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Sustainability of Livestock Farming in South Africa. Outlook on Production Constraints, Climate-Related Events, and Upshot on Adaptive Capacity

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Received: 9 February 2020; Accepted: 28 February 2020; Published: 25 March 2020



Abstract: The practice of pasture-based livestock farming systems in South Africa is susceptible to climate-related events, low production output, income fluctuation, and by extension poor adaptive capacity. Understanding the importance and gravity of sustainable livestock farming through adaptive capacity has been identified as a tool to cope in the face of the climate-related event which extends to production output. It is to this end, that the study explored the adaptive capacity and the socioeconomic determinants that influence this capacity used by the pasture-based livestock farmers in the study area. Random sampling technique was used to select a sample of 277 pasture-based livestock farmers in the study area from and their responses concerning on demography, farm-based characteristics, production constraints and adaptive capacity were used. Data were analyzed, in which the descriptive statistics, composite scores, and the extended ordered probit model were used to establish the results. The findings revealed the adaptive capacity score of low, moderate, and high to be 40.1%, 43.7%, and 16.2% respectively. Correspondingly, the model estimate revealed the significant factors that affect the adaptive capacity to include: the use of labor ($p < 0.05$), other sources of income ($p < 0.05$). Conversely, the age of the farmers ($p < 0.05$) and landowners ($p < 0.01$) was found significant but had a negative relationship to adaptive capacity. By implication, the study concluded that there is a need for fruitions of policies that support farmers' socioeconomic behavior to engage more in adaptive capacity and to improve the Sustainable Development Goals of the united nation as well as vision 2030 of the National Development Plan.

Keywords: pasture-based livestock farming system; adaptive capacity; production constraints; climate-related events; composite score; extended ordered probit; North West Province

1. Introduction

Over the centuries, livestock has formed the basis of human wellbeing through its contribution to the household economy, social status and food security [1]. As highlighted by [2], global livestock farming systems have evolved since the 18th century from agro-pastoralism through to the intensification in the 21st century. However, in developing countries, there exists a thin line between different types of livestock production systems [3]. Sustainability issues have been raised in livestock production as the global demand for protein-rich diets is forecasted to increase [4], amidst production challenges which are also exacerbated by climate change negative impacts [5,6]. The demand for livestock products has been fostered by an upsurge in the middle class in developing countries and an increase in the global population [4].

The livestock sector is a major consumer of the natural resources with approximately 80% of the agricultural land used for grazing and 8% of water consumption is for livestock systems [6].

Therefore, in as much as livestock systems are likely to suffer from climate change impacts, they are also considered contributors to the subject. Life cycle assessment studies have indicated that cattle production systems contribute to global warming (as a result of increased carbon dioxide and methane emissions) water depletion, contamination of water resources, and land pollution [7,8]. Apparently, industrialized farming system such as intensive beef production has a more carbon footprint and methane gas than the free-range or pasture led system [3].

By definition, sustainability in the livestock production sector relates to the ability of the system to meet the current demand for livestock products without jeopardizing future generations' use of resources and minimizing negative externalities [9]. Based on this premise, in order for the livestock systems to be considered sustainable, they should be able to meet the current and long-run economic, social and environmental obligations.

Contextual Background

In South Africa, 80% of the agricultural land is suitable for livestock production with the sector contributing approximately 40% to the agricultural income [10]. A dual system exists in the livestock farming sector with a highly commercialized system at one end and the subsistence on the other end. Cattle are the major livestock activity in the country in both commercial and smallholder farms. Cattle production in South Africa is more concentrated in the Eastern Cape, KwaZulu Natal, Free State, and Northwest [11]. Beef cattle account for approximately 80% of the national herd with dairy accounting for 20%. Approximately 60% of the beef cattle in South Africa are owned by commercial farmers and 40% by the emerging sector [11]. Three main beef production systems are common in the country: the intensive, semi extensive, and extensive production. The intensive production system ensures that specialists undertake the finishing stages of beef cattle and this is usually done in the feedlot. With clearly defined stages of production, feeding is monitored to produce the required weight in animals in the shortest period.

The primary production involves grazing animals on pastures and secondary production which requires finishing off of animals in the feedlot [10]. The bulk of the communal farmers allow animals to freely graze hence primary production and secondary production activities are combined [1]. Such systems are often referred to as extensive. However, sometimes there are overlaps between the production systems. Following [12], a more precise method of defining the production system is by what the animals eat and where they sleep. Production systems that allow the animals to forage their food more often than not and spend much of their lifecycle outside are referred to as pasture-based. The defining characteristic in pasture led systems is that supplementation of feed is rare and only temporary shelter is provided. Whilst pasture led systems in the industrialized sector are a result of consumer-driven demand for naturally fed animals, in the developing countries it is usually associated with a lack of resources for intensification therefore common in the smallholder sector [12]. In the context of this study, a pasture led production system will be used synonymously with extensive production.

Land redistribution schemes in South Africa has birthed a group of farmers known as emerging farmers. This emerging sector consists of land reform beneficiaries who have been given institutional support such as improved access to credit, extension and land rights in the bid to transform them to commercialized farmers [13]. The emerging farmers together with the communal farmers in South Africa constitute the smallholder section. In contrast to the commercial sector which is characterized by high levels of productivity and use of sophisticated machinery, the smallholder sector is often allied to a lack of access to adequate market facilities, high labor-intensity with low farm capital investment and little division of labor [14]. Cattle offtake in the smallholder sector is as low as 9% as compared to 30% in the commercial sector [15]. The problems facing smallholder farmers in Africa are complex and range from a lack of institutional support mechanisms to specific farmer related challenges.

The land issue has been at the center of public debate in the past decade, with smallholder farmers incapacitated by a lack of land rights and access to adequate agricultural land [15]. Ref [14], highlighted

a lack of investment, poor access to extension, lack of working capital and poor livestock management practices as the major constraints limiting emerging farmers from advancing to commercialized production in Limpopo province of South Africa. Similarly, Ref[13], indicated that in livestock systems, inadequate knowledge of livestock and pasture management and decrease in veld quality as a result of climate variability are the core factors that need to be addressed to improve sustainability in extensive livestock production systems.

The changing environmental, social, and economic context over time demands that livestock producers be more innovative. Environmental sustainability debates in cattle production are centered on the impacts caused by climate change and life cycle assessments of the sector. The authors of [5] projected that by 2020 in Africa, over 75 million people would be exposed to climate variability effects and extreme weather conditions such as drought, floods, and extremely hot conditions. The vulnerability of the agricultural sector arises from its sensitivity to rainfall and temperature changes. Generally, in Southern Africa, high incidences of drought, high temperatures, and unreliable rainfall have been experienced in the past years [16]. The region is considered as arid as it receives poor spatial rainfall distribution therefore water insecurity is a common problem [17]. Increased temperatures as a result of global warming effects are more detrimental in mixed farming systems and pasture led systems rather than industrialized livestock systems.

Though extreme cases of climate change can be predicted across different regions, adaptation measures may lower the impact [9,16,18,19]. Adaptation refers to practices applied to a system in response to predicted shocks or stresses to reduce harm and vulnerability from the outcome of such occurrences [20]. In climate-related events, the adaptive capacity assesses the range of activities that can be utilized to cope with the negative impacts of climate change or climate variability. Adaptation targets a specific system and is based on a local to regional intervention whereas mitigation broadly targets all systems in a global context [20]. Climate variability poses a serious strain on the smallholder production systems which are already operating under a limited resource base. In pasture led systems, in particular, climate variability poses a severe threat of reducing the quality and quantity of forage in the arid to semi-arid regions [17,21].

The objective of this study is, therefore, to identify and analyze production constraints and climate-related events that hinder the sustainability of PLFS and determine the socio-economic factors that influence the adaptive capacity of pasture-based livestock farmers in the study area. On the backdrop of consumer preferences towards pasture led beef due to the perceived nutritional, environmental animal welfare benefits [12], this study will provide insights on improving the sustainability of pasture led system in the South African context.

2. Materials and Methods

2.1. Description of the Research Area

The study was carried out in the North West province of South Africa. The country is located on the southern tip of Africa, with a magnitude of 1,233,404 km² and adjoined on three sides by nearly 3000 km of coastline, with the Indian Ocean to the east and the Atlantic Ocean to the west. There is a borderline between the country and Namibia in the north, Botswana, Zimbabwe, and Mozambique, in addition to enclosing two independent countries, the kingdoms of Lesotho and Swaziland. North West province is also referred to as Bokone Bophirima Province, a food basket of South Africa. As shown in Figure 1, the province is situated towards the western part of South Africa. It borders Limpopo to the North, Gauteng to the east, the Free State to the east and south, the Northern Cape to the south and Botswana to the west and north. Altitude ranges from 1000 to 2000 m above sea level. The total land area of the province covers about 116,320 km², and it contains 9.5% of the total area of South Africa.

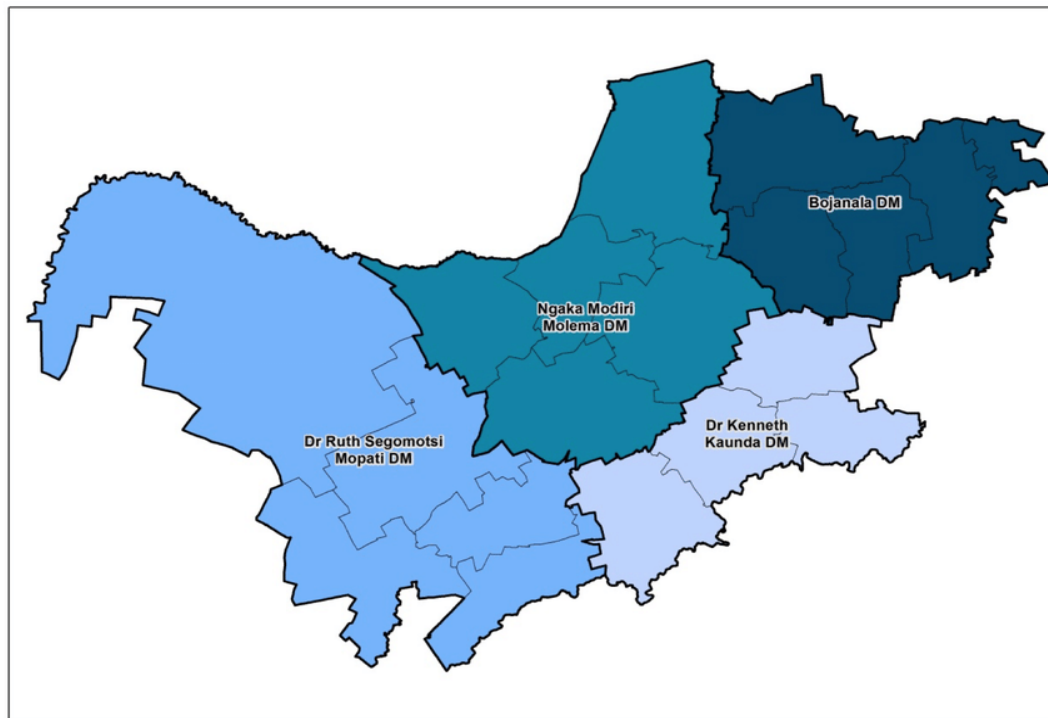


Figure 1. Map of North West municipalities, showing the study area. Source: <https://municipalities.co.za/provinces/view/8/north-west>.

The province is largely rural, while the major line of work is agriculture, though just the fifth main contributor to the GDP. North West is segmented into four district municipalities. The two districts municipalities earmarked for the study are Bojanala and Ngaka Modiri Molema (NMM), while the latter is the capital of the province, and situated at the center of the province. With the largest percentage of grazing land which justifies the concentration of cattle herds and high numbers of pasture-based livestock farmers compare to other regions, hence, Bokone Bophirima was chosen as the area for the study. In addition, Bokone Bophirima is identified for cattle farming with the largest herds of cattle found in Steelband.

2.2. Data Collection

Primary data were collected from the cattle farmers through an interview schedule using a semi-structured questionnaire, which was validated by two experts in the department of agricultural economics. The questionnaire was subdivided into sections based on the objectives of the study. A reliability test was done on the research instrument. The Pearson product-moment correlation method and split-half technique were adopted to ascertain the regularity of the instrument. A list of registered cattle farmers was obtained from the Provincial Department of Agriculture and Rural Development. The representative sample size was determined using Slovin's formula, as given in the Equation (1), afterward, questionnaires totaling 277 were doled out to the cattle farmers in the district via random sampling technique. Following [22] postulations, this was realized by adopting a quantitative model as illustrated below:

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where n is the sample size,

N = total population of cattle farmers in the two districts municipalities

e = maximum variability or margin of error (MoE). This is estimated at 5% (0.05),

1 = probability of the event occurring,
277 = the number of respondents sampled or sample size.

2.3. Data Analysis

The data for this study was based on cross-sectional data which were collected from the aforementioned study area in the year 2019. Data were coded and subjected to analysis using statistical software (XLSTAT and STATA version 15). Descriptive and inferential statistics were employed. Descriptive statistics such as frequency counts, median, mean values, variance, and standard deviation were used to describe the demography, farm-based characteristics, production constraints of PLFS. While the inferential statistics used were multicollinearity, to ensure the absence of collinearity among the variables, correlation matrix, principal component analysis to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variable, in other words it was used to identify and analyze production constraints and climate-related events that hinder the sustainability of PLFS. Lastly, the extended ordered probit regression model was used to model and determine the socio-economic factors that influence the adaptive capacity of pasture-based livestock farmers in the study area.

2.4. Empirical Model

Principal component analysis (PCA): PCA is an orthogonal transformation method of converting a set of possibly correlated observations into an uncorrelated linear set of variables. In dealing with many sets of variables, firstly, the dispersion matrix may be too much to study and interpret effectively, secondly, there may occur many pairwise correlations between the variables to consider, then, it is, therefore, necessary to use PCA to reduce the number of variables to a few combinations of data that are linear and interpretable in nature. The same each linear combination agrees to a principal component, in which the conversion or the transformation is presented in a way that the PC_1 has the highest variance possible under the constraint that it is orthogonal to the preceding components. However, the data are analyzed to give eigenvectors, eigenvalues, and variability. Eigenvectors and eigenvalues exist in pairs and every eigenvector has a corresponding eigenvalue. An eigenvector is a direction while an eigenvalue is a number that shows how much variance there is in the data in that direction [23].

The result obtained from the PCA is usually expressed in terms of factor loadings. The PCA that has an eigenvalue lower than 1 is considered inappropriate and contains less information which cannot be retained, while the PCA with eigenvalue higher than 1 is retained. Mathematically, we are transforming a set of variables (see Equation (1)) into new uncorrelated variables called *principal components* (see Equation (2)) that are linear combinations of original variables set.

$$X_j \quad (j = 1, 2 \dots \dots \dots , n) \quad (2)$$

$$PCI \quad (I = 1, 2 \dots \dots \dots , n) \quad (3)$$

Consider the linear combinations

$$PC_1 = a_{11}X_1 + a_{12}X_2 + \dots \dots \dots + a_{1K}X_K \quad (4)$$

$$PC_2 = a_{21}X_1 + a_{22}X_2 + \dots \dots \dots + a_{2K}X_K \quad (5)$$

$$PC_3 = a_{31}X_1 + a_{32}X_2 + \dots \dots \dots + a_{3K}X_K \quad (6)$$

$$PC_K = a_{K1}X_1 + a_{K2}X_2 + \dots \dots \dots + a_{KK}X_K \quad (7)$$

where PC_1 = the i th principal component, a_{ij} = component loadings (coefficients) and X_j = original variables.

In a nutshell, several variables that are considered constraints to livestock production, as well as climate-related events in the study area were used for the PCA where five-factor loadings were retained and transformed into a new set of variables which represents constraints to livestock production amidst of climate-related events. Therefore, the linear combinations give rise to first principal component (PC_1) accounts for the maximum possible proportion of the total variation in the X_j 's, the second principal component (PC_2) accounts for the maximum of the remaining variation (variance) in the X_j 's and so on. In this manner, we have $\text{var}(PC_1) \geq \text{var}(PC_2) \geq \text{var}(PC_3) \geq \dots \geq \text{var}(PC_p)$, where $\text{var}(PC_1)$ expresses the variance of PC_1 in the data set is measured.

Extended Regression Model (ERMs): The extended regression model was adopted because it takes care of endogenous covariates. Since the dependent variable is ordered in nature, an extended ordered probit regression model was used. The model is a generalized probit model that permits more than two discrete outcomes that are ordered. The ordered probit model is used to estimate relationships between a polytomous dependent variable that structurally orders against a set of regressor variables [24]. Firstly, the composite score was calculated from the set of questions in the questionnaire which allow the dependent variables to be categorized into three groups, namely; high adaptive capacity, moderate adaptive capacity, and low adaptive capacity. The categorizations were coded in a censoring value of 2, 1, and 0 respectively, after which an extended ordered probit regression model was employed to estimates the likelihood of socioeconomics characteristics that influence farmers' adaptive capacity to climate-related events. The model can be mathematically written as:

$$y^* = x^1\beta + e \quad (8)$$

where x and β are standard variables and parameter matrices, and e is a vector matrix of normally distributed error terms, and y^* is unobserved.

$$y = 0 \text{ if } y^* \leq 0 \quad (9)$$

$$y = 1 \text{ if } 0 < y^* \leq \mu_1 \quad (10)$$

$$y = 2 \text{ if } \mu_1 < y^* \leq \mu_2 \quad (11)$$

where μ_1 and μ_2 are the cut off points (intercept shifters).

The likelihood estimates of the socio-economics characteristic that influence adaptive capacity by an individual farmer are given as:

$$L = [\Phi(0 - X_i\beta)] z_{i1} [\Phi(\mu_1 - X_i\beta) - \Phi(0 - X_i\beta)] z_{i2} [1 - \Phi(X_i\beta - \mu_1)] z_{i3} \quad (12)$$

$$Z_{ij} = \begin{cases} 1 & \text{if } y_1 = j \\ 0, & \text{Otherwise for } j = 0, 1 \text{ and } 2 \end{cases} \quad (13)$$

3. Results and Discussion

Socioeconomic characteristics: The summary statistics of the farmers' demography, farm-based characteristics, and adaptive capacity profile were presented in Table 1. This explains the descriptive statistics in which the characteristics of the group gender was found to be 90.6% for men and 9.4% for women. The summary descriptive for the explanatory variables were presented in Table 1 below. Table 2 explains the levels of adaptive capacity and their percentages.

Table 1. Descriptive statistics.

Variable	Minimum	Maximum	Median	Mean	Variance (n – 1)	Std. Deviation
Gender	0.000	1.000	1.000	0.906	0.085	0.292
Farming Experience	0.000	23.000	10.000	9.614	29.267	5.410
Age	30.000	69.000	51.000	50.473	62.779	7.923
Marital Status	0.000	1.000	1.000	0.606	0.240	0.489
Education	0.000	1.000	1.000	0.603	0.240	0.490
Household Dependent	0.000	12.000	6.000	6.007	8.225	2.868
Occupation	1.000	6.000	1.000	1.325	1.524	1.235
Other Income Source	0.000	1.000	1.000	0.592	0.242	0.492
Labor Use	0.000	3.000	0.000	0.195	0.549	0.741
Own the Land	0.000	1.000	0.000	0.036	0.035	0.187
TLU	0.000	775.000	41.000	69.415	12414.403	111.420
Income	0.000	270,000.000	14,000.000	19,303.971	677,009,730.550	26,019.411
Adaptive Capacity	0.000	2.000	1.000	0.762	0.508	0.713

Source: Authors' Computation, 2020.

Table 2. Percentage of Adaptive Capacity of Pasture-based livestock farmers.

Adaptive Capacity	Frequency (%)
Low adaptive capacity	111 (40.1)
Moderate adaptive capacity	121 (43.7)
High adaptive capacity	45 (16.2)
Total	277 (100)

Source: Authors' Computation, 2020.

Analysis of production constraints and climate-related events: Several variables were considered as constraints to PLFS by the farmers in the study area. Included are the climate-related variables in which the farmers attempt to foster adaptive capacity. All variables were subjected to PCA analysis to generate a new set of linear uncorrelated variables which influence PLFS in the study area. Multicollinearity test and correlation matrix were also determined as shown in Tables 3 and 4, respectively where the mean VIF was 1.705. This shows that there was no presence of multicollinearity among the variables responsible for PLFS. Table 5 revealed the descriptive summary of the identified factors that influence pasture-based livestock production in the study area.

Table 3. Multicollinearity statistics test.

Variables	R ²	Tolerance	VIF
Shortage of labor (X ₁)	0.647	0.353	2.832
Inadequate rainfall (X ₂)	0.669	0.331	3.022
Fluctuation in the product price (X ₃)	0.500	0.500	2.000
Lack of storage facilities (X ₄)	0.362	0.638	1.568
Lack of fund and resources (X ₅)	0.661	0.339	2.953
Lack of access to buy input (X ₆)	0.368	0.632	1.582
Death of animal (X ₇)	0.234	0.766	1.306
Reduction in livestock number (X ₈)	0.196	0.804	1.244
Shortage of pasture (X ₉)	0.106	0.894	1.118
Pest and disease (X ₁₀)	0.139	0.861	1.162
Flood (X ₁₁)	0.329	0.671	1.491
Drought (X ₁₂)	0.123	0.877	1.140
Fire (X ₁₃)	0.239	0.761	1.314
Storm (X ₁₄)	0.123	0.877	1.140
Mean VIF			1.705

Source: Authors' Computation, 2020.

Table 4. Correlation Matrix.

Variables	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	X ₁₃	X ₁₄
X ₁	1													
X ₂	0.579	1												
X ₃	0.517	0.610	1											
X ₄	0.225	-0.150	-0.047	1										
X ₅	0.353	-0.113	0.196	0.006	1									
X ₆	0.455	0.395	0.413	0.316	0.044	1								
X ₇	0.218	0.057	0.052	0.038	0.380	0.160	1							
X ₈	0.238	0.081	0.103	0.003	0.375	0.095	0.180	1						
X ₉	0.087	-0.039	-0.055	-0.002	0.197	0.038	0.236	0.074	1					
X ₁₀	0.207	-0.002	0.109	0.099	0.248	0.062	0.148	-0.013	-0.031	1				
X ₁₁	0.124	-0.125	0.063	0.008	0.534	-0.033	0.096	0.219	0.014	0.115	1			
X ₁₂	0.117	-0.020	-0.012	0.085	0.184	-0.013	0.191	0.086	0.114	0.184	-0.025	1		
X ₁₃	0.106	-0.072	0.128	-0.094	0.446	-0.010	0.205	0.081	0.056	0.080	0.165	0.032	1	
X ₁₄	0.112	0.034	0.003	-0.195	0.096	-0.049	-0.002	0.144	0.002	-0.078	0.069	-0.127	0.034	1

Source: Authors' Computation, 2020. Note: Values in bold are different from 0 with a significance level alpha=0.05.

Table 5. Descriptive statistics of the production constraints and the climate related events.

Variable	Minimum	Maximum	Mean	Variance (n – 1)	Std. Deviation
Shortage of labor (X ₁)	1.000	3.000	2.430	0.478	0.691
Inadequate rainfall (X ₂)	1.000	3.000	2.347	0.814	0.902
Fluctuation in the product price (X ₃)	1.000	3.000	1.834	0.320	0.566
Lack of storage facilities (X ₄)	1.000	3.000	1.881	0.221	0.470
Lack of fund and resources (X ₅)	1.000	3.000	2.040	0.176	0.419
Lack of access to buy input (X ₆)	1.000	3.000	1.570	0.282	0.531
Death of animal (X ₇)	1.000	3.000	2.300	0.341	0.584
Reduction in livestock number (X ₈)	1.000	3.000	2.462	0.329	0.574
Shortage of pasture (X ₉)	1.000	3.000	2.603	0.248	0.498
Pest and disease (X ₁₀)	1.000	3.000	2.617	0.244	0.494
Flood (X ₁₁)	1.000	3.000	1.863	0.227	0.477
Drought (X ₁₂)	2.000	3.000	2.588	0.243	0.493
Fire (X ₁₃)	1.000	3.000	1.903	0.182	0.427
Storm (X ₁₄)	1.000	2.000	1.592	0.242	0.492

Source: Authors' Computation, 2020.

Table 6 explains the frequency and the relative frequency percentage in each category of variables considered as constraints to PLFS by the farmers in the study area.

Table 6. Categories, frequency, percentages and proportion of the production constraints and the climate related events.

Variable	Categories	Frequency per Category	Rel. Frequency per Category (%)	Proportion per Category
Shortage of labor (X ₁)	1	32	11.552	0.116
	2	94	33.935	0.339
	3	151	54.513	0.545
Inadequate rainfall (X ₂)	1	81	29.242	0.292
	2	19	6.859	0.069
	3	177	63.899	0.639
Fluctuation in product price (X ₃)	1	71	25.632	0.256
	2	181	65.343	0.653
	3	25	9.025	0.090
Lack of storage facilities (X ₄)	1	49	17.690	0.177
	2	212	76.534	0.765
	3	16	5.776	0.058
Lack of fund and resources (X ₅)	1	19	6.859	0.069
	2	228	82.310	0.823
	3	30	10.830	0.108
Lack of access to buy input (X ₆)	1	124	44.765	0.448
	2	148	53.430	0.534
	3	5	1.805	0.018
Death of animal (X ₇)	1	18	6.498	0.065
	2	158	57.040	0.570
	3	101	36.462	0.365
Reduction in livestock number (X ₈)	1	11	3.971	0.040
	2	127	45.848	0.458
	3	139	50.181	0.502
Shortage of pasture (X ₉)	1	1	0.361	0.004
	2	108	38.989	0.390
	3	168	60.650	0.606
Pest and disease (X ₁₀)	1	1	0.361	0.004
	2	104	37.545	0.375
	3	172	62.094	0.621
Flood (X ₁₁)	1	53	19.134	0.191
	2	209	75.451	0.755
	3	15	5.415	0.054

Table 6. Cont.

Variable	Categories	Frequency per Category	Rel. Frequency per Category (%)	Proportion per Category
Drought (X_{12})	2	114	41.155	0.412
	3	163	58.845	0.588
Fire (X_{13})	1	40	14.440	0.144
	2	224	80.866	0.809
	3	13	4.693	0.047
Storm (X_{14})	1	113	40.794	0.408
	2	164	59.206	0.592

Note: Category 1 = Less serious, Category 2 = Serious, Category 3 = Most serious. Source: Authors' Computation, 2020.

Table 7 reveals that Principal Component 1 (PC_1) contributed to 20.671 percent of the variations with an eigenvalue of 2.894 in the variables included in which the cumulative percentage is 20.671. The PC_1 is strongly associated with seven of the original variables. This suggests that these seven criteria or variables in the principal component vary together. The PC_1 increases with a shortage of labor, inadequate rainfall, fluctuation in product price, lack of funds and resources, lack of access to buy input, death of animals, and reduction in livestock number. This suggests that the effect or challenges of climate change on PBLs is greatly influenced by the aforementioned variables, which can be represented as follows: $(PC_1) = 0.813X_1 + 0.516X_2 + 0.652X_3 + 0.639X_5 + 0.548X_6 + 0.467X_7 + 0.432X_8$.

Table 7. Principal component analysis.

Variables	PC_1	PC_2	PC_3	PC_4	PC_5
Shortage of labor (X_1)	0.813	0.272	0.027	-0.020	0.076
Inadequate rainfall (X_2)	0.516	0.675	-0.232	0.161	-0.174
Fluctuation in the product price (X_3)	0.652	0.444	-0.207	-0.109	-0.226
Lack of storage facilities (X_4)	0.145	0.079	0.688	-0.296	0.490
Lack of fund and resources (X_5)	0.639	-0.630	-0.081	-0.113	-0.007
Lack of access to buy input (X_6)	0.548	0.461	0.241	-0.037	0.272
Death of animal (X_7)	0.467	-0.320	0.195	0.399	-0.040
Reduction in livestock number (X_8)	0.432	-0.254	-0.208	0.081	0.410
Shortage of pasture (X_9)	0.180	-0.256	0.149	0.672	0.178
Pest and disease (X_{10})	0.317	-0.164	0.340	-0.317	-0.444
Flood (X_{11})	0.336	-0.500	-0.196	-0.449	0.177
Drought (X_{12})	0.209	-0.216	0.456	0.291	-0.308
Fire (X_{13})	0.332	-0.424	-0.183	-0.065	-0.324
Storm (X_{14})	0.086	-0.082	-0.598	0.112	0.265
Eigenvalue	2.894	2.092	1.491	1.161	1.101
Variability (%)	20.671	14.941	10.650	8.293	7.863
Cumulative %	20.671	35.612	46.262	54.556	62.419

Source: Authors' Computation, 2020.

Following [25] principle, and [26], five factors (principal components) were extracted based on the result in Table 8, according to the responses of the respondents. Variables with a factor loading of above 0.40 and at 10% overlapping variance were retained while variables less than 0.40 were not retained.

The PC_2 contributed to 14.941 percent of the variation according to Table 7, with an eigenvalue of 2.092 and the cumulative frequency of 35.612 percent. Six variables are strongly associated in PC_2 . This is better explained that PC_2 increases with inadequate rainfall, fluctuation in product price, lack of access to buy input. However, it decreases with a lack of funds and resources, flood and fire. This indicates that the effect or challenges of climate change on PBLs were significantly influenced by the variables in the equation presented. $(PC_2) = 0.675X_2 + 0.444X_3 - 0.630X_5 + 0.461X_6 - 0.500X_{11} - 0.424X_{13}$.

The PC_3 reported the eigenvalue of 1.491, the variability and the cumulative percent were 10.650 and 46.262 respectively. The PC_3 increases with the lack of storage facilities, drought and decreases with storm. This indicates that these variables influence the effect or challenges of climate change on PBLs, and it can be represented as follows: $PC_3 = 0.688X_4 + 0.456X_{12} - 0.598X_{14}$. In the same vein, PC_4 contributed to 8.293 percent of the variations with an eigenvalue of 1.161 in the variables included in which the cumulative percentage is 54.556 percent. The PC_4 increases with a shortage of pasture, however, it decreases with flooding. This explains that a shortage of pasture and flood influence the effect or challenges of climate change on PBLs. This can be represented as follow: $PC_4 = 0.672X_9 - 0.449X_{11}$

Table 8. Bartlett's sphericity test.

Chi-Square (Observed Value)	Chi-Square (Critical Value)	DF	p-Value (Two-Tailed)	alpha
946.368	114.268	91	0.000	0.05

Source: Authors' Computation, 2020.

PC_5 as shown in Table 7 explained that variability percent is 7.863 with an eigenvalue of 1.101 while the cumulative percentage is found to be 62.419. There are three variables which are strongly associated in PC_5 . The explanation for this is that the effect or challenges of climate change on PBLs increases with a lack of storage facilities, reduction in livestock number and, however, decreases with pest and disease. This can be represented as follows: $PC_5 = 0.490X_4 + 0.410X_8 - 0.444X_{10}$.

Tables 8 and 9 show the tests that indicate the suitability and fitness of the PCA employed. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy indicates the proportion of variance of variables that might be caused by underlying factors. High values (close to 1.0) generally show that factor analysis may be useful for the data. On the other hand, if the value is less than 0.50, the results of the factor analysis will not be useful. Similarly, Bartlett's sphericity test was carried out to test the hypothesis that the correlation matrix. This is an identity matrix, which explains if the variables are unrelated and therefore unsuitable for structure detection. Small values (less than 0.05) of the significance level indicate that factor analysis may be useful with the data. The result from Tables 7 and 8 confirmed that the results from PCA were consistent and fit for the analysis.

Table 9. Kaiser-Meyer-Olkin measure of sampling adequacy.

Variable	Values
Shortage of labor (X_1)	0.628
Inadequate rainfall (X_2)	0.513
Fluctuation in the product price (X_3)	0.730
Lack of storage facilities (X_4)	0.312
Lack of fund and resources (X_5)	0.555
Lack of access to buy input (X_6)	0.760
Death of animal (X_7)	0.721
Reduction in livestock number (X_8)	0.736
Shortage of pasture (X_9)	0.602
Pest and disease (X_{10})	0.687
Flood (X_{11})	0.619
Drought (X_{12})	0.629
Fire (X_{13})	0.660
Storm (X_{14})	0.442
KMO	0.605

Source: Authors' Computation, 2020.

Socio-economics Determinants to Adaptive Capacity among Pasture-based Livestock Farmers in the Study Area: The result from Table 10 revealed that age, other income sources, labor use, own the land and income were statistically significant to adaptive capacity. In other words, adaptive capacity to climate change was determined and influenced by the above-mentioned factors in the study area.

Table 10. Ordered Logit Regression Model.

Adaptive Capacity	Coef.	Std. Err.	z	P > z
Gender	0.294	0.386	0.76	0.446
Farming Experience	0.029	0.020	1.49	0.137
Age	−0.029	0.017	−1.67	0.096
Marital Status	−0.230	0.213	−1.08	0.279
Education	0.126	0.257	0.49	0.626
Household Dependent	−0.023	0.034	−0.66	0.507
Occupation	−0.123	0.316	−0.39	0.696
Other Income Source	0.401	0.201	2.00	0.045
Labor Use	1.006	0.503	2.00	0.046
Own the Land	−2.083	0.722	−2.89	0.004
TLU	−0.001	0.001	−0.82	0.410
Income	0.000	0.000	9.22	0.000
/cut1	0.463	1.067		
/cut2	3.694	1.149		

Source: Authors' Computation, 2020. Number of obs = 277; Wald chi2(12) = 102.57; LR chi2(12) = 284.86; Log likelihood = -141.07526; Prob > chi2 = 0.0000; Pseudo R2 = 0.5024.

Table 11 shows the predictive margin test explains the outcome for each categories of the adaptive capacity.

Table 11. Predictive margins test.

	Margin	Delta-method Std. Err.	z	P > z
_predict				
1	0.407	0.019	21.32	0.000
2	0.425	0.025	16.87	0.000
3	0.168	0.017	10.14	0.000

Source: Authors' Computation, 2020. Number of obs = 277; Model VCE: OIM; 1._predict: Pr(adaptive capacity==0), predict (pr outcome(0)); 2._predict: Pr(adaptive capacity==1), predict (pr outcome(1)); 3._predict: Pr(adaptive capacity==2), predict (pr outcome(2)).

The marginal effect estimates of the results were shown in Table 12, which explains the effect of the margin for each categories of adaptive capacity.

Age was found negatively associated with a coefficient of 0.029 and significantly ($p < 0.05$) influence the adaptive capacity. This implies that an increase in age decreases the adaptive capacity. The age of a farmer plays a significant role in the sustainability of PLFS in the study area. The mean age of the farmers in the study area is 50.473, and this is not surprising as the majority of the farmers in the study area exhibit low outcomes towards high adaptive capacity. This could be attributed to the fact that old farmers are reluctant to adopt new things, measures of adaptive capacity were lacking. This result is supported by [27], who reported that age influence the level of adaptive capacity.

Table 12. Marginal effect estimates.

Variables	Marginal Effect for Y = Low Adaptive Capacity	Marginal Effect for Y = Moderate Adaptive Capacity	Marginal Effect for Y = High Adaptive Capacity	X
Gender *	−0.0000853	0.0357297	−0.049087	0.906137
Farming Experience	−0.0000734	0.0040151	−0.0044402	9.61372
Age	−0.0002242	0.0013189	0.00191	50.4729
Marital Status *	−0.0009519	−0.0112175	0.028839	0.606498
Education*	−0.0006024	0.1388094	−0.0343612	0.602888
Household Dependent	−0.0002296	0.0030022	0.0020499	6.00722
Occupation	−0.0025792	0.3432589	−0.0335177	1.32491
Other Income Source *	0.0055393	−0.1183727	−0.0022053	0.592058
Labor Use	0.0112927	−0.7057003	−0.0088369	0.194946
Own the Land *	−0.9844422	0.1541483	0.0584709	0.036101
TLU	0.0000407	−0.0009255	0.0002298	69.4152
Income	0.00000129	−0.00000216	−0.00000715	19304

(*) dy/dx is for discrete change of dummy variable from 0 to 1. **Source:** Authors' Computation, 2020.

The other source of income was positively associated (coefficient of 0.401) and statistically significant, thus influencing adaptive capacity. Farmers who engage in off-farm activities apart from earning income in farming tend to increase the adaptive capacity as the farmer would be able to afford facilities needed such as irrigation facilities among others. In the same train of thought, the level of income influences adaptive capacity. Income generated from agricultural activities also determines the level of adaptive capacity. The higher the income generated, the more likely a farmer tends to increase the level of adaptive capacity [28], reported similar results, that level of income in livestock farming determines the level of adaptive capacity among rural household farming in Ethiopia.

The use of labor was positively correlated and significantly ($p < 0.05$) influenced the level of adaptive capacity in the study area. The maximum number of labor use as found in Table 1, was three laborers, however, it was established that farmers with more labor use have a higher probability to increase the level of adaptive capacity. The reason could be that the farmer has more helping hands to adopt and carry out certain activities on the farm to increase the level of adaptive capacity. Activities such as farm management practices, implementation of irrigation, windbreaks among many others. This could be referred to as adaptation through human assets as explained by [29].

The landowner is another factor that determines the level of adaptive capacity in the study area. Owning the land was negatively associated with a coefficient of -2.083 and statistically significant. The reason for this result is that the knowledge and experience of the landowners determine the adoption of natural resources management and the level of adaptive capacity. This was supported by [23], who reported that landownership is likely to influence adoption if the innovation requires investments tied to the land.

Figure 2 shows the predictive margin graph of adaptive capacity used by pasture-based livestock farmers in the study area in the face of climate-related events. The high adaptive capacity is seen to be relatively low, followed by the low adaptive capacity. This graph is better explained in Table 2, where the percentage of high adaptive capacity, low adaptive and moderate adaptive capacity were given as 16.2%, 40.1% and 43.7% respectively.

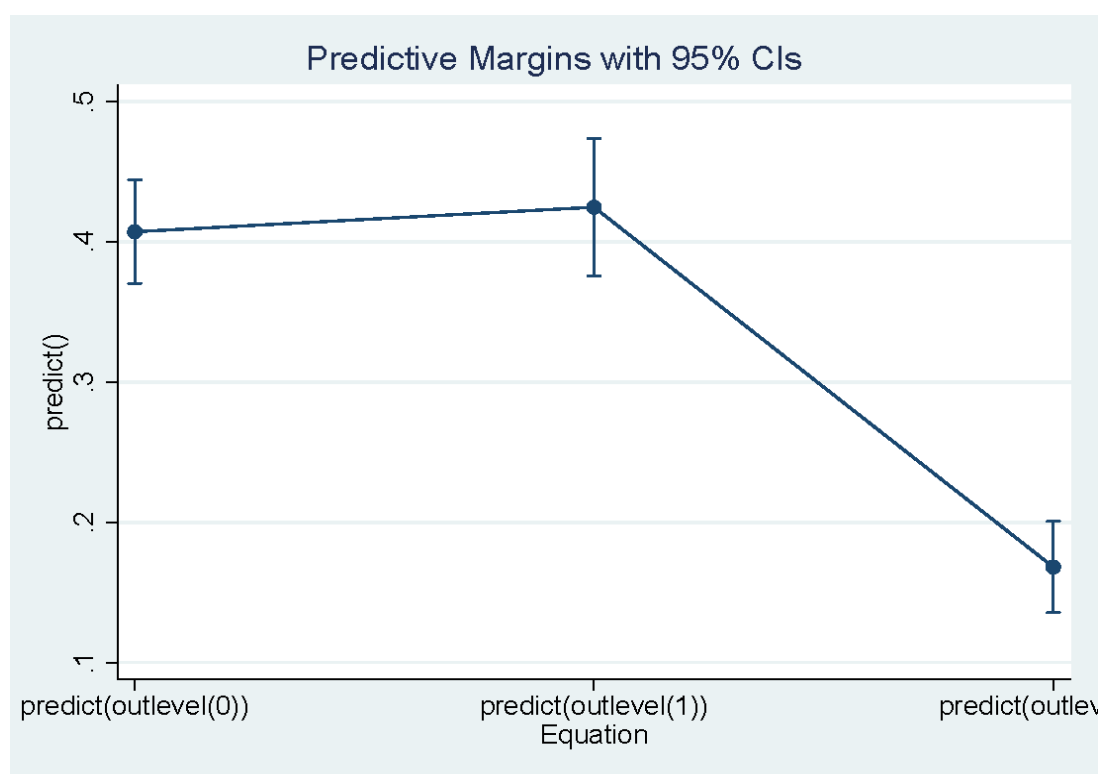


Figure 2. Predictive margins graph.

4. Conclusions

The results explained the production constraints and the climate related events which could possibly influenced the sustainability of pastured-based livestock farmers in South Africa. The study outlined age of the farmers, other sources of income from agriculture, the use of labor, and landowners, were significantly influenced the adaptive capacity of pasture-based livestock farmers. By implication, for pasture-based farmers to improve on adaptive capacity, the policy should be targeted towards the highlighted influenced factors. In the same manner, this translates to enhance the sustainable development goal (SDGs) of the united nation (Goal 1,2,3 and 12), as well as vision 2030 of the National Development Plan (NDP) which aims to eliminate poverty and reduce inequality, achievable through agriculture. This can also help the policymakers, department of agriculture, the researchers and other stakeholder concerns towards improving the adaptive capacity of PLFS, especially in the study area.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, O.S.O. and T.T.R.; Methodology, O.S.O.; software, O.S.O.; validation, O.S.O., M.A.A. and T.T.R.; formal analysis, O.S.O.; investigation, O.S.O., Rubhara, T.T.R. and M.A.A.; resources, M.A.A.; data curation, M.A.A.; writing—original draft preparation, O.S.O. and T.T.R.; writing—review and editing, O.S.O.; M.A.A. and T.T.R.; visualization, O.S.O.; M.A.A. and T.T.R.; supervision, M.A.A.; project administration, M.A.A.; funding acquisition, M.A.A. All authors have read and agreed to the published version of the manuscript.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: The research was funded by the Agricultural Research Council, Climate Change Collaboration Centre. This is a research collaboration entity for UNISA, University of Pretoria and Agricultural Research Council of South Africa.

Acknowledgments: The authors acknowledge the anonymous reviewers for improving the quality of this paper. The authors appreciate all the participants who contributed to this research, including ARC, University of Pretoria and University of South Africa.

Conflicts of Interest: The authors declare there is no conflict of interest.

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