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The use of Agro-Meteorology and climate information as drought coping strategies

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Abstract
Grazing is an essential exercise for smallholder livestock farmers, as it provides the feed needed to raise healthy and productive livestock. Subsequently, the purpose of this study was to appraise the importance of agro-meteorology and climate information as drought coping strategies. The use of agro-meteorology and climate information bears the potential to prepare and mitigate the impact of climate change on smallholder farmers. There is a diverse array of climatic information available in the public domain (rainfall, temperature, aridity, and projected climate). Such information was subjected to the geographical information system to establish the spatial variability of such parameters. The continuous monitoring data was subjected to the climate and earth system models to project the future climate. The subsequent thematic layers revealed that there is spatial variability of the rainfall in the Limpopo and Mpumalanga provinces. The eastern side experiences the optimal rainfall of about 1800 mmpa and decreases moving westward to the value of about 300 mmpa. The temperatures exhibit a similar trend. The projected rainfall revealed that there will be an increased rainfall intensity in the study area for the most part, meanwhile the temperature will also be increasing. The smallholder livestock farmers may adopt the climate information to plan their annual operations. The climate forecasts guide the farmers to establish a timeline directing which activities need to be executed at what time depending on water needs. Nonetheless, climate change has a significant impact on rangelands. Ultimately this negatively affects the quality and the quantity of the feeds. As global temperatures rise, pastures become drier and warmer, making it more difficult for plants to grow and thrive. This can make it more difficult for pastures to adapt to changing environmental conditions, further exacerbating the impact of climate change.

Keywords: Agro-meteorology, climate information, drought coping strategy, changing environment

Introduction

Grazing is an essential exercise for smallholder livestock farmers, as it provides the feed needed to raise healthy and productive livestock. Some of the fundamental reasons it is regarded highly include; it is a sustainable source of feed for livestock, as it is renewable and mainly naturally grown using minimal inputs, it can be particularly important in regions where other feed sources, such as grains or concentrates, are expensive or in short supply. Grazing is also a high-quality feed for livestock, as it is rich in nutrients such as protein, minerals, and vitamins. This can help to ensure that livestock are healthy and productive, and can provide a valuable source of protein and other nutrients for consumers. Pasture is also a key to food security for smallholder farmers, as it can provide a reliable source of feed for livestock throughout the year. Nonetheless, climate change has a significant impact on rangelands. Ultimately this negatively affects the quality and the quantity of the feeds. As global temperatures rise, pastures become drier and warmer, making it more difficult for plants to grow and thrive. This can lead to a reduction in the quantity and quality of feeds available for livestock, which in turn can impact their health, growth, and milk production. In addition to changes in temperature and rainfall patterns, climate change also brings with it increased frequency and intensity of extreme weather events such as droughts, floods, and storms. These events can cause significant damage to pastures, destroying crops, eroding soil, and contaminating water sources. Furthermore, changing climate patterns can also impact the distribution and abundance of plant species that make up pastures, leading to a loss of biodiversity and reduced resilience of the ecosystem. This can make it more difficult for pastures to adapt to changing environmental conditions, further exacerbating the impact of climate change. It is, therefore, critical for the smallholder to be familiar with all aspects of the projected weather to effectively manage their operations. Fortunately, in the context of South Africa, there is the South African Weather Service (SAWS), an entity that has been entrusted with the responsibility of acquiring, storing, and interpreting the climatological data in the country. Along the same line of duty, there has been in-depth research on weather presentation and climate predictions (Klopper *et al*., 1998; Landman and Manson, 1999; Tennant, 1999; O'Brien *et al*., 2000) [20, 22, 41, 33]. The principal mandate for the institution is the provision of the best climatological information for all the interested stakeholders in the country. In a multi-lingual nation like South Africa, it is imperative to ensure that the disseminated information reaches the intended audience in the most suitable language. If the information that is transmitted cannot reach the intended target or be comprehended properly, without any room for misinterpretation, it bears no value as it shall not support the decision-making process for smallholder livestock farmers (Glantz, 1977; Chagnon, 1992; Osunade, 1994; Mutiso, 1997; Huber and Pedersen, 1998; Eakin, 2002; Roncoli *et al*., 1999; Finan and Nelson, 2001; Roncoli *et al*., 2001a; Roncoli *et al*., 2002a; Luseno *et al*., 2000) [15, 7, 35, 30, 18, 12, 38, 14, 24]. The agricultural sector in South Africa is a climate-based operation.

This is mainly because the country experiences a relatively low mean annual precipitation which is even below the global average, so every rain-drop count. Moreover, the dawn of climate change worsens the situation, as the rainfall becomes more erratic and unpredictable with the frequent climate extreme events. In this regard, the sector is principally reliant on meteorological information to thrive, survive, prepare, and mitigate the impact of climate extremes. Therefore, the application of climate forecasts is a fundamental practice in the management of farming activities. The same information has the potential to mitigate the exposure of the farmers to the detrimental effects of climate change on the farming venture. (IRI, 2000). Moreover, climate forecasts institute significant constituents of agricultural management because they reduce the farming costs that are likely to rise subsequent to the climate extremes that are easily identified and combated as depicted on climate forecasts (Orlove and Tosteson, 1999; Wilbanks and Kates, 1999; Unganai, 2000; McGee, 2004; Ritchie *et al*., 2004) [34, 42, 27, 37]. Subsequently, the purpose of this study was to appraise the importance of agro-meteorology and climate information as drought coping strategies.

Research and Methodology

1. The study area

The study area is comprised of the Limpopo and Mpumalanga provinces. The two provinces are located in the north and the north-east of the Republic of South Africa. Limpopo Province has a spatial coverage of 125,000 km², and Mpumalanga has 80,000 km². Together, the two provinces institute a total land size of 205,000 km². According to the map in Figure 1 study area is located between 26.4° and 32° longitudes, as well as 21 and 26° latitudes. As the study area comprises the northmost provinces in the country, it shares international boundaries with Namibia, Botswana, Zimbabwe, and Mozambique on the progression from west to east.

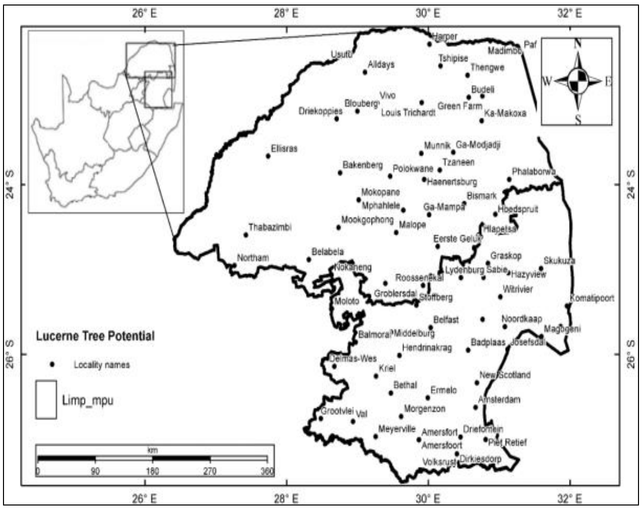

Fig 1: The geographical position of the study area in relation to the layout of the country (South Africa)

1.1 Physiography

According to Nemukula, *et al*., (2023) [31] and Musyoki, *et al*., (2016) [29], the general topographic layout of the Limpopo province resembles that of the Lowveld, which is an area that is attributed to the topographic relief that ranges from 150 to 600 m above the mean sea level. In spite of the near-perfect flat-land surface in the Limpopo Province, there are some mountains that appear in the central and southern parts of the province. The protruding part in the central portion of the province is subsequent to the development of the Soutpaneberg Mountain Range. These mountains extend over a distance of 130 km along the east-west directions, with a peak elevation of 2000 m above the mean sea level. Furthermore, the Soutpaneberg Mountain Range is mainly covered by thicket and bushes, meanwhile, the low altitude in the northern part is attributed to flat surfaces that are mainly covered with semi-desert vegetation.

Contrary to the physiography of the Limpopo Province, Mpumalanga Province can be divided into three major physiographic topographies which are the Highveld, Drakensberg Mountains, and the Lowveld. Highveld conforms to an area with an elevation that ranges between 1200 to 1800 m above the mean sea level. The Drakensberg which is mainly mountains is attributed to high elevation of up to 2300 m above the mean sea level. Lastly, the Lowveld is characterized by gentle undulating physiographic slopes that compose the Lebombo Mountains. The majority of the streams in the province drain water to the western side which eventually flows to the ocean.

1.2 Climate

The climatological setting of the northern part of South Africa is mainly defined as a dual season. There are two prominent seasons that are the dry-cold winter, and the hot-wet summer. There is spatial and temporal variation in the precipitation that is received in the Limpopo Province. The eastern part of the province receives the optimal amount of rainfall (1800mmpa), which is accompanied by a gradual decline from the optimum values with westward progression, and the far west receives the lowest amount of about 300mmpa. The effect of climate change is highly affecting the farming sectors, particularly the smallholder livestock farmers.

The climatic physiography of the Mpumalanga is altitude-dependent. The Highveld is attributed with a mean annual temperature of 16 °C (Netshakhuma, 2021; Maponya, *et al*., 2013) [32, 26], meanwhile, the subtropical Lowveld has a mean annual temperature of 23°. Precipitation portrays a similar trend to the Limpopo Province of westward decrease in frequency and quantity. The Highveld and Drakensberg receive a mean annual rainfall averaging from 510 to 760 mm and the Lowveld experiences over 1,000 mm annually (Netshakhuma, 2021; Maponya, *et al*., 2013) [32, 26]. Most of the natural vegetation in the province consists of various types of grassland or savanna parkland, with acacia trees.

2. Data Collection

SAWS is the national weather service in South Africa that is responsible for the provision of weather services which include, forecasting, warnings, and advisories. It also monitors and analyzes weather patterns and climatological trends. One of SAWS' key roles is to provide the government and other relevant stakeholders with information and guidance on the effects of climate change in South Africa. This includes assessing risks and vulnerabilities in agriculture, water resources, and public health, as well as developing adaptation strategies. This is important because it helps to understand and predict climate trends. SAWS monitors temperature, precipitation, and other weather patterns. This is achieved through the data gathered from the satellites and the ground stations. Such data then becomes instrumental in the establishment of the climate models that then appraise different predictive scenarios.

2.1 Mean annual rainfall

Rainfall data was sourced from South African Weather Services (SAWS). The daily rainfall data and daily temperatures were preferred due to their importance in smallholder farming. The selected weather stations have at least 10 years of monitoring data. SAWS has been collecting weather data since 1920. During surface development, regression analysis and spatial modeling were used.

2.2 SPI time series

1. This rainfall GIS surface, which covers South Africa, has been created from the data contained in the ARRC-ISCW climate databank. This databank contains historical rainfall data from the SA Weather Service and ARRC. This monthly rainfall GIS surface has been created from historical rainfall data for the period 1920 - 2013. The process of producing this rainfall GIS surface is as follows.

(a) rainfall data is extracted from between 1200 & 3000 mechanical & automatic stations. (b) the trend surface for a particular month is used for the interpolation.

(c) rainfall at a particular point is expressed in percentage of the previous rainfall trend surface. (d) the rainfall percentage value for a specific 10-day period is interpolated using inverse distance weight.

This method produces monthly rainfall surfaces that are consistent with the locations where precipitation is recorded, while still adhering to the climatological trends resulting from climatological variables such as topography and distance from the sea. The 2003 rainfall surfaces are generated by combining the above method with satellite rainfall estimates to complement rainfall data over the plateau of South Africa. The resultant monthly rainfall surfaces are summarised into quaternary catchments, each of which is represented by a +/- 1700 polygon in a Geographic Information System (GIS) covering the surface of South Africa.

For each of these catchments, the rainfall at the monthly to 48-month time scale is converted into a Surface Precipitation Index (SPI) for the catchment, resulting in a dataset of SPI values for several time scales per month since 1920. This dataset can be used to analyze the time series of the drought intensity classes by taking into account the traditional classification of SPI ranges.

Results and Discussions

1. The role of Climate in Smallholder livestock farming

South Africa is classified as one of the most-dry countries in the world, the mean annual rainfall that the country experiences (500mmpa) is lower than the global average (860mmpa) (Ingrid, & Rainier, 2012) [19]. Unfortunately, the situation is expected to aggravate with the intensification of climate change which is accompanied by significant alteration of the rainfall quantity (Anderegg, *et al*., 2021) [2] and patterns. In view of these unideal circumstances, the country is deprived of surface water resources. The majority of the streams are unsurprisingly periodic. Therefore, grazing become a prominent challenge for smallholder livestock farmers.

The development of the fodder bank is an ideal intervention to tame the aftermath of climate change. This should be able to provide some sort of relief during times of drought or extended drought spells. It should be considered that even the growth of the fodder bank will still be climate-dependent. Hence, smallholder livestock farmers should develop an activity timeline plan that is dependent on the climate forecasts such that the high-water demand activity are reserved for such time that there is rainfall

The daily weather forecast is provided by the SAWS through both print and electronic media and is published online 24 hours. Forecast information that is useful to farmers is part of a process that includes an examination of the current needs, problems, and context in which users operate. Forecasts, moreover, need to be expressed in the language of the users. Seasonal climate forecasts are issued as probabilistic outlooks for the future usually for a coverage period of three months and with a rather broad spatial coverage. Conveying notions of ‘probabilistic’ information to a variety of users is not easy. It is important for users to understand that all seasonal forecast information or data are given as probabilities and not as deterministic.

A significant constituent of sub-Saharan Africa is characterized by water-strained localities. This challenge is rooted in the low mean annual precipitation that the area receives which hinders the development of the surface water resources that the farmers may easily adopt for their farming activities. Ultimately, Kotir (2011) [21], renders rainfall as one principal determinants for farming in sub-Saharan Africa, as it is often the only available water resource at the disposal of the farmers.

1.1 Rainfall

The rainfall forecasts in South Africa are broadcasted on national television on a daily basis, to some extent using the vernacular languages. Figure 2 reflects the mean annual precipitation of the Limpopo and Mpumalanga Provinces. According to Kala (2012), the quantity of rainfall that an area experiences determines the nature of the agroecological framework that will prevail. If an area gets heavy rainfall (greater than 2,500 mmpa), a tropical forest is likely to form (Butler, 2005) [6]. Meanwhile, the area that receives little rainfall, exceeding only 400 mmpa, then the area will be dry (Butler, 2005) [6]. Additionally, rainfall also serves as a tool in making decisions about what type of livestock to pursue. This is also reflected in water availability, the nature of grasslands, and their respective resilience during the rainy season (Kochoni, 2019). In South Africa, grasslands are rarely irrigated, meaning they rely on rainwater for irrigation (Kotir, 2011) [21]. The daily rainfall can provide smallholder farmers with valuable insights into the amount and timing of rainfall in their area, which can help them plan for the needs of their animals. For example, if they know that there is going to be a dry spell, they can plan to supplement their animals' water intake with other sources, such as boreholes or troughs. On the other hand, if they know that there is going to be a lot of rain, they can delay grazing to allow pasture to recover and reduce the risk of overgrazing.

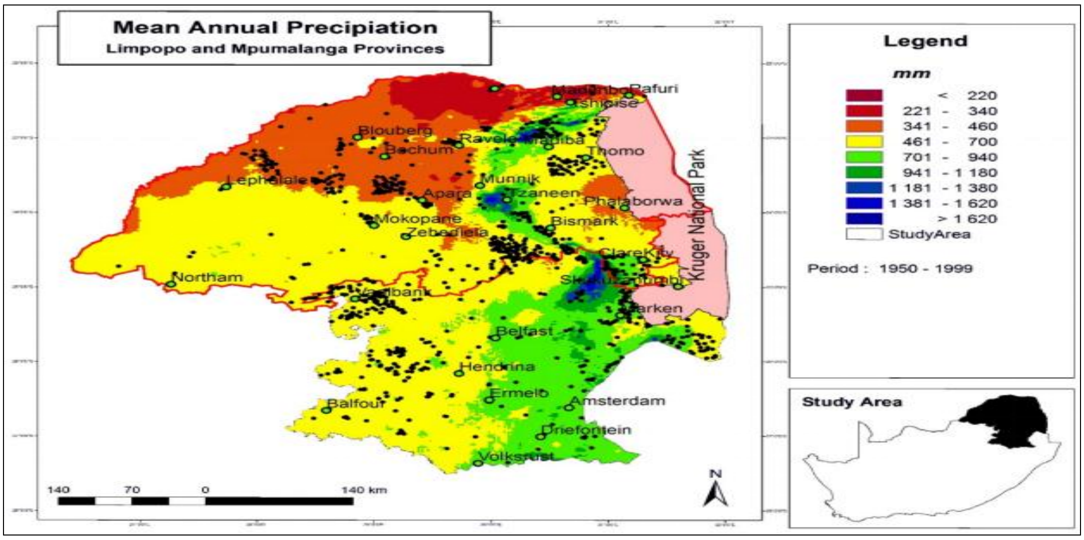

Fig. 2 Mean annual rainfall for Limpopo and Mpumalanga

It is worth noting that almost the entire precipitation that the area receives occurs in the summer. The map projects that there is spatial variability in the precipitation that is experienced throughout the aforementioned areas. The trend is denoted by a decrease with southward progression. The driest part occurs in the most northern part of the Limpopo province enticing the Limpopo River. This area experiences a mere 200 mmpa. Such an area is not ideal for livestock farming because it deprives the animals of adequate pastures, particularly during late summer and the entirety of the dry period. Furthermore, the area most depriving variable is the absence of surface water resources.

There are local microclimate zones arranged in the North-South direction that have above 1000 mmpa of precipitation. The localities instituting optimal rainfall areas include Dzimauli, Tshipise, Valdezia, Tzaneen, and Gateway. The first color represented by light brown, reflects the driest area, while the second color, symbolized by yellow, represents a relatively wet area. The global average rainfall is 860 mmpa (Ingrin and Rainier, 2012), and more than 90% of current studies show rainfall below the global average (Ingrin and Rainier, 2012). Low rainfall causes loss of surface water development; From this perspective, farmers' livestock activities are easily affected by the impacts of climate change. According to SA Explorer (2017), Mpumalanga typically receives about 610 mm of rainfall per year, with the majority of rainfall occurring mainly in mid-summer. It receives the lowest rainfall (8 mm) in June and the highest (89 mm) in January.

Mean total rainfall is the average amount of rain a region receives during the rainy season. In the context of the study area, this period is from October to February. According to the map in Figure 3, there are four types of rainfall. The microclimates of Dzimauli, Tshakhuma and Tzaneen) are very localized and small, but benefit from average rainfall greater than 650 mm. Farmers cluster around these localities to obtain a reliable water supply. Skukuza in Mpumalanga also received significant rainfall in excess of 530mm. Surprisingly, Mpumalanga is dominated by low rainfall, although the average annual rainfall suggests otherwise. Rainfall in this part only reaches 290 mm. Similar rainfall occurred on the northern edge of Limpopo, extending from Madimbo to Northam via Tshipise in the west of the province. Average rainfall between 290 and 530 mm occurs in the east, extending from the Kruger National Park and covering most of the area.

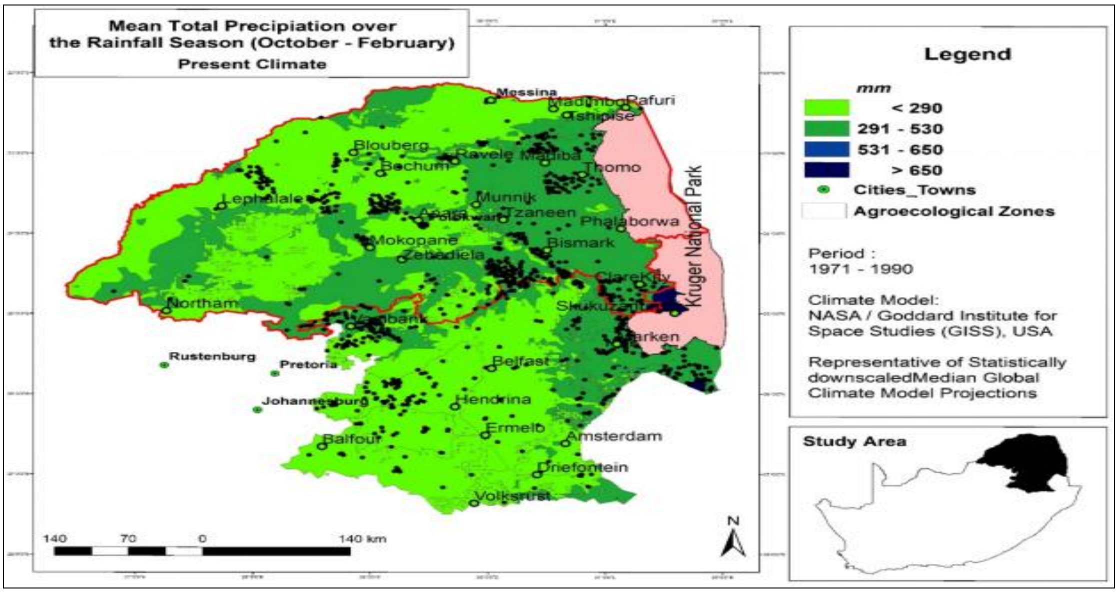

Fig. 3 Mean total precipitation for the wet season

1.2 Temperature Variability

There is a spatial agreement between rainfall, and mean annual temperature. The east is generally warmer with temperatures above 24°C (Figure 4). These temperatures cover the entire Kruger National Park. They also include towns a little further away from the national park, including Musina, The Lost City, and Bismark. The westward movement correlates with a decrease in temperature, temperatures in this part fluctuate between 20-22°C. The segments that include these temperatures also extend from western Musina to Northam, Lephalale, Swartwater, and Alldays (covering the entire Limpopo basin). Temperatures varied from 18 to 20°C across central Limpopo province, including Vaalwater, Bochum, Tzaneen, and Elim. The cool part of the area matches the microclimate of the two provinces. The lowest average temperatures occurred across Mpumalanga province (Figure 4). Although summers are hot, average temperatures below 10°C are normal. This implies that livestock susceptible to heat stress (such as dairy cows, beef cattle, and chickens) are most likely to occur in this area. Average maximum temperatures alongMpumalanga are relatively cooler than in Limpopo province. Maximum average temperatures of up to 38°C spread throughout the space (Figure 4).

The overall average temperature in these regions is about 32°C. This implies that it is possible to keep many types of livestock without subjecting them to heat stress. In contrast, much of Limpopo province has higher average temperatures.

This supports the view that the province is ideal for drought-tolerance and cold-intolerant livestock. This claim can be supported by the rise of goat farming in many parts of the province, the use of donkeys to plough fields, and the decline of livestock farming. It is generally accepted that climate change causes increase in temperature and frequency of extreme weather events (Easterling *et al*., 2000; Seneviratne *et al*., 2012) [13, 40]. The map in Figure 5 shows the spatial distribution of mean maximum temperatures in Limpopo and Mpumalanga. The map shows a general decrease in temperature from east to west. Global temperatures vary from below 30°C to above 44°C.

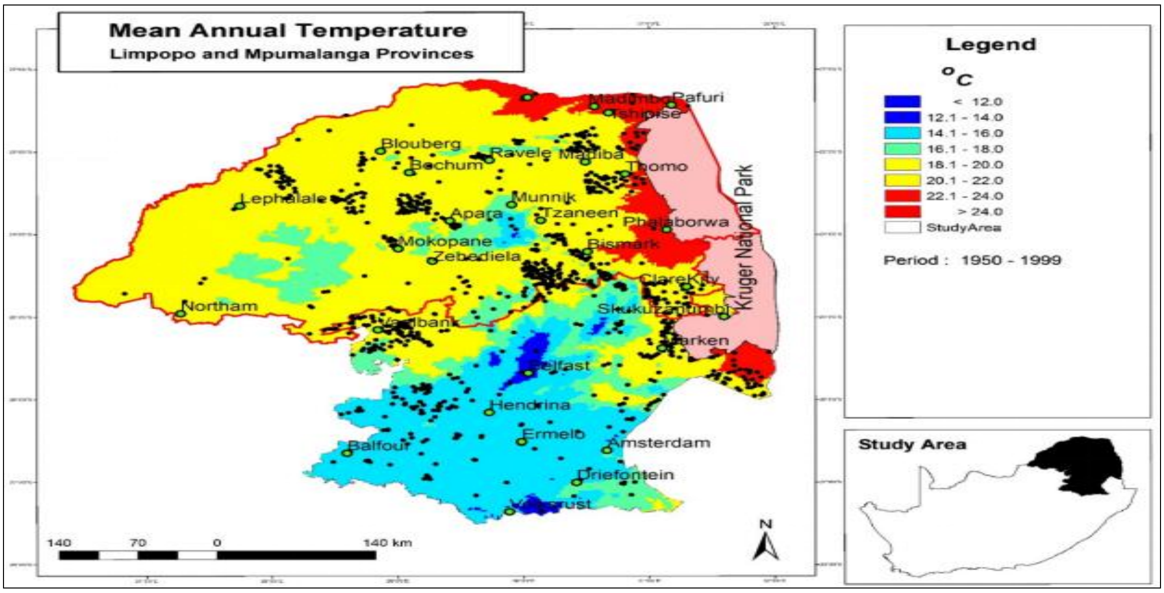

Fig 4. Spatial distribution of the mean annual temperature in Limpopo and Mpumalanga Provinces of South Africa

Climate change will have significant consequences for dairy, meat, and wool production, mainly through impacts on pasture and grazing productivity. Heat exhaustion in animals will reduce the animal's food consumption and lead to poor growth (Rowlinson, 2008) [39]. According to Alkire (2009) [1], livestock (cattle) appreciate temperatures between 10 and 26°C.

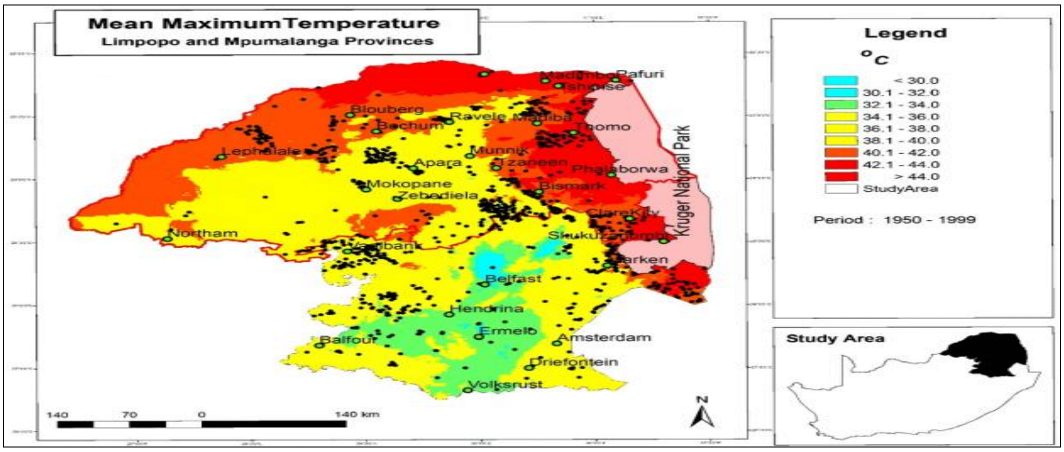

Fig 5. Mean maximum temperatures of Limpopo and Mpumalanga Provinces of South Africa

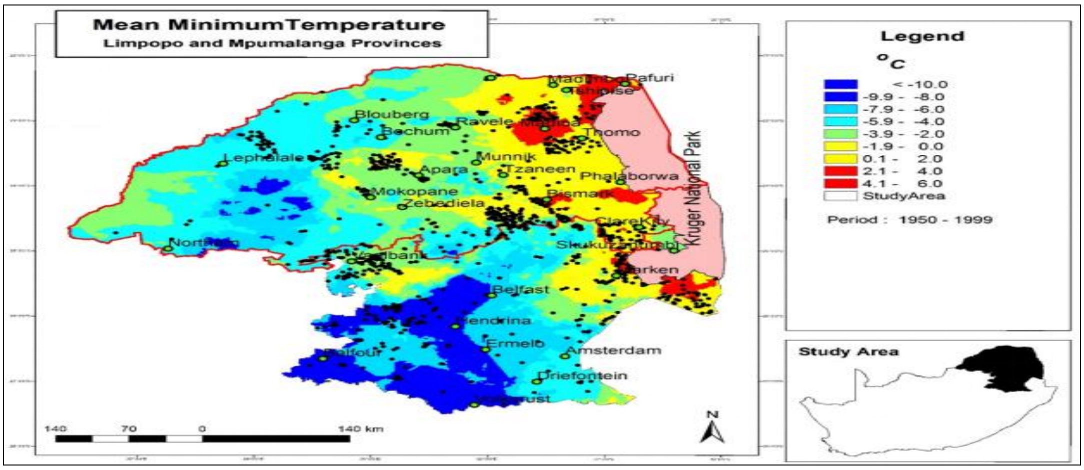

Fig 6 Mean minimum temperatures of Limpopo and Mpumalanga Provinces of South Africa

What is surprising is that although livestock farming is the most dominant agricultural activity of smallholders, almost the entire Limpopo province does not have optimal conditions for livestock farming. It is a pity because livestock farming is by far the most practiced type of animal husbandry. This is in response to the high productivity associated with this agriculture. It is also a traditional tool for measuring wealth. Summer has too high temperatures affecting livestock productivity. However, these conditions are ideal for raising goats and donkeys. Even if the latter does not have a strong market.

1.3 Climate projections

1.3.1 Comparison of the present and future climate projections

The future climatic projections were appraised and subsequently compared to the present conditions to reflect the future of the earth. Such comparison is crucial to the empowerment of the smallholder livestock farmers. The two maps in Figure 7 depict the mean total precipitation over the rainfall season (October – February) for the present climate (on-left) and mid-century (2065) (on-right), over Limpopo and Mpumalanga Provinces. It was calculated using daily medium-term global climate model projections using the approach that was refined by Lekalakala (2017) [23]. Climate and Earth system models are used for a variety of purposes, from studying the dynamics of past weather and climate systems to predicting future climate. These models simulate the physics, chemistry, and biology of the atmosphere, land, and oceans, and require massive supercomputers to produce climate forecasts. This value represents the average of statistical downscale model forecasts of daily climate conditions. ZAE is used as a spatial unit. According to the map on the right, precipitation is expected to increase mainly in the western part of the study area, this is because the selected or representative climate model shows a wetter climate than current conditions.

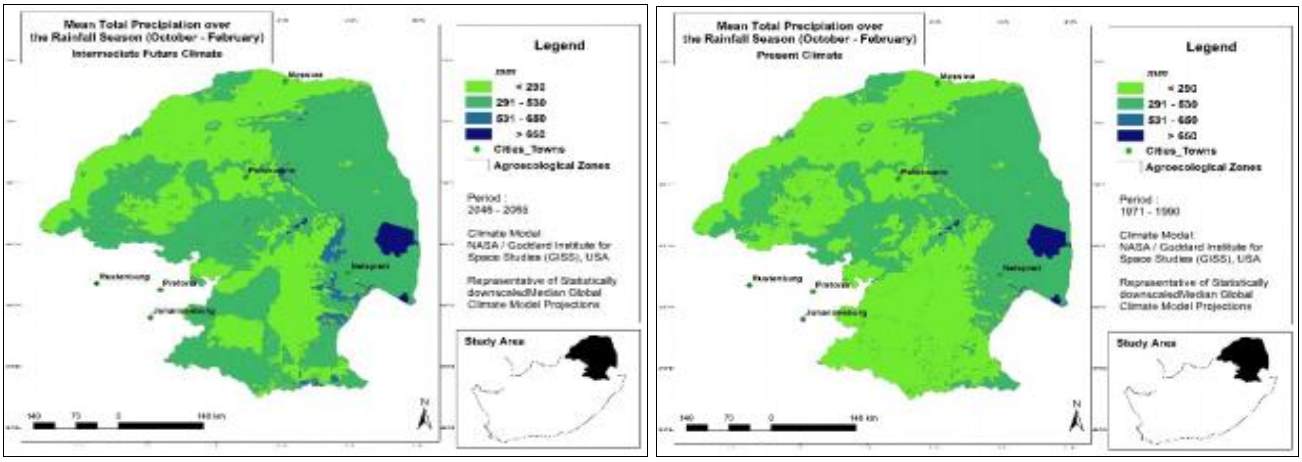

Fig 7. Mean total precipitation over the rainfall season (October – February) for present climate (on-left) and mid-century (on-right), over Limpopo and Mpumalanga Provinces.

The issuing of probabilistic future climate scenarios becomes a crucial instrument for decision-making. If the smallholder farmers adopt such a tool in their long-term planning, they are likely going to rip the benefits. If a farmer needs to make a significant investment, then the projections become key. Although the projection may insinuate the term in question is 2065, which may seem like a distant future, especially when taking into account the fact that the majority of the economic people would have retired, smallholder operations are a family initiative. Therefore, investing beyond the timeline of a farmer is never an issue for concern.

1.3.2 The frequency of the 14 dry days during the rainy season

The map in Figure 8 shows the assemblage of the frequency of the 14 dry days during the rainy season (October to February) for the current climate (left) and the future climate (2065: right). The frequency of more than 14 dry days during a rainfall season is likely to decrease more than 4 times on a median rainfall season over most parts of the study area for the projected date. Such a decline is attributed to the increase in rainfall. This implies that as much as there will be much more frequent rainfall in some areas, there are places that will be undergoing crucial reductions in precipitation. If there is any prospect of extending an allocated slot for livestock farming, it will be unwise to focus on areas that are shedding their rainfall intensity.

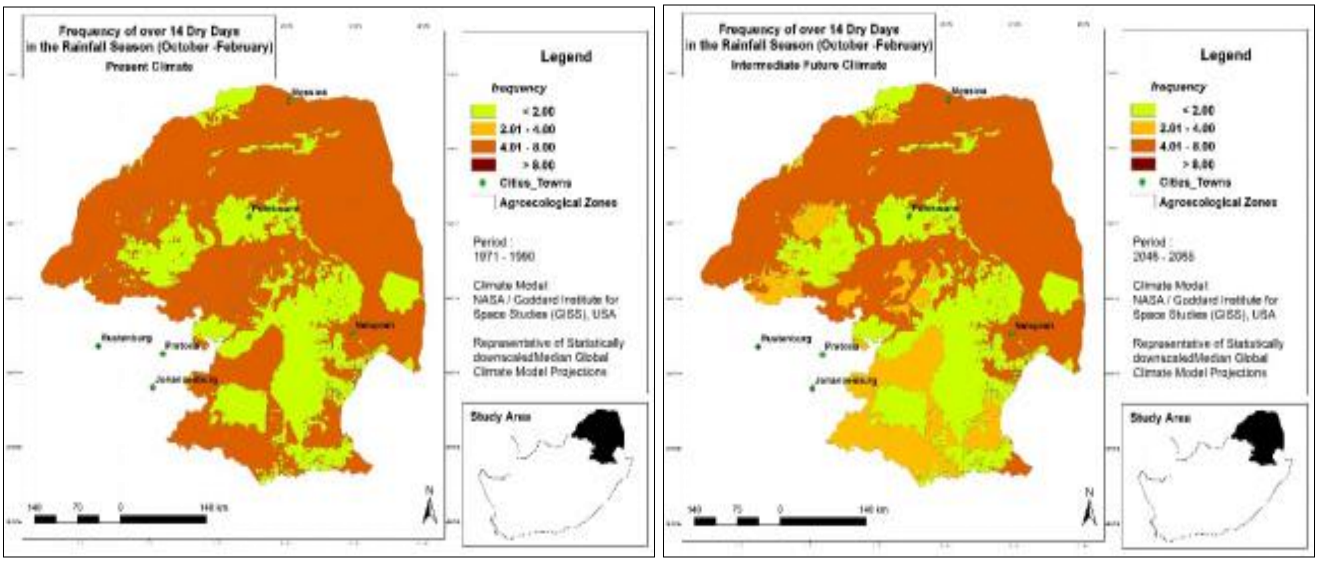

Fig 8. Mean frequency of more than 14 dry days over the rainfall season (October – February), present climate (on left) and mid-century scenario (on right)

2. Aridity Index within Agro-ecological Areas

The study area includes the Limpopo and Mpumalanga provincial areas. These provinces are classified as semi-arid with arid areas along the northernmost border between Limpopo and Botswana and Zimbabwe.

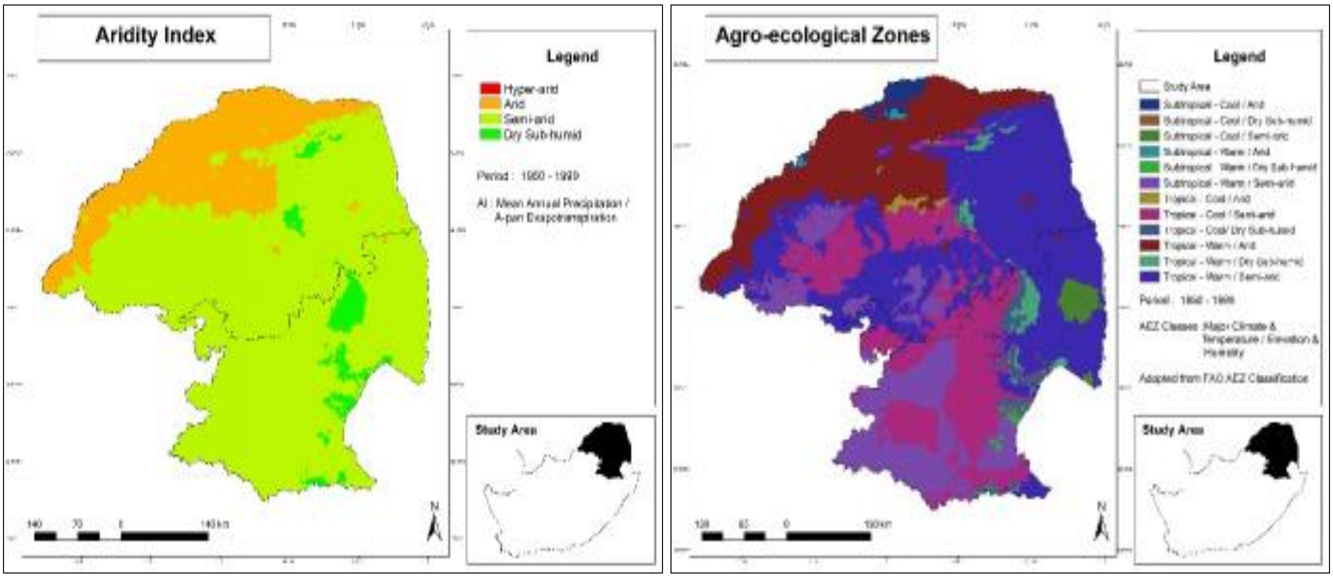

Fig 9. Climate characterization through the aridity index (left) and agro-ecological zones (right)

The Food and Agriculture Organization of the United Nations (FAO) has established the agroecological zones with the mandate to classify the agricultural systems with detailed descriptive demarcation. Such a novel classification system depends on factors such as climate and vulnerability. Accordingly, the study area was divided into agroecological zones (AEZs) defined by latitude, altitude, and temperature, as well as seasonality and rainfall distribution throughout the growing season.

The high water-demanding activities in the study area may not be supported due to the prevalent agroecological zones. Nonetheless, there are four prominent agroecological zones that are hyper-arid, arid, semi-arid, and sub-humid areas.

Due to the lower level of water resource availability, the situation can only be expected to worsen with climate change. Mainly because the phenomenon mainly manifests through the general increase of the temperature and drastic reduction of the precipitation (DEA, 2013). This recognized significance would include the impacts of reduced water availability, increased occurrence of water-borne and vector-borne diseases, incidence of invasive species, reduced crop yields, and pets, and many other issues related to human health (Rust & Rouille, 2013). Most of this phenomenon is due to the direct impact of increasing temperature regimes.

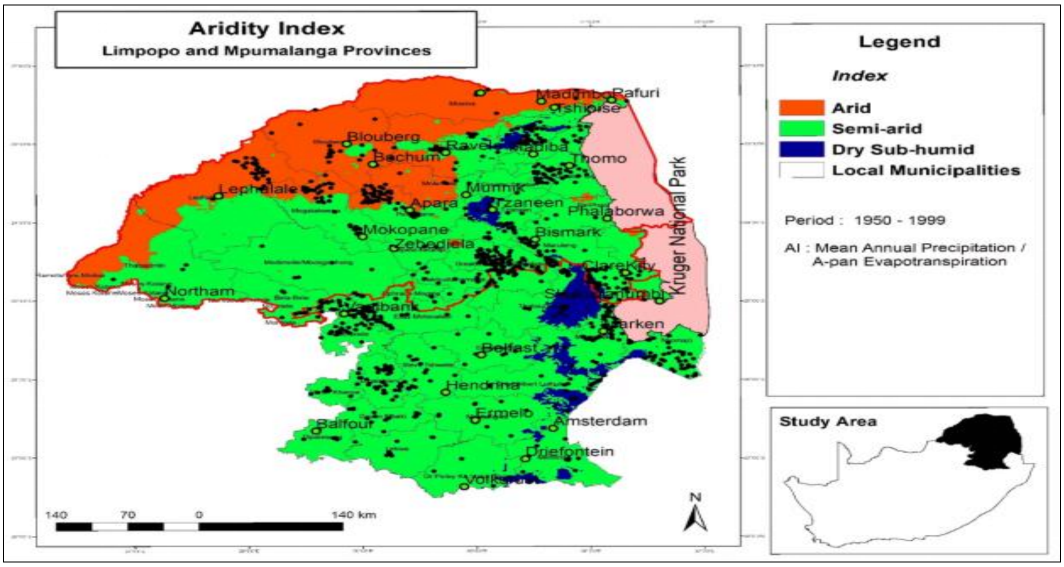

Fig 10. Spatial variability of the aridity index in Limpopo and Mpumalanga Provinces of South Africa.

The aridity index is a numerical indicator, which denotes the degree of dryness at a particular location based on the ratio of the evapotranspiration to the precipitation (Derya, *et al*., 2009) [11]. Maliva and Missimer (2012) [25] define aridity as a lack of moisture and a temporary reduction in the rainfall in an area, meanwhile, the increase in aridity represents a higher frequency of dry years over an area. The 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) [4, 10, 9, 17, 28]. A map in Figure 4.8 portrays the aridity index of the study area. The aridity index values reflect that the study area may be categorized into three discrete subsections; namely the arid, semi-arid and, dry sub-humid.

2.1 The arid area

The arid area stretches all the way from Thabazimbi to the east of Musina, forming an escarpment between the inland and the Limpopo River. According to (Griffins, 1985) [16], an arid area is characterized by a severe lack of water resources to the extent of hindering the development of plants and vegetation. Even the livestock may not thrive due to the lack of grazing in the area.

Such a lack is brought forth by the predominance of evapotranspiration to the rate of the precipitation (Derya, *et al*., 2009) [11]. Agricultural production in this category is impossible with the exception where there is irrigation. With irrigation being an exception, the recharge of water resources is likely a greater challenge as the extinction of the water resource is likely going to occur. This part of the area conforms to the Kalahari Dessert. The Mean maximum temperature map depicts that this section is amongst the hottest regions in the study area while it is also amongst the driest regions.

It is logical to assume that no agricultural production is possible in this area, the section shares the boundary with the Limpopo River, which is one of the biggest rivers in Southern Africa. Although water resources to sustain the livestock can be withdrawn from the Limpopo River, it is a transboundary, withdrawal of water from such a source is much more political than hydrological. Furthermore, cattle as the main livestock production, cannot tolerate high heat stress in the area. In order to lower heat production, farm animals reduce their physical activity as well (Collin *et al*., 2001) [8] and spend less time eating (Brown-Brandl *et al*., 2001) [5]. Feed refusal increases with body weight at high ambient temperatures (Quiniou *et al*., 2000) [36]. Higher temperatures tend to reduce animal feed intake and lower feed conversion rates (Rowlinson, 2008) [39]. Voluntary feed intake decreases curvilinearly with increasing environmental temperature resulting in reduced animal performance (Collin *et al*., 2001) [8]. In these regards, cattle farming in this region is highly exposed to the detrimental effects of climate change.

Should farmers have operations in these areas, they should have already had plans pertaining to the development of the supplementary feeds as grazing will not be available throughout the year.

2.2 Semi-arid area

Over 85% of the study area is recognized as a semi-arid area. The lowest mean annual rainfall and erratic precipitation patterns are the main factors that hinder farming in semi-arid regions (Aydın, 1995) [3]. Griffins (1985) [16], defines the semi-arid regions as an area whose evapotranspiration supersedes the potential precipitation. Consequently, the area experiences extended spells of the dry season and shorter wet periods. The arid area is characterized by a severe lack of water resources to the extent of hindering plants and vegetation. South Africa is predominated by two seasons, namely; winter and summer. In winter, the temperatures are cooler, which conforms to the ideal farming conditions. However, the water supply during this time is very marginal. Therefore, there is a need for water provision to sustain the livestock. Groundwater is often an obvious alternative to substantiate the insufficient water sources. Even when this is the case, boreholes are likely to fail at some point because of the deficiency in the groundwater recharge.

Pasture availability in this category is a critical issue of concern. This is mainly because it is based on rain-fed. During the extended spell of dryness, it does not recover and this subsequently strains the livestock. However, the livestock variability also translates to their water and pasture requirements. The animals that graze are likely to suffer the impacts more, while those that feed on bushes will flourish. The most ideal livestock type will be one that feeds on bushes, drought-tolerant, while farmers who are practicing cattle farming are somehow exposed to the impacts of climate change.

2.3 The sub-humid area

The dry sub-humid areas are 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. Dry spells are, however infrequent. This portion constitutes about 5% of the entire study area. The patches instituting this class occur along Thohoyandou, Levubu, Greater Tzaneen, Mbombela, Thaba Chweu, and, Chief Albert Luthuli which conforms to the microclimatic regions of the Limpopo and Mpumalanga Provinces. The majority of the commercial farms and agricultural hubs are located within these patches. The sub-humid area is attributed to relatively warm temperatures in comparison with the surrounding environment and comparably higher precipitation. Rainfall becomes a significant contributing factor to the water resource availability.

Subsequently, rainfall intensity of over 1000 mmpa yields to the development of the perennial streams concealing to this section. Pasture is mostly available and rejuvenates following precipitation. In spite of these, for the most part, it runs out in response to over-grazing as grazing capacity is often exceeded.

Early Warning System

Wigmore (2019) [43] defined the early warning system as the technology and associated policies and procedures designed to predict and mitigate the harm of natural and anthropogenic disasters and other undesirable events. An early warning system is critical for forecasting disaster prior to occurrence. In livestock farming, this enables the authority in place to trigger the relevant procedures and resources in the combat of the disaster. It is essential in the marginalization of the impacts of climate change. Two approaches are generally involved in the interpretations of early warning signs that are: traditional techniques and scientific techniques. The former is often undocumented and passed on from one generation to the next and is often practiced at a family or community level.

Table 1 shows the frequencies and the percent of the availability of the early warning system and operational level in Limpopo and Mpumalanga smallholder farmers. Most of the smallholder livestock farmers (80.77%) do not have any mode of the early warning system. A further 16.76% are not aware of any early warning system. Only 2.47% were aware of the early warning system. Out of those aware of the early warning system, they classified the system into the key stakeholder responsible. Disaster management was reported to be the most known early warning system provider with 57.14%. Secondly, the dryness of streams was also an imperative indicator of the down of the drought by 28.57%. Lastly, 14.29% are reliant on the local radio for weather forecasting. The District Municipality also offers an early warning system in the form of weather forecasting weekly and 3-monthly. Only a single respondent reported each of the two initiatives.

The inexistence of the early warning system implies that the farmers must absorb the entire hock of the impacts. In this regard, they are highly exposed to the impacts of climate change. Ninety-six percent of the respondents were not entirely informed when the early warning systems were installed. Only 2% outlined that the systems were introduced between 2016 and 2017 concurrently. However, 43.24% indicated that the existing systems are not effective. A further 54.73% were not sure if the system was informative. Only 2.03% believe that the early warning is an effective tool to get them prepared for the rising of the drought. To curb the dissatisfaction of the farmers with the efficiency of the existing systems, the livestock farmers (30%) require early warning education to stay alert. According to 40%, the dissemination of the information is also critical to be prepared to combat climatic extremes. Also, 20% are not aware of how the system should be improved. The limited information on the early warning system implies that most smallholder farmers are caught off-guard when such events unfold. Subsequently, they must absorb the total impacts of the extreme event due to their unpreparedness. These, therefore, indicate that smallholder farmers are highly exposed to the impacts of the climate extremes that are after climate change.

Table 1. Frequencies and respective percentages of smallholder farmers' perception of the availability of the early warning system

Availability of Early Warning system		Frequency	Percent
Early warning system	No	294	80.77
	Not sure	61	16.76
	Yes	9	2.47
	Total	364	100
National	Disaster management	4	57.14
	Dry of streams	2	28.57
	Local FM Radio (weather)	1	14.29
	Total	7	100
District	Disaster Management	1	1
	Distance Management	1	1
	Total	2	2
When was the system established	2016	1	0.66
	2017	2	1.32
	No	2	1.32
	Not sure	146	96.69
	Total	151	100
Does the early system function effectively	No	64	43.24
	Not sure	81	54.73
	Yes	3	2.03

	Total	148	100
What functions of early warning should be improved	Drill own borehole	1	10
	Don't know	2	20
	Information Availability	4	40
	Early warning Education	3	30
	Total	10	100

Based on the consultations with key Agricultural Advisors the early warning system of government is operational and effective at the level of less than 30 percent. The main challenge is the capacity of the government at the provincial level to deliver on the three key areas of the broader Disaster Management function namely Early Warning, Risk Assessment, and Disaster Recovery. Weather and Seasonal Fore-castings are developed and sent to the provinces for dissemination to the end-user who is the smallholder farmer. Provinces in the main have officials at the provincial level but have no dedicated human capacity in districts and local municipalities where the early warning information is supposed to be disseminated. Early warning and Disaster-related matters have not been fully assimilated in the organograms of the Department of Agriculture in the provinces. Agricultural Advisors also need to be trained on Early Warning systems whilst being assigned functions of disaster management individually and as a collective.

1. Contingency

Since the livestock smallholder farmers lack a robust early warning system, it is only logical that the impacts of the climatic extremes are always in proportion to the phenomenon itself. Therefore, the farmers are usually caught unprepared to deal with such events and have a mountain to climb to deal with such events. Table 2 shows the frequencies and the percent of the contingency to curb the impacts of climate change on the livestock.

In spite of the absence of the early warning system, 84.36% of the livestock smallholder farmers indicated that there are no contingency plans to alleviate the impacts of climate change on their farms. Only 15.62% have some sort of plan in place to mitigate the impacts of climate change. This implies that the farmers absorb all the impacts of the disaster when they strike. This translates to financial losses in the form of livestock death when there is a disaster impeding a serious need for disaster preparedness seminars.

Table 2. Frequencies and respective percentages of smallholder farmers' perception of the availability of Climate Change Contingency plans

Availability of Contingency Plans	Frequency	Percent
No	308	84.38
Yes	57	15.62
Total	365	100

The respondents who confirmed the existence of the contingency plan also revealed the intrusive aspects of the plan. Table 3 indicates the evolution that the contingency plan had undergone to deal with the recent challenges. Out of 54 respondents who responded to this section (79.63%) indicated that the contingency in place has undergone transformation within the past 5-10 years. This illustrates an attempt to stay relevant to marginalize the impacts of climate change. We are in a global world that is moving very fast, in response, an approach that was established 10 years ago would be outdated today. However, 20.37% insisted that the contingency plans have not been modified since inception. This would not be ideal to curb recent challenges. Although the study focused on the contingency to address climate change, the respondents leaned their response towards the drought.

Seventy-one comma eleven indicated that improved aspects of the plan incorporate the provision of the feeds 2.22% are planning to drill a borehole, and 20% are not sure how the improvement should be intertwined with their existing models. 4.44 and 2.22% indicated that there was the provision of water resources and the erection of a dam respectively.

Table 3. Frequencies and respective percentages of smallholder farmers' perception on the dynamic nature of the contingency plans

Contingency to climate change		Frequency	Percent
Have /the contingency changed in the last 5-10 years	No	11	20.37
	Yes	43	79.63
	Total	54	100
How did they change?	Providing feeds	32	71.11
	Plan to drill a communal borehole	1	2.22
	not sure	9	20
	Water provision	2	4.44
	Building a dam	1	2.22
	Total	45	100
Describe how the contingency have changed	Because of climate change	7	15.56
	Lack of grazing area	31	68.89
	Lack of water	2	4.44
	Others	5	11.11
		45	100
Do the contingency include agriculture and food security	No	345	96.64
	Yes	12	3.36
	Total	357	100

Four issues were cited for the alterations and adjustment of the contingency plans as answered by 45 respondents. The intensification of climate change was outlined by 15.56%, 68.89% revealed a lack in the grazing area, while 4.44 and

11.11 successively suggested a lack of water and other reasons for the evolution of the approach. Agriculture and food security were not part of the contingency (96.64%) while 3.36% suggested otherwise.

2. Early Warning System in context
It can be concluded from the study that the Early Warning system of government is operational and effective at the level of less than 30 percent. The main challenge is the capacity of the government at the provincial level to deliver on the three key areas of the broader Disaster Management function namely Early Warning, Risk Assessment, and Disaster Recovery. Weather and Seasonal Fore-castings are developed and sent to the provinces for dissemination to the end-user who is the smallholder farmer. Provinces in the main have officials at the provincial level but have no dedicated human capacity in districts and local municipalities where the early warning information is supposed to be disseminated.
Early warning and Disaster-related matters have not been fully assimilated in the organograms of the Department of Agriculture in the provinces. Agricultural Advisors also need to be trained on Early Warning systems whilst being assigned functions of disaster management individually and as a collective. The study, based on smallholder farmers' perceptions suggests a need for strategic shifts from natural pastures to small-scale feedlots. The shift should be coupled with the need to establish a dedicated fodder bank as a specialized business. For the farmers to cope and adapt to climate change there is a great need for an early warning system. The government should intervene by providing facilitated water and small-scale feedlot infrastructure for smallholder farmers.

Conclusions and Recommendations
Limpopo and Mpumalanga exhibit a diverse array of climatological conditions that may not be optimally ideal for livestock farming. The down of climate change is leading to the increasing frequency of dry spells and erratic rainfall patterns. Smallholder farmers need alternative grazing to sustain their livestock under the present conditions. The adoption of the climatological information bears the potential to reduce the exposure of the smallholder farmers to the impacts of climate change, it helps the smallholder farmers to manage their practices accurately based on the information at their disposal.
The climate information also reduces the loss associated with improper practices that expose the farmers to the impact of climate change. The farmers stand a better chance to commercialize their operations through the adoption of the appropriate preparedness plan and mitigation strategies.

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