FACTORS CORRELATING WITH THE ABILITY TO COPE WITH DROUGHT CONDITIONS IN THE GREATER LETABA LOCAL MUNICIPALITY, SOUTH AFRICA, 2014-2016

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Abstract. Drought is a major concern in the agricultural sector, especially due to its recurrence and adverse effects on the livelihoods of smallholder farmers. Vulnerability of smallholder farmers to drought is higher in developing countries such as South Africa than in developed countries. This is due to the high dependence on rainfall by farmers in developing countries. The need to understand the coping strategies adopted by these farmers to improve their resilience cannot be over emphasised. Factors associated with the ability to cope with drought conditions by smallholder livestock farmers were investigated using retrospective data collected from randomly selected smallholder farmers (n = 280). Data were analysed using descriptive statistics and multivariate analysis. The results revealed that farmer's adaptive capacity was influenced by the "Agricultural Centre", changes in farm management, practicing supplementary feeding before onset of the drought, introduction of supplementary feeding during the drought, and having access to clean water during the drought. This study highlighted the varying coping strategies adopted by smallholder livestock farmers that should be considered when designing intervention strategies and drought preparedness education programmes. There is a need for the development of area-specific proactive drought coping strategies and education programmes targeted at smallholder farmers.
Keywords: *climate change, coping strategies, smallholder farmers, livelihoods, vulnerability, drought resilience*

Introduction

Drought is associated with low rainfall and extreme high temperatures, among other things (Lottering et al., 2021a). It is regarded as one of the major factors responsible for deterioration of agricultural productivity, food security and livelihoods of smallholder farmers (Lottering et al., 2021a; Salite and Poskitt, 2019). This is attributed to the fact that agricultural activities of smallholder farmers are mainly rain-fed (Rakgwale and Oguttu, 2020). For example, according to Salite and Poskitt (2019), most smallholder farmers interviewed in a study conducted in Mozambique identified drought as the main factor responsible for reduced yields. Similarly, up to 60% smallholder farmers in a study that was conducted in KwaZulu-Natal, South Africa, indicated that they had adversely been affected by drought (Lottering et al., 2021c). In another study conducted in the Northern Cape Province of South Africa, Bahta and Myeki (2022) also observed that 79% smallholder farmers struggled to recover from the negative effects of drought.

In addition, existing literature on sub-Saharan African shows that drought mainly affects the vulnerable groups such as the poor and women.

Developing countries are reportedly the most vulnerable to the effects of drought given that most of the rural people in these countries rely on agriculture as their main source of livelihood (Goldin, 2019). For example, although continents such as Africa have experienced fast urbanization rates, most of its population still reside in rural areas (Sakho-Jimbira and Hathie, 2020) and are largely dependent on agriculture for income and food security (Meza et al., 2021; Sakho-Jimbira and Hathie, 2020). The vulnerability of smallholder farmers to drought is also attributed to the lack of support for development, which consequently compromises their coping capacity (Meza et al., 2021).

Available literature suggests that drought has become more prevalent, intense, and severe, which could be attributed to climate change (Lottering et al., 2021b; Orimoloye, 2022). Therefore, there is an urgent need to understand where the vulnerable people are located as well as the measures, they employ to cope with vulnerability (Lottering et al., 2021b).

According to recent literature, South Africa experienced the worst drought between 2015-2016 with rainfall ranging between 437 mm and 343 mm (Vetter et al., 2020). This is confirmed by Maponya and Mpandeli (2016) who state that a shortage of rain was observed in Limpopo over several months during the period 2015 and 2016. Nembilwi et al. (2021) also confirm these findings, noting that the 2015-2016 drought was most severe in the Mopani district in the Limpopo province, resulting in extreme water shortages and decreased crop yield and livestock herds, especially in smallholder farmers. It is for this reason that Limpopo, Mpumalanga, Free State, North-West and KwaZulu-Natal were pronounced as disaster areas.

Data on the effects of drought on smallholder farmers is scanty (Lottering et al., 2021a). Moreover, most studies on drought have focused on large-scale farmers, with few studies done on smallholder farmers and households (Lottering et al., 2021b). Available literature also generally suggests that research on drought is focused on vegetation, soil and perceptions (Vetter et al., 2020). Little has been done about the effects of drought on livestock (Bahta and Myeki, 2022; Vetter et al., 2020), this is despite the fact that livestock contributes almost half of the GDP derived from agriculture in Africa (Bogale and Erena, 2022). The few national studies that have been conducted on livestock, such as those done by Bahta and Myeki (2022), Lottering et al. (2021b) and Vetter et al. (2020) assessed the impact of drought on smallholder livestock farmers, determined socio-economic factors that make smallholder farmers susceptible to drought and studied the effect of drought on communal livestock.

To the best of our knowledge, none of these national studies investigated factors that predict the ability of smallholder livestock farmers to cope during drought conditions. Furthermore, there are a few international studies on coping strategies that could be sourced (Mardy et al., 2018; Abdullahi et al., 2022). Moreover, the few studies that could be sourced, were based on crops and had been conducted in countries such as Bangladesh (Mardy et al., 2018) and Nigeria (Abdullahi et al., 2022). Therefore, factors associated with the ability to cope with drought among livestock smallholder farmers are poorly understood. Furthermore, previous studies argue that data across socio-economic and cultural contexts are warranted, as the impact of drought between these disparities differs (Lottering et al., 2021b; Ruwanza et al., 2022). According to Ruwanza et al. (2022), research into coping strategies is necessary to facilitate better

understanding of the strategies that are adopted by farmers when faced with drought
conditions. Furthermore, identifying such factors could assist the policy makers to
augment the coping mechanisms and design locally appropriate and needs-based
strategies to improve on their resilience in the face of drought conditions. Therefore,
this study investigated factors that were correlated with the ability to cope with drought
conditions by smallholder livestock farmers in the Greater Letaba Local Municipality
(GLLM).

Study site

The study was conducted in the GLLM situated within the jurisdictional region of the
Mopani district in the Limpopo province in South Africa (*Fig. 1*). The majority (94%)
of the population of the GLLM resides on land under the custody of traditional
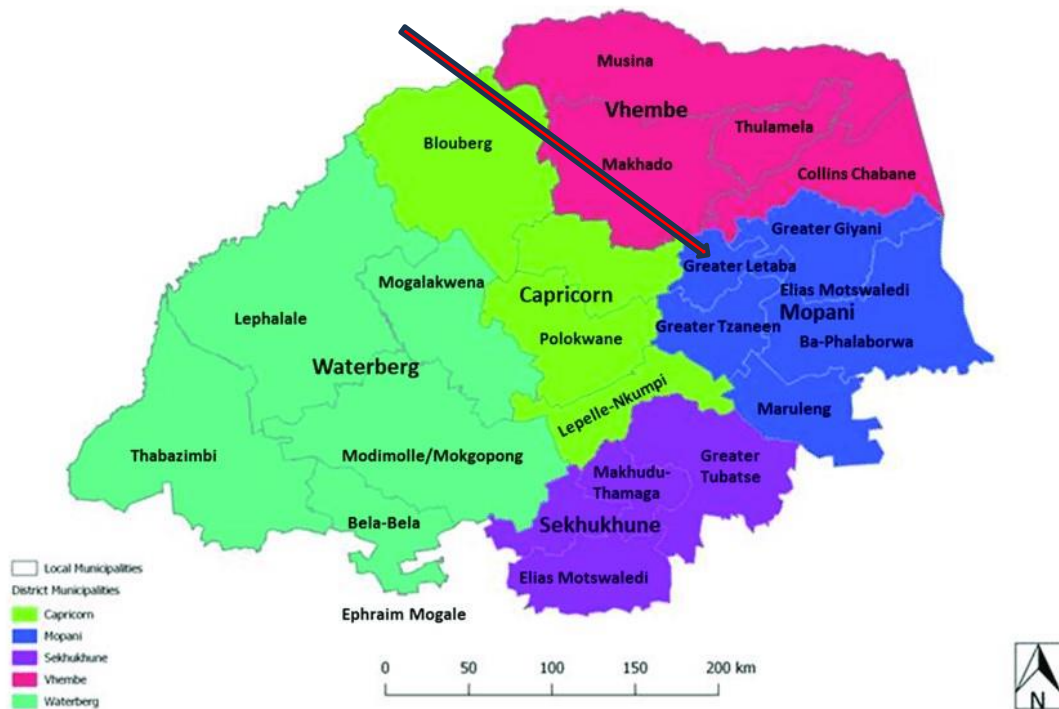authorities in rural villages.

*Figure 1. The map of Limpopo showing the districts within the province. Greater Letaba Local
Municipality, one of the five (n = 5) of district municipalities in Mopane district is where the
study was conducted (Map sourced from https://images.app.goo.gl/iNndNejorzMcrp1a9)*

The agricultural sector contributes about 16% of the GLLM Gross Domestic Product
(GDP). Moreover, it employs more than 19.8%% of the district's workforce (IDP,
2022) and continues to grow as an employment-generating activity. It is even tipped to
be the leading contender of the greatest employer in the municipality. In addition to this,
livestock farming constitutes one of the major agricultural activities in the study area.
However, due to its location in Limpopo, which is a dry Savannah sub-region, water
availability is the most significant limiting factor for agricultural production and growth
at the GLLM.

Materials and methods

Sampling and data collection

Retrospective data collected by Rakgwale and Oguttu (2022) were used in this study. A total of 281 farmers were randomly selected to participate in the survey. However, one farmer who had missing information was dropped from the analysis, leading to a study population of 280. Only farmers who reared either cattle alone or practiced mixed livestock farming (kept cattle plus other animals), and at the same time owned 10 or less hectares, were included in this study. A pretested questionnaire written in English and translated/transliterated into Northern Sotho (a local dialect) was used to collect data from the participants using face-to-face structured interviews. Data was collected from February to May in 2018. The questionnaire consisted of both closed and open-ended questions. All participants signed a consent form showing their willingness to voluntarily participate in the study. Ethics clearance for the initial study was obtained from the University of South Africa, College of Agriculture Ethics Committee (Reference No: 2017/CAES/127), and the Department of Agriculture and Rural Development in Limpopo, Mopani district. Permission to re-use the secondary data was secured from the same Ethics Committee of the University of South Africa, College of Agriculture and Environmental Sciences (Ref #: 2023/CAES_HREC/1460).

Data analysis

Descriptive statistics

Data were summarized using descriptive statistics, with all categorical variables summarized and presented as proportions. Continuous variables were assessed for normality (*Appendix 1*). Since none of the variables was normally distributed, continuous variables were summarized and presented as median and inter-quartile range (IQR).

Inferential statistics

In the first stage, univariate analysis, was performed to test for simple associations between the predictor variables and the outcome variable (coping with the drought) (*Appendix 2*). Variables with alpha level ≤ 0.20 in the binary univariate logistic regression models were included in the multivariate model.

The second step involved fitting a multivariable binary logistic regression model to assess the factors that were significantly associated with the farmers who indicated that they were able to cope with the drought conditions. The backward elimination selection method was used to select variables to retain in the final binary logistic regression model. The assumptions of the binary logistic regression model were checked before fitting the model.

Confounding was assessed by comparing the changes in model coefficients with and without the suspected confounders. If a variable was removed and the action resulted in a change of $\geq 20\%$ in the coefficient of any variable in the model, the variable that had been removed was considered a confounder and was thus retained in the model. This was regardless of whether it was significantly associated with the outcome variable or not.

Possible interactions were tested in the final main effects model. However, no interaction term reached statistical significance (p > 0.05). Therefore, interaction terms were not retained in the final model. Odds ratios (ORs) and their 95% confidence intervals were computed for variables included in the final model.

The Wald test was used to test for individual predictors in the model. With Ho: Coefficient of an independent variable is not significantly different from zero; therefore, by failing to reject the Ho, it means that removing the variable from the model would not ruin the model fit. Results of the Wald test are summarized in *Appendix 3*.

The Log likelihood ratio test was used to compare models. The model fit of the final model was tested using a Hosmer-Lemeshow test. Based on the results, there was a good model fit ($p > 0.05$).

The results of the sensitivity analysis are presented in *Appendix 4*. The predictive power of the model was assessed using the McFadden Pseudo R-squared and the ROC curve. With a $p = 0.56$ for the McFadden Pseudo R-squared, the model had a good predictive power. With the area under the ROC curve of 0.94204, it was concluded that the final model does a great job in predicting true positive and true negative values of the response variable (coping with drought conditions).

Results

The distribution of farmers based on ability to cope with the drought conditions.

The results in *Table 1* show that the median age of farmers who were not able to cope was 59 years (IQR: 47-70) compared to 58 years (IQR: 44-79) for farmers who indicated that they were able to cope. Similarly, the median years of experience (15 years; IQR: 9-18) for farmers who were not able to cope with the drought conditions, was slightly higher compared to the median years (12 years; IQR: 7-19) of experience for farmers who were able to cope.

Table 1. *The median age and years of experience of the participants by their ability to cope with the drought*

Variable	Able to cope	Not able to cope
	Median (IQR)	Median (IQR)
Age	58 (44-79)	59 (47-70)
Years in farming	12 (7-19)	15 (9-18)

Overall, 53.93% (n = 151) of the farmers surveyed indicated that they were not able to cope with the drought conditions in comparison to 46.07% (n = 129) who were able to cope (*Table 2*). More farmers from Bellevue did not cope (69.44%; n = 75) with the drought conditions, as compared to 41.25% (n = 33) in Mokwakwaila and 6.74% (n = 434) from Sekgosese who were not able to cope.

Based on sex of the respondents, there was a marginal difference between the number of female (58.16%; n = 57;) and male (n = 94; 51.65%) farmers who indicated that they did not cope with the drought conditions experienced over the study period. While based on the marital status of the farmer, the category of farmers who identified as widowers had a slightly higher number (n = 28; 60.87%) of individuals who were not able to cope with the drought conditions as compared to the other categories such as the divorced (n = 24; 54.55%), married (n = 43; 54.43%), single (n = 34; 50.74%) and widows (n = 22; 50%) that had fewer numbers who did not cope.

Table 2. *The results of test of difference of proportions showing the proportions of farmers by the various variables, based on how they responded to the question "Were you able to cope with drought conditions?"*

Variable	Level	Did not cope with drought		Able to cope with drought	
		n	*%*	*n*	*%*
Overall		151	53.93	129	46.07
Agricultural name	Bellevue	75	69.44	33	30.56
	Mokwakwaila	33	41.25	47	58.75
	Sekgosese	43	46.74	49	53.26
Sex	Male	94	51.65	41	48.35
	Female	57	58.16	88	41.84
Marital Status	Divorced	24	54.55	20	45.46
	Married	43	54.43	36	45.57
	Single	34	50.75	33	49.25
	Widow	22	50.00	22	50.00
	Widower	28	60.87	18	39.13
Education	No education	27	45.76	32	54.24
	Primary	49	71.01	20	28.99
	High School	39	50.65	38	49.35
	Tertiary	25	47.17	28	52.83
	Others	11	50.00	11	50.00
Farming Enterprise	Cattle alone	68	66.67	34	33.33
	Cattle and goat	36	53.73	31	46.27
	Cattle and pig	7	38.89	11	61.11
	Cattle and poultry	13	59.09	9	40.91
	Cattle and sheep	6	50.00	6	50.00
	Above 2 types	21	35.59	38	64.41
Drought awareness	Yes	102	49.04	106	50.96
	No	49	68.06	23	31.94

The results indicated that the category of farmers who had primary education had the highest proportion (n = 49; 71.01%) of farmers who did not cope with the drought. This was followed by farmers who had "no formal education" (n = 27; 45.76%), high school (n = 39; 50.65%), tertiary (n = 25; 47.17%) and other (n = 11; 50%).

Meanwhile, farmers who farmed with cattle alone had the highest proportion of farmers (n = 68; 66.67%) who were not able to cope with the drought conditions, followed by those who farmed with both cattle and poultry (n = 13; 59.09%). The category of farmers with the least number of farmers who were not able to cope with the drought conditions were farmers who farmed with both cattle and pigs (n = 7; 38.89%), cattle and sheep (n = 6; 50%), cattle and goats (n = 36; 53.73%) and any combination of any other two animal types (n = 21; 35.59%).

Farmers who indicated that they were not aware of the impending drought had a higher number of farmers (n = 49; 68.06%), who were not able to cope. On the contrary, just under half (49.04%; n = 102) of the individuals who were aware of the impending drought indicated that they did not cope with the drought (*Table 2*).

The category of farmers who sold between 0-10 animals had more farmers (n = 131; 59.01%) who were not able to cope with the drought conditions. Farmers who sold ≥ 21 animals over the drought period, had the least number of farmers (n = 4; 22%) who did not cope with the drought conditions (*Table 3*). The group of farmers who lost ≥ 6 animals during the drought conditions had a higher percentage of farmers (73.33%; n = 55) who indicated that they did not cope with the drought compared to only 46.83% (n = 96) of those who lost ≤ 5 animals.

As shown in *Table 3,* among the emerging livestock farmers surveyed, the category of farmers who sold off some animals in preparation for the drought had the lowest proportion of farmers (8.89%; n = 4) who did not cope with the drought, compared to those who adopted other methods of coping. For example, 62.50% (n = 20) of the farmers who prepared for the drought by buying supplementary feed for their animals, and 70.25% (n = 111) of the farmers who did not respond to the question "How did you prepare for the drought?" had higher proportions of farmers who did not cope with the drought. Farmers who drilled boreholes (n = 3; 42.86%) and those who selected 'other' (n = 13; 34.21%) also had higher numbers of farmers who did not cope with the drought conditions.

Among the different categories of farmers included in this study, the category of farmers whose source of water during the drought included streams (n = 61; 67.03%) and other sources of water (n = 25; 64.10%), had the highest proportion of farmers who were not able to cope. On the other hand, the category of farmers whose source of water included boreholes (n = 43; 39.82%) and municipal taps (n = 22; 52.38%) had lower numbers of farmers who were not able to cope with the drought conditions (*Table 3*).

As shown in *Table 3,* the category of farmers who indicated that they had not practiced supplementary feeding before the drought, had more farmers (n = 144; 61.54%) who were not able to cope with the drought conditions compared to only 15.22% (n = 7) among those that had been practicing supplementary feeding before the drought that did not cope with the drought. The category of farmers who indicated that they did not practice supplementary feeding during the drought, had a higher number of farmers (n = 92; 85.98%) who did not cope with the drought, as compared to only 34.10% (n = 59) among those who practiced supplementary feeding during the drought conditions that did not cope.

When farmers were asked to indicate the changes they experienced on their farms during the drought, the category that experienced high livestock mortality had the highest number of farmers (n = 40; 76.92%), who were not able to cope. This was followed by the category that experienced theft of their livestock (n = 29; 72.50), that had to travelled long distances in search of food and water for their animals (n = 42; 58.33%) and spent lots of money (n = 16, 57.14%) during the drought conditions. The category of farmers who opted for restricted feeding of their animals (n = 12; 25.53%) or sold off their animals at a low price (n = 2; 5.39%) during the drought conditions had the lowest proportions of farmers who indicated that they did not cope with the drought.

Farmers who did not have access to clean water during the drought conditions, had the highest number of farmers (n = 59; 76.62%) who were not able to cope. In comparison to only 45.32% (n = 92) of farmers who had access to clean water who indicated that did not cope with the drought.

Based on how farmers rated their access to clean water, the category of farmers who rated their access to clean water as bad (n = 59; 77.63%) or fairly good (n = 75; 60.98%) had the highest percentage of farmers who did not cope. Meanwhile, the farmers who rated their access to clean water as being good had the lowest proportion of farmers (n = 17; 22.99%) who did not cope with the prevailing drought conditions.

Table 3. *The proportion of farmers by various variables based on whether they were able to cope*

Variables	Level	Did not cope with drought		Able to cope with drought	
		n	%	n	%
Number of animals sold	0-10	131	59.01	91	40.99
	11-20	16	40.00	24	60.00
	≥ 21	4	22.00	14	77.78
Number of animals died	0-5	96	46.83	109	53.17
	≥6	55	77.33	20	26.67
Water source	Borehole	43	39.82	65	60.19
	Municipal tap	22	52.38	20	47.62
	Stream/river	61	67.03	30	32.97
	Other	25	64.10	14	35.90
Supplementary feed before onset of the drought	Yes	7	15.22	39	84.78
	No	144	61.54	90	38.46
Supplementary feed during	Yes	59	34.10	144	65.9
	No	92	85.98	15	14.02
Changes experienced on the farm	High amount of money spent	16	57.14	12	42.86
	High livestock mortality rate	40	76.92	12	23.08
	Travelling long distance to river/grazing site	42	58.33	30	41.67
	Restricted feeding	12	25.53	35	74.47
	Selling animals at little amount	2	5.39	11	84.62
	Theft of livestock	29	72.50	11	27.50
	Other	10	35.71	18	64.29
Access to clean water	Yes	92	45.32	111	54.68
	No	59	76.62	18	23.38
Rate of access to clean water	Bad	59	77.63	17	22.37
	Fairly good	75	60.98	48	39.02
	Good	17	20.99	64	79.01
Support from any institution	Yes	66	42.46	88	57.14
	No	85	67.46	41	32.54
Information source	Extension officer	44	37.29	74	62.71
	Newspaper	2	66.67	1	33.33
	Radio	28	70.00	12	30.00
	TV	10	58.82	7	41.18
	All sources	3	37.50	5	62.50
	Other	15	65.22	8	34.78
	No answer	49	69.01	22	30.99
Were you prepared for the drought?	Yes	40	32.79	82	67.21
	No	62	70.45	26	29.55
	No answer	49	70.00	21	30.00
What did you do to prepare for the drought?	Bought supplements	20	62.50	12	37.50
	Drilled borehole	3	42.86	4	57.14
	Sold animals	4	8.89	41	91.11
	Other	13	34.21	25	65.79
	Did not answer	111	70.25	47	29.75
Food sufficient	Yes	122	50.62	119	49.38
	No	29	74.36	10	25.64

According to the findings of this study, farmers who did not receive any help during the drought conditions had a higher percentage of farmers (n = 85; 67.46%) who were

not able to cope with the drought conditions. In addition, farmers who indicated that they received their information mainly through the radio (n = 28; 70%), newspapers (n = 2; 66.7%) and television (TV) (n = 10; 58.82%) had the highest percentages of farmer who were not able to cope. On the other hand, the category of farmers who received information about the drought from the extension officers (n = 44; 37.29%) or several media sources (n = 3; 37.5%) had the least percentages of farmers who indicated that they were not able to cope with the drought conditions (*Table 3*).

The farmers who indicated that they did not prepare for the drought and those who did not respond to the question had a higher proportion of farmers (n = 62: 70.45% and n = 49: 70%, respectively) who did not cope with the drought conditions. Lack of preparedness could be indicative of the poor extension services or lack thereof the same in the study area. In contrast, their counterparts who indicated that they were prepared for the drought conditions had a low number of farmers who were not able to cope (n = 40; 32.79%).

Table 3 also shows that the category of farmers who did not have sufficient food for their animals during the time of the drought had the highest number of farmers (n = 29; 74.36%) who did not cope with the drought. This contrasts with 50.62% (n = 122) of the farmers who had enough feed for their animals.

Factors significantly associated with the ability to cope during the drought conditions by emerging smallholder livestock farmers from Greater Letaba Local Municipality

The factors that were correlated with coping with the drought conditions are presented in *Table 4*. These were the Agricultural Centre where the farmer resides, change in livestock management, introducing supplementary feeding during the drought period and how farmers rated their access to clean water during the drought conditions. Based on the 'Agricultural centre' farmers from Sekgosese were 13 (Adjusted Odds Ratio (AOR):12.792; p = 0.000) times as likely to cope with the drought than farmers from Bellevue (Referent). Although the odds (AOR: 1.873; p = 0.343) of farmers from Mokwakwaila being able to cope with drought was higher than for farmers from Bellevue (referent), the difference was not significant.

With respect to changes in livestock management introduced during the drought, farmers who introduced restricted feeding of their animals had significantly higher odds (AOR 15.348; P = 0.002) coping with the drought than those who spent more on running the farm (referent). Likewise, farmers who adopted other changes in the management of animals during drought, had significantly higher odds (AOR: 10.306; p = 0.011) of coping during the drought than those who spent high amounts on running the farm as the referent.

The farmers who practiced supplementary feeding of their animals before the onset of drought conditions had marginally significantly higher odds (AOR: 4.365; P = 0.062) of coping with the drought conditions than those who had not practiced supplementary feeding before the drought conditions set in (reference level). Farmers who introduced supplementary feeding during the drought had significantly higher odds (AOR: 19.778; p = 0.000) of coping with the drought conditions than the referent group (spent more money on running the farm).

How the farmers rated access to clean water was significantly associated with the farmers' ability to cope with the drought, with farmers who rated access to clean water as being "Fairly good" having significantly higher odds (AOR: 4.275; p = 0.008) of being able to cope with the drought conditions as compared to those who rated access to water as being bad (referent). Similarly, farmers who rated access to clean water as

being good had significantly higher odds (AOR: 18.702 p = 0.000) of being able to cope with the drought conditions than the farmers who rated access to clean water during the drought as being bad.

Table 4. *Results of multivariate analysis showing factors correlated with the farmers' ability to cope with the drought conditions during the drought of 2014-2016 that affected the Limpopo province*

Variable	Levels	Odds ratio	P-value	95% Confidence limits	
				Lower limit	Upper limit
Agricultural name	Bellevue	1 (Ref)			
	Mokwakwaila	1.873	0.343	0.5118	6.854
	Sekgosese	12.792	0.000	3.979	41.123
Education level	No education	1 (Ref)			
	Primary	0.389	0.127	0.116	1.309
	High School	1.973	0.260	0.604	6.444
	Tertiary	0.889	0.868	0.221	3.567
	Others	0.402	0.348	0.060	2.703
Change in Livestock management	High amount of money spent	1 (Ref)			
	High livestock mortality rate	4.771	0.074	0.862	26.405
	Long travelling to river/grazing site	3.384	0.147	0.651	17.592
	Selling animals at little amount	4.477	0.212	0.425	47.222
	Theft of livestock	0.744	0.723	0.145	3.818
	Restricted feeding	15.348	0.002	2.701	87.216
	Other	10.306	0.011	1.726	61.525
Supplementary feed before	No	1 (Ref)			
	Yes	4.365	0.062	0.929	20.515
Supplementary feed during the drought	No	1 (Ref)			
	Yes	19.778	0.00	6.314	61.955
Rate access to clean water	Bad	1 (Ref)			
	Fairly good	4.275	0.008	1.461	12.511
	Good	18.702	0.000	0.0004	0.412
What you did to prepare	Drilled borehole	1 (Ref)			
	Bought supplement	0.125	0.157	0.007	2.223
	Sold animal	5.580	0.271	0.261	119.141
	Other	0.478	0.616	0.027	8.561
	No answer	0.075	0.071	0.005	1.249

Considering how the farmers prepared for the drought, if the farmer did not respond to the question, they were less likely to cope with the drought than the farmers who drilled boreholes as a coping strategy. However, the difference was marginally significant (AOR: 0.075; p = 0.071). Although the farmers who sold off their animals in preparation for the drought, had higher odds (AOR: 5.580; p = 0.271) of being able to cope with the drought compared to those who drilled a borehole in preparation for the drought, the difference was not significant. Meanwhile, farmers who bought supplementary feed for their animals in preparation for the drought were less likely (AOR: 0.125; p = 0.157) to cope with the drought than those who drilled a borehole in preparation for the drought. Once again, the difference did not reach significance.

Discussion

Findings reported here show variables that were correlated with coping during the drought period experienced by smallholder livestock farmers in the GLLM, and included: The Agricultural Centre where the farmer was based, changes in livestock management, supplementary feeding before the drought, introduction of supplementary feeding during the drought, how the farmer rated access to clean water during the drought and what the farmer did as preparation for the drought. Previous studies yielded varying findings regarding factors that predicted the ability to cope with drought. For example, the study done by Abdullahi et al. (2022) in Nigeria found that the source of loan, strategy adapted, source of income and access to extension services were highly significantly correlated with coping with the drought conditions. A study on resilience of smallholder livestock farmers by Maltou and Bahta (2019) revealed that access to credit, receiving assistance from the government (such as training and feed) during drought and being part of a co-operative had a significant impact on the ability to cope with drought. Oduniyi et al. (2020), on the other hand, found the use of labour, other income sources and landownership to be the drivers of resilience against drought in a study that was conducted in the North-West province in South Africa. Earlier studies have observed that drought conditions affect farmers differently (Lottering et al., 2021b; Ruwanza et al., 2022). This explains the disparities in the factors that were significantly associated with coping with drought conditions in this study and those identified by studies done elsewhere.

The results of the present study showed that the Agricultural Centre where the farmer resided significantly correlated with the ability of farmers to cope with drought conditions, with farmers residing in Bellevue more likely to cope than farmers in other centres. Shiferaw et al. (2014) also observed in their study on the state of vulnerability to drought and its impacts in sub-Saharan Africa that the impact of drought and resilience against it differed from one community to another. Available literature shows that there are several factors that could contribute to this. For example, it has been shown that access to social networks such as farmers' groups, friends, and family, play a significant role in enhancing the coping ability (Mardy et al., 2018). Therefore, considering that factors that predict the farmers' ability to cope with drought conditions often vary from one community to the other, it was not surprising to see these disparities between Agricultural Centres in the present study.

Changes in livestock management that were introduced by the farmers during the drought were correlated with coping with drought conditions. For example, farmers who implemented restricted feeding of their animals during the drought conditions had higher odds of coping with the prevailing drought conditions as compared to those who spent high amounts of money on running the farm. This can be attributed to the fact that, smallholder farmers are generally under-resourced (Ruwanza et al., 2022); therefore, spending a lot of money running the farm could have exhausted their resources. Consequently, this could have had a detrimental effect on their ability to meet future financial obligations. Furthermore, mitigation and adaptive strategies are more effective when they are proactive, rather than reactive (Lottering et al., 2021; Ruwanza et al., 2022). Spending a lot of money during drought as shown in this study, suggests that these farmers employed reactionary measures. For example, it is possible that farmers who spent more on running the farm were forced to spend thousands of rands to source supplementary feeding and buying water, subsequently increasing production costs and thus reducing their adaptive capacity. Moreover, it has been observed that the cost of feed for animals is usually higher during drought periods (Ruwanza et al., 2022).

However, while restricting feeding in the present study enhanced drought resilience, it has been associated with loss of weight (Ntali et al., 2023), poor health and death in animals (Matlou et al., 2021).

Farmers who introduced supplementary feeding before the drought set in, were more likely to cope with the drought than those who did not. Likewise, farmers who introduced supplementary feeding during the drought period had higher odds of coping with the drought than their counterparts who did not. The importance of investing in supplementary feeds before and during drought has also been mentioned in previous studies (Ncube and Lagardien, 2015; Ntali et al., 2023). The significance of supplementary feeding before the onset of the drought assists in pasture preservation while maintaining optimal nutritional needs of the animals. This preservation ensures that pastures are optimized by the time the drought period begins (Todd et al., 2018). However, introduction of supplementary feeds needs to be done gradually to allow the animal's digestive system to adapt. Otherwise, the practice could have detrimental effects on the animals and defeat the intended purpose.

Introducing supplementary feeding during drought conditions has the potential to reduce mortality among communal livestock herds, as was observed in a study conducted in KwaZulu-Natal (Vetter et al., 2020). According to Ntali et al. (2023), adoption of alternative grasses such as *Bracharia Ruziziensis* and *Cenchrus ciliaris* that are resistant to drought and, at the same time, are highly nutritious is another strategy that farmers use to cope with drought conditions. In a study by Ncube and Lagardien (2015), farmers bought and stored lucerne for up to five years to use it as supplementary feed during drought. This implies that merely investing in supplementary feed is not enough to enable farmers to cope with drought conditions. Farmers also need to invest in appropriate storage methods.

Smallholder agriculture is mainly dependent on rain for successful farming. Therefore, water is one of the most critical resources in agriculture. In view of this, disruptions in rain patterns threatens water availability and quality resulting in loss of grazing land (Ruwanza et al., 2022), loss of livestock and livelihoods (Bahta and Myeki, 2022; Ruwanza et al., 2022). It is, therefore, not surprising that in this study, farmers who rated their access to clean water as being fairly good or good, were more likely to cope with the drought conditions. A similar finding was also reported by Matlou et al. (2021) in a study conducted in the Northern Cape, South Africa. Matlou et al. (2021) also found that smallholder farmers were less resilient to drought due to lack of access to water. Similarly, lack of water was mentioned in a study that was carried out in Northern Cameroon as one of the main challenges hampering implementation of drought response strategies (Ntali et al., 2023).

Previous research suggests that most smallholder farmers adopt reactive measures towards drought, which aggravates the severity of its impact (Lottering et al., 2021b). Lack of preparedness has been attributed to lack of warning information, resources, governmental and institutional support (Ntali et al., 2023). The various ways of preparing for drought observed among livestock farmers include harvesting water, drilling boreholes, constructing wells and dams, planting animal feeds and selling animals (Lottering et al., 2021b; Ncube and Lagardien, 2015). However, selling of animals as a coping strategy has been reported to have a negative impact on coping and overall livelihoods of farmers, as market prices for animals usually decrease during droughts due to low animal weight (Bahta and Myeki, 2022; Ntali et al., 2023; Salite and Poskitt, 2019). This explains why farmers who sold off their animals as a coping mechanism were

less likely to cope with drought in the current study. Therefore, the findings reported in this study clearly showed that timing and type of coping strategy is crucial in strengthening adaptive capacity or drought resilience of smallholder livestock farmers.

In this study, educational level and drilling a borehole were not significantly correlated with the ability to cope with drought conditions. However, different authors have reported contrasting results on these factors. For example, findings of a study by Matlou and Bahta (2019) were consistent with findings reported here in that they too observed that education had no influence on the ability of farmers to cope with drought. Rakgase and Norris (2014) in their study conducted in Limpopo province, similarly, observed that education had no influence on the ability to cope with drought conditions. In fact, in the latter study, literacy levels not the education levels of the farmers had an influence on ability to cope with drought.

On the other hand, some previous studies have reported results that were inconsistent with the findings reported in the present study. For example, Abdullah et al. (2022) and Ntali and Lyimo (2022) observed that the level of education had an impact on the adaptive capacity of farmers. In support of this, Ntali and Lyimo (2022) argue that formal education may improve adaptive capacity of farmers by enabling them to access useful drought information or ability to diversify their livelihood activities. The contradictions observed between studies done elsewhere and the present study can be explained by differences in geographical areas where these studies were conducted. For example, the two last studies were conducted in Nigeria and Cameroon, respectively, where access to drought information might be different from the study area. In view of the findings reported in this study and others, coping strategies adopted during drought conditions should be tailor made to suit conditions in the affected areas.

Conclusion and recommendations

Agricultural drought results in adverse effects, especially among smallholder farmers who are often not equipped to deal with its adverse effects on livelihood and food security. Farmers in the present study adopted varied approaches in their attempt to cope with the drought conditions, some of which enhanced the ability to cope with drought, while some jeopardized the coping capacity. Some farmers adopted pre-emptive drought responses such as changing livestock management, supplementary feeding before and during drought and access to water, which enhanced their ability to cope with the drought conditions. This further affirms the significance of proactive measures in dealing with drought. Considering that drought is a recurring event, there is a need for each farmer to have a drought management plan in place to prevent panic and impulsively induced responses. Therefore, education and coaching of smallholder farmers in developing effective drought planning strategies should be prioritized. Secondly, policy makers should consider the socio-economic factors identified in the present study that predict the ability to cope with drought conditions when designing policies and interventions to assist farmers to cope with drought conditions in the future.

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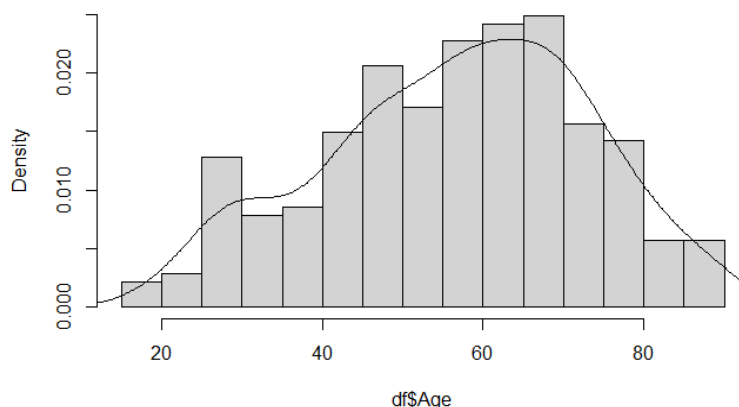
APPENDIX

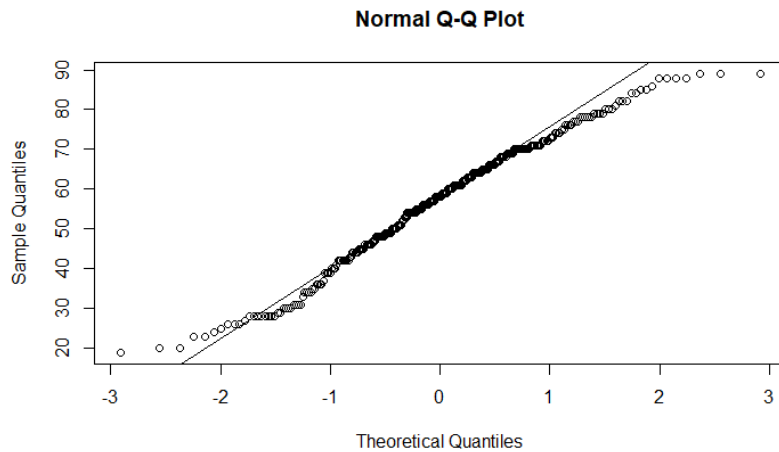### Appendix 1. Test for normality of continuous variables

Summary statistics

Mean	Median	Max	Min	25th Per	50th Per	75th Per	Quartile range
56.86	58	89	19	46	58	70	24

The histogram of the age values fitted with a normal distribution curve is plotted, the curve is negatively skewed.

A Normal Q-Q plot is plotted.

Normal Q-Q Plot

From the quantile plot above, normality of the Age variable is not assumed.

A Shapiro Wilk test is carried out to confirm whether the variable is not normally distributed, and from the results:

```
        Shapiro-Wilk normality test

data:  df$Age
W = 0.98118, p-value = 0.0009239
```
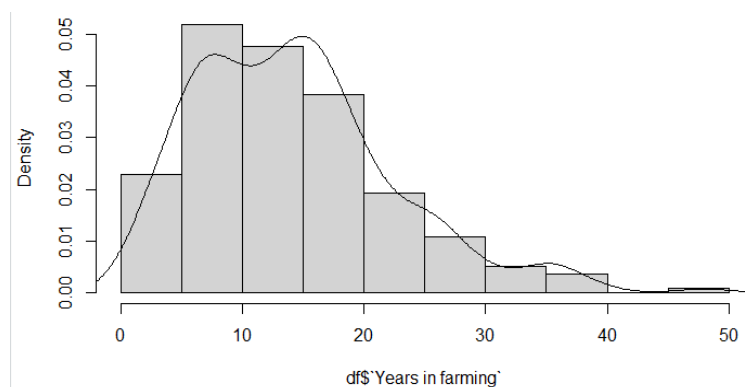
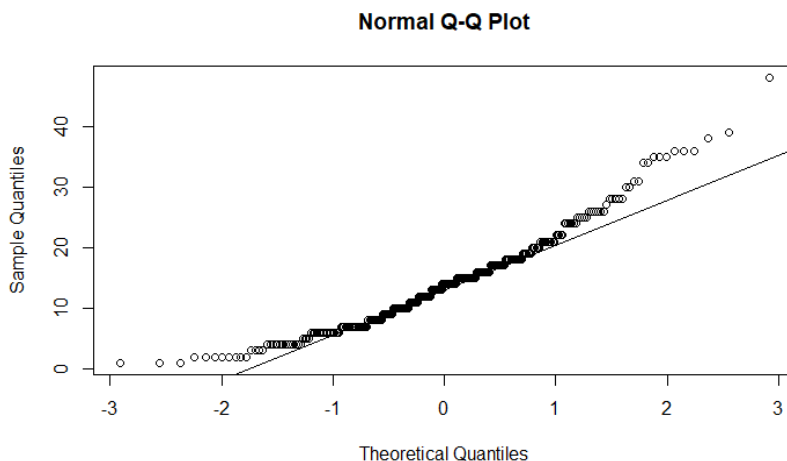The variable Age is not normally distributed.

Years in farming

Summary statistics

Mean	Median	Max	Min	25th Per	50th Per	75th Per	Quartile range
14.26	14	48	1	8	15	18	10

The histogram of the variable is plotted with a density curve fitted; the curve is positively skewed.

The Normal QQ plot is plotted.

Normal Q-Q Plot

From the quantile plot, normality is not assumed.
The variable is tested to confirm if it is not normal and from the results:

```
Shapiro-Wilk normality test

data:  df$`Years in farming`
W = 0.94903, p-value = 2.589e-08
```
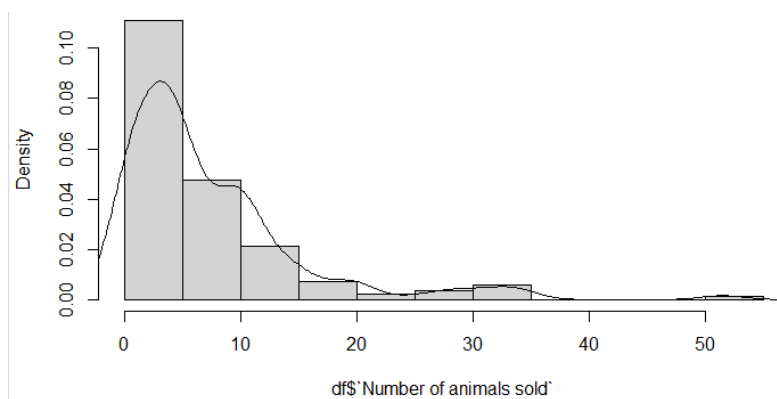
Since the P-value <0.05, it is concluded that the variable is not normally distributed.

Number of animals sold

Summary statistics

Mean	Median	Max	Min	25th Per	50th Per	75th Per	Quartile range
7.463	5	52	0	2	5	10	8

The histogram of the variable is plotted with a normal density curve fitted; the curve is positively skewed.

The Normal QQ plot is plotted.

Normal Q-Q Plot
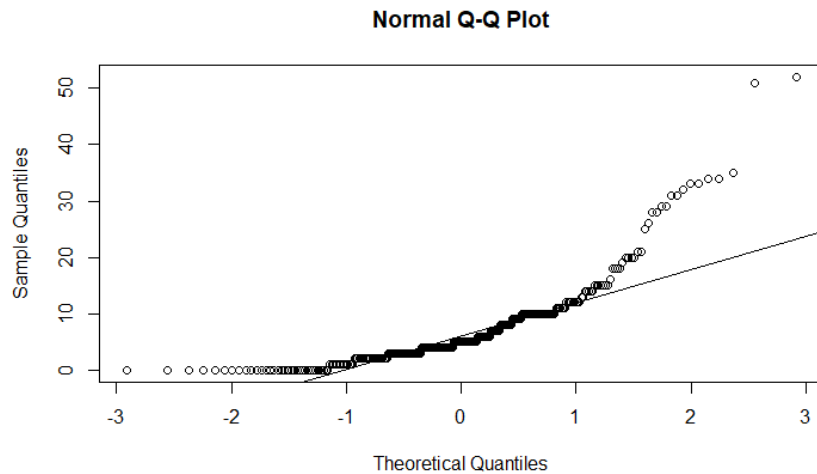
From the quantile plot, normality cannot be assumed.

A Shapiro Wilk test is performed to confirm that the variable is not normally distributed and from the results.

```
Shapiro-Wilk normality test

data:  df$`Number of animals sold`
W = 0.76554, p-value < 2.2e-16
```

With a P-value <0.05, the variable is not normally distributed.

Number of animals that died

Summary statistics

Mean	Median	Max	Min	25th Per	50th Per	75th Per	Quartile range
4.3	3	22	0	2	3	6	4

The histogram of the variable is plotted with a normal density curve fitted; the curve is positively skewed.

The Normal QQ plot is plotted.

Normal Q-Q Plot
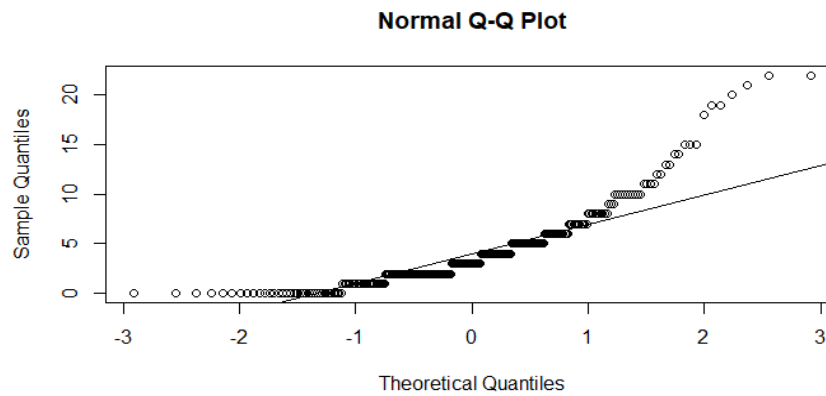
From this plot, normality cannot be assumed.

A Shapiro Wilk test is performed to confirm that the variable is not normally distributed and from the results.

```
           Shapiro-Wilk normality test

data:  df$`Number of animals died`
W = 0.82658, p-value < 2.2e-16
```
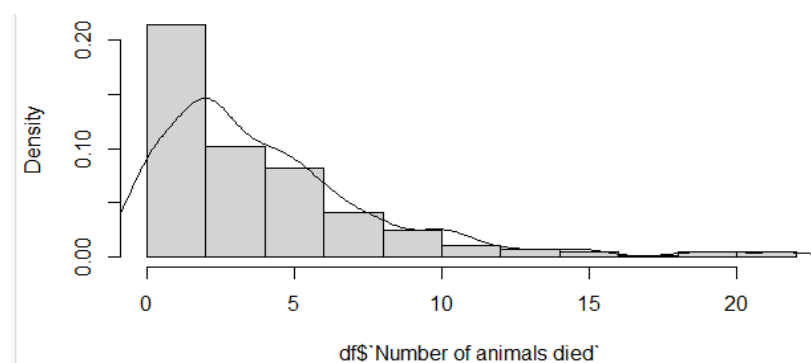
Since P-value <0.05, the variable is not normally distributed.

Appendix 2. Results of the univariate binary logistic regression analysis

Variable	Level	Did not cope with drought n (%)	Able to cope with drought n (%)	P-Value
Number of animals sold	0	131(59.01)	91 (40.99)	0.004 (Fisher's exact)
	1	16 (40)	24 (60)	
	2	2 (25)	6 (75)	
	3	1 (12.50)	7 (87.50)	
	4	1 (50)	1 (50)	
Number of animals died	0	96 (46.83)	109 (53.17)	<0.00 (Fisher's exact)
	1	40 (67.80)	19 (32.20)	
	2	8 (88.89)	1 (11.11)	
	3	7 (100)	0	
Agricultural name	Bellevue	75 (69.44)	33 (30.56)	<0.00
	Mokwakwaila	33 (41.25)	47 (58.75)	
	Sekgosese	43 (46.74)	49 (53.26)	
Gender	Male	94 (51.65)	41 (48.35)	0.297
	Female	57 (58.16)	88 (41.84)	
Marital status	Divorced	24 (54.55)	20 (45.46)	0.835
	Married	43 (54.43)	36 (45.57)	
	Single	34 (50.75)	33 (49.25)	
	Widow	22 (50.00)	22 (50.00)	
	Widower	28 (60.87)	18 (39.13)	

Education	No education	27 (45.76)	32 (54.24)	0.025
	Primary	49 (71.01)	20 (28.99)	
	High School	39 (50.65)	38 (49.35)	
	Tertiary	25 (47.17)	28 (52.83)	
	Others	11 (50.00)	11 (50.00)	
Farming enterprise	Cattle alone	68 (66.67)	34 (33.33)	0.005
	Cattle and goat	36 (53.73)	31 (46.27)	
	Cattle and pig	7 (38.89)	11 (61.11)	
	Cattle and poultry	13 (59.09)	9 (40.91)	
	Cattle and sheep	6 (50.00)	6 (50.00)	
	Above 2 types	21 (35.59)	38 (64.41)	
Drought awareness	Yes	102 (49.04)	106 (50.96)	0.005
	No	49 (68.06)	23 (31.94)	
What you did to prepare	Bought supplement	20 (62.50)	12 (37.50)	<0.000
	Drilled borehole	3 (42.86)	4 (57.14)	
	Sold animal	4 (8.89)	41 (91.11)	
	Other	13 (34.21)	25 (65.79)	
	No answer	111 (70.25)	47 (29.75)	
Water source	Borehole	43 (39.82)	65 (60.19)	0.001
	Municipal tap	22 (52.38)	20 (47.62)	
	Stream/river	61 (67.03)	30 (32.97)	
	Other	25 (64.10)	14 (35.90)	
Supplementary feed before	Yes	7 (15.22)	39 (84.78)	
	No	144 (61.54)	90 (38.46)	
Supplementary feed during	Yes	59 (34.10)	144 (65.9)0	<0.00
	No	92 (85.98)	15 (14.02)	
Livestock management change	High amount of money spent	16 (57.14)	12 (42.86)	<0.00
	High livestock mortality rate	40 (76.92)	12 (23.08)	
	Long travelling to river/grazing site	42 (58.33)	30 (41.67)	
	Restricted feeding	12 (25.53)	35 (74.47)	
	Selling animals at little amount	2 (5.39)	11 (84.62)	
	Theft of livestock	29 (72.50)	11 (27.50)	
	Other	10 (35.71)	18 (64.29)	
Access to clean water	Yes	92 (45.32)	111 (54.68)	<0.00
	No	59 (76.62)	18 (23.38)	
Rate of access to clean water	Bad	59 (77.63)	17 (22.37)	<0.00
	Fairly good	75 (60.98)	48 (39.02)	
	Good	17 (20.99)	64 (79.01)	
Support from any institution	Yes	66 (42.46)	88 (57.14)	<0.00
	No	85 (67.46)	41 (32.54)	
Information source	Extension Officer	44 (37.29)	74 (62.71)	<0.00
	Newspaper	2 (66.67)	1 (33.33)	
	Radio	28 (70.00)	12 (30.00)	
	TV	10 (58.82)	7 (41.18)	
	All Sources	3 (37.50)	5 (62.50)	
	Other	15 (65.22)	8 (34.78)	
	No answer	49 (69.01)	22 (30.99)	
Drought preparedness	Yes	40 (32.79)	82 (67.21)	<0.00
	No	62 (70.45)	26 (29.55)	
	No answer	49 (70.00)	21 (30.00)	
Food sufficient	Yes	122 (50.62)	119 (49.38)	0.006
	No	29 (74.36)	10 (25.64)	

Appendix 3. Wald test for individual variables in the model

Predictor variable	P-value
Died category	0.29804
Sold category	0.46304
Agricultural name	1.3681e-05
Education level	0.014064
What you did to prepare	0.0012509
Water source	0.069666
Supplementary feed during	1.5358e-05
Livestock management change	0.086251
Farming enterprise	0.19503
Access to clean water	0.1281
Support from any institution	0.51788
Information source	0.37595
Food sufficient	0.51865
Supplementary feed before	0.026857
Drought awareness	0.56457
Drought preparedness	0.96019

Appendix 4. Model fit and sensitivity analysis

Model fit

A Hosmer-Lemeshow test for goodness of fit is run.

```
Goodness-of-fit test after logistic model
Variable: Binary

        Number of observations =    280
Number of covariate patterns =    220
            Pearson chi2(199) = 202.93
                 Prob > chi2 = 0.4094
```

P-value = 0.4094, there is no evidence of lack of fit. Therefore, we can use this model to predict whether farmers are able to cope with drought.

Sensitivity analysis

Pseudo R-squared test was adopted to assess if the final model was better than a null model. With the Ho: Model is not significant from a null model (only the intercept as predictor). The results are observed below.

```
$Pseudo.R.squared.for.model.vs.null
                              Pseudo.R.squared
McFadden                              0.561282
Cox and Snell (ML)                    0.539127
Nagelkerke (Cragg and Uhler)          0.720325

$Likelihood.ratio.test
 Df.diff LogLik.diff Chisq    p.value
     -21      -108.45 216.9 1.6636e-34
```

The ROC curve for the model

Area under ROC curve = 0.9462
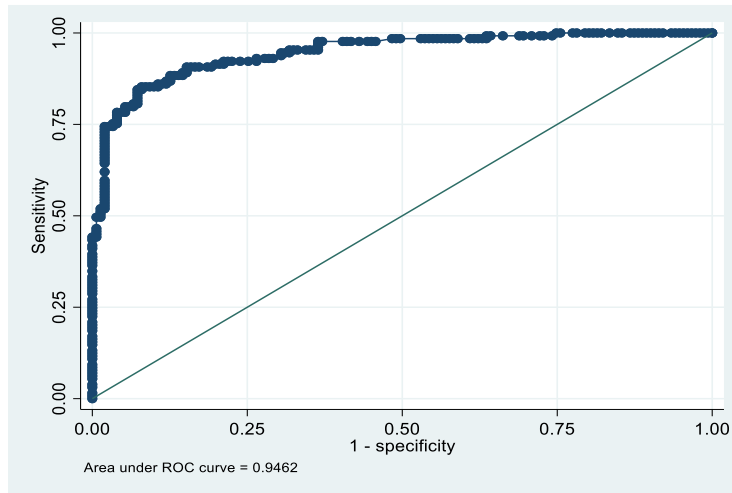
To validate the predicted values, we consider the area under the ROC curve that is 0.9462. Therefore, the model does a great job in predicting true positive and true negative values of the response variable (coping with drought).