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The Impact of Climatic Variability and Extremes on Livestock Water and Fodder Use in Limpopo and Mpumalanga Provinces of South Africa

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ABSTRACT:
The purpose of this study was to investigate the perceptions of Smallholder Livestock Farmers (SHLF) about the impact of climatic variability and extremes on livestock water and fodder use in Limpopo and Mpumalanga Provinces. Data were collected through a semi-structured questionnaire for an interview of 366 SHLF. The main sources of water for SHLF were perceived to be rivers (41%), municipal/piped water (40%) and boreholes (33%). Only 3 % and 7 % of the farmers were believed to have used wells and dams/ponds respectively as water sources for livestock. Cattle were perceived to have obtained water from 1-10 km, mainly from rivers. The majority of SHLF (97%) was believed to have accessed fodder from communal grazing. Even with the use of crop residues (59%) and own crop harvest (35%), inadequate grazing was perceived to be the biggest challenge for cattle and sheep. Based on the findings of the study, it was recommended that: (1) early warning information be interpreted and regularly presented to SHLF, (2) livestock reduction is encouraged when the adverse climate is anticipated, and (3) earth dams be constructed to harvest flood water at strategic catchment points for use in times of scarcity.

KEY WORDS: Communal grazing, Borehole, Crop Residue, Early Warning

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1. INTRODUCTION

Globally, the livestock sector is a central contributor to food systems, food security, poverty reduction and agricultural development. Livestock generates 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people. It is projected that about half a billion pastoralists depend on livestock keeping for food, income, and as a store of wealth, collateral, or safety net in times of need (FAO, 2022). The global contribution of livestock pastoral systems to the livelihood of the rural poor is estimated at 70% of the world's rural poor. In Sub-Sahara, Africa livestock accounts for 53% of the agricultural capital stock and contributes significantly (30%) to agricultural gross domestic product (GDP) (NEPAD, 2005). It is estimated that meat, milk, and eggs provide ~20% of the protein in African diets, and around 70% of the human population of Sub-Sahara Africa are primarily or partly dependent on livestock (Lenne, *et al.*, 2005). In South Africa, livestock production is one of the most important agricultural industries with beef cattle making up some nine (FAO, 1978) per cent of the gross value of agricultural production (DAFF, 2010). About 60 per cent of the national beef cattle are produced under extensive rangelands of which smallholder livestock farmers are also located. The contribution of the livestock industry is about 34.1 % to the total domestic agricultural production and provides 36% of the population's protein needs [RMRDSA, 2018; RMRDT, 2008). It is estimated that South Africa produces 21.4% of the total meat produced on the continent and 1% of global meat production (Bembridge, 1987). An analysis of beef cattle markets and value chains for smallholder farmers in South Africa by (Nengovhela, *et.al.,* 2019) indicated that the national herd of cattle was around 13 million with over 5.5 million located in the poor rural communities. Cattle from poor pastoral communities comprise about 40% of the national herd but contribute only 5% to South Africa's GDP from beef. They are said to be dead or unproductive biological assets for the country as these herds make minimal contributions. Stroebel, *et. al.,* (2008), further elaborated that the benefits obtained from smallholder pastoral livestock systems (SPLS) are derived from products that are not sold on the market. They are not accounted for in the country's economic systems. They are referred to as non-market functions (Otieno, *et.al.,* 2016) or intangible (Kosgey, *et.al.,* 2004) describes them as basic commodities from livestock that are not marketed but are consumed by the household (Z-goods). In recent times global, continental, and country-based interventions have been done to sustain the SPLS. This has been done through national, regional and international influenced policies, funding instruments, economic trade agreements and environmental protocols. Globally there are variable success stories to improve the livelihood, income, and linkages for rural smallholder pasture-based livestock farmers (SPbLF) with the market, veterinary support, funding, and natural resources such as grazing and water. Several authors including the review by Odiniyi, *et.al.,* (2020) identified various sustainability challenges that confront SPbLF. Some of the challenges include but are not limited to lack of land rights, and the tragedy of farming communally (Mapiye, *et.al.,* 2009). Major constraints identified were lack of investment, poor access to extension, lack of working capital and poor livestock management practices (Khapayi, *et.al.,* 2016). Similarly, MacLeod, *et.al.,* (2008), mentioned inadequate knowledge of livestock and pasture management and a decrease in veld quality due to climate variability as the core factors that need to be addressed to improve sustainability in extensive livestock production systems. Since the dawn of South African democracy, there has been a growing consensus coupled with government interest from the premise that the major constraint limiting SPbLF was the lack of commercialization as compared to the thriving large commercial system with developed values chains (Nesamvuni, *et.al.,* 2003). The inconsistency is that South Africa's commercial beef markets are dominated by grain-fed beef, with feedlots supplying >80% of beef that is linked to retail stores. Although some SPbLF does supply into the feedlot value chain, many are compelled by social and cultural preferences for keeping older animals. Also, the common breed being produced which includes the indigenous Nguni and Nguni-types are not suitable for feedlot finishing due to their slower growth rates and lower mature sizes. Economically, the SPbLF also loose through the disincentive brought by the carcass classification system that favours younger animals which receive premium prices if they are slaughtered at less than 2 years of age and are finished on grain (Nengovhela, *et.al.,* 2019). The impact of climatic variability and extremes adds to the total sustainability discussions in SPbLF cattle production. The vulnerability of the SPbLF sector is due to its sensitivity to rainfall and temperature changes. (Weindl, *et.al.,* 2017) projected that water usage for livestock production would increase by 19 to 36 per cent compared to present consumption levels from surface water resources (i.e. rivers, lakes and dams). Projections for the future indicate that South Africa will experience high incidences of drought, high temperatures, and unreliable rainfall (Nesamvuni, *et.al.,* 2012; Engelrecht, *et.al.,* 2020). The projected rise in temperatures to climatic extremes will have a negative influence on SPbLF rather than on the established commercial livestock systems (Nesamvuni, *et.al.,* 2012; Tshikolomo, *et.al.,* 2022). The purpose of this study was to investigate the perceptions of SPbLF about the impact of climatic variability and extremes on livestock water and fodder use in Limpopo and Mpumalanga Provinces of South Africa.

2. MATERIAL AND METHODOLOGY

2.1. Study Area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively (Figure 1). Only Vhembe and Gert Sibande District Municipalities were chosen because of the proximity and convenience of having Small-holder Livestock Farmers that are organised and within reach to the investigators.

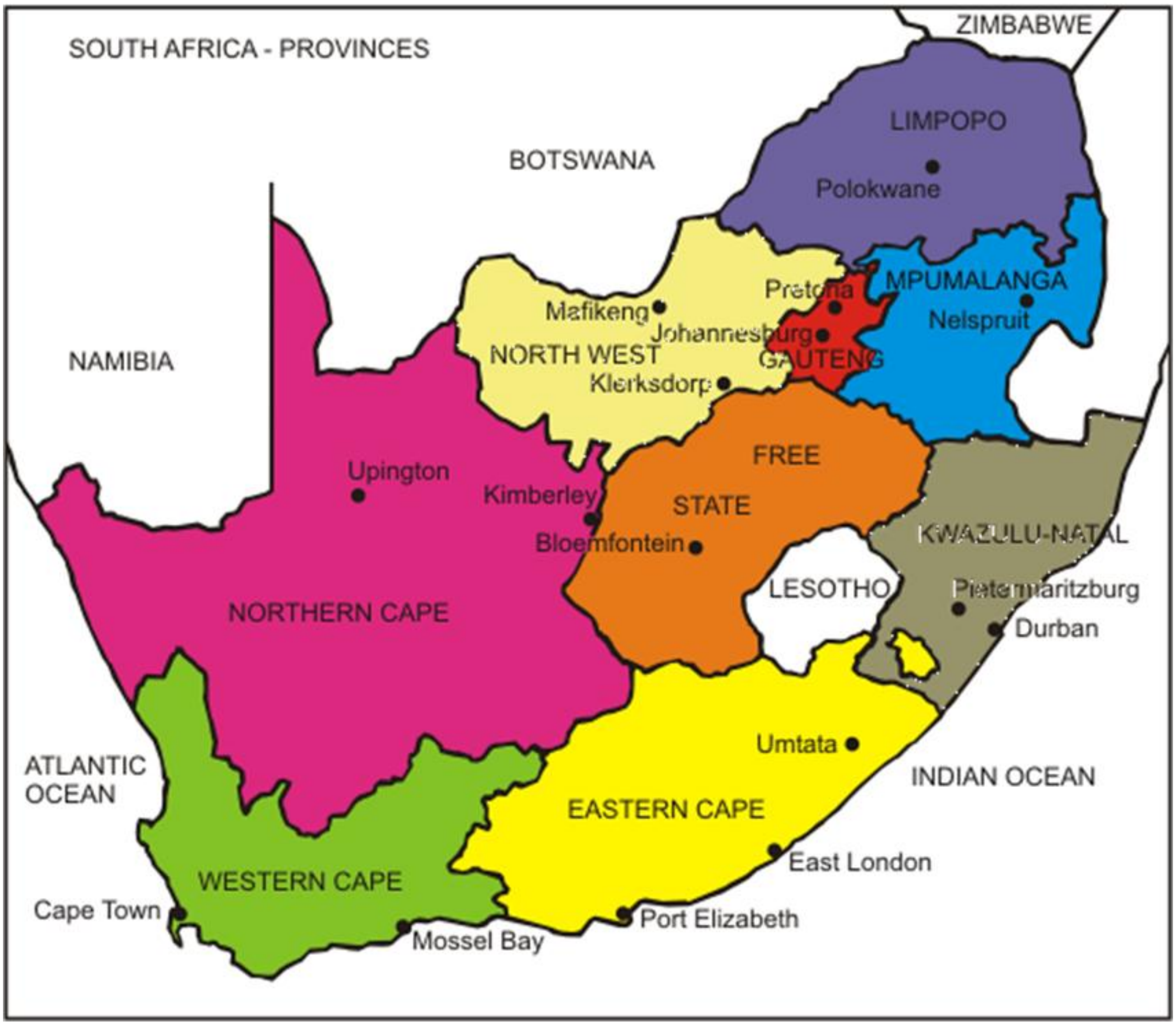

Figure 1: Map of South Africa showing Limpopo and Mpumalanga Provinces

2.2. Agro-ecological mapping of water resources in the study area

An evaluation of the location of SPbLF in relation to the three major resources of water mainly rivers, boreholes and piped municipal water can help improve access and use. Figure 2 shows the availability of streams throughout the study area. The SPbLF are situated throughout the two provinces, however, their density is variable. Most SPbLF clustering throughout conforms to the microclimatic regions that experience high rainfall.

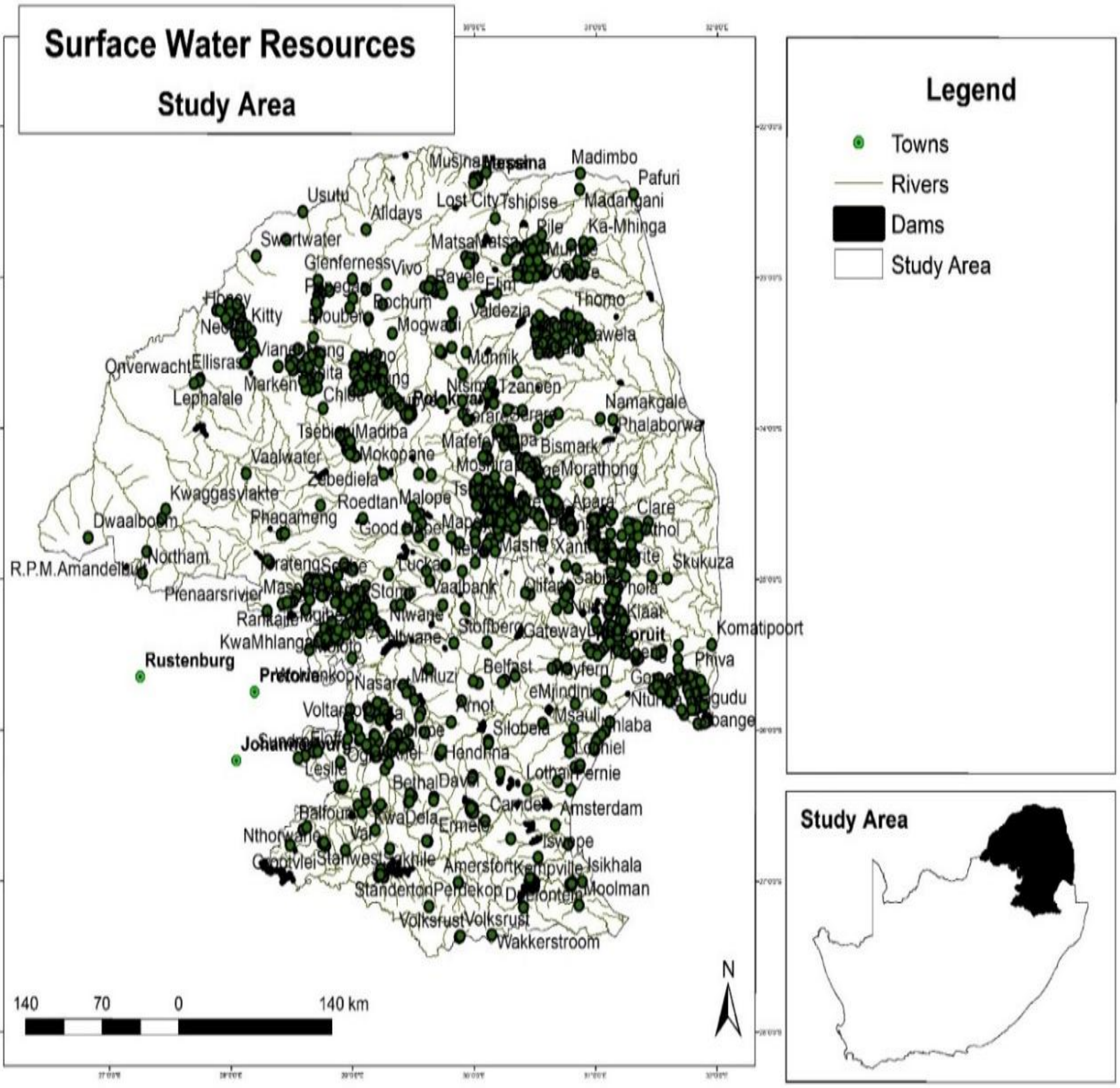

Figure 2: Map of surface water resources in farmer settlement areas in Limpopo and Mpumalanga Provinces of South Africa

In Figure 3, the map indicates the groundwater resources throughout the province and the locations of SPbLF. The variability in the borehole density between the two provinces indirectly signifies the variance in the surface water resource. The aridity nature of most parts of the Limpopo Province compels the farmers and other water users to turn their focus to groundwater resources.

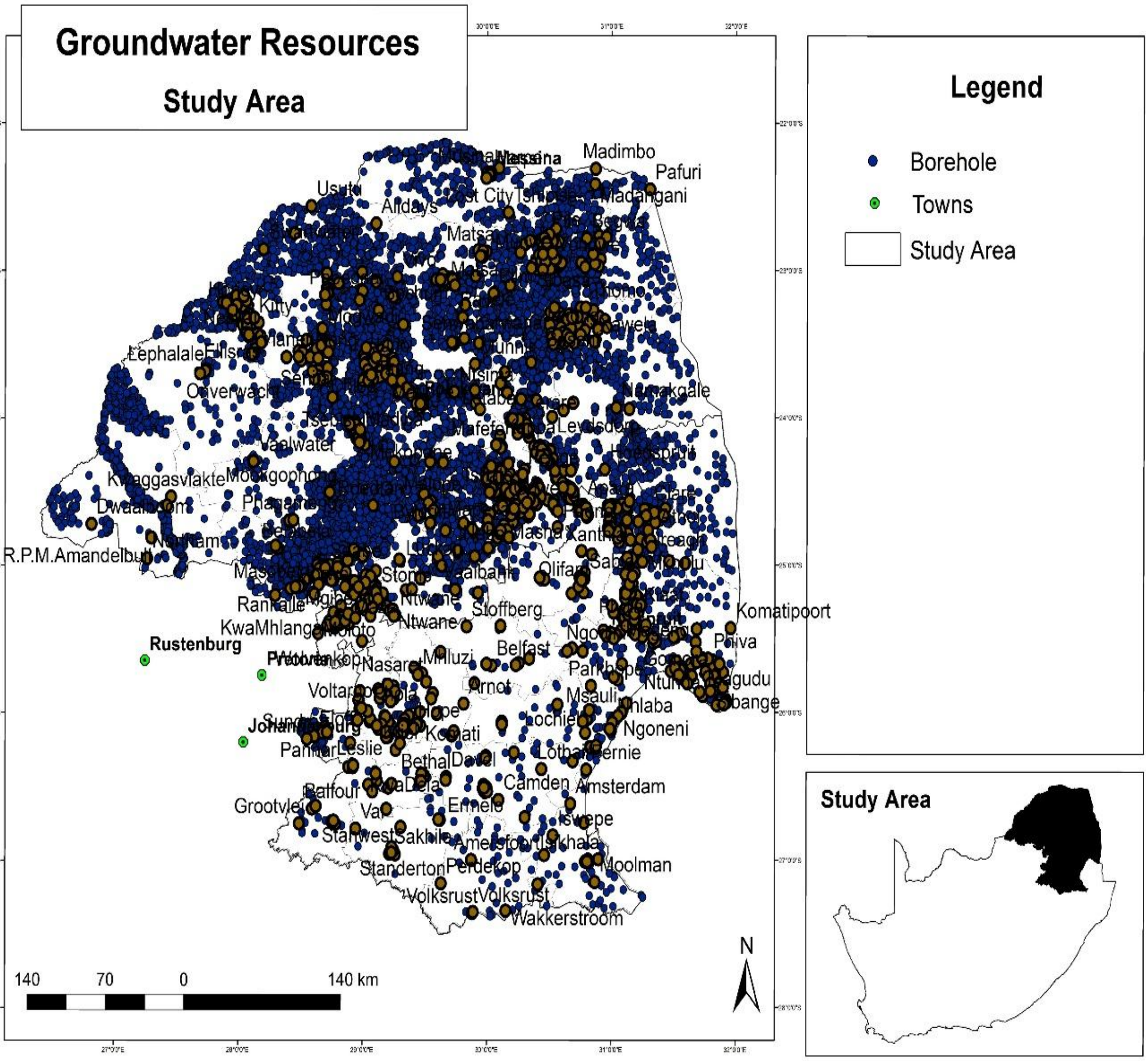

Figure 3: Map of groundwater resources used in farmer settlement areas in Limpopo and Mpumalanga Provinces of South Africa

2.3. Data Collection

Data was collected through a descriptive survey using structured questionnaires, observations and interviews with individuals and focus groups. Also, spontaneous questions were developed for interaction with the interviewee (Schulze, 2002). The structured questionnaire contained both open and close-ended questions. At least 366 small-holder farmers were interviewed using a semi-structured questionnaire to elicit responses on vulnerability. The average response rate on questions was 75 per cent. The questionnaire included among others demographic and economic household characteristics; livestock and crop production; access to extension services; credit access; hazard occurrence; adaptation strategies pursued; coping strategies; level of resilience and other information as indicated in the methodology. The study adopted the Framework and/ or a system by (Lindoso, 2012). To determine livestock water use efficiencies focus was on the sensitivity attributes. The main water-related indicators were the source, access, use and distance to water by small-holder farmers and their households. The study used GIS facilities for spatial data analyses (Ormsby, 2001). The GPS mapping obtained point data on water sources which were referenced to attribute data from records and repts.

2.4. Population of small-holder Farmers

In the two districts, all four local municipalities of Vhembe (Makhado, Musina, Collins Chabane and Thulamela) and seven of Gert Sibande (Chief Albert Luthuli, Msukaligwa, Mkhondo, Dr Pixley Ka Isaka Seme, Lekwa, Dispaleng and Govan Mbeki) were considered. The population of interest were 23 283 livestock households from 362 villages in Vhembe and 27 706 livestock households from 183 villages in Gert Sibande. The number of households sampled for the interview was 366 for both Vhembe and Gert Sibande Local municipalities respectively.

2.5. Sampling Procedure

Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and about four in Mpumalanga. An effort was made to have a minimum of at least 10 farmers per village out of the randomly sampled household. We used stratified sampling to obtain a representative sample of villages and households for interview. A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The two-stage sampling was conducted as follows: (a) Stage 1: 10% of the villages from the four local municipalities were randomly sampled and (b) Stage 2: 10% of the households from villages sampled in Stage 1 were randomly sampled. Simple random sampling was used at each stage of sampling.

2.6. Data Analysis

Quantitative data were transcribed into MS Excel Package and analysed statistically using the SAS Package (SAS Institute Inc, 2008, SAS Institute Inc, 2009). The Procedure FREQ of SAS was used to generate simple frequency tables for variables of interest. Selected data were summarized in an Excel Spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents mainly the qualitative data.

3. RESULTS

3.1. Climatic variability and vulnerability analysis

Climate characterisation The study area, i.e. the Limpopo and Mpumalanga Province, is classified as predominantly a semi-arid region (85%) (Figure 4, **(**left), with an arid area (10%) found along the far northern border of the Limpopo Province with Botswana, Zimbabwe and Mozambique Countries. Only five per cent of the area is sub-humid.

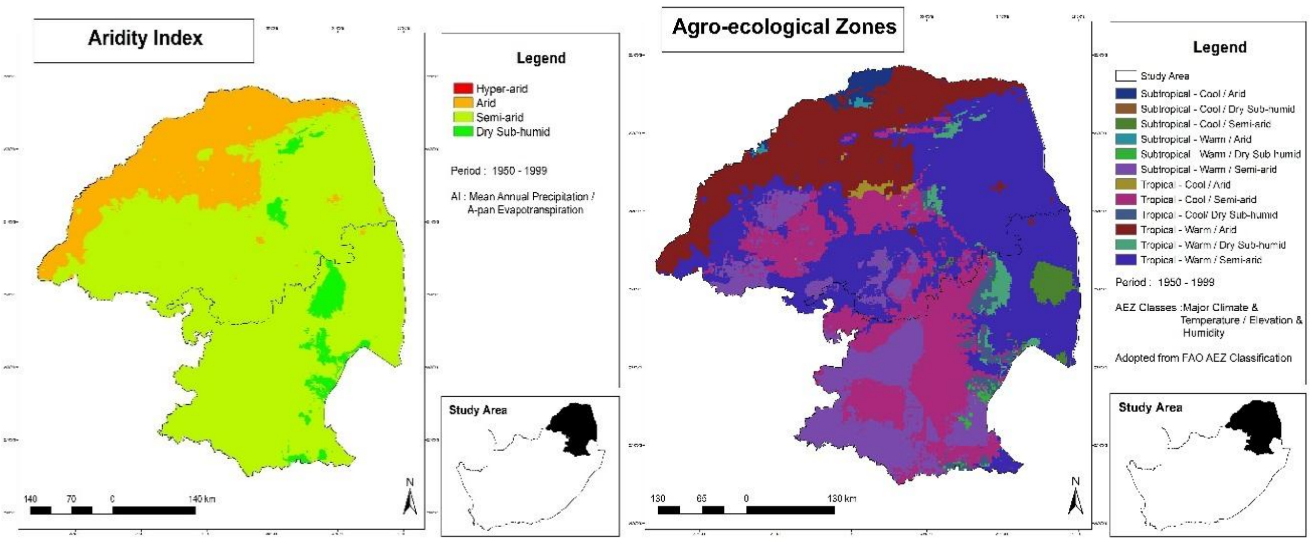

Figure 4: Climate characterization through the aridity index (left) and agro-ecological zones (right)

A more detailed classification based on (FAO,1978)was conducted, at which in **Figure** (right) Agro-Ecological Zones (AEZs), based on major climate zones, moisture zones (water availability) and highland-lowland (cool or warm based on elevation). The factoring in elevation provides more information as to the local conditions and its usual zonation for the classification of the various livestock production system and determination of their likely climate-related risks, as well as vulnerability Climate analysis The mean total precipitation over the rainfall season (between October and February), as shown in Figure 5, was computed using middle-of-the-road global climate model daily projections determined using an approach presented in a study by (Lekalakala, 2017).

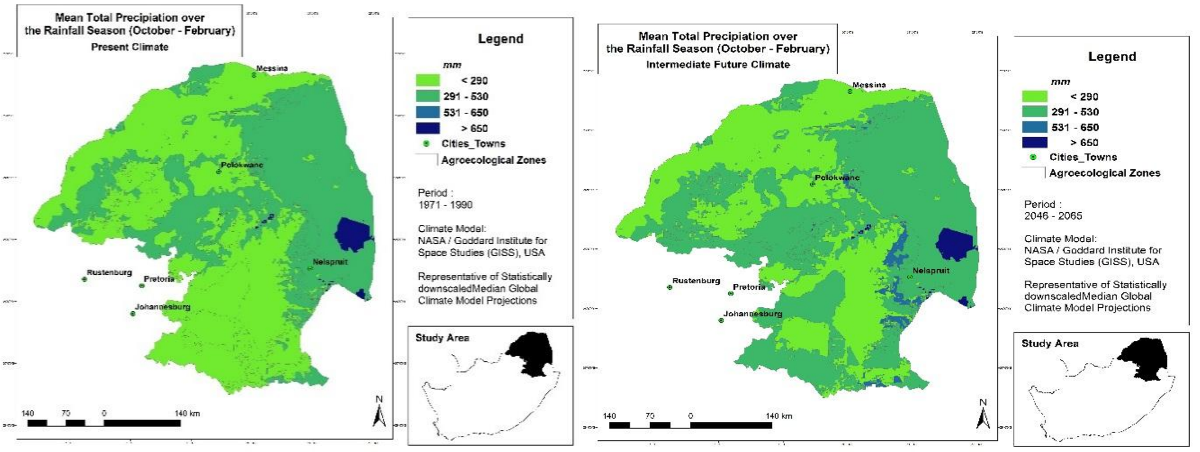

Figure 5: Mean total precipitation over the rainfall season (October – February) for present climate (on left) and mid-century (on right), over Limpopo and Mpumalanga Provinces

This represents the median of the statistically downscaled model projections of daily climate conditions. The AEZs were used as spatial units. The rainfall is projected to increase mostly in the western parts of the study areas, this is due to the selected or representative climate model showing a wetter climate than the present condition.

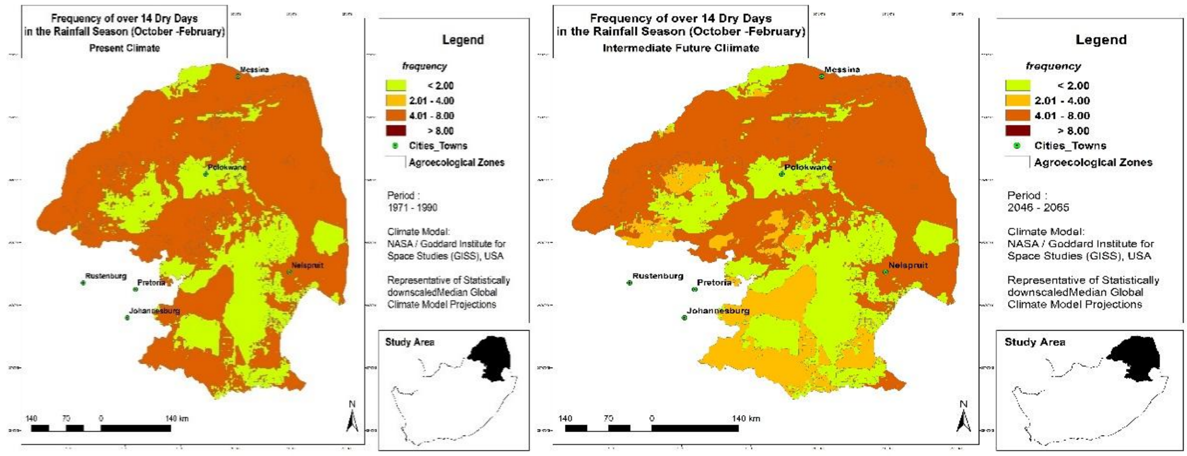

Figure 6: Mean frequency of more than 14 dry days over the rainfall season (October – February), present climate (on left) and mid-century scenario (on right)

The frequency of more than 14 dry days during a rainfall season (i.e., between October and February) for the present climate scenario is depicted in Figure Figure 6 (on left) is likely to experience more than 4 times a median rainfall season over most parts of the study area. This is postulated to decline in some parts of the study area; however, the frequency of the dry spells is projected to remain high in most areas in the mid-century. This decline is attributed to the increase in rainfall, as shown in Figure 6 to the representative median climate model postulating wetter conditions over certain areas compared to present conditions.

3.2. Vulnerability analysis

The exposure index, as shown in Figure 7, under present climate conditions suggests that there is a high vulnerability, which is climate-based, over most of the AEZs and very high vulnerability concentrated mainly along the northern border. The mid-century vulnerability projections suggest a reduction in the exposure index too high. The reduction in vulnerability along the northern border is due to the global climate model projecting a future that is wetter than the present, this is a median of the future projections. This climate analysis indicates that the study area is already under high vulnerability to climate extremes, which is most likely to increase with an increase in temperature as projected by all of the (IPCC, 2007, Nkondze, *et.al.*, 2014) climate models.

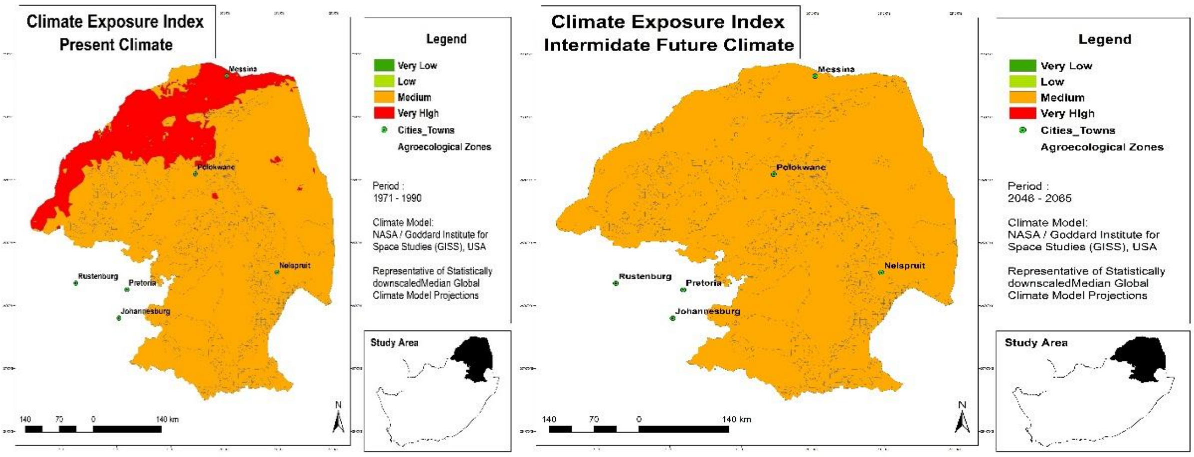

Figure 7: Mean of climate exposure index over Limpopo and Mpumalanga Provinces, for Present climate (on left) and mid-century climate (on right)

3.3. Livestock categories, objectives of keeping livestock and market

livestock categories

Table 1 indicates the major species of livestock that are kept by smallholder pasture-based livestock farmers (SPbLF). Most of the livestock farmers had cattle (98%), followed by goats (15%), chickens (8%), pigs (6%) and sheep (3%) (Table 1).

Table 1: Frequencies and their associated percentages of smallholder pasture-based livestock farmers (SPbLF) and major species of livestock they keep.

Livestock type	Yes		No		
	Frequencies	%	Frequencies	%	Total
Cattle	360	98.4	6	1.6	366
Sheep	10	2.7	356	97.3	366
Goats	53	14.5	313	85.5	366
Pig	20	5.5	346	94.5	366
Chicken	30	8.2	336	91.8	366

Livestock Market Most of the SPbLF kept livestock for meat (98%), followed by cultural (52%), ceremonies (45%), cash or sales (41%) and manure (40%). Almost all (99%) SPbLF sold their animals live and mostly to the local community (93%) and butchery (7%). Farmgate prices are negotiated within the local community with a target of rural consumers (91%). Prices are influenced by the local community demand. It was observed that consumers/buyers are responsible for transporting livestock to the butchery. In general, SPbLF did not sell the hides (84%) and the small margin that sells (Khapayi, *et.al.*, 2016) target butchery, churches, and the community.

3.4. The scale of farming, land ownership, and access to electricity

The frequencies and their associated percentages of farm type,

land ownership and access to electricity are shown in Table 2. Most of the SPbLF practised small scale farming (99%). With regards to land ownership, it was observed that livestock farmers do not own the land (99%) and their livestock grazed/browsed on communal land. The luxury of partitioning the land into different livestock enterprises such as planting pastures or mixed farming becomes a pipe dream for SPbLF. Livestock is more likely to experience a shortage of feeds due to exposure to drought and shortage of rainfall. The majority (97%) of farmers had access to electricity in their houses however, most of the livestock farmers (85%) indicated non-electrification in their farms as they practice their farming on communal land. Electricity allows access to information through TV media and telephone.

Table 2: Frequencies and percentages of farm type, land ownership and access to electricity on the farm

	Frequency	Per cent
Farm type		
Small scale	361	98.9
Large scale	4	1.1
Total	365	100

Land ownership where livestock graze/browse		
Own	2	0.6
Lease	1	0.3
Communal	362	99.2
Total		
Access to electricity in the house?		
No	10	2.7
Yes	355	97.3
Total	365	100
Access to electricity on the farm		
Yes	53	15.3
No	293	84.7
Total	346	100

3.5. Perceptions and experience on environmental factors affecting pasture-based livestock production

The main environmental challenges greatly affecting livestock production are listed in Table 3. Grazing (> 66%) was mentioned as the main environmental challenge, affecting cattle, sheep, and goats followed by temperature, pests and diseases, rainfall, and water. The forage quality and quantity available for grazing livestock in the current study seemed to be affected by the combination of increased temperature and lack of rainfall (water).

Table 3: Frequencies & associated percentage of the SPbLF perception of main environmental challenges greatly affecting livestock Production.

	Cattle	Sheep	Goats	Chickens	Pig
Rainfall	11 (3.0)	2 (11.1)	8 (4.8)	5 (5.2)	2 (4.8)
Temperature	38 (10.4)	2 (11.1)	31 (18.7)	31 (32.0)	11 (26.2)
Grazing	279 (76.9)	12 (66.7)	118 (71.1)	18 (18.6)	2 (4.8)
Pests & diseases	27 (7.4)	2 (11.1)	6 (3.6)	1 (1.0)	18 (42.9)
Lack of water	8 (2.2)	0	3 (1.8)	0	(21.4)

3.6. Perceptions and experience on socio-economic challenges affecting pasture-based livestock production

Table 4 shows the socio-economic challenges faced by SPbLF. Lack of grazing/feeds seems to be consistently the main socio-economic challenge faced by SPbLF for Cattle (91%), Goats (92%), and chicken (44%), respectively. Other socio-economic factors listed by few livestock farmers included lack of shelter, poor extension, theft, lack of knowledge and farm labour. It was interesting to note that the pig farming SPbLF mentioned poor extension as their main socio-economic challenge through lack of feeds (24%) was their second challenge. Corroborating the environmental challenge of chicken farming SPbLF mentioned as the temperature in Table 3, the second socio-economic challenge for the poultry farmers was shelter (17%). It was important to note that beyond the mention of feeds as the main socio-economic challenge for most of the livestock, the number of SPbLF associated with the other challenges was extremely small.

Table 4: Frequencies (N) and respective percentages (%) of main socio-economic challenges faced by farmers for each enterprise

Challenges	Cattle		Goats		Chickens		Pig	
	N	%	N	%	N	%	N	%
Lack of feed	330	90.9	151	92.1	43	44.3	10	27.0
Lack of shelter	3	0.8	8	4.9	16	16.5	5	13.5
Poor extension	9	2.5	1	0.6	12	12.4	15	40.5
Theft	12	3.6	2	1.2	3	3.1	3	8.1
Lack of knowledge	8	2.2	2	1.2	15	15.5	3	8.1
Other	0	0	0	0	8	8.2	1	2.7
Total	362	100	164	100	97	100	37	100

3.7. Perceptions and experience of SPbLF on the impact of fodder on livestock production

Sources of Grazing

The sources of grazing or feed for livestock are shown in Table 5. The study showed that SPbLF reported 97%, 75%, and 59 % communal grazing (97%), bought in feeds (75%) and crop residues (59%), respectively, as sources of grazing or feed for livestock. Few of the SPbLF fed their livestock agro-processing by-products (25%) and own crop harvest (35%). It follows logically that the exposure to climate change led them to supplement feeds when the grazing becomes scars. Almost 100% of the livestock farmers did not receive government support in terms of feeds for livestock. The assessment of the condition of communal grazing status by the SPbLF was rated as average (55%) and bad (43%), respectively.

The benchmark used for poor grazing conditions was mainly the indicator of less grass cover with bush encroachment. This was due to a combination of overgrazing, poor livestock management and drought condition.

Table 5: Frequencies and associated percentages on sources of grazing for livestock

	Yes		No	
	Frequencies	%	Frequencies	%
Communal grazing	350	96.7	12	3.3
Private pastures/leys/fallows	27	9.2	265	90.8
Crop residues	184	59.4	126	40.6
Bought in feeds	239	74.7	81	25.3
Agro –processing by-products	72	24.7	219	75.3
Government support	14	4.8	280	95.2
NGO support	12	4.1	283	95.9
Own crop harvest	106	34.8	199	65.2
Other	13	5.2	238	94.8

Reasons for the increase and decreases in herd sizes

Table 6 shows the frequencies & associated percentages of reasons for the increase and decrease in herd size in recent 2 years and the last 10-20 years. Most of the SPbLF indicated a natural increase (calving, lambing, or farrowing) as the main reason for the increase in a herd, drove and flock sizes (Table 6). The highest increase was for pigs mainly due to their reproductive character of litters with 91 per cent followed by goats with similar fecundity with 88 per cent and cattle with 82 per cent. Fowls as birds are at 68 per cent. The same trend was observed even in the last 10 to 20 years of recall by SPbLF. Other reasons cited by a few SPbLF for the increase were purchased (buy-in), donations and receiving a dowry. The main reason for the decrease in livestock followed the same trends like the increase. The highest reason to reduce their herd drove and flock sizes in the recent two years were mainly selling or slaughtering. Goats were the highest at 73 per cent of the SPbLF which reduced numbers through selling and slaughtering followed by pigs at 67 per cent and cattle at 54 per cent. The disparity between goats and pigs may be attributed to the religious restrictions in the communities against the consumption of pork. Proportionally, 26 per cent of the SPbLF in the recent two years and 22 per cent in the last 10-20 years reported drought as the reason for the decrease in cattle.

Table 6: Frequencies & associated percentages of reasons for the increase and decrease in herd size in recent 2 years and last 10-20 years

	Cattle	Goats	Pigs	Fowls
Increase in recent 2 years				
Purchased (buy in)	21 (11.9)	7 (7.7)	2 (6.1)	9 (22.0)
[1]Natural Increase	144 (81.8)	80 87.9)	30 (90.9)	28 (68.3)
[2]Other reasons of increase	11 (6.2)	2 (4.1)	0	4 (9.8)
Increase in the last 10- 20 years				
Purchased (buy in)	7 (5.0)	4 (6.2)	17(85.0)	2 (7.4)
[1]Natural Increase	121(85.8)	55 84.6)	0	25 (92.6)
[2]Other reasons of increase	13 (9.2)	6 (9.2)	3 (15)	0
Decrease in the recent 2 years				
Disease related death	21 (15.22)	3 (9.1)	2 (22.2)	10 (47.6)
Drought related death	36 (26.1)	4 (12.1)	1 (11.1)	3 (14.3)

Sold/slaughtered	75 (54.3)	24 72.7)	6 (66.7)	8 (38.1)
[3]Other reasons of decrease	6(4.3)	1 (3.0)	0	0
Decrease in the last 10- 20 years				
Disease related death	20 (15.7)	9 (20.5)	2 (13.3)	6 (24.0)
Drought related death	28 (22.0)	9 (20.5)	2 (13.3)	6 (24.0)
Sold/slaughtered	70 (55.1)	25 56.8)	11 (73.3)	9 (36.0)
[3]Other reasons of decrease	9 (7.1)	1 (2.3)	0	4 (16)

[1]Natural Increase refers to calving/lambing/farrowing

[2]Other reasons for increase refer to donation/received form dowry/ good management

[3]Other reasons for the decrease refer to theft/ paid dowry/ predation/ weather

3.8. Perception of the impact of climate change on livestock production

The SPbLF perception on the impact of climate change is indicated in Table 7. Perceptions of the impact of climate change on livestock production were based on SPbLF observation of less grass in pastures, drying streams, an outbreak of diseases, death of livestock due to excessive heat or cold, shortage of feeds, drinking water and unknown disease and floods. Most SPbLF believed that less grass in pastures (91 %) and drying of river streams (34 %) were due to climate change. Only 20% of SPbLF perceived that the death of their livestock was due to floods, while 39.9 % of the smallholder farmers believed that their livestock died due to lack of drinking water. Because of the unfeasibility of movement of swine during a flood, the number of swine losses was the highest of any livestock species. Droughts and floods are recurring environmental challenges in several rural communities across the country. Few SPbLF believed that there were outbreaks of diseases (24%) and death of livestock due to an unknown disease (29.2%).

Table 7: Frequencies and their associated percentages of the SPbLF perception of the impact of climate change on livestock.

Perception of the impact of climate change on livestock	Frequencies and (Percentages)	
	Yes	No
Less grass in pastures	332 (90.71)	34 (9.29)
Less shrubs in pastures	109 (29.78)	257 (70.22)
New grass species invasion of pastures	3.0 (0.82)	363 (99.18)
New shrubs invasion of pastures	8.0 (2.19)	358 (97.81)
Drying streams	123 (33.6)	243 (66.4)
Raising of exotic breeds	14 (3.83)	352 (96.17)
Outbreak of livestock diseases	88 (24.0)	278 (76.0)
Increase in parasitic populations	71 (19.4)	294 (80.6)
Death of livestock due to heat stress/ cold	127 (34.7)	239 (65.3)
Death of livestock due to shortage of feeds	202 (55.19)	164 (44.81)
Death of livestock due to shortage of drinking water	146 (39.89)	220 (60.11)
Death of livestock due to unknown diseases	107 (29.23)	259 (70.77)
Death of livestock due to floods	74 (20.22)	292 (79.78)

3.9. Perceptions and experience of SPbLF on water resources and water use

Perceptions and experience of SPbLF on water resources

Frequencies and their associated percentage of the main source of water for each type of livestock are illustrated in Table 8. Most of the SPbLF indicated that river streams as the main source of water for cattle and donkeys. Whereas tap water and borehole were equally shared by sheep and goats as the sources of water. Tap water was reported as the main source of water for chickens (61%) and pigs (67%).

Table 8: Frequency and respective percentages of SPbLF using a different source of water for livestock types

Source of Water	Cattle		Goats		Chickens		Pig	
	Number	%	Number	%	Number	%	Number	%
Dam	35	9.7	3	1.9	3	3.1	3	7.1
River	237	65.4	12	7.2	2	2.1	1	2.4
Tap water	23	6.4	82	49.4	59	60.8	28	66.6

Borehole	65	18.0	68	41	31	32.0	8	19.1
Other	1	0.3	1	0.5	2	2.1	1	2.4
Total	361	100	166	100	95	100	41	100

It was also noted that few farmers (<10%) reported that their cattle, sheep, goats, pigs, and chickens had access to the dam as the source of water. The change in rainfall frequency and amount, and subsequent depletion of the water resources are some of the classical impacts of climate change. When SPbLF were requested to give their perceptions and observations on the drying of the streams, two-thirds of the farmers (66%) indicated that they have not observed anything along with the drying of the streams in the last decade and a third (33%) affirmed to the depletion of the water in the streams.

Livestock and distance travelled to furthest water sources

The percentage and frequencies of the distance travelled by livestock to drink water are presented in Table 9. Livestock drank water at the household were reported to be (35%) while some travelled < 1 km (27%), 1-5 km (36%) and 6-10 km (2%) for water. Sources of water for livestock are shown in Table 9, where 41.3%, 40.4% and 32.8 % of the livestock farmers used river, municipal/piped water, and borehole, respectively, as the sources of water for their livestock. Only 2.5 % and 7.4 % of the farmers used water wells and dams/ponds, respectively as the water sources for livestock.

Frequencies & respective percentages on distance travelled to furthest water Source

Category	Frequency	Percent
At household	126	34.9
<1km	98	27.1
1-5 km	130	36.0
6-10 km	7	1.9
Total	361	100

Livestock Categories and distance travelled to water sources

Table 10 shows the percentage of enterprises per household that travelled a distance to a water source. When farmers were asked to give the distance to a water source for each enterprise (Table 10), the majority of SPbLF (>79%) indicated that sheep, goats, chickens, and pigs drank water in the household. Cattle seemed to get water at the household and travelled up to 10 km to access water. The recommended benchmark is four kilometres.

Table 10: Frequency & respective percentages of SPbLF & corresponding distance their livestock travel to a water source

Enterprise	Cattle		Goats		Chickens		Pig	
Distance	Number	%	Number	%	Number	%	Number	%
At household	87	23.9	131	78.9	83	88.3	38	92.7
<1 km	103	28.3	27	16.3	9	9.6	1	2.4
1-5 km	107	29.4	8	4.8	2	2.1	2	4.9
6-10 km	65	17.9	0	0	0	0	0	0
>10 km	2	0.5	0	0	0	0	0	0
Total	364	100	166	100	94	100	41	100

Smallholder Pasture-based Farmer's experience & perceptions on sustainable & effective water use

Table 11 shows the frequencies of SPbLF perception on the sustainability of the water system in the eco-system. Most farmers (60 per cent) believed water use was moderately managed for long term sustainability. Only 11 per cent of the farmers were of the view that water use in their communities was sustainably managed. On the contrary, 13 per cent of the farmers had a view that water resources were very poorly managed for long term sustainability.

Table 11: Frequencies and respective percentages of SPbLF and livestock water use

Sustainability of Water Use	Number	%
Very Poor	48	13.1
Poor	57	15.6
Moderate	219	59.8
High	40	10.9

TOTAL	364	100

Perception and experience of SPbLF on the effectiveness of water use Table 12 shows the major constraints to effective water use. The major constraint was identified as salinity by 61 per cent of the SPbLF. The cost of accessing water was identified by 15 per cent of the farmers whereas shortage and or access was identified by 13 per cent of SPbLF.6

Table 12. Frequencies & respective percentages of SPbLF perception on constraints on effective water use

Constraints of Water Use	Number	%
Salinity	224	61.2
Shortage / Access	46	13.0
Conflicts	18	5.0
Costs	56	15.3
Total	345	100

4. DISCUSSIONS

This is the first interprovincial study that was conducted factoring the five identified agro-ecological zones of Limpopo and about four in Mpumalanga. The study inculcated the connection between climate attributes and the perception of the farmers on these attributes on their livestock production. The engaged SPbLF were located within the two provinces, districts, local municipalities, villages and then households. In terms of the context of the Communal Pastoral Landscapes (CPL) in the study area: Limpopo Province has 30 per cent of the land area under CPL whereas the land under CPL is about 46 per cent in Mpumalanga. The two provinces contribute to the CPL nationally which constitute around 12 to 13 % of the land surface area carrying about half of the total grazing animals (Rootma, *et.al.,* 2015; Notenbaert, *et. al.,* 2010). About 80 – 86 per cent of these CPL can only be used for grazing with only 14 per cent used for arable production (Bembridge, 1987).

4.1. Climatic Variability and vulnerability analysis

The study area is climatically classified as an environmental risk area, owing to erratic rain-fed and/or insecure sources of irrigation on which the production systems are dependent (Rust, *et.al.,* 2013). The prevailing environmental conditions in the context of 85 per cent semi-arid, in the study area, are postulated to have far-reaching implications under climate change (DEA, 2013). This postulated implication is said to include the impacts of reduced water availability, and an increase in the occurrence of vector and waterborne diseases.

Also, as the prevalence of incidence of invasive species, the decline in crop and livestock productivity, and many others related to human-wellbeing (Rust, *et.al.,* 2013). Most of this will be attributed to the direct impacts of an increase in temperature regimes.

The climate analysis indicates that the rainfall is projected to increase mostly in the western parts of the study areas, this is due to the selected or representative climate model showing a wetter climate than the present condition. According to Mpandeli, *et.al.,* (2014), the study area is characterized by high climatic variability. This is the main challenge because the area is a semi-arid area with low, unreliable rainfall. The impact of lower rainfall has negative effects on the agricultural sector, low rainfall results in decreases in agricultural activities, loss of livestock, shortage of drinking water, low yields, and shortage of seeds for subsequent cultivation (Mpandeli, *et.al.,* 2014).

The exposure index, as shown in Figure 7, under present climate conditions suggests that there is a high vulnerability, which is climate-based, over most of the AEZs and very high vulnerability concentrated mainly along the northern border. The mid-century vulnerability projections suggest a reduction in the exposure index too high. The reduction in vulnerability along the northern border is due to the global climate model projecting a future that is wetter than the present, this is a median of the future projections.

This climate analysis indicates that the study area is already under high vulnerability to climate, which is most likely to increase with an increase in temperature as projected by all the (IPCC, 2007), climate models. Recent studies, particularly in southern Africa, are suggesting that the projected climate change is already being felt or would be experienced in the region near to the mid-century earlier than the projected the year 2100 (Leclere, *et.al.,* 2014). This is said to require transformational adaptation measures, of which Pelling (2011), states that it would be in response to adverse risks and vulnerability that may require significant and permanent transformation. Transformation from other production systems to livestock and/or rangelands has been suggested as one of the likely pathways to be adopted (Otieno, *et.al.,* 2016). In South Africa, there has been a shift to game farming and livestock production. This study on livestock would contribute significantly toward adaptation studies and efforts in the region.

4.2. Agro-ecological mapping of water resources in the study area

An evaluation of the location of SPbLF in relation to the three major resources of water mainly rivers, boreholes and piped municipal water helps in the improvement of access and use. The SPbLF were distributed throughout the two provinces, however, their density was variable. Most SPbLF were clustered throughout the study area and conformed to the microclimatic regions that experience high rainfall. The study area experienced two rainfall seasonality, i.e., early summer and mid-summer mostly in December and January respectively, (Schulze 2007). The SPbLF are exposed to the impacts of climate change despite their proximity to the streams. This is particularly because most of the streams were periodic, meaning they only flow water during summer. Furthermore, one of the most prominent impacts of climate change in the context of South Africa is the increasing frequency of drought and floods. These imply that some prevalence of the periodic streams is likely to increase. On the other hand, the proximity to the streams implies that they are prone to washing ways during floods.The results of the study indicated that there was variability in the borehole density between the two provinces which indirectly signifies the variance in the surface water resource. The aridity nature of most parts of the study area compelled the SPbLF and other water users to turn their focus to groundwater resources. The abundance of the groundwater resources indirectly suggests that the farmers are to a particular level not exposed to the impacts of climate change.However, all sectors of the economy may also hypothetically be turning to groundwater resources. Exposure to SPbLF may also be the unsustainable management of the underground aquifer. In the unfortunate event that this unfolds, the farmers will be exposed to the predicament impacts of climate change.

4.3. Livestock categories, objectives of keeping livestock and market

The profile of the SPbLF was similar to the rest of the African continent farmers who are known to keep cattle as an insurance policy for when droughts ruin annual crops [Swinton, 1988, Fafchamps, *et.al.*, 1998; Otieno, *et.al.*, 2016). It has been observed in South Africa that livestock has the potential to become micro-businesses, particularly in rural areas. Most of the SPbLF kept livestock for meat, cultural, ceremonies, cash or sales, and manure. Similar reasons for keeping livestock were also reported by (Nthakheni, 2006; Musenwa, *et.al.*, 2007; Goni, *et.al.*, 2018). It was noted that only 19 % of the farmers kept livestock as an investment. Households with livestock were more resilient to climate change (Nkonde, *et.al.*, 2014) since they would sell them in the event of financial shock and food shortage, thereby reducing vulnerability. The results of the study indicated that most of the decrease in numbers in the recent two years and the past 10 to 20 years was due to selling and slaughtering for local community markets. In the context of the study, livestock can be assumed to be both financial, as well as social capital. It is financial capital in the shape of insurance, cash, saving, credit, and gifts. It is social capital as it symbolizes wealth and prestige, and is linked to tradition, identity, friendship, respect, and festivity. Practically it is a feature of rural households to see livestock because they contribute to the income, food supply, soil productivity, and agricultural traction, legal land ownership also allows one access to agricultural credit and proving legal ownership of the land accelerates the process of obtaining public credits and acts as a guarantee for personal credits (Lindoso, *et.al.*, 2014).

4.4. The scale of farming, land ownership, and access to electricity

The SPbLF in this study were small-scale, farming communally with access to electricity in their households. It was the assertation by (Lindoso, *et.al.*, 2014) that the percentage of the population devoted to smallholder farming is a good sensitivity indicator. In most cases, they can't respond to climatic influences due to their socio-economic and ecological conditions. The specific socio-political situation in South Africa, where past agricultural policies persistently marginalized small-scale black farmers by curtailing their access to resources such as land, water, credit, and technical know-how (Coetzee, *et.al.*, 1992; Kirsten, *et.al.*, 1998; Shackleton, 1993). This is a further indication of the increased sensitivity of South Africa's SPbLF to climate change. It is well known that farmers with large landholdings stand a better chance of diversifying their farming practice to adapt to climate change than those with small landholdings. Landless households are mostly affected by climatic shocks (Senbeta, *et.al.*, 2009). The use of communal grazing by SPbLF makes them more vulnerable to climate change with less adaptive capacity because of their dependence on climatic conditions and the natural resource base. Wani, et.al., (2009), reported that rain-fed agricultural systems dominate much of tropical agriculture and are extremely vulnerable to climate change. A significant proportion of the SPbLF used crop residues (59%) and bought in feeds (79%).

Rovere, *et.al.*, (2009), made observations that agricultural systems that depend entirely on crops are at great risk of collapse. The access to electricity in their SPbLF households gives them some leverage to have some adaptive capacity in terms of access to key information and to collectively self-organize (Jones, *et.al.*, 2011).

4.5. Perceptions and experience on environmental and socio-economic factors affecting pasture-based livestock production

Grazing was mentioned as the main environmental challenge, affecting cattle, sheep, and goats followed by temperature, pests and diseases, rainfall, and water. The forage quality and quantity available for grazing livestock in the current study seemed to be affected by the combination of increased temperature and lack of rainfall (water). Temperature affects most of the critical factors for livestock production such as water availability, animal production, reproduction, and health (Roitberg, et.al., 2016). An increase in temperature between 1 and 5 ºC might induce high mortality in grazing cattle Howden, *et.al.*, 2008) and as a mitigation measure, they recommended sprinklers, shade, or similar management to cool the animals. Farmers (43%) mentioned pests and diseases as the environmental challenges affecting pigs. Several livestock health problems related to climate change have been reported (Nardone, *et.al.*, 2010). Lack of feeds was reported by most farmers (>90%) as a socio-economic challenge faced by cattle, sheep, goats, and donkeys. Other socio-economic factors listed by few livestock farmers included lack of shelter, poor extension, theft, lack of knowledge and farm labour. Corroborating the environmental challenge of chicken farming SPbLF mentioned temperature with their second socio-economic challenge shelter. Recent studies, particularly in southern Africa, are suggesting that the projected climate change is already being felt or would be experienced in the region near to the mid-century earlier than the projected the year 2100 (Leclere, *et, al.,* 2014). This is said to require transformational adaptation measures, of which Pelling, (2011), states that it would be in response to adverse risks and vulnerability that may require significant and permanent transformation. Transformation from other production systems to livestock and/or rangelands has been suggested as one of the likely pathways to be adopted (Otino, et.al., 2016). In South Africa, there has been a shift to game farming and livestock-game productions.

4.6. Perception and experience of SPbLF on the impact of climate change on fodder and livestock production

The perception and experience of SPbLF were that there is less grass and drying of rivers and streams. The climate change impact on livestock production is believed to be in two ways, direct and indirect. The most significant direct impact of climate change on livestock production comes from the heat stress (Seijan, *et. al.,* 2016), while most of the production losses are incurred via indirect impacts of climate change largely through reductions or non-availability of feed and water resources. The potential impacts on livestock include changes in production and quality of feed crop and forage (Polley, *et.al.,* 2013; Thornton, *et.al.,* 2009), water availability (Henry, *et.al.,* 2012), animal growth and milk production (Henry, et.al., 2012), diseases (Nardone, *et.al.,* 2010; Thornton, *et.al.,* 2009), reproduction (Nardone, *et.al.,* 2010), and biodiversity. It is believed that livestock production and productivity will be one of the most susceptible sectors to climate change due to changes in the hydrological cycle, temperature balance and rainfall patterns which have a negative impact on livestock production and productivity (Mwiturubani, 2010). The increasing temperature may also increase the exposure and susceptibility of animals to parasites and diseases (Marcogliese, *et.al.,* 2001; Sutherst, 2001), especially vector-borne diseases (Tabachnick, 2010). The effects of climate change on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility (Thornton, *et.al.,* 2009). Droughts and floods have been commonly experienced in many parts of Africa South Sahara, especially around the Horn of Africa and the Sahel (Kotir, 2010). Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes (Thornton, *et.al.,* 2009). The capability to develop adaptations and survive extreme conditions becomes more difficult as the disturbance becomes increasingly more unpredictable and severe, as shown by both theoretical and empirical studies (Colinet, *et.al.,* 2015; Roitberrg, *et.al.,* 2016). In the livestock farming sector, it is important to identify areas that are prone to heavy flooding, as this will be crucial information for farmers to decide whether livestock farming should be continued in those areas.

4.7. Perception and experience of SPbLF on water resources and use

The main source of water in the study area was the river system mainly attributed to the grazing fields that are outside of the residential area. The provision of municipal/piped water and borehole infrastructure was a good intervention by the government. However, the over-reliance of the farmers on the river implies that they are highly exposed to climatic extremes. This is partly because; Limpopo and Mpumalanga Provinces are spatially confined to the arid to semi-arid climatic configurations (Mpandeli, *et al.,* 2014). These zones receive low rainfall that is exclusively experienced in summer and endure dry winter (Mpandeli, *et al.,* 2014). Subsequently, there are minor perennial streams. This implies that the livestock is highly exposed to climatic extremes, especially during extended spells of dry seasons. On the other hand, municipal water is insufficient for the sustenance of domestic needs and is often interrupted by mechanical failures and breakdowns. An attempt to install the prepaid water system could not be affordable for livestock being reliant on surface water supply prone to drought. Most of the SPbLF indicated that sheep, goats, chickens, and pigs drank water in the household. Cattle seemed to get water at the household and travelled up to 10km. Pratt, *et.al.,* (1977) recommended 4 km for cattle without stress; the maximum distance for small livestock was 15 km, and 30 km was the maximum distance for livestock at stress levels. Although 30 km is the distance livestock must walk during water scarcity periods, cattle and small stock will normally graze up to 10-15 km away from a water source (MOA and LD, 2002). The SPbLF perception on the sustainability of the water system in the eco-system indicated that water use was moderately managed for long term sustainability. Only 10.9 per cent of the farmers were of the view that water use in their communities was sustainably managed. On the contrary, 13 per cent of the farmers had a view that water resources were very poorly managed for long term sustainability. The major water uses constraints identified by SPbLF were salinity, cost of accessing water and shortage and or access to water.

Coping strategies to deal with climate change

Coping strategies/adaptation measures involve production and management system modifications, breeding strategies, institutional and policy changes, science, and technology advances, and changing farmers' perception and adaptive capacity [Rowlinson, *et.al.,* 2008; USDA, 2013). SPbLF employed various strategies that are largely dependent on the perception, level of education and affordability tied to their levels of income (Ndamani, *et.al.,* 2015). The following were found to be the coping strategies of smallholder farmers:

Governance at Village Level

Village community members together with SPbLF formed intra-village committees – each village has an umbrella committee of eight people. The subcommittees are then also formed that deal with specific issues on Livestock, Rain-fed crops, Irrigation Schemes, Water, and in certain areas Land Care and Seed Multiplication. In the formation of these committees, there is a greater consciousness to include women and youth, though some villages have specific Women and Youth committees. In the main, the sub-committees manage and collaborate between villages on matters relating to natural grazing, source of water and theft. Two members of the sub-committees are nominated to represent a village in the inter-village committees on Livestock, Rain-fed crops, Irrigation Schemes, Water and Theft.

Drought Coping Strategies

SPBLF reported taking different types of adaptation measures to deal with climate change. During high temperatures livestock farmers provide water for livestock, allow livestock to graze near the river, water stored in containers, use boreholes, provision livestock feeds, and supplements, sell livestock to buy feeds supplements and livestock stay inside when temperatures are high.

Flood – heavy Rains Strategies

During floods, SPbLF provides medication, dip, shelter, store water using containers and dams, irrigate using river water, avoid grazing during rain and provide feed supplements.

Long term Strategies

The local governance committees at the village level have long term plans to deal with climate extremes. (a) Despite the gross lack of knowledge, awareness, sources of funding, land and markets, there is a growing realization by SPbLF that they should spare part of their rain-fed land and irrigation scheme to grow their fodder; (b) Central to these strategies is also disjointed access to weather-related information (Early Warning System) and cooperation between farmer groups and or committees with agricultural extension services. (c) The power of many that come with the formation of committees helps SPbLF to mobilise support from Traditional Leaders, Municipal Councillors and Municipal Officials on Local Economic Development projects such as roads, dams, boreholes, and other community needs related to service delivery.

5. CONCLUSIONS

Smallholder Pasture-based Livestock Farmers (SPbLF) have the potential to create thriving enterprises within rural communities. The main objective of keeping livestock is for meat production, cultural ceremonies, cash, and manures. Natural increase (calving, lambing, or farrowing) is the main reason for the increase in the recent 2 and last 10-20 years and selling or slaughtering was the main reason for the decrease in livestock for the last 10-20 years. SPbLF is situated in areas that conform to the microclimatic regions that experience high rainfall. Purposefully for their locations, the main source of water is the river system. The main environmental challenges affecting livestock are drought, lack of grazing, heat stress, pest, diseases, and lack of water. The municipal/piped water together with boreholes was found to be the second and third level stream for farmers to access water. Municipal piped water to farmer's households was critical to supply small-stock, chickens, and pigs within homesteads. Cattle seemed to get water within 10 km mainly to the river sources which are within the recommended 30 km distance for livestock to avoid stress levels. Most SPbLF accessed fodder from communal grazing. It follows logically that the exposure to climate change led them to buy feeds when the grazing becomes scarce. Even with the use of crop residues and own crop harvest grazing was found to be the biggest challenge for large stock (cattle) and small stock (sheep). In this regard SPbLF Smallholder farmers reported taking different types of adaptation measures to deal with climate change like provision of water, allowing livestock to graze near the river, water storage, provision of feed supplements and selling of livestock to buy feeds. For sustainable socio-economic well-being of smallholder farmers and to adapt to changes in geo-climatic conditions, intensive production systems are proposed. Based on the findings of the study, it was recommended that: (1) early warning information be interpreted and regularly presented to SPbLF for them to timeously be aware of pending weather patterns, (2) livestock reduction is encouraged for seasons when the adverse climate is anticipated (especially droughts in which both water and grazing tend to be scarce), (3) earth dams be constructed to harvest flood water at strategic catchment points (accessible to livestock farming villages) for use in times of scarcity, (4) Heat and drought tolerant breeds of livestock be promoted especially for areas that have high aridity indexes.

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