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A framework to monitor and evaluate the vulnerability of smallholder livestock farmers: a case study of Limpopo & Mpumalanga Provinces

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Abstract. A study was carried out to assess the level of vulnerability of smallholder livestock farmers to provide appropriate support response to the changing climate. Central to the investigation was to develop a monitoring and evaluation framework with SMARTT indicators in the design, planning, implementation, assessment and evaluation of the vulnerability of smallholder livestock farmers. Fieldwork was conducted in both Limpopo and Mpumalanga provinces. Only Vhembe and Gert Sibanda District Municipalities were chosen based on the proximity and convenience of having Smallholder Livestock Farmers that were organized and within reach to the investigators. The sampling frame consisted of a database of village households owning livestock in Vhembe (4 municipalities) and Gert Sibande (7 municipalities) districts. Data was collected through a descriptive survey using structured questionnaires, observations, and interviews from individuals and focus groups. A structured questionnaire was developed where respondents were interviewed each being asked a standard set of questions posed in the same way each time. At least 469 small-holder farmers were interviewed using a semi-structured questionnaire to elicit responses on vulnerability. The questionnaire included among others demographic and economic household characteristics; livestock and crop production; access to extension services; credit access; hazards occurrence; adaptations strategies pursued; coping strategies; the level of resilience and other information as indicated in the methodology. This paper presents a theoretical and conceptual M&E framework while also positing that if such a framework is mainstreamed, it will enhance impact and outcomes. Informed by Lindoso (2011) the Framework for vulnerability assessment and adaptive response of smallholder livestock farmers, had three main attributes, namely: exposure, sensitivity, and adaptive capacity. Exposure as an attribute of vulnerability was the magnitude and frequency of the climate stimuli and was considered as an external property of socio-ecological systems. Indicators were developed under the thematic areas of aridity, drought, temperature, precipitation, wind and vegetation. Sensitivity was referred to as the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances. The proposed thematic areas in which indicators were developed were involvement in smallholder livestock farming (%), access to water by both farmers (%) and livestock (%), distance to water sources by both SHF (%) and livestock (%), quantity & frequency of water – availability (%) and quantity (litres/ capita/ day), livestock water use efficiency (m³/annum), livestock production systems.

Adaptive capacity was referred to as the 'ability of socio-ecological systems to administer, accommodate, and recover from eventual environmental disturbances; it was assumed to be a function of wealth, technology, education, information, skills, and infrastructure, access to resources, and stability and management capabilities. He proposed thematic areas identified were demography of livestock farmers, product diversification, capacity building, access to electricity and financial support. Demographic factors had different influences on the capacity of smallholder livestock farmers to adapt to adverse effects of climate change and variability on the farming enterprises. An ideal SHAE should be one with a matric, have experience in the hands-on production of a particular commodity such as beef cattle, have received training in the commodity value chain and is not older than 60 years.

Keywords. adaptability, exposure, sensitivity, vulnerability

1. Introduction

Vulnerability can be defined as the susceptibility of human systems to natural phenomena and is frequently associated with specific losses or damages (Morton 2007). Ncube et al. (2016) define vulnerability as the extent to which one is prone, at-risk or likely to be food insecure. As further indicated by Ncube et al. (2016), vulnerability has two sides, namely: (i) an external side with risks, shocks and stress to which an individual is subject, and (ii) an internal side with a lack of means with which to cope when facing loss.

Vulnerability is most often associated with poverty but can also arise when people are isolated, insecure and defenceless in the face of risk, shock or stress (Birkman, 2006). Gbetibouo & Ringler (2009) conceptualized vulnerability as a state that exists before encountering a climatic shock. In general, climate change researchers agree that vulnerability is determined by the level of exposure to an event or impact and the corresponding adaptive capacity (IPCC, 2001; Yohe and Tol, 2002). However, beyond exposure, there has to be a level of sensitivity for vulnerability to occur. Vulnerability is a state or a process, rather than a set of biophysical impacts arising from a particular event (Adger et al., 2004; O'Brien et al., 2004) while adaptive capacity is the ability of a system to adjust to or cope with, stress (Adger and Vincent, 2005; Brooks et al., 2005; Luers et al., 2005). Therefore, vulnerability can be summarized as a function of three attributes, exposure, sensitivity, and adaptive capacity.

1.1 Exposure

Exposure relates to the degree of climate stress upon a particular unit of analysis; it may be represented by either long-term changes in climate conditions or climate variability, including the magnitude and frequency of extreme events (O'Brien et al., 2004). Exposure can be interpreted as the direct danger (i.e., the stressor), and the nature and extent of changes to a region's climate variables (e.g. extreme weather events that may associate with factors such as temperature and precipitation). Exposure as an attribute of vulnerability is linked to the type, magnitude and frequency of the climate stimuli (Smithers and Smit 1997), and is sometimes considered as an external property of socio-ecological systems (Gallopín 2006).

1.2 Sensitivity

Sensitivity is the extent to which a body is either adversely or beneficially, directly or indirectly affected by climate change and variability (IPCC, 2007). Sensitivity emerges from the interface between climate events and socio-economic systems, reflecting the susceptibility of a system to certain disturbances (Finan and Nelson, 2001). Sensitivity describes the human-

environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact. Gallopín (2003) referred to sensitivity as the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances. This measure, which herein reflects the responsiveness of a system to climatic influences, is shaped by both socio-economic and ecological conditions and determines the degree to which a group will be affected by environmental stress (SEI, 2004; Turner et al., 2003).

1.3 Adaptive capacity

Adaptive capacity is considered “a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities” (McCarthy et al., 2001, p. 8). The number of livestock owned, ownership of radio and quality of residential homes are commonly used as indicators of wealth in rural African communities (Vyas and Kumaranayake, 2006). According to Smith and Lenhart (1996), countries with well-developed social institutions are considered to have greater adaptive capacity than those with less effective institutional arrangements. Wealth enables communities to absorb and recover from losses more quickly (Cutter et al., 2000). Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses or to cope with the consequences.

Adaptive capacity can be defined as the “ability of socio-ecological systems to administer, accommodate, and recover from eventual environmental disturbances” (Smit and Wandel 2006). In socio-ecological systems, it is linked to governance aspects that allow rapid transitions between options every time response to an environmental change becomes necessary (Smit and Wandel 2006; Adger et al., 2009; Holling and Meffe 1996). Therefore, the strengthening of institutions and organizational landscapes—social capital, legislation, information flows, resources, learning capacity, and accumulated knowledge—are vital to adaptation (Dietz et al., 2003; Eakin and Lemos, 2010). Adaptive capacity also relies on the availability of technical support to implement adaptive strategies and access financing mechanisms (Smit and Wandel, 2006; Jones and Boyd, 2011). Adaptive capacity is highly dependent on the capacity of farmers and their families to access key information and to collectively self-organize (Smit and Wandel, 2006; Jones and Boyd, 2011). Reading and writing are basic conditions for farmers to have the ability to access information available in written and electronic media and to use that information for the exercise of their citizenship, thus creating conditions for adaptation to climate change (O’Brien et al., 2004).

The objective of this report was to review thematic areas under each of the three attributes and existing indicators, and where necessary develop new indicators, based on Lindoso (2011) Framework on Vulnerability. The report will subsequently validate conclusions on the capacity to adapt to the adverse effects of climate change and climate variability.

2. Material And Methods

2.1. Study Area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively. Only Vhembe and Gert Sibanda District Municipalities were chosen based on the proximity and convenience of having Small Holder Livestock Farmers that are organised and within reach of the investigators.

2.2. Data Collection

Data was collected through a descriptive survey using structured questionnaires, observations and interviews from individuals and focus groups. A structured questionnaire was developed where respondents were interviewed each being asked a standard set of questions posed in the same way each time. Also, spontaneous questions were developed for interaction with the interviewee (Schulze, 2002). The structured questionnaire contained both open and close-ended questions. Close-ended questions collected quantitative data which were structured with less flexibility. At least 469 smallholder 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 & economic household characteristics; livestock and crop production; access to extension services; credit access; hazards occurrence; adaptations strategies pursued; coping strategies; level of resilience and other information as indicated in the methodology. The study adopted the Framework and or system by Lindoso (2011).

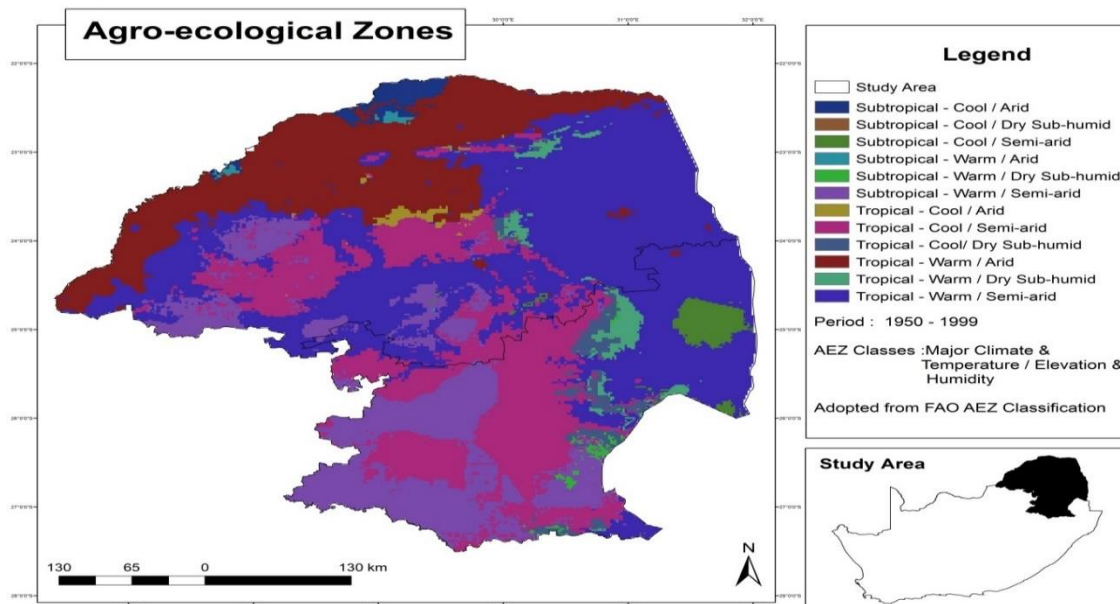


Figure 1. Agro-ecological zones of the Limpopo and Mpumalanga Provinces of South Africa (FAO, 1978)

The framework has three levels: (a) The first level (sensitivity) is the agro-productive system in which the family survival relies on the quality of production, (b) the second level (adaptive capacity) adopts the perspective of the agricultural establishments of the farmer and his family analysing the socio-economic and political institutions fragilities focusing on the local scale, and (c) the third level (exposure) deals with the experience of the said farmers to hazards.

To determine livestock water use efficiencies focus was on the sensitivity attributes. The main water-related indicators were around the source, access, use and distance to water by smallholder farmers and their households. The main sources of water assessed were homestead well, borehole, wetland, dam, and or stream. The distance to access such water resources were also be elicited and quantified. Based on previous studies the following assumptions for drought conditions were made: (i) that humans can travel a maximum of 5 km to fetch water in a day (being 10 km with the return journey); (ii) 10 km is the maximum distance for cattle to access

a water source. It was assumed that water sources exceeding a 5five km radius are beyond realistic reach for domestic water supplies, and hence are only available for livestock. A maximum distance to water should not exceed 15 km from any village. The second approach (b) was the use of secondary data from Provincial Departments of Agriculture, Land Affairs and Water Affairs. The study will utilize GIS facilities for spatial data analyses (Ormsby et al., 2001). The GPS mapping obtained point data on water sources will be matched with attribute data from records and reports.

GIS thematic maps were developed to show major water resources of the local district and villages showing the location of water sources and their types (springs, pans, dams, boreholes, wells and waterholes as well as derived maps of access to water. Other attributes of the local municipality of the village will be rainfall, land use-cover, drainage systems, hydrogeology and grazing potential.

2.2.1. The population of smallholder 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. Only the total number of households owning livestock in a particular village was available and not the individual household identities. The number of households sampled for the interview was 286 and 183 for Vhembe and Gert Sibande Local municipality respectively, a total of 469. The households were from 35 villages in the four local municipalities of the Vhembe district and seven local municipalities of the Gert Sibande district.

2.2.2. Sampling Procedure

Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and about four in Mpumalanga (shown in Figure 1). The 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 *PROC SUREVEYSELECT* allows the selection of probability-based random sampling where sampling in different categories or classes depends on the number of units within that class. It is appropriate for handling selection bias. 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.

2.3. Data Analysis

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

3. Results and Discussions

Informed by the Lindoso (2011) Framework for vulnerability assessment and adaptive response of smallholder livestock farmers, the presentation and discussion of results was under the three main attributes, namely: exposure, sensitivity, and adaptive capacity.

3.1 Exposure

Exposure as an attribute of vulnerability is linked to the type, magnitude and frequency of the climate stimuli (Smithers and Smit 1997) and is sometimes considered as an external property of socio-ecological systems (Gallopín 2006). Guided by Lindoso (2011) Framework, numerous thematic issues and indicators were proposed for inclusion under this attribute (Table 1).

Table 1 Exposure based thematic areas and indicators revised from the Lindoso (2011) Framework for the vulnerability of smallholder livestock farmers

Thematic area	Proposed Indicator
1. Aridity & drought	a) Aridity Index (AI)
	b) Drought
2. Precipitation	a) Annual Distribution of Rainfall (ADR)
	b) Floods
3. Temperature	a) Mean Annual Temperatures (MAT)
	b) Thermal Heat Index (THI)
4. Wind	a) Wind occurrence
5. Vegetation	a) Normalised Difference Vegetation Index (NDVI)

3.1.1 Thematic area: Aridity & drought

(a) Aridity Index (AI)

Aridity Index (AI) is a numerical indicator that denotes the degree of dryness at a particular location based on the ratio of evapotranspiration to precipitation (Derya, *et al.*, 2009). Maliva and Missimer (2012) defined aridity as a lack of moisture and the temporary reduction in the rainfall in an area, meanwhile, the increase in aridity represents a higher frequency of dry years over an area. Aridity indexes that are based on temperature and precipitation are commonly used all over the world (Baltas 2007; Deniz *et al.*, 2011; Croitoru *et al.*, 2013; Hrnjak *et al.*, 2013; Moral *et al.*, 2015).

Over 85% of the study area is recognized as semi-arid. The low mean annual rainfall and erratic precipitation pattern are the main factors that hinder farming in semi-arid regions. Only five per cent of the study area was found to be in sub-humid areas ideal agricultural zones. Farming in this area is possible with the sole dependence on rain-fed practices. However, this area is not immune to drought. The last 10% of the study area was aridly characterized by a severe lack of water resources to the extent of hindering the development of vegetation. Such a lack is exacerbated by the higher evapotranspiration compared to the rate of precipitation (Derya, *et al.*, 2009). Agricultural production in this category is impossible except for portions with irrigation. The study area, therefore, presents various levels of exposure of livestock farmers to adverse effects of aridity.

(b) Drought

Drought may be defined as an extended period of unusually dry weather with no rain or other precipitation. The majority (84%) of the livestock farmers revealed that the most imperative environmental challenges were the incorporation of drought, heat, and fires. Agricultural production flourishes under optimal production conditions. The intensification of the drought poses a greater challenge than what meets the eye, as the focal area is located in a sub-optimal potential area that is already water strained.

3.1.2 Thematic Area: Precipitation

(a) Annual Distribution of Rainfall (ADR)

Rainfall is the fundamental driving force and pulsar input behind most hydrological processes (Schulze, 1995). As affirmed by Kotir (2011), precipitation is one of the key determinant factors for livestock production in Sub-Saharan Africa because it is the sole source of water supply. It provides the water resource for drinking and plays a crucial role in rejuvenating the pastures (Omokanye *et al*, 2018). The mean total precipitation indirectly insinuates the state of the water resources in any given area (Omokanye *et al*, 2018).

Kala (2012) suggests that the amount of precipitation that a particular area experience dictates the nature of the agro-ecological setting that shall prevail. If an area receives a high amount of rainfall (more than 2500mm per annum), a rain forest is probably going to occur (Butler, 2005). On the other hand, if an area receives little rainfall that barely exceeds 400mm per annum, the area will be dry (Butler, 2005). This area experiences about 200mm per annum. There are localized microclimate zones that are arranged in a north-south direction that experience above 1000mm per annum. According to Sa Explorer (2017), Mpumalanga normally receives about 610mm of rain per annum, with most rainfall occurring mainly during mid-summer. The Province receives the lowest rainfall (8mm) in June and the highest (89mm) in January. As shown by Tshikolomo (2012), the annual rainfall for Limpopo Province is estimated at 604mm per annum (almost the same as for Mpumalanga) with the lowest rainfall received in July and August (7mm each) and the highest in February (109mm).

(b) Flood

Flood occurs when a river's discharge exceeds its channel's volume causing the river to overflow onto the area surrounding the channel, known as the flood plain. Land degradation and floods contributed 2.06% and 1.18% respectively of exposure to adverse effects of climate change and variability. Only 0.59 of respondents outlined those environmental issues related to floods do not affect them. The responses reveal that very few smallholder livestock farmers had the occurrence of floods as an issue of concern and make sense as the study area was described as predominantly arid and semi-arid. The views of the smallholder livestock farmers lament that the environment is bound to fail to support livestock farming, more especially under the smallholder farmers as they lack basic infrastructure, resources, and capital to condition the environment for edifying the production.

3.1.3 Thematic Area: Temperature

(a) Mean Annual Temperature (MAT)

There are spatial conformities between precipitation and temperature. The mean annual temperatures in the study area were generally warmer with the temperatures mostly above 24°C. These temperatures cover the entirety of the Kruger National Park, incorporating the towns that are a bit far from the National Park which includes Musina, The lost City, and

Bismark. Progression to the westward part of the study area correlates with a decline in temperatures. The temperatures in these western parts range between 20-22°C. The overall temperature ranges from just below 30°C to over 44°C.

(b) Thermal Heat Index

Thermal Heat Index (THI) is an index that combines air temperature and relative humidity, in shaded areas, to posit a perceived equivalent temperature. Livestock has certain acceptable THI values above which the animals are subjected to various levels of stress. For beef cattle < 74 THI – Normal; 74 to 78 THI – Alert; 78 to 84 THI – Danger; > 98 THI – Emergency.

For Dairy cattle < 72 THI – No stress; 72 to 78 THI – Mild stress; 78 to 89 THI – Severe stress; 89 to 98 THI – Very severe stress; > 98 THI – Death. The ability of the livestock farmer to keep animals under temperature and humidity conditions that generate normal THI is therefore important for successful farming. With seasonal variations and the general increase in temperature associated with global warming, the adaptive capacity of the farmer and indeed of the animals is important for sustainable livestock farming.

3.1.4 Thematic Area: Wind

(a) Wind

Among the major exposure of livestock farmers to the effects of wind is when some disasters are associated with the occurrence of wind hit. Wind disasters contribute to tremendous physical destruction, injury, loss of life, and economic damage. The effect of wind damage may not be limited to the wind damage itself as concurrent heavy rains and flooding often wreak additional havoc (Stephani, 2012). Although the livestock farmers did not reveal the extent to which they were exposed to wind disasters, the occurrence of wind-related disasters in the study area was reported from one year to the other. The exposure of the farmers to wind disasters could result in issues such as the destruction of shelters, both for households and for livestock.

3.1.5 Vegetation

(a) Normalised Difference Vegetation Index (NDVI)

Normalised Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). As shown by Mpandeli et al. (2019), NDVI may be used to assess water stress. Poor vegetation (associated with negative NDVI values) suggest poor grazing for the livestock farmers. With the seasonal variation of rainfall followed by variation in water stress levels, the NDVI in the study area tends to vary across seasons accordingly with green dense vegetation in summer compared to that in winter.

3.2 Sensitivity

Sensitivity may be referred to as the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances (Gallopín, 2003). Following exposure, the attribute of sensitivity is therefore very important as presented in the Lindoso (2011) Framework for vulnerability and adaptive response. Accordingly, pertinent thematic issues and indicators were proposed for inclusion under this attribute (Table 2).

Table 2 Sensitivity based thematic areas and indicators revised from the Lindoso (2011) framework for the vulnerability of small-scale farmers

Thematic area	Proposed indicator
1. Involvement in smallholder livestock farming	a) Proportion of population involved in smallholder livestock farming (%)
2. Access to water	a) Establishments in which producers have access to water (%) b) Establishments in which livestock have access to water (%)
3. Distance to the water source	a) Distance covered by smallholder farmer to the furthest water source (km) b) Distance covered by livestock (animals) to the furthest water source (km)
4. Quantity & frequency of water access	a) Establishment in which producers access different quantities of water (<i>litres/capita/day</i>) b) Establishments in which producers have frequent availability of water (%)
5. Livestock water use efficiency	a) Livestock water use efficiency (m ³ / annum)
6. Livestock production systems	a) Establishments in which producers practice rain-fed farming (%) b) Establishments in which producers use communal grazing (%) c) Establishments in which producers feed livestock with crop residues (%) d) Establishments in which producers used private pastures (%) e) Establishments in which producers procured feeds (%)

3.2.1 *Thematic area: Involvement in smallholder livestock farming*

(a) Proportion of population involved in smallholder livestock farming (%)

The proportion of the population involved in smallholder farming tends to reflect the level of sensitivity of the farmers to various climatic and related factors to which they are exposed. Higher proportions of the population with their larger populations of livestock tend to be more sensitive compared to smaller proportions of the population, and this may be attributed to increased competition for resources associated with higher proportions.

3.2.2 *Thematic area: Access to water*

a) Establishments in which producers have access to water (%)

Access to water may have a strong influence on the degree of sensitivity of the livestock farming households to various attributes to which they are exposed. Smallholder livestock farmers with limited access to water would be expected to have a higher level of sensitivity than their counterparts with abundant access to water. The main source of water for farmers was the river system (41.3%). The municipal/piped water (40.4%) closely follows the streams. The borehole was found to be the third level stream. The dam/pond, and water well, constituted 7.40%, and 2.50% respectively. The over-reliance of the farmers on the river implies that they are highly exposed to climatic extremes.

(b) Establishments in which livestock have access to water (%)

As would be the case with smallholder farmers access to water, livestock (animals) enterprises with limited access to water would be expected to have a higher level of sensitivity than their counterparts with abundant access to water.

The main source of water for cattle (65%) was the river whereas tap water and boreholes were equally shared by goats. Tap water was reported as the main source of water for chickens (61%) and pigs (67%). It was also noted that few farmers (<10%) reported that their cattle, goats, pigs and chickens had access to the dam as the source of water.

3.2.3 *Thematic area: Distance to the water source*

(a) Distance covered by smallholder farmer to the furthest water source (km)

Distance to the water source tends to have some influence on the degree of sensitivity of livestock farmers to the factors of exposure, both for household members and for livestock. Longer distances to the water source tend to be associated with higher levels of sensitivity compared to shorter distances. For instance, smallholder livestock farming households travelling longer distances to access water would be more sensitive to changes in the cost of energy (to access the water) than those travelling shorter distances (assuming the households are of similar economic status).

More farmers (53%) travelled a distance of 1-5km to the river as a water resource. Three in ten (31%) travel between 6 and 10 km to the river. Access to water was also through community tap or boreholes which were used to provide water outside each household. The majority of households accessed the community tap within less than a kilometre whereas 17% had to travel between 1 and 5km. The indoor tap (93%), pumped water (100%) and rain harvest (95%) were all accessed by the majority of households within less than a kilometre.

(b) Distance covered by livestock (animals) to the furthest water source (km)

As is the case with distance covered by members of smallholder farmer households to the furthest water source, the distance covered by livestock also tends to influence the level of sensitivity of the livestock enterprise to factors of exposure. The findings of the study revealed that some livestock drank water at the household (35%), some travelled < 1 km (27%), 1-5 km (36%) and 6-10 km (2%) to the furthest water source. The majority of farmers (>79%) indicated that goats, chickens and pigs drank water at the household. Cattle had to travel 1 -10 km to their water sources mainly rivers. It is recommended that cattle travel less than 4 km without stress; the maximum distance for small livestock is 15 km, and 30 km was the maximum distance for livestock at stress levels. Although 30 km is the distance livestock have to walk during water scarcity periods, cattle and small stock will normally graze up to 10-15 km away from a water source.

3.2.4 *Thematic area: Quantity & frequency of water access*

(a) Establishment in which producer's access different quantities of water (litres/capita/day)

The quantity of water accessed by a livestock farming household (litres per capita per day) also tend to have some influence on the degree of sensitivity of the farming household to various factors to which the household is exposed.

Households receiving lesser quantities of water would be expected to be more sensitive to adverse factors of exposure than their counterparts who receive more quantities.

Water used for cooking and drinking in livestock farming households in the study area was between 11 and 30 litres per household per day. Considering the requirement of 37.5 litres per capita per day (Tshikolomo et al., 2012), the livestock farming households in the study area may be regarded to be highly sensitive to adverse factors of exposure. The quantity of water for washing, irrigation and livestock drinking was within the range of 101 to 300 litres per household per day.

(b) Establishments in which producers have frequent availability of water (%)

The frequency of availability of water to smallholder farmers also tends to influence the degree of sensitivity to various factors of exposure. It would be expected for a lower frequency of availability of water to associate with a higher level of sensitivity and vice versa. Most farmers (84%) accessed water more frequently from the river compared to seven in ten (72%) who frequently obtained water from the communal tap. Fewer numbers of households accessed water more frequently from pumped water sources (38%), taps in the yard (36%), indoor tap and communal well (7%), respectively.

3.2.5 *Thematic area: Livestock water use efficiency*

(a) Livestock water use efficiency (m^3/annum)

The water use efficiency of livestock (m^3/annum) tends to also influence the degree of sensitivity of the livestock farming enterprise to adverse climatic and other factors. Livestock with lower water use efficiency would consume more water per unit period and would therefore suffer more during the period of scarcity, i.e. the livestock would be more sensitive. In the same vein, the livestock with higher water use efficiency would consume a lesser quantity of water per unit period and would be less sensitive to adverse conditions associated with water scarcity.

3.2.6 *Thematic area: Livestock production systems*

(a) Establishments in which producers practice rain-fed farming (%)

The extent of smallholder farmer reliance on rain-fed farming has some influence on the degree of sensitivity of such farmers on adverse conditions of lower (or total lack of) rainfall. Farmers who are highly reliant on rain-fed farming tend to be more sensitive to adverse conditions associated with lower rainfall while those less reliant on rain-fed farming would accordingly be less sensitive. For instance, farmers who are highly reliant on rain-fed farming for the production of fodder will suffer more during dry seasons with no (or too low) rainfall while those who also produce under irrigation will be able to produce some fodder (as long as their sources of irrigation water continue flowing).

(b) Establishments in which producers use communal grazing (%)

The type of land tenure of smallholder farmers has some influence on the type of veld management and hence on the degree of enterprise sensitivity to factors that may adversely affect the availability of grazing. Generally, privately owned land tends to be managed better than communal land. Resultantly, communally owned grazing lands tend to be more overgrazed compared to land that is privately owned. Livestock farmers dependent on communal land, therefore, tend to be more sensitive to climate and related factors that are associated with a reduction in grazing. The majority of smallholder livestock farmers (97%) in the study area depend on communal land for their grazing; hence they would be expected to be highly sensitive to adverse factors associated with reduced grazing.

(c) Establishments in which producers feed livestock with crop residues (%)

Crop residues provide complimentary grazing to livestock farmers. Accordingly, livestock farmers with access to crop residues for grazing tend to be less sensitive to adverse effects of factors associated with grazing reduction. The farmers without access to crop residues would be more sensitive when exposed to climatic and other factors associated with adverse effects of loss of grazing. In the study area, crop residues were reportedly used by six in ten (59.4%) of the livestock farming households and those would be expected to be less sensitive to loss of their regular grazing.

(d) Establishments in which producers used private pastures (%)

The influence of private pastures on the degree of sensitivity to adverse effects of factors associated with grazing reduction is opposite to that of communal grazing. While communal grazing is associated with higher sensitivity, private pastures are associated with lower sensitivity. Unfortunately, only about one in ten (9.2 %) of the livestock farmers in the study area were reported to use their private pastures. It is those smaller proportion of farmers who could be expected to have lesser sensitivity to exposure to climatic and related factors associated with grazing reduction. As already indicated, the majority of the livestock farmers relied on communal grazing and had a high level of sensitivity.

(e) Establishments in which producers procured feeds (%)

The smallholder farmers able to afford feeds were able to procure a substitute for grazing and were less sensitive to exposure to factors with the adverse effect of grazing reduction. Three in four (75%) of the farmers in the study area were reportedly able to afford feeds, and these would be expected to be less sensitive.

3.3 Adaptive Capacity

Guided by the Lindoso (2011) Framework, pertinent thematic issues and associated indicators for adaptive capacity are shown in Table 3. Adaptive capacity is referred to as the 'ability of socio-ecological systems to administer, accommodate, and recover from eventual environmental disturbances' (Smit and Wandel 2006). As indicated earlier, adaptive capacity is a function of wealth, technology, education, information, skills, and infrastructure, access to resources, and stability and management capabilities' (McCarthy et al., 2001, p. 8).

3.3.1 Thematic issue: Demography of livestock farmer

(a) Establishments in which producers were of different gender categories (%)

The gender category of a livestock farmer would likely have some influence on the capacity of the farmer to adapt to adverse conditions to which they are sensitive. As affirmed by IFPRI (2015), gender differences are likely to influence the capacity of farmers to adapt to climate change as well as their choices of climate change adaptation strategies. The majority of livestock farmers in the current study were males (63%) with close to two in five (37%) being females. That affirmed Ijatuyi *et al.* (2017) who revealed that up to three in four (75%) of Nguni producers in the North-West Province of South Africa were men. With majority ownership of livestock projects, men are probably able to make appropriate farming decisions that reflect improved adaptive capacity to challenges such as climate change and variability.

Table 3 Adaptation based thematic issues and indicators reviewed from the Lindoso (2011) Framework for the vulnerability of small-scale livestock farmers

Thematic issue	Proposed indicator
1. Demography of livestock farmer	a) Establishments in which producers were of different gender categories (%)
	b) Establishments in which producers were of different age categories (%)
	c) Establishment in which producer had different levels of education (%)
	(d) Establishments in which producers had different employment status (%)
	e) Establishments in which producers had different income levels (%)
2. Product diversification	a) Establishments in which producer had diversified products (%)
3. Capacity building	a) Establishments that had competent administrator (%)
	b) Establishments in which producer was a membership of producer association (%)
	c) Establishments in which producers received training and technical assistance (%)
4. Access to electricity	a) Establishments in which producer had access to electricity for household and/or farming enterprise (%)
5. Financial Support	a) Establishments in which producer received financial support (%)
	Establishments in which the producer received material infrastructural support (%)

(b) Establishments in which producers were of different age categories (%)

As was proposed for gender, age would also likely influence the level of adaptive capacity of livestock farmers to adverse climatic and related factors to which they are sensitive. The influence of age would be based on factors such as the experience gathered over the years and the energy levels available for certain ages with older farmers probably being more experienced but having lower energy levels while the contrary would apply for younger farmers. As revealed by Mulinyac, (2017), farmers within the ages of 30-34 years are likely to fully understand the issues involved in farming and accompanying climate change adaptation strategies. The older, knowledgeable, and experienced farmers could be resistant to change and thus may not see the need of employing new technologies compared to traditional models of farming that they are familiar with (Fussel and Klein, 2006).

Two in three (65,7%) of farmers in the area under study were aged 55 years and above of which almost two in five (37,6%) were aged >65 years. Farm productivity has been shown to deteriorate with the farmer's age, especially among the smallholders who largely rely on their physical labour to execute many farming responsibilities (Uddin et al., 2014, Labbe et al., 2016).

(c) Establishment in which producer had different levels of education (%)

The level of education also tend to have some influence on the extent to which a farmer can access new information and technology, not only through improved literacy that enables the farmers to access written information but also through the increased ability to search for information using modern information technologies. In the area under study, one in six (18.2%) smallholder livestock farmers were completely illiterate, about two in five (37.5%) had primary education at most, with one in four (25.8%) having had some secondary/high school education. Only 17.5% of respondents had College or University education. Based on these findings, four in five (81.5%) of the livestock farmers only had secondary education at best. Reading and writing are basic conditions for farmers to have the ability to access information available in written and electronic media and to use that information for the exercise of their citizenship, thus creating conditions for adaptation to climate change (O'Brien et al., 2004a) and other adverse factors to which they could be sensitive.

(d) Establishments in which producers had different employment status (%)

The employment status of livestock farmers tends to have some influence on their adaptive capacity to adverse effects of climate change and variability. The influence of employment status would be informed by such issues as the prospects for income derived from employment (positive influence) and the time committed by the farmer to his / her employment which could be used for livestock farming (negative influence). About half (50.5%) of the livestock farmers in the study area were involved in various types of employment, probably mostly on a part-time basis. Some 86.7% of livestock owners were full-time farmers, and of those, four in five (82.2%) were heads of the household while 4.5% were other household members. Only 13.4% of livestock farmers in the area under study were part-time. Considering the time commitment to farming, smallholder livestock farmers in the study area would mostly possess the capacity to adapt to the adverse effects of climate change and variability.

(e) Establishments in which producers had different income levels (%)

High-income households can afford their needs much more than low-income households and will therefore have better adaptive capacity to adverse conditions faced by their farming enterprises. According to Nouman et al. (2013), household income is also one of the determinants of the amount of credit that can be borrowed by the farmers, including those in livestock farming.

High-income livestock farming households can therefore not only better afford needs such as production inputs and other livestock production factors, but would also easily qualify for credit to procure the assets that would otherwise not be affordable.

In the area under study, three in ten (29.0%) livestock farmers reported a monthly income of R3001-R5000 while half (50,4%) of them revealed their annual income to be R5 001-R20 000. The top income households were one in five (18.6%) who earned R10 001 and above per month and 4.4% who earned R60 001 and above per annum. High-income livestock farming households will be better adaptive to the adverse effects of climate change and variability when compared to their low-income counterparts.

3.3.2 *Thematic issue: Product Diversification*

(a) Establishments in which producer had diversified products (%)

Product diversification is often adopted as a business risk management strategy and may be associated with a high capacity to adapt to adverse conditions to which an enterprise may be sensitive. Livestock farmers involved in various types of livestock enterprises (e.g. large stock, small stock, etc.) and/or crop enterprises (e.g. fruit, vegetables, and field crops) would be expected to have a high capacity to adapt to adverse climatic and related conditions to which they are sensitive. The high adaptive capacity would be a result of both the ability of some enterprises to escape when others are hit by adverse conditions and the ability of some enterprises to complement each other. For instance, a livestock-crop system may allow for the animals to feed on the crop while the crop receives manure from the animals. Another diversified system could include livestock pasture.

In the area under study, livestock farmers diversified to various animal commodities. Although the main type of livestock for the respondents were cattle, it was evident in the study that other commodities were produced, and those included sheep (mean = 10.38), goats (mean = 14.50), chickens (mean = 18.80), pigs (mean = 10.65), and donkeys (mean = 7.33). Although the farmers who diversified would have some increased adaptive capacity, the numbers of the various animal commodities included in the diversification are rather too small for a significant increase in adaptive capacity.

3.3.3 *Thematic issue: Capacity building*

(a) Establishments that had competent administrator (%)

The level of education has a strong influence on the extent to which a farmer can access new information and technology, not only through improved literacy that enables the farmers to access written information but also through the increased ability to search for information using modern information technologies. Where necessary, it could also help if the farming enterprise could hire the services of an administrator with requisite competency, especially in skills such as administration and accounting skills.

(b) Establishments in which producer was a membership of producer association (%)

The membership of a livestock farmer to a relevant producer association has some influence on the capacity of the farmer to adapt to adverse climatic and related conditions to which the farming enterprise may be sensitive. Livestock farmers who are members of producer associations would be expected to possess high adaptive capacity than their non-member's counterparts. Among others, the increase in adaptive capacity of livestock farmers who are members of producer associations would be a result of the members acquiring some helpful information at the meetings of the associations. In the area under study, livestock farmers neither belonged to a farmers' union (99.7%) nor a producer organization (100%), and these suggest that they lacked exposure to knowledge and information and would possess the low adaptive capacity to adverse conditions to which their enterprises would be sensitive.

(c) Establishments in which producers received training and technical assistance (%)

The capacity of livestock farmers to adapt to adverse climatic and other conditions to which their enterprises are sensitive may be highly influenced by the extent to which they receive training and technical assistance. Receipt of training and technical assistance empowers

the livestock farmers with knowledge and information that may be necessary to help the farmers adapt to adverse conditions faced by their enterprises. It was disappointing to note that almost all the livestock farmers (99.5%) in the area under study had not received any training in livestock farming, suggesting that the farmers were likely to lack some important knowledge and information and would hence possess the low adaptive capacity to adverse conditions to which their enterprises would be sensitive.

3.3.5 *Thematic issue: Access to electricity*

(a) Establishments in which producer had access to electricity for household and/or farming enterprise (%)

Livestock farmers access to electricity for consumption by both the household and the farming enterprise has some influence on / her capacity to adapt to adverse effects of climate and related factors to which their farming enterprises may be sensitive. The increased adaptive capacity resulting from access to electricity would be based on the convenience of ease of access to energy which allows farmers to allocate their time to farming.

In the absence of electricity, livestock farming households set aside time for activities such as a collection of firewood, and this deprives them of the time to focus on farming. It was pleasing to note that up to 97.3% of the livestock farmers in the study areas had access to electricity. Accordingly, up to 87.4% of the livestock farming households used electricity for cooking. The livestock farming households relying on electricity for cooking would have more time to attend to farming activities and would likely possess more capacity to adapt to adverse effects of climate and related factors to which their enterprises would be sensitive. Also, electricity allows access to key information through TV and telephone, and this further increases the adaptive capacity of the livestock farmers (Jones and Boyd, 2011).

3.3.4 *Thematic Issue: Receipt of support*

(a) Establishments in which producer received financial support (%)

Access to financial support empowers livestock farmers and increases their capacity to adapt to adverse climate and related conditions to which their farming enterprises would be sensitive. Almost all the farmers (99.2%) in the area under study did not have access to financial support, hence their adaptive capacity would be expected to be low when financial support is considered.

(b) Establishments in which producer received infrastructure support (%)

Just as described for financial support, livestock farmer access to infrastructure and other material support empowers them (the farmers) and increases their adaptive capacity to adverse effects of climate and related factors to which their farming enterprises would be sensitive.

4. Conclusions:

It was evident from the study that the Lindoso (2011) Framework does not suffice for vulnerability assessment and adaptive response of smallholder livestock farmers in the Limpopo and Mpumalanga Provinces of South Africa. The framework omitted some of the important indicators, and those were included in the review of the indicators under each of the attributes. The indicators omitted in the original framework were reflected under each attribute as follows:

(i) Exposure –
Drought; floods; Mean Annual Temperature (MAT); Thermal Heat Index (THI); wind occurrence; and Normalized Difference Vegetative Index (NDVI);

(ii) Sensitivity –
Distance covered by smallholder farmer to the furthest water source (km); Distance covered by animals to the furthest water source (km); Establishments in which producers accessed different quantities of water (%); Establishment in which producers had frequent availability of water (%); Livestock water use efficiency (m³/annum); Establishments in which producers practice rain-fed farming (%); Establishments in which producers used communal grazing (%); Establishments in which producers fed livestock with crop residues (%); Establishments in which producers used private pastures (%); and Establishments in which producers procured feeds (%);

(iii) Adaptive capacity –
Establishments in which producers were of different gender categories (%); Establishments in which producers were of different age categories (%); Establishments in which producers had different levels of education (%); Establishments in which producers had different employment status (%); Establishments in which producers received financial support (%); and Establishments in which producers received material infrastructure support (%).

5. Recommendations:

For a different type of business, the Lindoso (2011) Framework should be further reviewed to develop the most appropriate set of indicators.

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