gwala et al., 2021).

Although climate change is problematic to smallholder farmers, using appropriate adaptation strategies is one of the most promising ways to reduce its associated effects (Lemessa *et al*., 2019). Adaptation to climate change can lead to achieving Sustainable Development Goal (SDG) 13, which calls for urgent action to combat climate change and its impact. However, Popoola et al. (2019) reported that smallholder farmers in communal areas of the Eastern Cape province of South Africa have limited ability to cope with climate change. The main reason for this is that most smallholder farmers can only use short-term adaptation strategies to limit the impact of climate change on agricultural production (Mdoda, 2020). This can be attributed to several factors affecting smallholder farmers' adaptation strategies to climate change (Myeni & Moeletsi, 2020; Mtitsilana et al., 2021; Mangwane & Oluwateyo, 2021). Despite several studies documenting factors affecting smallholder farmers' adaptation strategies to climate change in South Africa, there is still limited understanding of the factors affecting livestock smallholder farmers' adaptation choices. Yet, an in-depth understanding of the determinants of smallholder farmers' choice of adaptation strategies to climate change can help to design appropriate adaptation interventions (Ashraf *et al*., 2014). Therefore, it is against this background that this study is carried out to determine the factors affecting livestock smallholder farmers' choices of adaptation strategies to climate change. This study seeks to answer the following question: What factors affect livestock smallholder farmers' choices of climate change adaptation strategies in Raymond Mhlaba Local Municipality?

2. MATERIAL AND METHODS

2.1. Description of the Study

The study was conducted in Raymond Local Municipality in the Eastern Cape Province of South Africa focusing on Gaga, Gqumashe, Dyamala, and Ncera villages. The municipality has a total population of 162 000, with about 70% living in villages and farms (Raymond Mhlaba Local Municipality IDP, 2020). Livestock is the primary agricultural activity for commercial and subsistence farming in Raymond Mhlaba's local municipality (Mukuhlani *et al.,* 2019). Nguni cattle are the most-kept livestock breed in the study area due to their tolerance to harsh climate conditions (Adekunle, 2014).

The research area is a semi-arid region, with annual rainfall ranging from 425.5mm to 480mm, with most rainfall occurring in the summer (Ehiobu *et al.,* 2020). The temperature ranges from 4 degrees Celsius in the winter to 38 degrees Celsius in the summer (Maroyi, 2017). Raymond Mhlaba Local Municipality is one of South Africa's most vulnerable municipalities to climate change (Hlaiseka *et al.*, 2016). Variable rainfall, frequent droughts, increased vulnerability to food insecurity, and significant land degradation are all characteristics of the studied area (Raymond Mhlaba Local Municipality IDP, 2020).

2.2. Theoretical Framework

Climate change is negatively affecting smallholder farmers in developing countries. As a result of such devastating effects on their productivity, mitigating and adapting to the impacts of climate change, farmers usually adopt several adaptation strategies, with the decision to use a given strategy being directed by the Utility Maximisation Theory and the protection motivation theory of Rogers (1983), which assumes that farmers' intention to adapt depends on the threat appraisal and coping appraisal.

The study adopted a Utility Maximisation Theoretical approach. The theory hypothesises that economic units (farmers) make decisions directed by the anticipated benefit they expect from such a decision amidst a set of constraints. Sankalpa et al. (2022) argued that this theory is an unobservable indicator that a set of observable factors can, however, project. The theory states that the adaptation strategy would only be used if its use's expected net benefits surpass the net benefits from non-use. Different factors influence the choice of each climate adaptation strategy available to farmers. Thus, smallholder farmer's choice of which adaptation strategy to engage in can be based on utility maximisation. If U_{i0} is the utility derived from the adaptation strategies used by farmers, while U_{i1} is the expected utility from the adaptation strategies, then, although not observed directly, the utility that a farmer i derived from adapting a given measure of the farmers responding to climate change (j) can be expressed as:

$$U_{ij} = X_i\beta_j + \tau_{ij} \quad j = 1,2,3; \quad i = 1,\ldots\ldots\ldots,n$$

Where

X_i is a farm-specific function, the factors that influence livestock farmers' choice of adaptation practices to climate variability, β_j is a parameter to be estimated, τ_{ij} is a disturbance term with mean zero and constant variance. The adaptation strategy variable is a multiple response. n = 1, are the individual livestock farmer and j= 1,…J are the alternative adaptation strategies. In this model, we estimate that livestock farmers are rational decision-makers who maximise the utility of adaptation strategies in their farming activities. We also forecast that farmers who face climatic-related stresses in their farming activities will look for adaptation strategies. If farmer i makes the choice of adaptation, in particular, we assume that Uij has the maximum utility among the J adaptation strategies. Prob ($U_{ij} > U_{ik}$)… for all other k ≠ j, the probability of the livestock farmer choosing a specific alternative j is given by the probability that the utility of that substitute to the farmer is greater than the utility to that farmer of all other alternative J.

The study also used the protection motivation theory. Protection Motivation Theory (PMT) is a commonly used framework for understanding responses to triggers that alert persons to a potential threat. This theory connected farmers' perception variables and their adaptation decision-making. The analysis of this theory is to make sure that the linkage does identify perception variables that drive or hinder adaptation decisions. PMT was initially developed to explain the human response to the fear of health threats (Bagagnan et al., 2019). PMT was first developed by Rogers (1975) to describe the effects of health hazards on individuals' attitudes and behaviours. The PMT states that people (farmers) facing a threat will adopt behaviours that protect themselves if they deem the risk of the threat (climate change) to be high (Rippetoe & Rogers, 1987; Chipfupa et al., 2021). The theory assumes that if the loss due to climate change is deemed lower than the cost of adapting, they are expected to maintain the status quo. Otherwise, they will adapt. For some, climate change risks stimulate fear and anxiety, which under the PMT model would be expected to influence attitude change and decision-making towards adaptive practices.

2.3. Study Design and Sampling Procedure

This study aimed to determine the factors affecting livestock smallholder farmers' choices of adaptation strategies to climate change in the study area using quantitative and qualitative methods. The study used a cross-sectional survey of 220 livestock farming households. The study used purposive and random sampling to select Raymond Mhlaba Local municipality. The municipality was chosen purposively because it is one of the most vulnerable municipalities in the Amatole District to the impacts of climate change, which is evidenced by the prolonged drought, fluctuating temperatures, and its fragility and sensitivity to climate variability (Mtyelwa et al., 2022). The study employed random sampling to select four villages in Raymond Mhlaba Local Municipality due to their potential for agricultural production (livestock production). Then, a sample of livestock farmers was selected from each of the four villages using proportionality sampling based on the population size. The desired sample size of 220 livestock farmers was purposively selected.

2.4. Data Collection

The survey was carried out using a semi-questionnaire standard. The questionnaire's first part covers farmers' characteristics and accessibility to supporting institutions. Farmers' perceptions of climate change were then related to past trends from weather-related data. Farmers were asked to describe the changes in climate change parameters. These parameters – expressed as changes in mean temperatures, amount of rainfall, the frequency, duration, and intensity of dry spells and droughts, the timing, duration, and intensity of rain, the start/end of growing seasons, the frequency and intensity of storms and floods were analysed in this study compared to 30 years ago. The questionnaire consists of methods of adaptation to climate change and constraints for smallholder farmers to implement adaptation strategies. The questionnaire was pre-tested with 20 farmers in Keiskammahoek to check its reliability and to train enumerators. The survey was conducted from February to August 2019 and involved 220 livestock farmers as respondents.

2.5. Data Analysis

The collected data was coded in Excel and transported to STATA 13 for analysis. The study used descriptive statistics and multinomial logistic regression for analysis. Descriptive statistics such as percentages, graphs, and frequency were applied to analyse the demographic and socioeconomic characteristics of the sample respondents.

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2.6. Analytical Framework

The study used multinomial logistic (MNL) regression to estimate factors influencing livestock farmers' choice of adaptation strategies in responding to climate change effects in the study area. The MNL model was specified as follows:

$$p(Y = J/X = \frac{exp\ (X\beta_j)}{(1 + \sum_{j=0}^{j} exp\ (X\beta_j)} \text{.................}1$$

Where

βj is a K x 1 vector and j = 1; 2, 3, 4, 5, 6 ……….J.

Equation (1) can only provide the direction of the effect of contextual background on choosing a particular adaptation strategy. The marginal effect is attained by distinguishing equation (1) with respect to independent variables of interest. The marginal probability for a typical independent variable was given as:

$$\frac{\partial P\ (Y = J/X)}{\partial X_k} = P(Y = J/X)\left(\beta_{jk} - \sum_{j=0}^{J=1} P_j\beta_{jk}\right) \text{.........}2$$

The study considered adaptation strategies such as the use of a mixed crop-livestock farming system (MCL), herd destocking (HD), concentrated supplementary feeding (CSF), dipping of livestock in liquid treatments (DL), vaccination of livestock (VL), construction of shade to reduce heat (CS), and lastly, water harvesting and storage (WHS). The study's application of information on climatic and weather inconsistency was a base outcome. To guarantee that the study's results are robust, the study carried out the following tests to evaluate the occurrence of heteroskedasticity and multicollinearity. Through the Breusch Pagan, White Cameron, and Trivedi Decomposition tests, the study found changeable variances (heteroskedasticity) over various dependent variables.

TABLE 1: Variables Used in the Model

Variable	**Description**	**Measurement**	**Expected sign**
Dependent variable			
Independent variables			
X_1	Gender of the farmer	1= male, 0 = otherwise	-
X_2	Age of the farmer	Actual years	-
X_3	Marital status of the farmer	1= married, 0 = otherwise	+

X_4	Family size of the farmer	1 = > 4, 0 = otherwise	+
X_5	Years spent in school by the farmer	1= actual years spent in school, 0 = otherwise	+
X_6	Household source of income by the farmer	1= social grants, 0 = otherwise	-
X_7	Farming years by the farmer	Actual years of farming	+
X_8	Distance to the agricultural marketing center	1= 10 km, 0 = otherwise	-
X_9	Access to extension agents by the farmer	1= access to extension agents, 0 = otherwise	+
X_{10}	Access to a financial institution by the farmer	1= access to finance, 0 = otherwise	-
X_{11}	Member of farm organization	1= member of farm organization, 0 = otherwise	+
X_{12}	Household monthly income	1=> 1500, 0 = otherwise	+
X_{13}	Occupation by the household head	1= full time farmer, 0 = otherwise	+
X_{14}	Knowledge of climate change by the farmer	Dummy, 1 = have knowledge of climate change, 0 = otherwise	+
X_{15}	Access to climate information by the farmer	Dummy, 1 = access to climate information	+
X_{16}	Farmer perceive climate change	Dummy, 1 = increase in rainfall and decrease	+

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		in temperature, 0 = otherwise	
X_{17}	Farmer adaptation strategies to climate change	Dummy, 1 = adapting to climate change, 0 = otherwise	

3. RESULTS

3.1. Demographic Characteristics of Livestock Farmers

The results in Table 2 show that most livestock producers in the study area were predominantly male (63%). These results were in line with Mdoda and Mdiya (2022) and Dasmani et al. (2020), who indicated that males dominate livestock farming more than their female counterparts. This could be attributed to the fact that males are landowners and heads of the family who make family decisions. The average age of the farmers was 47 years, and they had a family size of 6 persons per household. These results align with Ahmed and Ahmed (2019), who highlighted that livestock farming belongs to the productive workforce with the provision of family labour. About 53% of the respondents in the study area were married and, thus, played a crucial role in farm decisions and providing family labour to assist in many farm activities. The total number of livestock units owned by farmers was 50. Livestock was strictly used for subsistence and sales as they generated livelihoods from practising agricultural activities.

The results further revealed that livestock farmers spent an average of 11 years in school, equivalent to secondary education. This suggests that farmers were literate and could read and interpret climate information for the betterment of the farm. These results agree with Mdoda (2020) that smallholder farmers are well educated, given an average of 10 years or more spent in school, which increases their knowledge and awareness about climate change to adapt to changing weather. Farmers had about 12 years of farming experience. This is important as it helps to transfer knowledge and expertise to young farmers for continuity and sustainable livestock production. Household monthly income from social grants and livestock sales was ZAR 6 345.21, which was crucial in sustaining the farm and household expenses. About 64% of livestock farmers indicated access to extension services, including climate information and new farming techniques. However, 65% of the farmers indicated limited access to credit support depending on social grants to sustain their farming.

TABLE 2: Characteristics of Livestock Smallholder Farmers

Variable	**Frequency**	**percentage**
Gender		
Male	139	63
Female	81	37
Marital Status		
Windowed	29	12
Married	116	53
Single	75	34
Access to credit		
Yes	77	35
No	143	65
Access to extension services		
Yes	141	64
No	79	36
Variable	**Mean**	**T-test**
Age	47.08 (8.90)	0.034**
Years spent in school	11.30 (9.10)	0.015**
Total Livestock size (TLU)	50.36(11.45)	0.008***
Family size	5.51 (2.31)	0.008***
Farm experience	12.32 (9.34)	0.087
Distance to markets and institutes	25.10 (6.10)	0.023**
Household monthly income	6 345.21 (4.32)	0.015**

3.2. Livestock Smallholder Farmers' Perception of Climate Change

Climate change is a global phenomenon that affects smallholder farming negatively. Livestock farmers in the study area were not an exception, and they perceived some noticeable changes in weather forecasts over the past 12 years. Figure 3 demonstrates the perception of climate change noticed by farmers. Livestock farmers have noticed a decline in rainfall patterns over the past years, which resulted in prolonged drought, especially in the study area, given that the area is a karoo region. This negatively affected livestock farming and grazing pastures. These results agree with Yetisgin et al. (2022) that rainfall patterns have changed over the years, and there is an increase in dry spells due to prolonged drought. The livestock farmers also perceived an increase in average temperatures. Farmers noticed a change in both minimum and maximum average temperatures. These studies agree with Mdoda (2020), Elum et al. (2017), and Mdoda (2015) that average temperatures have increased rapidly both during the day and night, which affects agricultural productivity. As a result of the decline in rainfall and rise in temperature, the drying season has shortened, which poses a serious threat to livestock farming in the study area. The last perceived climate change by livestock farmers was violent winds, which negatively affected agricultural activities, especially livestock farming.

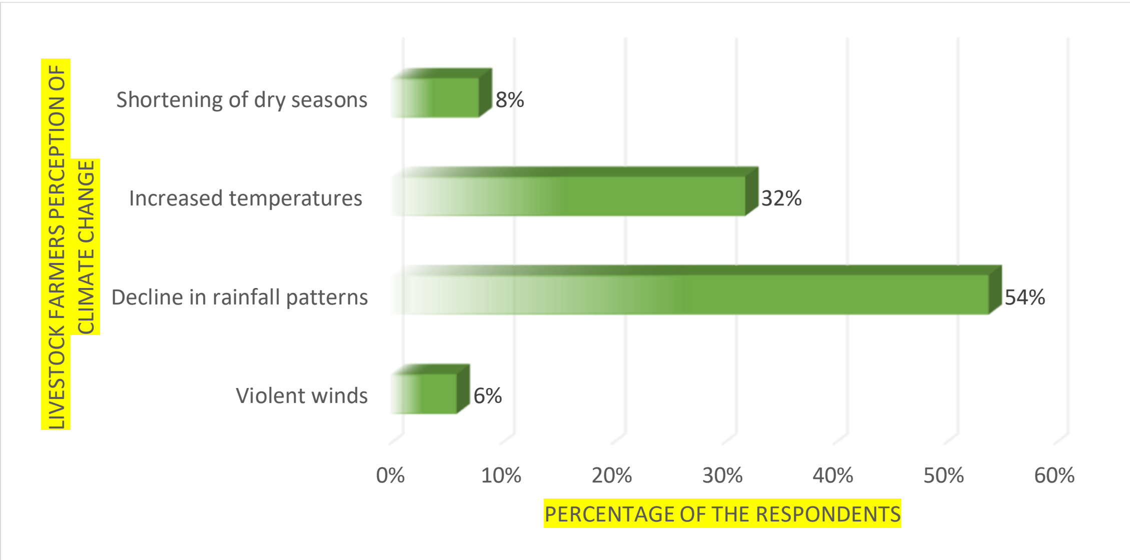

FIGURE 3: Livestock Smallholder Farmers' Perception of Climate Change

3.3. Perceived Effect of Climate Change on Livestock Farming

Livestock farmers do perceive changes in climate change. As a result, most farmers indicated the direct impacts of climate change on livestock production and productivity. Table 3 below shows the perceived impact of climate change on livestock farmers in the study area. A decrease in grazing pastures was the first impact noticed by farmers, as available pastures are not suitable for livestock. The changes in weather conditions have affected grazing's carrying capacity. Climate change has impacted the dry matter content as well as the nutritional value of grazing pastures; as a result, they are reduced to a great extent due to the damaging impacts of climate change, mainly due to the rise in temperature and increased levels of CO2 concentration in the atmosphere. These results aligned with Akshit et al. (2020), who stated that an increase in average temperatures negatively reduces fodder production and grazing pastures. The study results revealed an increase in livestock deaths (70%) due to the prolonged drought, which resulted in the dryness of rivers and dams that provide livestock with water and shortages in grazing pastures.

Climate change has resulted in increased livestock pests and diseases (66%) and increased land degradation (68%), which negatively affect the availability of grazing pastures for livestock. These results were in line with Fadina and Barjolle (2017). The results further revealed that climate change has increased by dry spells because of prolonged drought and a decline in rainfall, which has consequently affected livestock production. Lastly, there is an increase in feed shortage due to changes in the distribution, and the amount of rainfall has affected the agricultural system in the area.

TABLE 3: Distribution of Respondents by the Perceived Effect of Climate Change

Perceived effect of climate change	**Percentage**
Increased livestock pests and diseases	66%
Increased land degradation	68%
Decrease in grazing pastures	78%
Increase in dry spells	64%
Increase in livestock deaths	70%
Increase in a feed shortage	60%

3.4. Livestock Smallholder Farmer's Adaptation Strategies Employed

The study results revealed seven adaptation strategies frequently used by livestock farmers in response to the effects of climate change on their farming activities. The strategies adopted by farmers were mainly to reduce the effects of prolonged drought, which dominates the study area and affects farmers. Figure 4 illustrates strategies adopted by livestock farmers in the study area. Forage cropping was livestock farmers' most dominant adaption strategy (78%). Livestock farmers believed that herd destocking (70%) was the second most used adaptation strategy by livestock farmers. Other adapted strategies were vaccination of livestock (68%), dipping of livestock in liquid treatments (66%), constructive shade to reduce heat (64%), concentrated supplementary feeding (64%), and lastly, water harvesting and storage (58%).

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The use of constructive shade to reduce heat is the most common among smallholder farmers as it is easy to build and less expensive (Mdoda et al., 2020). These adaptation strategies were the multiple strategies livestock farmers adopted to enhance livestock productivity in the study area.

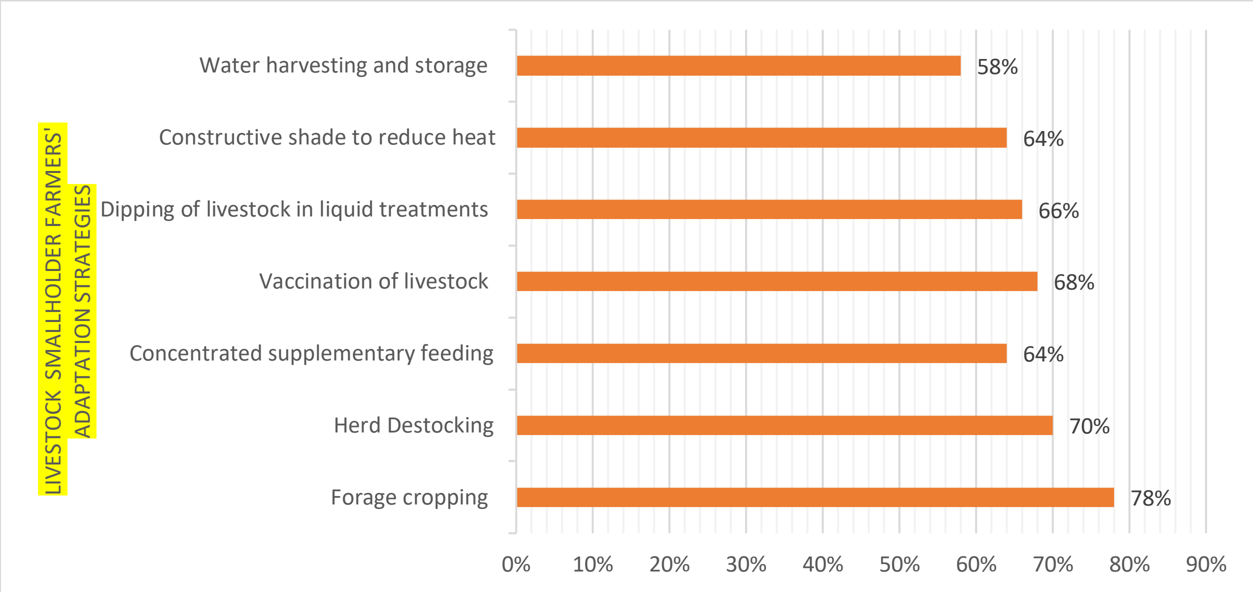

FIGURE 4: Demonstrating Choice of Adaptation Strategies by Livestock Smallholder Farmers

3.5. Challenges Faced by Livestock Smallholder Farmers While Employing Adaptation Strategies

Meanwhile, livestock farmers respond to climate change by adopting various adaptation strategies. They were challenged by different barriers that made adaptation difficult. The result presented in Figure 5 revealed that the most important barriers were poor access to climate information, limited financial capital, and conflict over grazing and resources, which were significant barriers to effective adaptation to climate change. From the study results, it can be revealed that livestock farmers had poor access to climate information, which limited their adaptation capabilities and suddenly forced them to rely on other farmers for information. The second challenge was financial capital, which is a challenge not only in this municipality but also in almost all the smallholder farmers in the Eastern Cape Province, of which this study area forms part. Due to the nature of farming, smallholder farmers find it hard to access financial support. Livestock farmers lack financial capital, which is crucial to purchasing farming inputs, attending training to increase climate change awareness, and investing in innovative technology designed to mitigate climate change. Lastly, livestock farmers were experiencing conflict over grazing land and resources as most farmers did not agree to using allocated grazing pastures for certain periods.

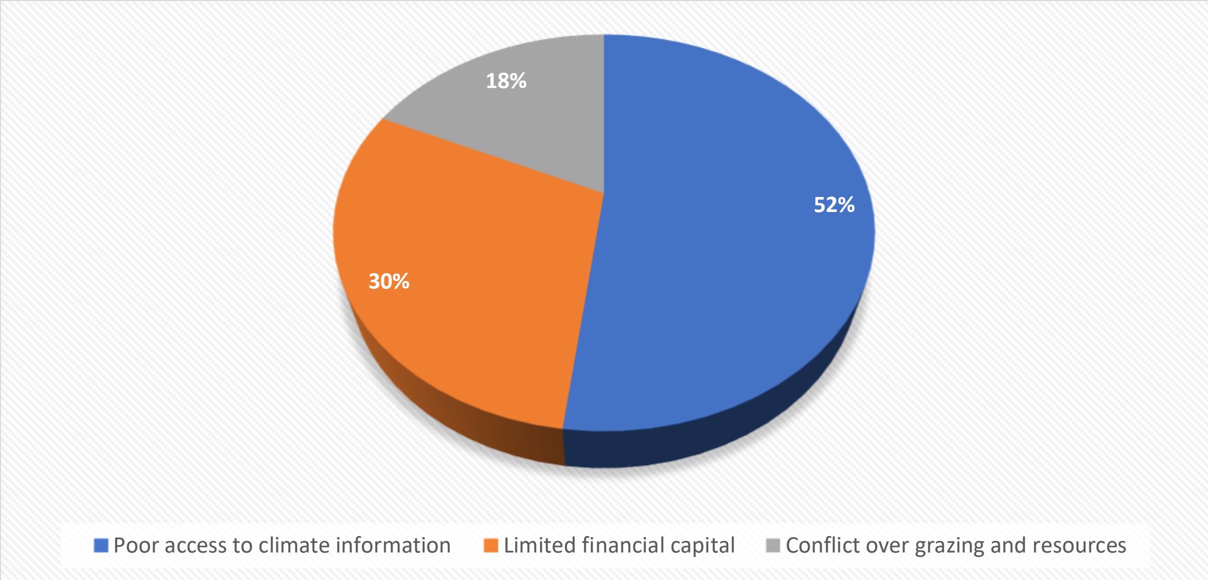

FIGURE 5: **Barriers to Adaptation to Climate Change by Livestock Farmers**

3.6. Factors Influencing the Choice of Adaptation Strategies Employed by Livestock Smallholder Farmers

The multinomial logit model was used to estimate the determinants of livestock farmers' choices of adaptation strategies to climate change effects. Table 4 presents the estimated coefficients of the MNL model, along with the significance levels. The study used water harvesting and storage as a subjective base category for the multinomial logit model fit. The likelihood ratio statistics specified by chi-square statistics were highly significant ($p < 0.000$), signifying the model's strong explanatory power. It was distinguished that the parameter estimates of the MNL model provided only the direction of the effect of the independent variables on the dependent variables and did not represent the actual magnitude of change of its probability. As stated in the hypotheses above, the multinomial logistic regression model results showed coefficient estimates surveyed the expected signs.

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TABLE 4: Parameter Estimates of Multinomial Logit Model for Climate Change Adaptation Decision

Variables	**Forage cropping**	**Herd destocking**	**Vaccination of livestock**	**Dipping of livestock in liquid treatments**	**Constructive shade to reduce heat**	**Concentrated supplementary feeding**
Years spent in school	0.389 ** (0.456)	1.773*** (0.550)	0.172** (0.033)	0.298** (0.086)	0.252** (0.032)	0.891*** (0.045)
Age	0.618 (0.446)	-0.178 ** (0.031)	0.512 (0.331)	-0.290 ** (0.127)	0.341 (0.212)	1.076 *** (0.024)
Total Livestock Units	0.415 ** (0.207)	0.317 *** (0.046)	0.242** (0.131)	0.279 ** (0.112)	-0.620 ** (0.427)	1.019 *** (0.006)
Access to extension services	1.196*** (0.557)	0.628 ** (0.410)	0.264 ** (0.098)	0.721 ** (0.453)	0.420 (0.275)	1.230 *** (0.489)
Household income	0.754 ** (0.430)	0.293 (0.167)	0.559 (0.368)	0.481 (0.299)	0.365 (0.189)	0.606** (0.294)
Climate change awareness	0.508 ** (0.368)	1.189 *** (0.632)	0.541 ** (0.360)	1.078 *** (0.752)	0.408 (0.273)	0.965 ** (0.628)
Constant	−2.455 (0.043)	−1.717** (0.078)	2.504** (0.042)	−1.884 (0.118)	−1.252*** (0.991)	1.537** (0.017)
Log Likelihood : -175.473	*Number of observations: 220*	*LR chi^2 (70): 128.16*	*Prob > chi^2: 0.0000*	*Pseudo R square 0.590*	*The base category: water harvesting and storage*	

Note: * and ** are Significant at 1% and 5% probability levels, respectively.**

Multinomial logistic regression analysis was estimated to determine the factors influencing smallholder farmers' choice of adaptation strategies to cope with the effects of climate change (Table 4). The results indicated that years spent in school by farmers had a positive coefficient and was statistically significant at a 1% level for herd destocking and concentrated supplementary feeding while was significant at 5% for forage feeding, vaccination of livestock, dipping of livestock with treatment effect, and constructive shade to protect heat. This implies that a unit increase in years spent in the school year will increase the probability of farmers adapting to climate change. This is because spending more years in school increases farmers' knowledge about innovations being implemented and increases farmers' awareness about climate change and information about agricultural techniques used. These results agree with Kangogo et al. (2021) and Belay et al. (2017) that education received by farmers through spending more years in school increases the adoption rate of new technologies based on their awareness of the possible benefits of the planned climate change adaptation measures. These results further agree with Mdoda (2020) that educated farmers have a better adaptation rate to climate change effects than less educated and illiterate farmers.

The farmer's age is very important in farming and is also used as a proxy for farm experience. The farmer's age had negative (herd destocking and dipping of livestock with treatment) and positive (concentrated supplementary feeding) coefficients. The age variable was significant at 1% for concentrated supplementary feeding and 5% for herd destocking and livestock dipping with treatment. These results mean that an additional year in farmers' age will result in farmers decreasing their chances of choosing herd destocking and dipping of livestock with treatment as adaptation strategies. On the other hand, an increase in farmers' age will increase the chances of choosing concentrated supplementary feeding as an adaptation strategy. Livestock farmers with many years of experience in livestock rearing were more aware of climate change and its effects and are developing adaptation strategies. The increase in the age of farmers also increases the farming experience of farmers, which plays a key role when it comes to farm operations as well as in observing changes over time so that they compare them to current climatic conditions, allowing them to respond by developing strategies to mitigate effects of climate change. The reason for the reduction in the selection of herds for the destocking and dipping of livestock by farmers is that most livestock farmers do not have herdsmen to assist them with their livestock. So their best way is to decrease that with the experience they have while, on the other hand, they select concentrated supplementary feeding as they can quickly

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adapt due to the reduced work required. These results agree with Idrissou et al. (2020) and Feleke et al. (2016) that as farmers get older and more experience, they will choose to concentrate on supplementary feeding for their livestock rather than selecting other adaptation strategies as they know what is best for their livestock.

Total livestock unit was another significant variable at 1% and 5%, respectively. The TLU had a negative coefficient for constructive shade to reduce heat while a positive coefficient for concentrated supplementary feeding, forage feeding, livestock vaccination, and livestock dipping with liquid treatment. These results imply that a unit increase in TLU by 1% will induce a decrease in choosing a constructive shade to reduce heat as an adaptation strategy. In comparison, an increase of 1% in TLU will induce an increase in choosing concentrated supplementary feeding, forage feeding, livestock vaccination, and livestock dipping with liquid treatment as adaptation strategies by livestock farmers. These results agree with Menghistu et al. (2021), Gebru et al. (2020) and Idrissou et al. (2020) that changing climatic conditions have forced farmers to think otherwise due to unsatisfactory feed resources and grazing available as well as finance maintaining pastures and dipping tanks being insufficient enough, these strategies of reducing herd, focus on concentrated feed, dipping with treatment, vaccination of livestock and forage cropping is the only adaptation strategies which smallholder livestock farmers can afford.

Household income had a positive coefficient and was significant at a 5% level for forage cropping and concentrated supplementary feed. This suggests a positive relationship exists between household income to forage cropping and concentrated supplementary feed. This implies that a unit increase of additional ZAR 1 in farmers' household income will induce an increase in choosing forage cropping and concentrated supplementary feed as adaptation strategies. This is because livestock farmers can afford to purchase forage cropping and concentrated supplementary feed. Household income increases the financial resources of farmers, and their capacity to take care of their animals also increases. These results agree with Menghistu et al. (2021) that household income plays a crucial role in livestock farmers' adaptation strategies based on their financial resources.

Access to agricultural extension services is very important for farming and is crucial in disseminating information. The study results reveal that access to extension services had a positive coefficient and significance at a 1% and 5% level, respectively, of all adapted strategies by livestock. This implies that farmers with access to extension services will likely adapt to climate change due to available information provided by extension agents. This is because livestock farmers are constantly receiving more frequent agricultural extension services, and they are up to date, which makes it easier for these farmers to adopt forage feeding, vaccination of livestock, dipping of livestock with treatment effect, and constructive shade to protect heat, herd destocking and concentrated supplementary feeding as adaptation strategies. Access to agricultural extension services benefits livestock farmers by providing climate-related information that increases their chances of adapting to climate change (Mdoda, 2020). These results agree with Zeleke et al. (2022) that having access to extension services increases the likelihood of livestock farmers adopting multiple adaptation strategies to enhance livestock production.

Climate change awareness had a positive coefficient and was statistically significant at 1% and 5% levels, respectively, for adaptation strategies by livestock farmers. This implies that a unit increase of 1% in climate change awareness induces an increase in livestock farmers' choice of adaptation strategies. Smallholder livestock farmers who perceive changes in climate change are most expected and observed to use adaptation measures. These results agree with Gebru et al. (2020) that climate change awareness plays a crucial role in making farmers aware of climate change and using adaptation strategies in their farming.

4. SUMMARY AND CONCLUSION

The study revealed that over the past ten years, farmers have observed a decline in rainfall and an increase in temperatures. This led to prolonged drought events, which negatively affected livestock farming by deteriorating conditions of grazing pastures, increased livestock pests and diseases, and a high mortality rate in the stock. Additionally, the results showed that most smallholder livestock farmers used several adaptation strategies to cope with climate change disasters: forage cropping, herd destocking, livestock dipping, and shade construction. The study also revealed that socioeconomic factors such as age, education level, household income, and access to agricultural extension services influenced livestock smallholder farmers' choice of adaptive strategies in response to the effects of climate change. Therefore, a conclusion drawn from the study is that socioeconomic determinants and access to agricultural extension services play a significant role in smallholder farmers' choices of adaptation strategies to climate change. This study recommends the need for policies and programs addressing

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socioeconomic inequality while improving smallholder farmers' access to agricultural extension services.

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6. COMPETING INTEREST STATEMENT

The authors declare no conflict of interest.

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