Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate

Report to the

WATER RESEARCH COMMISSION

By

Azwihangwisi Edward NESAMVUNI

KHANIMAMBO INNOVATIVE SOLUTIONS

With Contributions from

Khathutshelo Alfred Tshikolomo
Limpopo Department of Agriculture & Rural Development

Ratunku Gabriel Lekalakala
South African Weather Service

Thomas Raphulu
Limpopo Department of Agriculture & Rural Development

Khuthadzo Ndwambi
Khanimambo Innovative Solutions

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EXECUTIVE SUMMARY

A study was undertaken to assess the level of vulnerability of smallholder livestock farmers in order to provide an appropriate support response to the changing climate. The specific objectives were to: (a) Conduct a vulnerability assessment of smallholder livestock farmers to the impacts of climate change; (b) determine future climate change impacts on livestock in the smallholder sector; (c) characterise the impacts of climate extremes on livestock production (drought, heat waves, floods, etc.); (d) determine the livestock water use efficiency (current and in the projected climate change); (e) identify priority areas in the country where this smallholder farming sector will be affected and determine the necessary adaptive responses; and (f) recommend adaptation strategies that will increase the farmers' resilience and adaptive capacity. On the basis of these six objectives, five scientific papers were written and accepted for congress presentation and publication by the South African Agricultural Extension Congress 2020 and the South African Society of Animal Sciences Congress 2020. The papers formed the framework of all the chapters of this report and present results addressing each specific objective: (a) by investigating the demographic characteristics of smallholder livestock farmers in the Limpopo and Mpumalanga provinces of South Africa and their impact on the capacity of the farmers to adapt to climate change and variability; (b) characterising the agro-ecological attributes of smallholder livestock farming areas in the Limpopo and Mpumalanga provinces; (c) studying the perception of smallholder farmers on the impact of climatic variability and extremes on livestock production in the Limpopo and Mpumalanga provinces; (d) managing climate risks using seasonal climate forecast information in Vhembe District in Limpopo Province; (e) investigating the impact of climatic variability and extremes on livestock water and fodder use in the Limpopo and Mpumalanga provinces; and (f) characterising the impacts of climate change on livestock production systems at national level.

Fieldwork was conducted in both the Limpopo and Mpumalanga provinces. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers who were organised and within reach of 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, and asked a standard set of questions posed in the same way each time. At least 469 smallholder 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, hazard occurrence, adaptation strategies pursued, coping strategies, the level of resilience and other information as indicated in the methodology. The region was classified as predominantly semi-arid, with arid areas found along the far northern border of the Limpopo Province with Botswana, Zimbabwe and Mozambique.

Classification of the study area where the smallholder farmers are farming was based on the FAO framework of 1978 in agro-ecological zones (AEZs), based on major climate zones, moisture zones (water availability) and highland-lowland (cool or warm, based on elevation). An assumption was made to the effect that AEZs are said to be influenced by latitude, elevation, and temperature, seasonality, and rainfall and distribution. The factoring in of elevation provided more information to the local conditions and its usual zonation for the classification of various livestock production system and determination of their likely climate-related risks, as well as vulnerability.

In terms of demographic characterisation, the results indicated that respondents were mainly heads (58.7%) and parents (25.7%) to heads of households and were mostly male (63.4%) with good health (97.8%) associated with high adaptive capacity to climate change and variability. Regarding socio-economic status, four in five (81.5%) of the livestock farmers had only secondary education at most, and incomes were generally low, probably associated with low capacity to adapt to climate change and variability. To the contrary, the quality of housing for the livestock farmers was either top (48.5% of farmers) or medium (47.4%). Some 45.9% of farmers owned 4 to 5 rooms, 44.5% owned six or more rooms, with 88.5% of them having financed their houses. Almost all the respondents (97.3%) had access to electricity, and these suggest a high capacity to adapt to climate change and variability. With regards to aspects of livestock farming, one male (40.1% of households) and female (39.3%) member was fit to work in farming, livestock was owned by heads (52.9% of the households) and by children (29.0%), affirming a high capacity to adapt to climate change and variability. Almost all respondents (99.2%) used communal land, had fewer livestock, lacked training (99.5%), never belonged to a farmers' union (99.7%) or producer organisation (100.0%), and had no access to financial support from government (99.2%) associated with low adaptive capacity.

The results of the agro-ecological attributes showed that there was spatial variability in the precipitation throughout the study area. The area was found to receive an average of 200 millimetres per annum (mmpa). There were localised microclimate zones that were arranged north-south that experience more than 1000 mmpa. The temperatures within the study region were generally warm, with temperatures exceeding 24°C, especially the north-eastern parts. The aridity index values in the study area were divided into three discrete subsections: the arid, semi-arid and, dry sub-humid. The arid areas were found to be the hottest regions in the study area, while it is also amongst the driest regions, with a serious lack of water resources. Over 85% of the study area was recognised as a semi-arid area. The low mean annual rainfall and erratic precipitation pattern are the main factors that hinder farming in the semi-arid regions. The dry sub-humid areas constituted about 5% of the entire study area. The patches instituting this class conformed to the microclimatic regions of the Limpopo and Mpumalanga provinces. The sub-humid area is attributed with relatively warm temperatures in comparison with the surrounding environment and comparably higher precipitation of over 1000 mmpa.

The study region was found to be a risk area, owing to changing environmental conditions, mostly as a result of the rainfed and/or insecure water sources upon which the livestock production systems are dependent. The implications include the impacts of reduced water availability, an increase in the reoccurrence of vector and waterborne diseases, prevalence of invasive species, and a decline in crop and livestock productivity.

In studying the perceptions of the smallholder farmers, it was reported that almost all the farmers (96%) have heard about climate change, with only a few farmers (4%) who had no knowledge of climate change. The medium for the conveyance of climate change information was mainly radio (94.32%). Newspaper and, television were also efficient media in the conveyance of this information, each with an outreach of 16.76% and 32.67% respectively. In terms of the impact of climate change on livestock production, the majority of farmers (77.87%) experienced a dip in rainfall quantity and frequency as the major visual evidence of climate change. Similarly, 80.87% of the farmers outlined that the most imperative predicament that is correlated to climate change was drought. Central to the impact of drought was the fact that 90% of the farmers confirmed that there was a change in grass availability. They said that the lack of natural pastures contributed to major livestock fatalities, of which over half of the farmers (55.19%) attested as the cause. It was therefore important to evaluate the content of the awareness campaigns. The study found that 86.67% of the farmers who attended awareness meetings indicated that the discussions prioritised the importance of adapting to climate change. However, the majority of farmers (80.77%) did not have access to an early warning system. This was coupled with a lack of any contingency plans by most of the farmers (84.36%) to deal with the impact of drought on their farms. Farmers (19%) who had contingency plans indicated that improved aspects of the plan should incorporate the provision of feeds, the drilling of boreholes, and the erection of a dam.

The contribution of this study also covered the role of climate information as a strategy to manage climate risk, including various coping and climate change adaptation strategies. Some of these strategies used to counteract climate risk are traced, drawing from various international, local case studies and mixed farming. The majority of smallholder farmers in the Vhembe district have been experiencing extreme climatic risk, high climate variability and change for some time. The majority of these smallholder farmers are vulnerable to all types of climate risk due to their low adaptive capacity, lack of access to technology as a result of low level of education, lack of financial resources, low level of resilience and high level of poverty. However, the majority of the smallholder farmers in the Vhembe district practice mixed farming and use different adaptive strategies as a way of preserving assets for future livelihoods. These include planting drought-tolerant varieties, crop diversification, and planting crops that require less water. In addition, some smallholder farmers use local climate indicators to monitor climate risk, adjust fertilizer input, and use rainwater harvesting techniques. These have huge implications for the feeding of livestock through crop residues. The use of the surface precipitation index (SPI) showed that the Musina area in the Vhembe district received significant SPI for the years 1924, 1958, 1977, 1986, 2000 and 2013. Low SPI values indicate drought conditions, while high values indicate wet conditions. This area had more than 1.5 SPI above the mean. It was also noted that serious dry spells were experienced in Musina in the years 1922, 1941, 1970, 1983 and 1992. During these dry spells, the majority of farmers lost large numbers of livestock, experienced a shortage of drinking water, low yields, as well as a shortage of seeds for subsequent cultivation. The driest period in the Musina area was in 1983, during which the majority of farmers had to seek assistance from the government. So too did large-scale commercial farmers. It was observed that different institutions in the country, including the South African Weather Services, the Agricultural Research Council, and the Limpopo Provincial Department of Agriculture, issue and disseminate seasonal forecast information to different districts. including Vhembe. Most of the time, the information is disseminated to end-users in simple ways, but there is a need to find out more about end users' needs.

Spatial mapping of the smallholder farmers indicated that they are located in agro-ecological zones where surface (rivers and dams) and sub-surface water are available. The main sources of water for the smallholder farmers were the river (41%), municipal/piped water (40%) and boreholes (33%). Only 3% and 7% of the farmers used water well and dam/pond, respectively, as the water sources for livestock. Women older than 18 years (47.3%) and teenage women between 10 and 18 years (25.4%) were the main carriers of water from the water sources. The main water use by households was for cooking (84%), washing (46.7%), and drinking (44.1%). Municipal piped water to farmers' households was critical to supply sheep, goats, chickens and pigs within homesteads. Cattle seemed to get water within 1 -10 km, mainly to the river source, which was within the recommended 30 km distance for livestock to avoid stress levels. The majority of smallholder livestock farmers (97%) accessed fodder from communal grazing.

Even with the use of crop residues (59%) and own crop harvest (35%), grazing was found to be the biggest challenge for large stock (cattle) and small stock (sheep). The greatest challenge for poultry farmers was the increase in temperatures, whereas for pigs it was pests and diseases. The study, based on smallholder farmers' perceptions, suggests a need for strategic shifts from natural pastures to small-scale feed lots supported by fodder banks. In addition, a need was identified for a shift into small stock farming based on agro-ecological analysis. The government should intervene by providing facilitated water and small-scale feedlot infrastructure for smallholder farmers.

The research also covered the perception of farmers on the impact of climate change on livestock production. The majority of the livestock farmers perceived notable changes in climate patterns (93%), decreased rainfall (87%), increased temperatures (79%) and agreed that the frequency of droughts had increased over the years (88%). Smallholder farmers believed that there is an impact of climate change on their livestock production. Perceptions on impact of climate change on livestock production were based on observations of less grass in pastures, drying streams, outbreak of diseases, death of livestock due to excessive heat or cold, shortage of feeds, drinking water and unknown diseases and floods. The majority of livestock farmers practice free range or backyard production systems (80%) under small-scale production, and their livestock are directly and indirectly affected by climate change. It was observed that the majority of livestock farmers do not own the land (99%) and their livestock grazed/browsed on communal land. The use of communal grazing by livestock farmers makes them more vulnerable to climate change with less adaptive capacity. The majority (97%) of farmers had access to electricity in their houses. Most livestock farmers had cattle (98%), followed by goats (15%), chickens (8%), pigs (6%) and sheep (3%). On average, livestock farmers had 16 years of farming experience, with farming experience ranging between 3 and 70 years. On average, farmers kept 16.70, 12.50, 14.82, 19.07, 7.0 and 11.53 of cattle, sheep, goats, fowls, donkeys and pigs, respectively. Males were mentioned as the main member of the household responsible for selling/slaughtering (74%), animal health (72%), purchasing (69%), breeding decisions (67%), herding (56%), and feeding (56%) activities. The majority of livestock farmers indicated rivers as the main source of water for their cattle and donkeys and their cattle travelled 1 to 10 km to access water (proxy to water stock), especially from the river. Grazing (> 66%) was mentioned as the main environmental challenge, affecting cattle, sheep, goats and donkeys, followed by temperature, pests and diseases, rainfall and water. Smallholder farmers reported taking different types of adaptation measures to deal with climate change, such as provision of water, allowing livestock to graze near the river, water storage, and provision of feed supplements and selling of livestock to buy feeds. Livestock farmers are highly vulnerable to climate change with less adaptive capacity and need financial and political support to improve their adaptive capacity from the government.

In conclusion, the study findings point to the following: (a) that demographic factors had different influences on the capacity of smallholder livestock farmers to adapt to the adverse effects of climate change and variability on the farming enterprises. This was true for all the three types of demographic factors studied, namely personal characteristics, economic status, and aspects of livestock farming; (b) farmers must diversify farming with hardy indigenous small frame cattle and goats; (c) smallholder farmers be encouraged with stimuli to produce fodder for own livestock feeding and or of fodder banks and small feedlots; (c) extreme climate may naturally drive cattle farming into incorporation into the game industry for communities surrounding the game parks be they national or locally owned by communities. The climatic risk against cattle farming may tend to be higher in extreme climates than for game farming at the expense of red meat production; (d) smallholder farmers cope with extreme climate events such as drought by selling some animals to save money for the purchase of fodder, which is their biggest constraint.

It is recommended that:

(a) Research should be conducted as a follow-up study to investigate the impact of climate change on land use across agriculture to environmental conservation of biodiversity (natural vegetation to game). The current debate on game farming and the shift from beef cattle ranching can create a profitable continuum

(b) Research be conducted on other factors/indicators (demographic and non-demographic) that may influence the smallholder farmer's capacity to adapt to climate change and variability, be it livestock or crop farmers; an integrated indicators report was done for this study with a comprehensive list of indicators to be validated

(c) The results of the study have shown agro-ecological differences and ways of adaptation by smallholder farmers that necessitate follow-up studies beyond Limpopo and Mpumalanga. The impact of extreme climate in most provinces may necessitate new extension approaches to farming e.g., livestock and game, production of fodder trees intercropped with fodder crops, and production of fertilizer trees

(d) It is highly recommended that indigenous small stock (goats and sheep) be the preferred farming animal as they are drought tolerant, as farmers that are practicing cattle farming will be more likely exposed to the impacts of climate change due to a lack of feed and water

(e) A strategic shift for large stock farmers (cattle) is recommended from natural pastures to small-scale feedlots with provision of cover against heat stress. The shift should be coupled with the need to establish dedicated fodder banks as a specialised business. A follow-up study on land available and suitable for fodder production per province and in each municipality should be done

(f) Crop models, especially for crops that also play a role in livestock fodder, may need to be reviewed with special consideration for groundwater as a source in the context of some areas where groundwater is the only source of irrigation water

(g) The results of the study indicate that for the farmers to cope and adapt to climate change there is a great need for an early warning system

(h) The results of the research should be shared with the government and related agencies to inform policies on farmer support for improved response to the adverse effects of climate change and variability.

ABBREVIATIONS AND ACRONYMS

1. **ADR** – Annual Distribution of Rainfall
2. **AEZ** – Agro-ecological Zones
3. **AI** – Aridity Index
4. **ARC** – Agricultural Research Council
5. **ARC-ISCW** – Agricultural Research Council – Institute of Soil, Climate & Water
6. **DAFF** – Department of Agriculture, Forestry & Fisheries
7. **DEA** – Department of Environmental Affairs
8. **DLUSM -** Land Use and Soil Management
9. **FAO** – Food & Agricultural Organization
10. **Freq.** – Frequency
11. **GIS** – Geographic Information System
12. **GPS** – Global Positioning System
13. **HVI** - Household Vulnerability Index
14. **IPCC -** Intergovernmental Panel on Climate Change
15. **Kg** – Kilograms
16. **Km** – kilometre
17. **LEI** – Livelihood Effect Index
18. **LER** – Land Equivalent Ratio
19. **LGP** – Length of growing period
20. **LUT** – Land Utilization Type
21. **LVI** – Livelihood Vulnerability Index
22. **LVI-IPCC** – Livelihood Vulnerability Index- Intergovernmental Panel on Climate Change
23. **MAT** – Mean Annual Temperature
24. **MCDA** - Multi-criteria Decision Analysis
25. **MDBSA** – Municipal Demarcation Board of South Africa
26. **Mm** – millimetres
27. **Mmpa** – millimetres per annum
28. **NDVI** – Normalized Difference Vegetation Index
29. **NGO** – Non-governmental Organization
30. **PDA** – Provincial Departments of Agriculture
31. **SAS** – Statistical Analysis System
32. **SAWS** – South African Weather Service
33. **SPI** – Surface Precipitation Index
34. **StatsSA** – Statistics South Africa
35. **THI** – Thermal Heat Index
36. **Tmax** – Maximum Temperature
37. **WRC** – Water Research Commission

DEFINITIONS

1. **Adaptation to climate change:** Refers to adjustments in human and natural systems in response to actual or expected climate stimuli or their impacts that moderate harm or exploit beneficial opportunities.
2. **Adaptation:** The quality of being able to adjust to new conditions – adaptability is an advantage in the harshest competitive environment, the capacity to be modified for a new use or purpose.
3. **Adaptive capacity:** Considered a function of wealth, technology, education, information, skills, and infrastructure, access to resources, and stability and management capabilities. The ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
4. **Agricultural production system**: The production methods for sustaining plant growth, which include practical management tools, husbandry practices, and management philosophies.
5. **Agro-ecological zone**: A land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints of land use.
6. **Agro-ecological zoning:** The division of an area of land into smaller units, which have similar characteristics related to land suitability, potential production and environmental impact.
7. **Aridity index**: A numerical indicator of the degree of dryness of the climate of a given location. The index serves to identify, locate or delimit regions that suffer from a deficit of available water, a condition that can severely affect the effective use of the land for activities such as agriculture or stock-farming.
8. **Cattle water use efficiency**: Estimations of water use to produce 1 kg of livestock or expressed as the ratio of the net beneficial livestock-related outputs and services to the water lost through evapotranspiration (ET) in producing them.
9. **Climate change:** The statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). May be due to natural internal processes or external factors such as persistent changes to the atmosphere or changes in land use.
10. **Climate forecasting**: The description of the future state of the climate, that is, the average or expected atmospheric and earth-surface conditions, for example, temperature, precipitation, humidity, winds, and their range of variability **Seasonal Forecasting**: Same as climatic but now seasonal and interannual climate predictions, made many months in advance, provide useful information for planners and policy makers.
11. **Climate risk**: Refers to risk assessments based on formal analysis of the consequences, likelihoods and responses to the impacts of climate change and how societal constraints shape adaptation options. Applying current knowledge to understand climate risk is further complicated due to substantial differences in regional climate projections, expanding numbers of climate model results, and the need to select a useful set of future climate scenarios in their assessments.
12. **Climate variability**: The variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events. The deviations of climatic statistics over a given period (e.g., a month, season, or year) when compared to long-term statistics for the same calendar period. **Variability** may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external factors (external variability).

13. **Climate**: “Average weather” is the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over time, ranging from months to thousands or millions of years.
14. **Competitive risks**: If companies do not take measures to reduce climate risks, they are competitively disadvantaged. This might lead to increased production costs caused by obsolete technologies and therefore to decreased profits.
15. **Cropping system**: A system, comprising soil, crop, weeds, pathogen and insect subsystems, that transforms solar energy, water, nutrients, labour and other inputs into food, feed, fuel or fibre. The cropping system is a subsystem of a farm system.
16. **Database**: An organised, integrated collection of data stored for use by relevant applications, with data being accessed by different, logical paths. In theory the data are application independent.
17. **Ecological-economic zoning**: A kind of zoning that integrates physical land resources elements with socio-economic factors and a wider range of land uses in zone definitions.
18. **Economic adaptive capacity:** Financial assets, including built infrastructure and a number of features enabling economic development.
19. **Evapotranspiration:** The combined loss of water from a given area over a specified time by evaporation from the soil surface and by transpiration by plants.
20. **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 changes in climate variability, including the magnitude and frequency of extreme events. Or the nature and degree to which a system is exposed to significant climatic variations.
21. **Farming system:** A decision-making unit, comprising a farm household, cropping and livestock systems, which produces crops and animal products for consumption and sale.
22. **Geographical information system:** A system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which is spatially referenced to the earth.
23. **Goat water use efficiency**: Estimations of water use to produce 1 kg of livestock, or expressed as the ratio of the net beneficial livestock-related outputs and services to the water lost through evapotranspiration (ET) in producing them.
24. **Grassland-based systems**: A subset of solely livestock production systems in which more than 10 percent of the dry matter fed to animals is farm-produced, and in which annual average stocking rates are less than ten LU per hectare of agricultural land.
25. **Grazing capacity:** The carrying capacity of a pasture or area of the range, usually expressed as the number of animals (as cattle) that it will support for a specified length of time or indefinitely.
26. **Growing period:** The time of year when both moisture and temperature conditions are suitable for crop production.
27. **Heat wave:** A period of abnormally and uncomfortably hot and usually humid weather.
28. **Household vulnerability index:** A statistical tool for measuring household vulnerability.
29. **Human adaptive capacity:** Skills, education, experiences and general abilities of individuals combined with the availability of ‘productive’ individuals.
30. **Institutional adaptive capacity:** Government-related infrastructure (fixed assets): utilities such as electricity, transportation, water, institutional buildings and services related to health, social support, and communications.

31. **Irrigated mixed-farming systems:** A subset of the mixed systems in which more than 10 percent of the value of non-livestock farm production comes from irrigated land use.
32. **Land capability**: The ability of the land surface to support natural plant growth/ wildlife habitat or artificial crop growth/ human habitat. Thus, it indicates the type of land use (viz., human habitation, agriculture, pastures, forests, wildlife habitat, etc.) that is suitable over a particular type of land. Different lands have different capabilities depending on the land characteristics such as slope, soil type, soil depth and erosion conditions. If certain land characteristics are not conducive for agriculture, it is desirable to utilise or ensure the continuity of that land area for other land uses.
33. **Land characteristic**: A property of the land that can be measured or estimated.
34. **Land equivalent ratio:** The ratio of the area needed under sole cropping to one of intercropping at the same management level to give an equal amount of yield. LER is the sum of the fractions of the yields of the intercrops relative to their sole crop yields.
35. **Land evaluation**: The assessment of land performance when used for a specified purpose.
36. **Land quality**: A complex attribute of land that acts distinctly in its influence on the suitability of land for a specified use.
37. **Land utilisation type**: A use of land defined in terms of a product, or products, the inputs and operations required to produce these products, and the socio-economic setting in which production is carried out.
38. **Landless livestock production systems:** Subset of the solely livestock production systems in which less than 10 percent of the dry matter fed to animals is farm-produced and in which annual average stocking rates are above ten livestock units (LU) per hectare of agricultural land.
39. **Length of growing period:** The continuous period of the year when precipitation exceeds half of Penman evapotranspiration, plus a period required to evapotranspire an assumed soil moisture reserve and when mean daily temperature exceeds 6.5 °C.
40. **Litigational risks**: Similar to the tobacco industry, industries producing excessive greenhouse gases (GHG) are exposed to the risk of an increasing number of lawsuits if damages can be correlated to emissions.
41. **Livestock water productivity (use efficiency)**: estimations of water use to produce 1 kg of livestock or expressed as the ratio of the net beneficial livestock-related outputs and services to the water lost through evapotranspiration (ET) in producing them.
42. **Mixed-farming systems**: Livestock systems in which more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities.
43. **Model**: A simplified representation of a limited part of reality with related elements.
44. **Multi-criteria decision analysis:** A set of techniques used to solve problems that involve several objectives being considered simultaneously. In the context of integrated land use planning and management, MCDA techniques are applied to analyse various land use scenarios, considering simultaneously several objectives, such as maximising revenues from crop and livestock production, minimising costs of production and environmental damage from erosion.
45. **Natural adaptive capacity:** Endowments and resources of a region belonging to the biophysical realm, including forests, air, water, arable land, soil, genetic resources, and environmental services.

46. **Physical risks**: Direct risks of climate change negatively impact agriculture, fisheries, forestry, healthcare, real estate and tourism. For example, storms and flooding damage buildings and infrastructure, and droughts lead to crop failure.
47. **Pig water use efficiency**: Estimations of water use to produce 1 kg of livestock, or expressed as the ratio of the net beneficial livestock-related outputs and services to the water lost through evapotranspiration (ET) in producing them.
48. **Potential yield:** The maximum yield that can be achieved by a given crop cultivar in a given area, based on radiation and temperature.
49. **Production risks**: Production shortfalls can result from direct or indirect climate risks, i.e., hurricanes damaging oil production facilities can lead to supply disruption and increased prices. Also, the price of energy will rise as heat waves cause water scarcity, impacting the supply of power plant cooling water.
50. **Production system**: A particular series of activities (the management system) carried out to produce a defined set of commodities or benefits (produces).
51. **Rain-fed mixed-farming systems:** A subset of the mixed systems in which more than 90 percent of the value of non-livestock farm production comes from rain-fed land use.
52. **Regulatory risks**: Governmental endeavours to reduce climate costs have direct effects on the economy. For example, Kyoto-Protocol emissions targets could be realised by implementing emissions trading, requiring the cost of emissions to be quantified monetarily. These costs would be used by companies to evaluate investment decisions. Factoring in emissions costs will cause prices to rise, therefore impacting consumer demand. The insecurity of legislation leads to indefinite postponement of projects and investments.
53. **Reputational risks:** Companies publicly criticised for their environmental policies or high emissions might lose customers because of a negative reputation.
54. **Resource management domains**: Regions designated for identical treatments, i.e., land development plans, nature conservation programmes, and classified based on ecological-economic zoning.
55. **Sensitivity:** The extent to which a body is either adversely or beneficially, directly or indirectly affected by climate change and variability. The degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)
56. **Sheep water use efficiency**: estimations of water use to produce 1 kg of livestock or expressed as the ratio of the net beneficial livestock-related outputs and services to the water lost through evapotranspiration (ET) in producing them.
57. Smallholder Farmer: Farmers owning small plots of land on which they grow subsistence crops and one or two cash crops, relying almost exclusively on family labour.
58. **Social adaptive capacity:** People's relationships with each other through networks and the associational life of their community.
59. **Soil mapping unit**: An area of land delineated on a map. A soil mapping unit may consist either of a single soil type or of multiple soil types occurring as a complex or association.
60. **Soil type**: A specific unit of soil with definable ranges of characteristics. May correspond to the lowest hierarchical unit of a soil classification system, including specification of phase.

61. **Solely livestock production systems**: Livestock systems in which more than 90 percent of dry matter fed to animals comes from rangelands, pastures, annual forages, and purchased feeds, and less than 10 percent of the total value of production comes from non-livestock farming activities.
62. **Spatial variability**: Occurs when a quantity that is measured at different spatial locations exhibits values that differ across the locations. Spatial variability can be assessed using spatial descriptive statistics such as the range.
63. **Stakeholder**: An individual, community, government, or NGO that has a traditional, current or future right to make decisions on land.
64. **Sustainable land use**: Use of the land that does not progressively degrade its productive capacity for a defined purpose.
65. **Thermal regime:** The amount of heat available during the growing period. Thermal regime can be defined either in terms of temperature or degree days.
66. **Vulnerability:** The degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system.
67. **Weather forecasts:** A prediction of the state of the atmosphere a few days in advance is made in various countries using standard procedures.

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Mr Joel Mamabolo	Department of Agriculture, Land Reform and Rural Development
Ms Kedibone Cheue	Department of Agriculture, Land Reform and Rural Development
Dr Ikalafeng Kgakatsi	Department of Agriculture, Land Reform and Rural Development
Mr R.R. Ramugondo	Limpopo Department of Agriculture & Rural Development
Dr Maanda Dagada	Mpumalanga Department of Agriculture, Environment & Land Reform
Mr Noel Ottle	Environmental Monitoring Group
Dr Nick Walker	Aurecon
Ms Judith Seopa	Agricultural Research Council
Ms Brigid Letty	INR
Prof K. Ayisi	University of Limpopo

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Livestock production in South Africa contributes a significant amount of income to the economy compared to other agricultural activities, such as grain crops and horticulture. Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien et al. 2004, Morton, 2007). Because smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reduction in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (Hertel and Rosch, 2010). Information on the vulnerability of small-scale livestock farmers to the impacts of climate change in South Africa is very limited. The project will also develop strategies to improve livestock water use efficiency with its associated water foot-print depending on the identified final product of the value chain. The research will, in brief, characterise the impacts of climate extremes on livestock production in the small-scale farming sector.

1.2. PROBLEM STATEMENT

Livestock is adversely affected by the detrimental effects of extreme weather. Climatic extremes and seasonal fluctuations in herbage quantity and quality affect the well-being of livestock and lead to declines in production and reproduction efficiency (Sejian, 2013). The impact of climate change increases the problem of water scarcity; pasture land shortage and disease dynamics. Diseases in livestock result in severe effects on livestock survival, marketability, animal health and livelihoods (Gardner 2012). On the other hand, livestock production is one of the major consumers of freshwater (Molden et al., 2010). Water used to grow livestock feed is far greater than water required to meet the drinking requirements of the livestock. Drinking water accounts for only about 2% of the total water need for livestock production, with much of the remainder being accounted for by water needed for feed production (Peden et al., 2007). Increasing the efficiency of water used for livestock feed production could reduce future demands for agricultural water. The demand for water per livestock species was well articulated through the Challenge Program for Water and Food using the case of the Nile Basin (Peden, et.al., 2009). The extent of the impact of climate extremes on livestock production has not been investigated at local community level.

1.3. AIM OF THE STUDY

The aim of the project is to assess the level of vulnerability of smallholder livestock farmers in order to provide appropriate support response to the changing climate.

1.4. OBJECTIVES

The project had the following objectives:

- Conduct a vulnerability assessment of smallholder / small-scale livestock farmers to the impacts of climate change
- Determine future climate change impacts on livestock in the smallholder / small-scale sector
- Characterise the impacts of climate extremes on livestock production (drought, heat waves, floods, etc.)
- Determine the livestock water use efficiency (current and in the projected climate change)
- Identify priority areas in the country where this small-scale farming sector will be affected and determine the necessary adaptive responses
- Recommend adaptation strategies that will increase the farmers' resilience and adaptive capacity

1.5. OUTLINE OF THE REPORT

The report is organised such that Chapter 1 (this chapter) presented the Introduction, Chapter 2 presents the review of literature, and Chapter 3 presents livestock farmer demography and adaptive capacity to climate change and variability in Limpopo and Mpumalanga provinces of south Africa. Chapter 4 deals with agro-ecological characterisation of smallholder livestock farming systems in Limpopo and Mpumalanga provinces, Chapter 5 presents smallholder farmers' perceptions on the impact of climate variability and extremes on livestock production in Limpopo and Mpumalanga provinces, and Chapter 6 addresses managing climate risks using seasonal climate forecast information in Vhembe District of Limpopo Province. Then Chapter 7 deals with climate vulnerability and smallholder livestock water and fodder use analyses, Chapter 8 is on adaptive capacity of smallholder livestock farmers to the impacts of climate change, and Chapter 9 presents a localised framework to monitor and evaluate the vulnerability of smallholder livestock farmers in Limpopo and Mpumalanga provinces. This is followed by Chapter 10 on the projection of the national outlook on vulnerability – agro-ecological characterisation of livestock farming systems at national level projected from provincial level. Chapter 11 presents the publications to date generated from the study, while Chapter 12 reflects on the capacity building on students and extension officers. Chapter 13 provides conclusions and recommendations. The report was structured in such a way that each chapter is a standalone, assumes the form of a publishable manuscript, and is accordingly comprised of items such as an abstract, introduction, research methodology, results and their discussion, conclusions, and references. As a result of this structuring of the report, a limited amount of information was repeated across some of the chapters, and this was necessary to ensure coherence and good flow of the presentation.

CHAPTER 2: LITERATURE REVIEW

The literature review was organised into four main themes, namely, (1) vulnerability assessment of smallholder / small-scale livestock farmers to the impacts of climate change, (2) determine future climate change impacts on livestock in the smallholder / small scale sector, (3) impacts of climate change on water-related extremes, characterise the impacts of climate extremes on livestock production (drought, heat, waves, floods, etc.), and (4) determine the livestock water use efficiency (current and in the projected climate change), and climate, vulnerability and water use analyses of the livestock sector.

2.1 VULNERABILITY ASSESSMENT OF SMALL HOLDER/SMALL SCALE LIVESTOCK FARMERS TO THE IMPACTS OF CLIMATE CHANGE

2.1.1 INTRODUCTION

The adverse effects of climate change and variability has become an environmental and socio-economic problem which is increasingly causing climate-driven hazards to people around the world (Scholze, Knorr, Arnell, & Prentice, 2006). Mapping agriculture's vulnerability to climate change is of paramount importance in developing countries, as the sector has high relevance from social, environmental and economic perspectives. Agriculture is especially vulnerable to climate change, since it is based on agro-productive systems that are dependent on environmental conditions such as temperature, nutrient availability and water accessibility (Rosenzweig and Hillel 2008; Lobell et al. 2011). In addition, Lin et al. (2007) indicated that agriculture is also one of the sectors most sensitive to climate change because any degree of climate change can be associated with severe negative impacts on agricultural production and related processes.

Rural communities are believed to be particularly vulnerable to climate change (Holmes, 2007; Turpie and Visser, 2013). This vulnerability of rural households in Africa is caused not only by exposure to climate change, but also by a combination of social, economic and environmental factors that interact with it (David et al., 2007). By implication, climate change poses environmental, social and economic challenges for South African societies, particularly rural communities with high dependence on natural resources (Fairbanks and Scholes, 1999; Turpie and Visser, 2013). Smallholder farmers constitute a significant portion of the world's population, with an estimated 450 to 500 million smallholder farmers worldwide, representing 85% of the world's farms (Nagayet, 2005). In South Africa, climate change is predicted to result not only in higher temperatures, but also in sporadic rainfall patterns and frequent droughts (Turpie and Visser, 2013). These severe weather events, coupled with the country's already scarce water resources, are expected to have a significant effect on the forestry and agricultural sectors, which are substantial components of the country's rural livelihoods and economies (Quinn et al., 2011; Turpie and Visser, 2013).

2.1.2 CLIMATE CHANGE

Climate change refers to a long-term (over a decade) change in climate patterns that can be identified by changes in the mean and/or the variability of its properties whether due to natural variability or as a result of human activity. It may involve gradual changes in long-term average conditions of climate; greater variability in normal conditions; or changes in the frequency, magnitude, and distribution of extreme events (Smit et al., 2000).

Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien et al., 2004). Because smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (McDowell & Hess, 2012).

Climate change manifestations in the form of rising temperatures, changes in water availability and increased levels of carbon dioxide are expected to affect farming and forest based livelihoods in various ways (Sonwa et al., 2012). The Intergovernmental Panel on Climate Change (IPCC, 2007) highlighted that Africa will be one of the continents that will be hardest hit by the impact of climate change due to an increased temperature and water scarcity despite the fact that Africa represents only 3.6% of emissions.

2.1.3 VULNERABILITY

There are many definitions of vulnerability. 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) defines vulnerability as the extent to which one is prone, at risk or likely to be food insecure. Ncube et al. (2016) further indicated that vulnerability has two sides, namely an external side with risks, shocks and stress to which an individual is subject and an internal side or being defenceless, meaning 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) conceptualised 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 (Intergovernmental Panel on Climate Change - IPCC, 2001; Yohe and Tol, 2002). The social science literature recognises that 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) and reveals that 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 summarised as a function of three attributes, namely, exposure, sensitivity and its adaptive capacity. Indicators of the three attributes are shown in Table 2.1.

(a) 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 changes in 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., temperature, precipitation, extreme weather events). 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).

(b) 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).

(c) 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). Number of livestock owned, ownership of a radio, and quality of residential homes are commonly used as indicators of wealth in rural African communities (Vyas and Kumaranayake, 2006). Smith and Lenhart (1996) indicated that 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, p. 287). In socio-ecological systems, it is linked to governance aspects that allow rapid transitions between options every time a 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 organisational 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 adaptation 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).

Cooperatives are relevant for adaptive capacity since they facilitate access to public policies and to the production scale necessary to be inserted in the market (Jones and Boyd 2011; O'Brien et al., 2004). Two adaptive capacity indicators measure these aspects. First, 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). Second, from an organisational perspective, cooperatives are relevant for adaptive capacity since they facilitate access to public policies and to the production scale necessary to be inserted in the market (O'Brien et al., 2004; Jones and Boyd, 2011).

2.1.4 ASSESSMENT OF VULNERABILITY

Several studies presenting assessments of vulnerability to climate change are currently available. Most of the studies assessed vulnerability as a function of three attributes: sensitivity, adaptive capacity, and exposure (O'Brien et al., 2004; Gallopín, 2006; Birkmann, 2007; Hahn et al., 2009). This section attempts to integrate both complementary approaches, namely social vulnerability (Brooks et al., 2005) and risk assessment studies (Alcamo et al., 2008; Torresan et al., 2008).

The improvement of indicators used to evaluate the vulnerability of human systems and their capacity to respond to climate change is a response to the growing demands of decision makers for regular information with high spatial and temporal resolution (Vincent, 2007; Fraser et al., 2011). The application is expected to identify areas with higher exposure or lower adaptive capacity in order to address adaptation efforts (Smit and Wandel, 2006).

Table 2.1. ATTRIBUTES AND INDICATORS USED TO ASSES VULNERABILITY OF SMALLHOLDER FARMING (LINDOSO, 2011)

Vulnerability of smallholder farming	Attributes of Vulnerability	Indicator
	Sensitivity (S)	Level of smallholder farming's income dependence on vegetable and livestock production (%)
		Municipal population occupied in smallholder agriculture (%)
		Number of households with access to water supply (%)

		Number of rain-fed smallholder farms (%)
		Sensitivity of the smallholder farm productive system (%)
	Adaptive capacity (AC)	Smallholder system product diversification (%)
		Establishments in which the producer is the landowner (%)
		Establishments in which the administrator can read and write (%)
		Establishments in which the producer is a member of an association or union (%)
		Establishments that receive technical assistance (%)
		Agricultural establishments with access to electricity
	Exposure (E)	Aridity Index (AI)
		Annual distribution of rainfall

Exposure, Sensitivity and Adaptive capacity indicators are used to assess the vulnerability of smallholder farming to climate change as adopted from IBGE (SIDRA) and Funceme (2011). The Sensitivity and Adaptive Capacity sub-indexes are generated by a simple average of the five indicators comprising each of them. Data from the weather services is used for the Exposure attributes (Lindoso et al., 2014). The formula used to calculate vulnerability is = V + S + (1-AC) divided by 3, where V is vulnerability, S, sensitivity and AC, adaptive capacity. Bottom-up approaches such as interviews, participant observation, ethnography, and focus groups are also incorporated to assess vulnerability (Bellon et al., 2011; Jones and Boyd, 2011).

Lindoso et al. (2014) assessed vulnerability of smallholder farming to climate variability from three perspectives or levels: the agricultural systems level – with production diversification and resources constituting the pillar of family livelihood; the household level, analysing socio-economic, political and institutional aspects through local lenses; and the municipality level – observing the households' sets of socioeconomic and institutional indicators. Livestock has significant sensitivity to climate variability. Even though animals lose weight during the dry season and some actually die, in the Semi-Arid, livestock is considered a more robust agricultural activity to cope with dry conditions than crops (Toni and Holanda, 2008).

(a) Household Vulnerability Index (HVI)

Household Vulnerability Index (HVI) is a statistical tool for measuring household vulnerability. This tool was developed by the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) between 2004 and 2007 using statistical research methods on data from seven countries: Swaziland, South Africa, Botswana, Lesotho, Namibia, Zimbabwe and Zambia (Majahodvwa et. al., 2014).

(b) Factors affecting vulnerability

The factors that contribute to vulnerability include rapid population growth, poverty and hunger, poor health, low levels of education, gender inequality, fragile and hazardous location, and lack of access to resources and services, including knowledge and technological means and disintegration of social patterns (social vulnerability) (Majahodvwa et. al., 2014).

(c) Demographics

Elderly households are more vulnerable because they are not engaged in productive and income-generating activities. Vulnerability assessed at the national level, for example, can conceal variations in local vulnerability (O'Brien et al., 2004a); likewise, adaptation strategies developed for national implementation may be inappropriate for local contexts (Adger et al., 2005). In assessments of vulnerability in developed nations, where basic food security, political stability, human health and physical infrastructure are not of primary concern, a number of measures have emerged (John Parkins and MacKendrick, 2007).

The emphasis on vulnerability studies for these nations tends to be on institutional and political factors, as well as the economic circumstances that magnify damage from undesirable events, including debt, market dependency, economic inequality and access to financial and natural resources, and physical infrastructure (Handmer et al., 1999; Cross, 2001; O'Brien et al., 2004b). These international assessments have documented striking differences in global vulnerability, whereby many developing nations in Africa and Asia face vulnerability concerns that far exceed those in Western Europe and North America (e.g. Moss et al., 2000; IPCC, 2001; Brooks et al., 2005). The Food and Agriculture Organization of the United Nations (FAO, 2006) has suggested that vulnerability to climate change differs across space and time due to the numerous contributing factors. Climate change exposure is believed to be location specific. For example, communities in semi-arid areas may be most exposed to drought whereas coastal communities will have a higher exposure to sea level rise and cyclones. Lowlands can be adversely affected by flooding and soil salinization due to predicted sea level rise and groundwater salinisation. The areas impacted by reduced snowfall and melting glaciers can face severe droughts due to a decrease in water availability for meeting crop water requirements (IFAD, 2013). Demographic factors influencing the vulnerability of smallholder livestock farmers to climate change and variability include:

- Financial support

Financial support helps households to deal with shocks to their livelihoods, and so households that receive remittances are more likely to be in the low-vulnerability category.

- Knowledge of climate change

Households with some knowledge of climate change are less likely to be highly and moderately vulnerable than households with less knowledge.

- Shocks experienced by households

The five major shocks that result in lower yields are droughts, significant increases in food prices, crop diseases or pests, damaged houses and theft. Households that produce their own food are more likely to be affected by climate change. Other shocks include loss of employment, the failure of household businesses, non-payment of salary and illness of household members and/or household head. (Ncube et al., 2016)

(d) Infrastructure

Smallholder farmers live in precarious conditions and are intrinsically vulnerable to any shocks that affect their agricultural systems (Harvey et al., 2014). As in much of rural Madagascar and other parts of Africa (Barret et al., 2004; Bryan et. al, 2009), the farmers live in rustic houses, lack electricity and running water, own few assets and rely on natural ecosystems for drinking water, firewood, wild foods and materials for household construction. Hurvey et al., (2014) found that the remoteness of farm villages and lack of adequate road infrastructure increases farmer vulnerability. The livelihood implications of this isolation are significant, as farmers have difficulties getting their products to market as well as obtaining agricultural inputs; in addition, farmers generally have to pay higher prices for agricultural inputs in remote areas, reducing their profit margins (Minten et al., 2007).

(e) Farming system

The farming system used is significantly important because smallholder farmers have been identified as most vulnerable to climate change impacts, both in developed and developing countries (Adger, 2006). For the last two decades, the vulnerability of agricultural production to climate change effects increasingly became the focus of comprehensive research (Tan, 2004). Smallholder farming is a special case within the agriculture sector since it produces more than food: it also preserves specific cultural and social traits (Adger et al., 2009; Lemos et al., 2002). However, its adaptive capacity is compromised, especially when compared to large-scale agriculture, for which access to funding and productive infrastructure is easier (Morton, 2007).

Harvey et al. (2014) conducted a study on extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar using household surveys and focus group discussions. It was reported that the farmers live in rustic houses, lack electricity and running water, own few assets and rely on natural ecosystems for drinking water, firewood, wild foods and materials for household construction. The majority of households in all three landscapes are chronically food insecure, which makes them extremely vulnerable to any climate or non-climatic shocks that further reduce agricultural production and food availability.

Sattar et al. (2017) conducted a study on the assessment of smallholder farmer's vulnerability due to climate change in arid areas of Pakistan. Three different composite indices were used to assess the vulnerability of smallholder farmers to climate change: Livelihood Vulnerability Index (LVI), Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change (LVI- IPCC), and Livelihood Effect Index (LEI). The methodology used for calculating the indices was adapted from Hahn et al. (2009) and Khajuria and Rabindranath (2012), so as to include specific climatic and contextual conditions (Parry et al., 2007). The study has highlighted the problematic state of smallholder farmers in Pakistan, their high exposure to the climatic hazards and the earnest need to decrease both their present and future vulnerability to these dangers. Small landholdings, less innovation, low capitalization and various non-climatic stressors tend to build vulnerability. However, the strength components such as family labour, crop expansion and indigenous knowledge cannot be depreciated.

Derrick et al., (2017) examined the vulnerability of smallholder maize farming households to climate change in the Brong-Ahafo region of Ghana by employing the Livelihood Vulnerability Index emphasizing access to and utilization of water resources. The empirical results revealed that farming households in Wenchi Municipality were more vulnerable in terms of major components such as water, food, natural disaster and climate variability, social network, and health and socio-demographic profiles than those in Techiman Municipality.

2.2 DETERMINE FUTURE CLIMATE CHANGE IMPACTS ON LIVESTOCK IN THE SMALLHOLDER / SMALL-SCALE SECTOR

2.2.1 INTRODUCTION

Climate change is expected to have a major impact on water resources. In some regions increases in magnitude and frequency of extreme events are already being observed, and some experts are attributing this to a changing climate. Global increases in temperature will have profound effects on evaporation, which in turn affects atmospheric water storage and hence magnitudes, frequencies and intensities of rainfall events as well as the seasonal and geographical distribution of rainfall and its inter-annual variability. A high degree of uncertainty remains, particularly in the anticipated changes in rainfall characteristics with climate change. Water resource managers, in particular, face the challenge of incorporating the added uncertainty of the impacts of climate variability and climate change on hydrological responses into their decision-making process.

(a) Anticipated Global Climate Change and Water Resources

Since climate extremes which result in floods and droughts; it is imperative that water resource managers are aware of the current forecasts of climate change, and of their likelihood of occurrence and their likely effects on water resources (Table 2.2).

TABLE 2.2. SUMMARY OF ALREADY OBSERVED CHANGES, PROSPECTS FOR THE FUTURE AND LIKELY IMPACTS ON WATER RESOURCES (SOURCE: IPCC, 2001)

Climate Change Forecast	**Climate Change Observed**	**To Occur in 21st Century**	**Effects on Water Resources**
Higher maximum temperatures and more hot days over nearly all land areas	Likely	Very likely	Water resources reduced
Higher maximum temperatures, fewer cold days and frost days, over nearly all land areas	Very likely	Very likely	Water resources reduced
Diurnal temperature ranges reduced over most land areas	Very likely	Very likely	
Increases of heat index over land areas	Likely over many areas	Very likely over most areas	Water resources reduced

More intensive precipitation events	Likely over many northern hemisphere mid to high latitude areas	Very likely over many areas	More frequent and more severe floods
Increased summer continental drying and associated risk of drought	Likely in a few areas	Likely over most mid-latitude continental interiors	More frequent and more severe droughts
Increases in tropical cyclone peak wind intensities	Not observed in the few analysis available	Likely over some areas	More frequent and more severe storm-surge floods
Increases in mean and peak precipitation intensities in tropical cyclone	Insufficient data	Likely over some areas	More frequent and more severe floods

b) Why do water resources matter?

At the global scale, withdrawal and net consumption of water is expected to grow substantially during the next 50 years, owing to an increase in population, quality of life and food production. In addition, even if the trend of a decrease in net consumption continues in several of the most developed countries, the global increase of water use by 2025 is expected to be in the range of 25-50 %, according to several development scenarios (Cosgrove and Rijsberman, 2000). In essence, renewable water resources are finite, as they are limited by the flux of freshwater brought to, and withdrawn from, the continents by the processes of the hydrological cycle. Nevertheless, it is generally accepted that the available water resources are not equivalent to the sum of the annual river flows to the oceans. Floods compose a large proportion of the flows and when they occur as extreme events, they characterize a disaster rather than a beneficial resource. River flows are very unevenly distributed with time. Almost everywhere on earth, river regimes show a strong seasonal variation.

In areas such as the sub-tropics, or in Mediterranean type climates, flows are often ephemeral and at times limited to a few weeks of the year. In cold regions, winter flows may be reduced significantly as a result of the retention of water in the form of snow and ice. The spatial variability of surface flows is also striking. In the rural areas of developing countries the travel distance and time required for accessing and collecting the water can be long. Depending upon geological features, ground water may be a convenient water supply option. However, frequently a ground water source may be unusable, either because of the make-up of its natural chemical constituents (e.g. salt, arsenic) or because of anthropogenically induced pollution (e.g. nitrates). In addition, shallow aquifers may not withstand harsh, dry seasons and as a consequence groundwater resources, as well as surface flows, may dry up.

In order to adapt to the variability of water resources in time and space, water supply and reticulation systems have been developed (e.g. dams, transfers of water by canals and pipes). However, the required investment in labour and/or capital implies the grouping of users around, or in, cities or market towns. Nevertheless, a sizeable proportion of the world’s population still lives in scattered rural habitats and these people depend on the availability of water in its ‘natural form’ for satisfying their basic needs such as drinking, cooking, sanitation, cattle watering and agriculture.

In differing climate regimes (e.g. sub-tropical, semi-arid, Mediterranean-type), such ‘natural’ availability of water is highly variable within a given year and between one year and the next. Any reduction in the amount of water resources or small changes in their distribution in time will lead to serious impacts for these communities if they are not supplied with potable water from external sources. The concept of freshwater should not be reduced to that of a mineral flowing through channels, canals and pipes. Freshwater is an essential driver of terrestrial and aquatic ecosystems. Any state of equilibrium in the distribution of terrestrial ecosystems results from a balance between climatic conditions and the capacity for resilience of the systems to variations in those climatic conditions.

Any change in the variability of climate, or any trend in any one of its components, may lead to latitudinal and altitudinal shifts in the distribution of terrestrial ecosystems (e.g. rainforests, savannas, steppes). In a given watershed (also termed catchment or basin), these changes might have tangible effects on the water budget and thus on the availability of water resources. Freshwater ecosystems (such as ponds, lakes, wetlands and river channels) are essential components of the environment. They provide support for the existence of aquatic and terrestrial wildlife, environmental goods (e.g. water, foods) and services (such as flood attenuation, depletion of organic pollution). In many regions, fish are a key element in the social and economic organization of human communities and are the first source of proteins, and sometimes the only one, especially for the poor. Unfortunately, water is also associated with specific diseases. There are several ways in which water is involved in the transmission of disease:

Waterborne diseases result of the contamination of water by human or animal faeces, or by urine infected by pathogenic viruses or bacteria, in which case the disease is transmitted directly when the water is drunk or used in the preparation of food. Water-washed diseases are those resulting from inadequate personal hygiene because of scarcity or inaccessibility of water. These include many waterborne diseases as well as typhus. Water-based diseases are those arising from parasites that use an intermediate host that lives in or near water (e.g. guinea worm).Water-related diseases are diseases borne by insect vectors, which have habitats in or near water (e.g. malaria). Water-dispersed diseases are infections whose agents proliferate in freshwater and enter the human body through the respiratory tract (e.g. Legionella). With regard to water-related diseases, aquatic ecosystems are extremely sensitive, both positively and negatively, to any changes, including those related to climate change (e.g. changes in temperature of water, depth of water, velocity of water in streams).

Although figures show that at the global level the increase of water demands and uses appears as being the determinant driver in what can be considered as a looming crisis, it must be pointed out that the relationship of humans with water is largely defined at the local level, with water being considered either as a resource or as an ecosystem. Global, and even national indicators, hide the obvious fact that for all beings, scarce water means survival and no water at all means death within a few days. In many stressed environments, the resource component in the demand/supply balance may, indeed, become the key issue if the resource is modified in total amount or in its temporal or spatial distribution by, for example, changes to mean climates and climatic variability.

(c) Preparation for the future

To be able to assess any changes in river flows, aquifer levels or freshwater ecosystems and to predict their behaviour in the future, two conditions need to be met, viz. (1) we need to have ready access to sufficient and reliable local data and information to address issues of changes in hydrological responses for a given basin or region and (2) we need to have the capacity to model hydrological processes realistically.

Contrary to climate information, which is generally collected for scientific purposes, most information on hydrology and water resources is collected for management purposes. The consequence is an institutional fragmentation of the collection process country by country, and even within a single country, where different water use sectors (e.g. energy, navigation, agriculture, domestic supply) may operate their own specific networks and use different procedures for the collection, storage and retrieval of data. Moreover, while there is a long tradition of exchanging, or freely disseminating, atmospheric information at the global level, the free availability of water-related data remains, in many cases, a sensitive issue as it applies to an economic resource.

Several initiatives, including Resolution 25 (Cg-XIII) adopted by the World Meteorological Organization WMO) are advocating sharing of hydrology related data. However, there is still a long way to go to match the effectiveness of the World Weather Watch of the WMO. The retrogression of many national meteorological and hydrological services, and consequently of the maintenance and operation of their networks and field stations, are another very serious cause for concern. The governing concept seems to be that any water crisis is, in the first instance, a management crisis or a supply side issue, rather than a resource crisis.

This may be true in global terms. However, political interest in, and financial support for, the monitoring of weather and water resources has been shrinking markedly in most countries. The effects of such a rationale are definitely jeopardizing our capacity for addressing some major issues of water resources under conditions of current climate variability and possible future change, as well as for forecasting and monitoring accurately water-related disasters and for planning the equitable share of the benefits of water in large transboundary river basins.

2.2.2 IMPACTS OF CLIMATE CHANGE ON WATER-RELATED EXTREMES

a) Background

Natural disasters associated with extreme events occur regularly throughout the world. There has been increased attention on extreme weather and climate events over the past few years, as a result largely of exponentially increasing losses which have been associated with them. These losses are as a result largely mainly to an increase in the vulnerability of society as a whole to extreme events (Kunkel et al., 1999). In many cases this increased vulnerability has not been matched by an appropriate increase in adaptive capacity. Increased population concentrations in flood prone areas, as well as land use and river channel changes are the main contributors to this enhanced vulnerability.

(b) Floods

For millennia, people have settled in floodplains in order to till fertile soils, use the flat terrain for settlements, and have easy and safe access to water and to use the river for transport. Riverine floods are natural phenomena: they have always occurred and people have tried to benefit from them to whatever extent possible. However, in recent decades, humans have become more exposed to the risk of floods. Different pressures have combined to increase population densities in flood-prone areas, including shortage of land, which has caused encroachment into floodplains. In particular, the mushrooming of informal settlements in endangered zones and around mega-cities in developing countries has occurred as people migrate towards economically developed city centres. The hope of overcoming poverty drives poor people migrate, frequently into places vulnerable to flooding and where effective flood protection is not assured. In fact, in many countries such places are left uninhabited on purpose, exactly because they are flood-prone. As a consequence, riverine floods have affected large numbers of people in recent years – on average more than 100 million people per year. From 1990 to 1996 there were 6 major floods throughout the world in which the number of fatalities exceeded 1000 while there were 22 floods with losses exceeding $US 1 billion each. According to the Red Cross, floods in the period from 1971 to 1995 affected more than 1.5 billion people worldwide. This total includes 318 000 killed and over 81 million homeless (IFRC, 1997).

In addition, the impact of floods has had increasingly detrimental and disruptive effects on, *inter alia*,

- Human health (e.g. the increased spreading of diseases such as diarrhoea or leptospirosis in flooded areas);
- Settlements and infrastructure;
- Coastal areas;
- Financial services (including insurance and reinsurance);
- Transport;
- Water supply;
- Agriculture; and
- Ecosystems.

Though floods can lead to loss of lives and livestock, they can also have positive spin-offs. Floods are the lifeblood of many ecosystems, including the floodplains and deltas. When flooded periodically, these wetland ecosystems supply important products (e.g. arable land, fisheries, livestock grazing), functions (e.g. groundwater recharge, nutrient cycling) and attributes (e.g. biodiversity), which have contributed to the economic, social and environmental security of rural communities worldwide for many centuries. Floods are also very important for fish migration and sediment transport. Furthermore, it is becoming more widely recognized that reduction in the frequency and magnitude of flooding caused by dam alters the conditions to which ecosystems have adapted and may degrade the natural services that provide benefits to people. In response, the release of managed floods was recommended by the World Commission on Dams (2000) and agreed as best practice as part of dam management by the World Bank (Acreman, 2002).

(c) How do we prepare for the future?

Flood protection measures can be structural or non-structural. Structural measures include dams, flood control reservoirs, i.e. constructing reservoirs where the excess flood waters can be stored, and then released as a controlled flow to help alleviate the flood problem by attenuating flood peaks, and dikes.

Non-structural measures include zoning, i.e., regulation of development in flood hazard areas by allowing only low-value infrastructure on the floodplains, forecasting systems for warning, evacuation, relief and post-flood recovery, flood insurance, i.e. the division of risks and losses among a higher number of people over a long time period, capacity building by improving awareness of the impacts of flooding, understanding of the processes involved and what is implied in flood preparedness, forecasting systems hold considerable promise for the future. They may be divided into short-term forecasts, e.g. for flash floods, requiring the use of high technology such as radar or remote sensing as the basis for quantitative precipitation, and hence flood, forecasts and triggering flood action plans, Medium-term forecasts, which include the use of seasonal climate forecasts for reservoir operations, advice on agricultural production and, where applicable, information on snow cover, and long-term forecasts, which need to be developed for designing flood protection systems. Finally, it is important to rectify common misconceptions about floods, e.g. that floods occur at semi-regular intervals and that floods in the future will be similar to those of the past.

(d) Droughts

Droughts have several direct and indirect consequences on human livelihoods. A direct consequence of drought is crop loss, which can, in turn, cause starvation among humans if alternative food sources are not available. Indirectly, water shortage contributes to the proliferation of diseases, as people lack water for basic hygiene. If a drought persists, people are often forced to migrate. A drought occurs because of a lack of available water. This can manifest itself either through a lack of precipitation per se, or from a lack of available soil moisture for crops, or reduction of surface flows below a critical threshold, or of the amount of water stored in reservoirs, or reduced levels of groundwater. The impact of drought in a region depends on the adaptive capacity of the humans or ecosystems to cope with the lack of available water in its various forms. Droughts cause severe crop losses not only in semi-arid regions, but also in well-watered countries.

Semi-arid to arid regions generally displays a strong climate variability (temporal and spatial) and hence has to cope with extremely dry situations on a frequent basis. Future climate changes are expected to change the frequency, severity and geographical location of droughts. However, in addition to climate variability and climate change, socio-economic changes generally increase vulnerability of particular populations to drought. For example, socio-economic drivers such as population growth or increasing demand for water per capita or loss of traditional knowledge and practices to adapt to drought or urbanisation, can all contribute to an exacerbation of a region's vulnerability to drought.

(e) What do we expect for the future?

There are a number of possible reasons for an increase in the frequency and severity of droughts in any particular region (IPCC, 2001). There is a growing risk of summer droughts in most mid-latitude continental interiors during the 21st century. Less precipitation and higher temperature may occur simultaneously, reducing available water resources while at the same time increasing evaporative demand. As temperatures increase and evaporative demands from crops and natural vegetation increase, these demands can be met only up to a point, as the consequent loss of water in the soil may not be compensated for by increases in precipitation. It is possible that in many different regions of the earth, there will be an increased risk of droughts arising from more frequent and/or more intense El Niño events. In many regions changes in the seasonal distribution of precipitation may have an even more marked impact upon water resources than changes in total annual precipitation.

The effects of any decrease in precipitation may be amplified through the hydrological system. Runoff in especially semi-arid and arid regions will decrease at a much higher rate than underlying decreases in precipitation, and groundwater recharge and hence groundwater resources may decrease even more than the change in runoff. Increased climatic pressure will increase the vulnerability of societies and the water related sectors in particular, to other global change processes, notably population growth in areas already at risk, and in particular within developing countries with their more limited adaptive capacities.

(f) What are our information needs?

Meteorological, and in particular hydrological data, are not available at the required resolution and coverage for adequate drought studies. Many monitoring networks are currently in a state of retrogression. Access rights to existing data are often very limited. The capability to distinguish between natural climate variability and climate trends is limited by the data coverage, quality and issues of access to the data.

(g) How do we prepare for the future?

There are both traditional (indigenous) and technological approaches to coping with the risk of drought. Any technological management of drought requires a medium (seasonal) to long-term (annual to decadal) climate forecasts and, therefore, the appropriate modelling tools. This information then has to be translated into early warning and reaction chains.

Supply-side drought protection measures include the following:

- Supplies of water should be augmented by exploiting surface water and groundwater in the area. However, intensive groundwater withdrawals for drought management are not a sustainable remedy. It has caused severe land subsistence in many countries, including Mexico, the USA, Japan, China and Thailand.

- Transfers can be made from surface water sources (lakes and rivers) and from groundwater, if socio-economically and environmentally acceptable.
- Storage of water can be increased. Groundwater reservoirs (aquifers) which store water, when available, can be more advantageous than surface water storage, despite the pumping costs, because of the reduction in evaporation losses.

However, this classical drought management policy is becoming increasingly difficult to implement because of its consequences on the environment. For example, when a large upland reservoir storage was created in Thailand, allowing regulation of dry season flow in the upper and middle basin to satisfy domestic and irrigation water demand, upstream activity resulted in a serious decline in water quality, particularly in the lower part of the basin area. In recent years the emphasis on action plans to combat drought has increasingly shifted from supply side management by provision of water resources in required quantities, to effective demand side management for the finite, and scarce, freshwater resource, i.e. seeking ‘mega-litres of conserved water’ rather than ‘mega-litres of supplied water’.

Possible demand-side measures include:

- Improved land use practices
- Watershed management
- Rainwater/runoff harvesting
- Recycling water (e.g. use of treated municipal waste water for irrigation)
- Development of water allocation strategies among competing demands
- Reduction of wastage
- Improvements in water conservation via reduction of unaccounted water and
- Water pricing and subsidies.

Drought contingency planning also requires thorough consideration, including:

- Restrictions on water use
- Rationing schemes
- Special water tariffs and
- Reduction of low-value uses such as agriculture.

(h) Coping with climate variability and climate change in water resources

Long-term changes and increased variability in climate will require that humans develop strategies to adapt to the new conditions. From the perspective of the water resources manager, the question is raised as to how new climatic conditions will affect the strategy of sustainable water resource management. Adaptation and coping strategies are not new. Since the time of Noah’s flood, societies and civilisations have adapted to the vagaries of climate variability through various coping mechanisms and adaptation strategies. Societies and political systems were organized around the need to control, regulate and distribute water for irrigation and food production. Hence, coping and adaptation strategies are as old as civilisation itself. What are new are the improved technologies that allow for more efficient use of water in industry, households and agriculture, as well as more efficient water management systems (e.g. storage, conveyance, and treatment). In Noah's time it took a providential hint to build a boat in time to escape the flood. Today, people rely on early warning systems and flood forecasts to warn them of an impending flood.

2.3 CHARACTERISE THE IMPACTS OF CLIMATE EXTREMES ON LIVESTOCK PRODUCTION (DROUGHT, HEAT, WAVES, FLOODS, ETC)

2.3.1 INTRODUCTION

Climate change refers to a long term (over a decade) change in climate patterns that can be identified by changes in the mean and/or the variability of its properties whether due to natural variability or as a result of human activity. It may involve gradual changes in long-term average conditions of climate; greater variability in normal conditions; or changes in the frequency, magnitude, and distribution of extreme events (Smit et al., 2000). The adverse effect of climate change and variability has become an environmental and socio-economic problem which is increasingly causing climate-driven hazards to people around the world (Scholze, Knorr, Arnell, & Prentice, 2006). Climate change is also expected to alter pest and disease outbreaks, increase the frequency and severity of droughts and floods, and increase the likelihood of poor yields, crop failure and livestock mortality (Morton, 2007). Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien et al,. 2004).

Climate extremes can be placed into two broad groups:

- Those based on simple climate statistics, which include extremes such as a very low or very high daily temperature, or heavy daily or monthly rainfall amount, that occur every year; and
- More complex event-driven extremes, examples of which include drought, floods, or hurricanes, which do not necessarily occur every year at a given location. (Easterling et. al., 2000).

Climate change manifestations in the form of rising temperatures, changes in water availability and increased levels of carbon dioxide are expected to affect farming and forest based livelihoods in various ways (Sonwa et al., 2012). Because smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (McDowell & Hess, 2012).

The Intergovernmental Panel on Climate Change (IPCC, 2007) highlighted that Africa will be one of the continents that will be hard hit by the impact of climate change due to an increased temperature and water scarcity and yet

Africa represents only 3.6 percent of emissions. The purpose of this section is to give reviews of the impacts of climate extremes on livestock production.

2.3.2 CLIMATE CHANGE

The climate impacts anticipated for developing country are similar to those being experienced around the world: general warming (day and night temperatures all year round); changes in rainfall timing and quantities; changes in seasons (longer summers); increased climate variability (e.g. floods, droughts and heat waves); higher sea-levels; and increasing frequency and intensity of extreme weather events (IPCC, 2007). The potential impacts on livestock include changes in production and quality of feed crop and forage (Polley et al., 2013; Thornton et al., 2009), water availability (Henry et al., 2012), animal growth and milk production (Henry et al., 2012), diseases (Nardone et al., 2010; Thornton et al., 2009), reproduction (Nardone et al., 2010), and biodiversity (Reynolds et al., 2010). These impacts are primarily due to an increase in temperature and atmospheric carbon dioxide (CO_2) concentration, precipitation variation, and a combination of these factors. The climate change impact livestock production in two ways, direct and indirect. The most significant direct impact of climate change on livestock production comes from the heat stress. (Sejian et. al., 2016), while most of the production losses are incurred via indirect impacts of climate change largely through reductions or non-availability of feed and water resources. It is believed that livestock production and productivities will be one of the most susceptible sectors to climate change due to changes in the hydrological cycle, temperature balance and rainfall patterns which have a negative impact on livestock production and productivity (Mwiturubani, 2010).

In South Africa, climate change is predicted to result not only in higher temperatures, but also in sporadic rainfall patterns and frequent droughts (Turpie and Visser, 2013). These severe weather events, coupled with the country's already scarce water resources, are expected to have a significant effect on the forestry and agricultural sectors, which are substantial components of the country's rural livelihoods and economies (Turpie and Visser, 2013; Quinn et al., 2011). Climate change is affecting rains, increase in the frequency of drought and the rise in temperatures, threatening the availability of fresh water for agricultural production and other uses (Kotir, 2010). The Intergovernmental Panel on Climate Change (IPCC, 2007) concluded that climate change may severely compromise food production and food security in many African countries. This is mainly because farming in Africa is highly dependent on rain-fed agriculture (GECHS, 2008) either through crop production or livestock rearing.

Impacts facing the agricultural sector include a reduction in the amount of land that is suitable for arable and pastoral agriculture, a shortened growing season and a decrease in yields, particularly along the margins of semiarid areas (Turpie et al., 2002). Notenbaert et al. (2010) observed climatic trends that included reduced productivity of animal feed, higher disease prevalence, and reduced fresh water availability. This was due to the negative effects of lower rainfall and more droughts on crops and on pasture growth, and to the direct effects of high temperature and solar radiation on animals.

2.3.3 CLIMATE EXTREMES

There is common agreement that climate change is causing an increase in climate variability and in the occurrence and magnitude of extreme weather events (Easterling et al., 2000; Seneviratne et al., 2012). Sergio et al. (2018), as modified from Pickett and White (1985), defined disturbance as any relatively discrete and unpredictable event in space and time that alters individual performance and the structure of populations, communities or ecosystems through modification of resource availability and the physical environment.

Disturbances may affect animals through: (1) direct effects, like mortality, displacements and redistributions caused by hurricanes or fires; (2) indirect abiotic effects, mediated by changes in the physical environment, like removal of nesting or foraging substrates (e.g. trees for woodpeckers); and (3) indirect biotic effects, mediated by alteration of the biological environment, such as changes in food availability, predators or pathogens (Sergio et al., (2018). Droughts and floods are recurring environmental challenges in several rural communities across the country (DEAT, 2004). The capability to develop adaptations and survive extreme conditions becomes more difficult as the disturbance becomes increasingly more unpredictable and severe, as shown by both theoretical and empirical studies (Estay et al., 2014; Colinet et al., 2015; Roitberg and Mangel, 2016).

2.3.3.1 Temperature extremes

(a) Temperatures

Climate change will have far-reaching consequences for dairy, meat and wool production mainly via impacts on grass and range productivity. Heat stress on animals will reduce the rate of animal feed intake and causes poor performance growth (Rowlinson, 2008).

Extreme temperature events include heat waves, cold waves, and the number of days exceeding various temperature thresholds. Temperature affects most of the critical factors for livestock production, such as water availability, animal production, reproduction and health. The direct impacts of air temperature, humidity and wind speed capable of influencing growth rate, milk production, wool production and reproduction have been reported by Houghton (2001) and Rust and Rust (2013).

(b) Heat waves/high temperatures

High temperatures results in heat stress in animals, shortage of water, reduced quality and quantity of feeds. A heat wave is a period of abnormally and uncomfortably hot and usually humid weather. Higher temperatures are much more hazardous for growing/finishing and breeding animals than a cold environment. Livestock with high production potential are at greatest risk of heat stress, thereby requiring the most attention (Niaber & Hahn, 2007). In a hot environment, when the air temperature is above the upper critical temperature, the ability to lose heat is limited; therefore, farm animals reduce their feed intake and thus the heat increment in order to keep the thermal equilibrium. In order to lower the heat production, farm animals reduce their physical activity as well (Collin et al., 2001) and spend less time with eating (Brown-Brandl et al., 2001). Feed refusal increases with body weight at high ambient temperatures (Quiniou et al., 2000). Higher temperatures tend to reduce animal feed intake and lower feed conversion rates (Rowlinson, 2008). Voluntary feed intake decreases curvilinear with increasing environmental temperature resulting in reduced animal performance (Collin et al., 2001). High temperatures cause loss of appetite in pigs; however, both the upper critical temperature and the rate of feed refusal are influenced by the relative humidity of the air (Collin et al., 2001; Huynh et al., 2005). High temperatures not only impair growth, but also change body composition and thus can impair the nutritive value and quality of pork. Prolonged heat stress (30-33ºC) reduces the rate of protein deposition in growing and finishing pigs (Kerr et al., 2003; Le Bellego et al., 2002). Heat stress on hens will reduce reproduction efficiency and consequently egg production because of reduced feed intake and interruption of ovulation (Nardone et al., 2010; Novero et al., 1991). When animals are exposed to thermal stress, metabolic and digestive functions are often compromised due to altered or impaired feeding activity (Mader, 2003). Nesamvuni et al., (2012) conducted a study to project impacts of temperature and humidity on feedlot cattle in South Africa using temperature humidity index as an indicator of heat stress.

It was reported that temperature, humidity index projections suggest that production in Eastern Cape, KwaZulu-Natal and North West Provinces with the highest number of cattle compared with other provinces is likely to be affected by emergency heat stress index in future climate conditions. They further indicated that it is evident from the projections that heat stress will increase in the intermediate and distant future and this will necessitate measures to be put in place to reduce the adverse effects of increased temperatures. Crawford (2007) reported that if animals are not managed properly, heat stress in feedlots can cause decreased animal performance and may even lead to death.

In the case of meat production, beef cattle with higher weights, thick coats, and darker colours are more vulnerable to warming (Nardone et al., 2010). Global warming may reduce body size, carcass weight, and fat thickness in ruminants (Mitloehner et al., 2001; Nardone, 2000). In cows and pigs, heat stress, it affects oocyte growth and quality (Barati et al., 2008; Ronchi et al., 2001), impairment of embryo development, and pregnancy rate (Hansen, 2007; Nardone et al., 2010; Wolfenson et al., 2000). Howden et al. (2008) reported that increases in temperature between 1 and 5 ^{o}C might induce high mortality in grazing cattle.

The combined stressors had major effects on growth and reproductive parameters of livestock. When the animals were subjected to heat and nutritional stress as separate stressors, the impact of these was not as detrimental to growth and reproductive performance, as was the case when the animals were subjected to both stressors at the same time (Sejian et al., 2011). When two stressors occur simultaneously, the impact on the biological functions necessary for adaption and maintenance during the stressful period may be severe (Sejian et al., 2013).

(c) Low temperature

The effects of cold temperature on livestock production have not been studied much. Few studies reported cold-related decreases in milk yield (Brouček et al., 1991) and increases in mortality (Morignat et al., 2015; Stull et al., 2008). In a cold environment the rate of oxidation increases, in other words, the body “burns” more nutrients, thus boosting its heat production, in order to compensate for the higher heat loss caused by the lower ambient temperature.

Shivering is a tool aiding this process; since the energetic efficiency of muscle work is low, the resulting heat production is quite significant. Hypothermia and death, resulted when heat loss exceeds heat production. The maintenance energy requirement of animals increases in a cold environment, which reduces the amount of energy available for production. In cold temperatures the higher energy consumption is associated with a relatively lower energy supply due to the poorer digestibility of nutrients.

(d) Diseases

Increasing temperature may also increase exposure and susceptibility of animals to parasites and disease (Marcogliese, 2001; Sutherst, 2001), especially vector-borne diseases (Tabachnick, 2010). The effects of climate change on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility (Thornton et al., 2009). In terms of livestock, there are a number of diseases which may become increasingly pervasive with changing climate. Heat stress may reduce disease resistance or immune responsiveness of domestic animals; however, it depends on several variables, such as species and breed, duration of the exposure, severity of stress, and the type of immune response considered.

A moderate heat stress would probably not modify immunological parameters (Lacetera et al., 2002); severe heat stress, however may cause immune suppression, such as the lower number of circulating white blood cells (Heller et al., 1979) and a reduction in antibody production (Zulkifi et al., 2000). The continent of Africa is generally noted to be hot and dry with current trends showing warmer spells than it was 100 years ago (Hulme, 2005; Kurukulasuriya and Mendelsohn, 2008; Kotir, 2010). Sub-Saharan Africa (SSA) is anticipated to warm as it lies in tropical and subtropical latitudes, where temperatures are high throughout the year (Kotir, 2010).

(e) Precipitation

Increasing mean temperatures and declining precipitation reduce the dietary crude protein and digestible organic matter content of grass; it is unlikely, however, that any future increases in precipitation would compensate for the declines in forage quality following from the projected temperature increases (Craine et al., 2010). Forage quantity and quality are affected by a combination of increases in temperature, CO_2 and precipitation variation. The rainfall pattern is mainly influenced by El-Niño Southern Oscillation (ENSO) events in Sub-Sahara Africa and these often result in frequent extreme weather events such as droughts and floods which lead to reduced food production causing severe food shortages (Haile, 2005). In many parts of Sub-Saharan Africa (SSA), natural disasters revolve around either too much rain (flooding) or too little rain (drought). Unpredictable rainfall and increased temperatures are projected to increase the frequency and intensity of the extreme weather events. Droughts and floods have been commonly experienced in many parts of SSA especially around the Horn of Africa and the Sahel (Kotir, 2010).

(f) Floods

Literature on impact of floods on livestock is very scares. It is known that hundreds of thousands of livestock animals, principally poultry and swine, died in the flood (Wikipedia 2012). “Livestock – including cattle, goats, sheep and poultry – drowned or were swept away. In addition, flooding destroyed grazing areas and led to increased incidence of livestock diseases. Since 1901 – 2007, flooding is second to epidemics in the frequency of natural disasters in the Southern African Development Community (SADC) Region. The damage caused by flooding is approximately 2 470 million US$ over the same time frame. In 2000, cyclones Eline and Gloria caused 700 million US $ of flood damage in Mozambique.

Damages amounted to three times their 1999 export value. (SADC report). Inchaisri et al. (2013) reported that the majority of livestock losses were in poultry and swine farms. Because of the unfeasibility of movement of swine during a flood, the number of swine losses was the highest of any livestock species. So in the livestock farming sectors, it is important to identify areas that are prone to heavy flooding, as this will be crucial information for farmers to decide whether livestock farming should be continued in those areas. Flood, may affect the form and structure of roots, change leaf growth rate, and decrease total yield (Baruch and Mérida, 1995).

(g) Droughts

Droughts are one of the most emblematic climate extremes. Drought is a climatic phenomenon which has the potential to impact a wide region, depending on the size and extent of the climate force. From an agricultural point of view, drought is understood as a shortage of moisture in the root zone of crops. From a hydrological perspective, drought concerns reductions in stream flows and in water stock above and below ground (Palmer, 1965). From a meteorological perspective, the definition of drought focuses on moisture deficits (Gregory 1986). Countries are impacted differently through the drought, depending on their dependence and value of water-dependent sectors such as agriculture. It may represent a period when monthly or annual precipitation is lower than some specific percentage of normal or a period of days in which the precipitation is less than a particular small amount (Byun and Wilhite, 1999; Palmer, 1965). Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes (Thornton et al., 2009).

Drought has affected America, Europe and Africa in the last decade, and the 2003 drought and heat waves in Europe led to significant damage in terms of livestock productivity and mortality. Drought frequently adversely affects agricultural production in various provinces, including Limpopo, Free State, parts of the Western Cape and Northern Cape (e.g. Sowetan, 2003). The most vulnerable are always the poor because they do not have the means to deal with the negative effects of drought. (Mandleni, 2011). Ciais et al. (2005) asserted that the total eco-system productivity as well as total carbon sequestration in Europe decreased due to the recent drought conditions. It has been reported that heat waves and drought may increase water demands of agriculture, which can lower water tables and trigger even more frequent and severe drought in nearby, more natural ecosystems (e.g. wetlands, Poff et al., 2003; Green et al., 2017). Aridity, water deficiency may lead to a drop in groundwater levels, alteration and thinning of pasture flora, and in consequence of a decline in feed supply, besides aggravating the problems of water supply (Babinszky et al., 2011).

2.3.4 COPING STRATEGIES

Coping strategies refer to action or activities used by farmers or households usually very short time spans to survive when confronted with unanticipated livelihood failure (Babi et al., 2005). Pastoralists employ various coping strategies to deal with climate and non-climate stress. Some of the common coping strategies are migrating to market centres, seeking casual employment, seeking refuge in education (GECHS, 2008). In East African, Somali, Redille, Gabbra and Samburu have shifted from cattle husbandry to camel rearing in response to the deterioration of their environment (Le Hou'erou, 1996) and in another country, Turkana, farmers has increased the proportion of goats to sheep. Gwambene and Majule (2009) observed coping strategies commonly used by the pastoralists to cope with the main hazard of drought to include; buying food (on credit), getting assistance from relatives, seeking for relief food, selling livestock and other household assets to buy food, borrow food, seek for casual work, reducing the number of meals, skipping meals, engage in petty businesses, and moving to market centres. A number of measures have been suggested to mitigate against the effects of heat stress and these include: strategic use sprinklers or shade and manipulation of dietary energy density (Mader, 2007).

Bester et al. (2003) reported that resource poor farmers rely on livestock or mixed farming for their livelihoods to cope with climate extremes. However, Ncube et al. (2016) observed that more than 70% of the resource-poor farmers in South Africa are situated in harsh agro-ecological zones where cropping is marginal. Mixed crop-livestock systems enable farmers to integrate different enterprises on the farm: Livestock provide draft power to cultivate the land and manure to fertilise the soil, and crop residue occasionally feed livestock in some areas. Moreover, income from livestock may be able to buffer low crop yields in dry years (Herrero et al. 2010). The synergies between crop and livestock rearing offer many opportunities for sustainably increasing production since they can raise productivity and resource use efficiency for farming households (Ncube et al., 2016).

2.4 DETERMINE THE LIVESTOCK WATER USE EFFICIENCY (CURRENT AND IN THE PROJECTED CLIMATE CHANGE)

2.4.1 INTRODUCTION

Livestock provides people, especially the poor in developing countries, with multiple benefits derived from diverse animal species and breeds. Estimating Livestock Water Productivity or efficiency requires estimates of the total value of these goods and services. Monetary units are used for benefits and Livestock Water Production Efficiency is expressed in units such as Rands /km^3 of water. As a tool, the Livestock Water Production Efficiency helps stakeholders to systematically understand the livestock-water interactions in a variety of systems. In most developing livestock production system outputs from such will include milk, meat, hides, and farm power produced from livestock. To produce these outputs, the animals, particularly cattle, need water for drinking and for producing their feed/forage. Depleted water, on the other hand, refers to the water that is lost through evaporation, transpiration (evaporation of water from the plants), and downstream discharge. Once depleted, water is no longer available and has no further value within the system. Water contamination is a depletion process that makes water less valuable to future users even though it may remain within the system.

In assessing Livestock Water Production Efficiency, a basic requirement is estimating livestock-related water inflow, depletion, and storage. Generally, livestock production competes heavily with both humans and plants for the world's water supply. Based on the assessment framework done in developing countries, there are four basic livestock keeping strategies that can help improve Livestock Water Production Efficiency. These are optimal feed sourcing, enhancing animal productivity, conserving water resources, and providing drinking water to livestock, especially cattle. These strategies involve supply-side and demand-side management of both water resources and animal products as indicated in Figure 2.1.

The four strategies, along with the Livestock Water Production Efficiency assessment framework, underpin the research undertaken on a basin-wide and country-specific basis in Uganda, Sudan and Ethiopia. The framework identified the following four strategies to increase Livestock Water Production Efficiency: (a) Selection of feeds that require relatively little water and produce enough quality dry matter and nutrients; (b). Integration of animal science knowledge (e.g. veterinary science) into water development; (c) Water conservation associated with livestock keeping; and (d) Optimally distributing livestock: feed and drinking water resources over large areas to maximize animal production through access to underutilized pasture far from water while preventing overgrazing and water degradation near watering points.

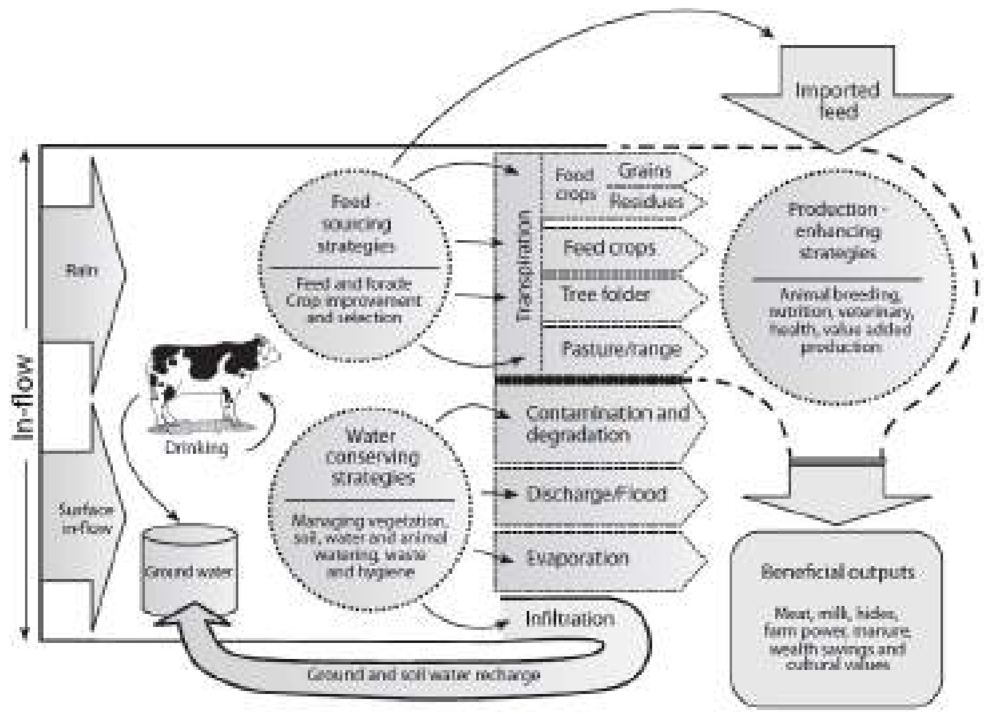


Figure 2.1. **Livestock Water Production Efficiency Assessment Framework**

2.4.2 FOUR BASIC STRATEGIES OF LIVESTOCK WATER PRODUCTION EFFICIENCY

(a) Feed sourcing

One key strategy for increasing Livestock Water Production (LWP) Efficiency lies in selecting the most water-productive feed sources that produce enough feed to meet the animals' needs. Feed water productivity estimates vary 80-fold from the most to the least efficient, due in part to biology and inconsistent methodologies. High Livestock Water Production Efficiency does not necessarily mean high levels of production and livestock keepers need to maintain profitable enterprises. Thus, the approach to increase Livestock Water Production Efficiency through feed sourcing demands must be carefully planned. The feed must meet the nutritional requirements of the animal. This includes estimating the water productivity of the feed with the ratio of metabolisable energy or protein content of actual water depleted. Manure management can also have a major influence on the net benefits derived from livestock and thus on Livestock Water Production Efficiency. In extensive production systems, around 50 % of the feeds ingested by animals is excreted as manure. Approximately, half of the depleted water supports animal maintenance and production. The other half of the depleted water supports manure production and, with well-managed rangelands, directly supports ecosystem services.

Manure is highly valued and widely used for replenishing soil fertility, domestic fuel and construction of houses. However, manure can also be a major cause of environmental degradation, such as water contamination. Water used to feed animals for traction is an input into crop production. When the primary use of an animal is for farm power, beef production, then becomes a by-product of animal production and is only “produced” when an animal is no longer capable of cultivating land.

(b) Enhancing animal productivity

Increasing the ratio of feed energy for production to maintenance has high potential for increasing LWP. In Africa, feed scarcity limit intake, implying that most consumed feed is used to support maintenance, leaving little for production. Relying only on aggregate monetary valuation of LWP does not include the disaggregation of animal products into diverse nutrients required for human nutrition. Animal food sources provide essential nutrients such as Vitamin B12 and micronutrients that are often not readily available to poor farmers producing crops on nutrient-depleted soils.

(c) Conserving water resources

The primary challenge to conserving agricultural water is maintaining high levels of vegetative ground cover to promote increased transpiration, infiltration and soil water holding capacity and decreased evaporation and discharge.

Grazing Practices: We suggest limiting animal stocking rates to levels that allow moderate production and to avoid overgrazing. Overgrazing often removes excessive ground cover or shifts plant species composition from palatable to unpalatable types.

Grassland: When well-managed grassland is often the best land use for capturing rainfall, encouraging storage in soil and promoting transpiration and plant production, particularly in dry lands and on steep slopes, input into crop production. When the primary use of an animal is for farm power, beef production, then becomes a by-product of animal production and is only “produced” when an animal is no longer capable of cultivating land.

(d) Providing drinking water

Drinking water must be of high quality and available in small but adequate quantities. Although the cost of providing a unit of drinking water may also be high, the amount of water drunk is less than 2% of that needed to produce feed. Livestock drink about 25 to 50 litres/TLU/day, with variation dependent on many factors, such as species, breed, ambient temperature, water quality, feed intake and water content of feed. More importantly, strategically allocating drinking water opportunities over time and space (seasons and landscapes) optimally distributes livestock, especially cattle, to make more effective use of forages without overgrazing the land. In Africa, livestock watering points are often inadequate in number and sub-optimally distributed and managed. During dry seasons in some areas, livestock travel for hours to reach watering points, resulting in significant loss of energy.

2.4.3 CONCLUSION

Where livestock are important components of farming systems, there is a need to integrate livestock management, crop management, land and water use practices and resource degradation into one integrated framework. The LWP framework is a starting point. When tested in diverse production systems, the generic framework was robust in handling conditions ranging from extensive grazing systems to intensive mixed crop-livestock systems at local, watershed and basin livestock-induced soil erosion.

2.5 CLIMATE, VULNERABILITY AND WATER USE ANALYSES OF LIVESTOCK SECTOR

2.5.1 CLIMATE CHARACTERISATION

The study area, i.e. the Limpopo and Mpumalanga provinces, is classified as predominantly a semi-arid region (Figure 2.2 , left), with arid area found along the far northern border of the Limpopo Province with Botswana, Zimbabwe and Mozambique Countries. A more detailed classification based on FAO (1978) was conducted, at which in Figure 2.2 (right) agro-ecological zones (AEZs), based on major climate zones, moisture zones (water availability) and highland-lowland (cool or warm based on elevation). The AEZs are said to be influenced by latitude, elevation, and temperature, seasonality, and rainfall and distribution during the growing season (HarvestChocie, 2010). The factoring in of elevation provides more information as to the local conditions and its usual zonation for the classification of the various livestock production system and determination of their likely climate-related risks, as well as vulnerability.

The areal classification such as this study area are said to be risk areas, owing to changing environmental conditions, mostly as a result of the rain-fed and/or unsecure sources of irrigation water upon which the production systems are dependent on (Rust & Rust, 2013). The prevailing environmental conditions, such as those in the study area, are postulated to have far-reaching implications under climate change (DEA, 2013). This postulated implication is said to include the impacts of reduced water availability, increase in occurrence of vector and waterborne diseases, the prevalence of incidence of invasive species, decline in crop and livestock productivity, and many others related to human-wellbeing (Rust & Rust, 2013). Most of this will be attributed to the direct impacts of an increase in temperature regimes.

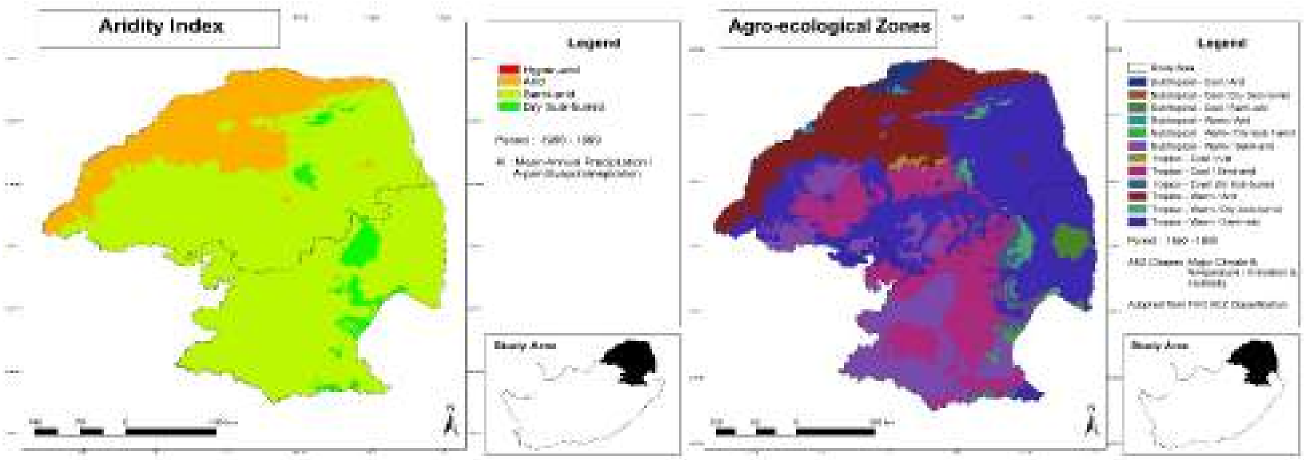


Figure 2.2. Climate characterisation through the aridity index (left) and agro-ecological zones (right)

2.5.2 CLIMATE ANALYSIS

The mean total precipitation over the rainfall season (between October and February), as shown in Figure 2.3, was computed using middle-of-the-road global climate model daily projections determined using an approach present in a study by Lekalakala (2017). This represents median of the statistically downscaled model projections of daily climate conditions. The AEZs were used a spatial unit. The rainfall is projected to increase mostly in the western parts of the study areas, this is due to the selected or representative climate model showing a wetter climate than present condition. A wider range of plausible futures will be presented in the next report and from state-of-the-art global climate models.

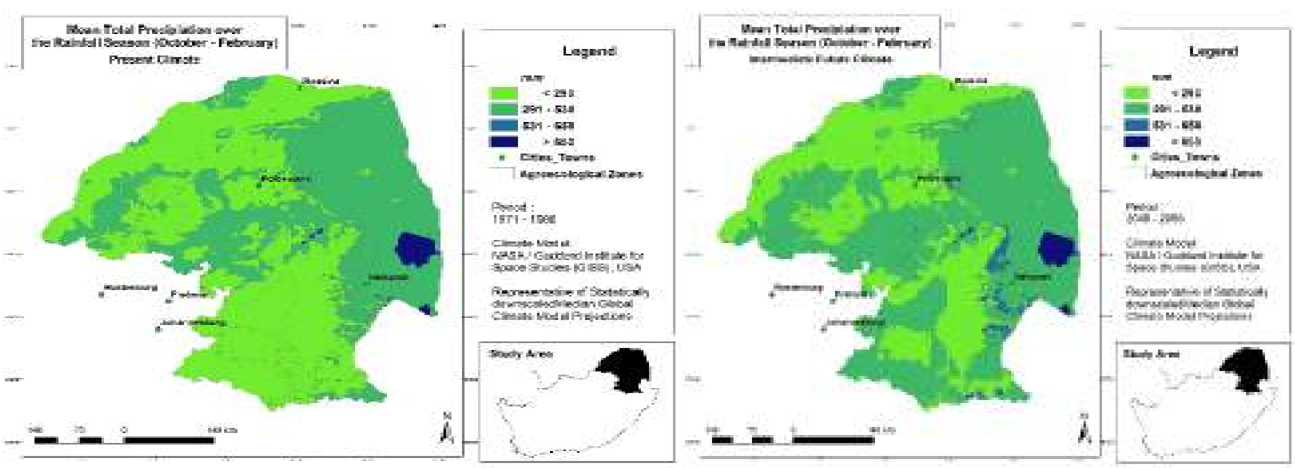


Figure 2.3. Mean total precipitation over the rainfall season (October – February) for present climate (on-left) and mid-century (on-right), over Limpopo and Mpumalanga provinces

The frequency of more than 14 dry days during a rainfall season (i.e. between October and February) for the present climate scenario, depicted in Figure 2.4. Figure 2.4 (on-left) is likely to be experience more than 4 times on a median rainfall season over most parts of the study area. This is postulated to decline in some parts of the study areas, however, the frequency of the dry spells are projected to remain high over most areas in the mid-century. This decline is attributed to the increase in rainfall, as shown in Figure 2.4 to the representative median climate model postulating wetter conditions over certain areas compared to present conditions.

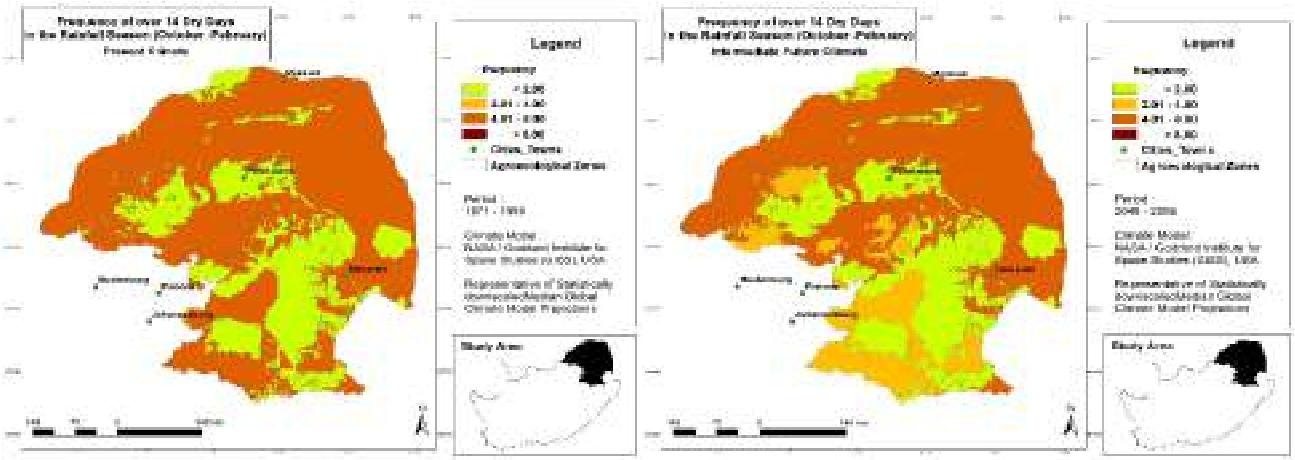


Figure 2.4. Mean frequency of more than 14 dry days over the rainfall season (October – February), present climate (on-left) and mid-century scenario (on-right)

2.5.3 VUNERABILITY ANALYSIS

The vulnerability in semi-arid areas, such as the study location, is said to come about as a result of the prevailing environmental conditions (such as climate, soil, activities) together with the areal governance, socio-economic, health, education, culture and human demographic issues (Spear et al., 2015). The above mentioned factors will be considered in the more comprehensive vulnerability assessment which will involve a detailed survey questionnaire and supported by measured climatic data. A climate based vulnerability analysis is presented based on the climate exposure index.

The exposure index, as shown in Figure 2.5, under present climate conditions suggests that there is a high vulnerability, which is climate based, over most of the AEZs and very high vulnerability concentrated mainly along the northern border. The mid-century vulnerability projections suggest a reduction in the exposure index too high. The reduction in vulnerability along the northern border is due to the global climate model projecting a future that is wetter than present, this is a median of the future projections.

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

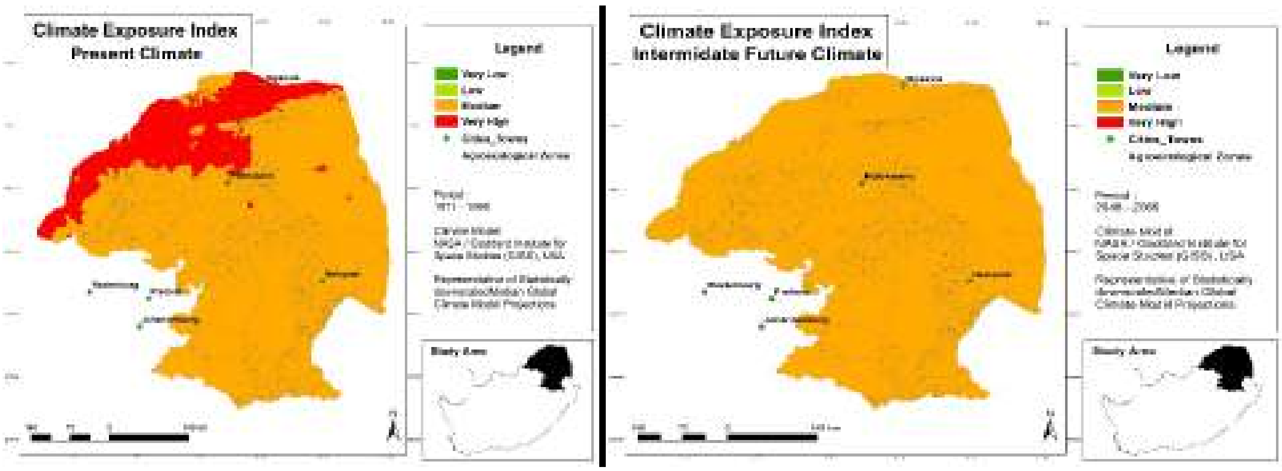


Figure 2.5. Mean of climate exposure index over Limpopo and Mpumalanga Provinces, for Present climate (on-left) and mid-century climate (on-right)

2.5.4 LIVESTOCK WATER USE AND WATER EFFICIENCY

Water use and availability within the livestock production sector has been poorly studied, specifically competition with other uses, alternative uses, multiple uses and benefits of a certain resource in a specific location (Rojas-Downing et al., 2017). This limitation in knowledge would lead to maladaptation, and hence might contribute towards increasing pressure on the finite water resources. The sector is estimated to be consuming 8 % of the global water supply, through the industries intensive feed based production. Weindl et al. (2017) projected that water usage in livestock production would increase by 19 to 36 % compared to present consumption levels from surface water resources (i.e. rivers, lakes and dams).

In this study water usage in the livestock production is put as an important component of the agricultural water resource management, therefore making the development and adoption of water smart agricultural strategies for sustaining livestock production demands and improve water management in agriculture, in light of the recent climate projection studies and growing demand for water. In this preliminary analysis, we present current water use and efficiency of the livestock sector. The next report will include management scenario simulations, and climate projections of water usage and likely water use efficiencies with the sector.

(a) Source of water resources

In this section sources of water are discussed, of which, are predominantly used by the livestock farming sector.

In Figure 2.6, the two main sources of water supply for the sector are shown, which are surface (rivers and dams) and sub-surface (groundwater accessed mainly by boreholes) water resources. This water sources are mostly multiple uses, i.e. share with other water users, this indicates the existing competition for both water resources. The scarce and limited water resources in the predominantly semi-arid region, of South Africa, presents challenges in the production and sustainability of the agriculture sector. The main determinants of access to surface water sources are location, availability of resources for allocation and the reliability of supply of the source, if it’s a perennial or non-perennial source. In most farming areas within the study area, groundwater resources serve as either an alternative or main water supply. The diversification of sources of water supply ensures a sustained water supply. Another source of water supply mostly recently gaining popularity is the adoption of rainwater harvesting in response to dry spells. It is by noting that this water used for livestock production might be of lower quality than that consumed by other crop production, industries and domestic use. Factoring in the issue of water quality, the competition with other water users might be as significant.

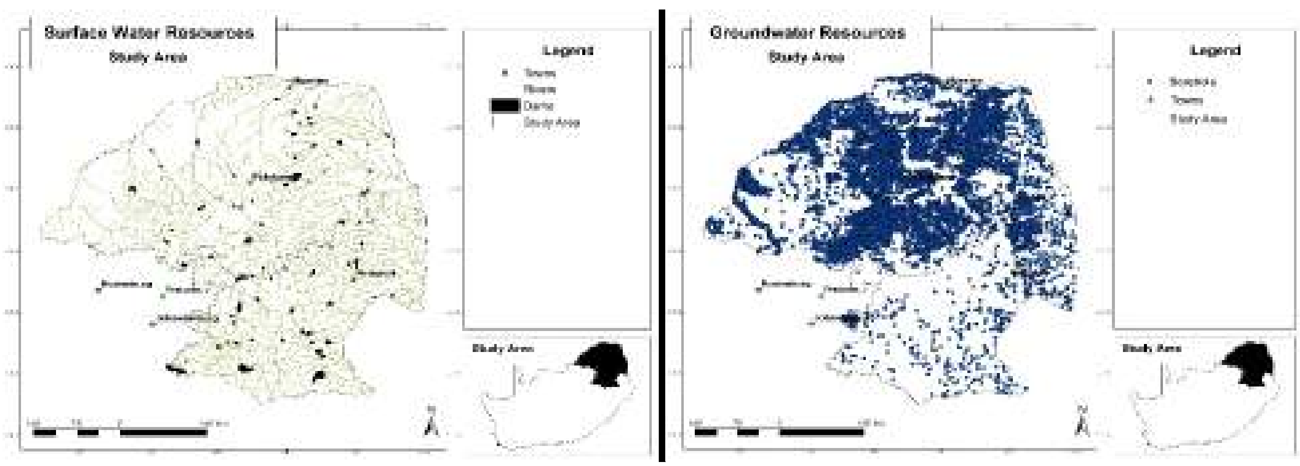


Figure 2.6. Sources of water resources used in the livestock sector, with surface water from rivers and dams (on-left) and groundwater accessed through boreholes (on-right)

(b) Livestock water use

The water used by the livestock sector was determined by computing registered water uses by livestock farmers in South Africa (registered in line with the Department of Water Affairs). The water used in the livestock sector is associated with stock watering, feedlots, dairy, pastures and other on-farm needs. According to the 2014 National State of Water Resources report by the Department of Water and Sanitation, the livestock watering accounted for only 0.25% of the total registered water users in South Africa.

The water usage across South Africa varies with the least recorded use, less than 80 000 m^3, in the Luvuvhu/Letaba water management area, and over 1 447 0000 M^3 water use along the parts of the Western and Eastern Cape Provinces, and the North-West Province, as shown in Figure 2.7. Within the Study area, i.e. Limpopo and Mpumalanga Provinces, the water use ranges from 80 000 to 1 080 000 m^3.

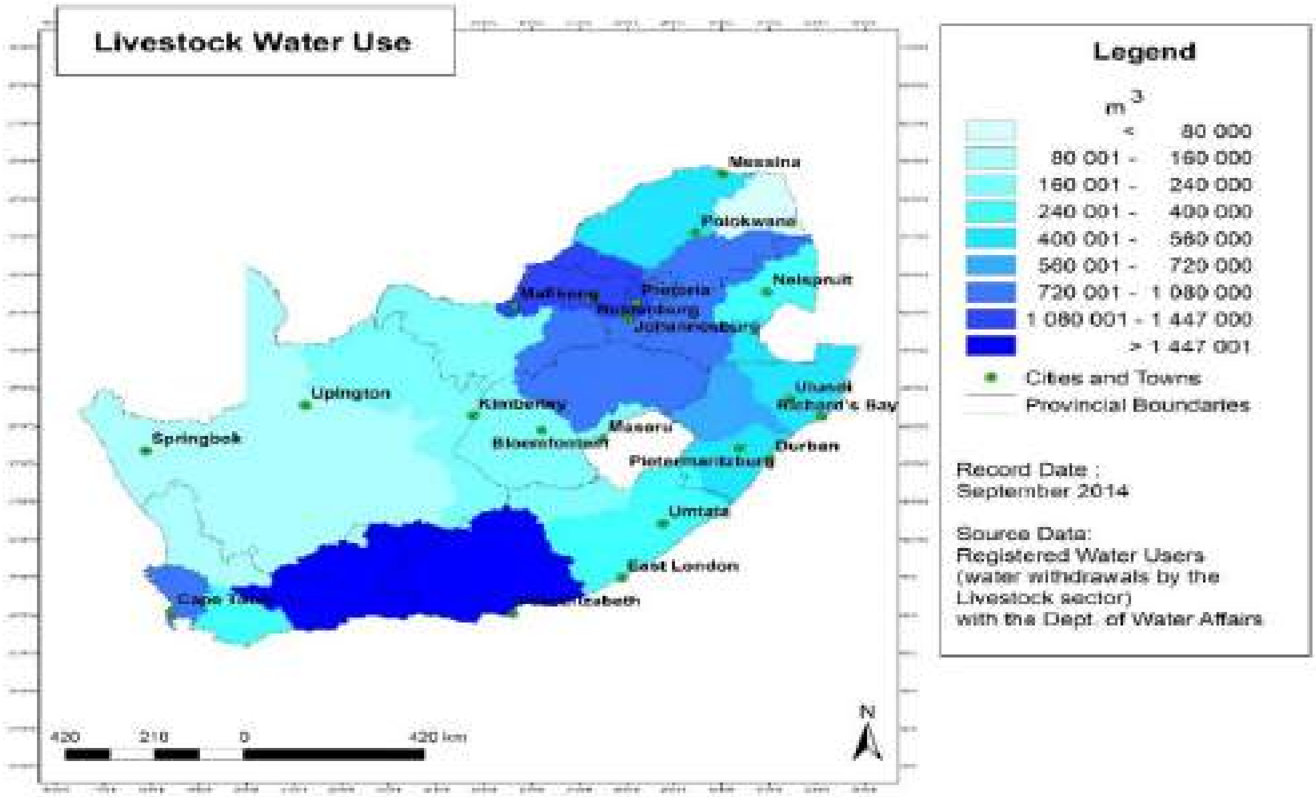


Figure 2.7. Livestock water use in South Africa, determined from water user registry by the Department of Water and Sanitation of 2014

(c) Livestock water use efficiency

The growing demands for livestock products has an influence on the already limited water resources. The improvement of the livestock water use efficiency (WUE) will, therefore, contribute towards the agricultural water use efficiency and thus reduce competition with other water users (Kebebe et al., 2015). The livestock WUE computed below were based on livestock numbers as estimated by the Department of Agriculture and registered water user withdrawals. The livestock WUE over South Africa, in Figure 2.8, shows the estimated livestock water productivity with the least water efficient production indicated by yellow to brown (<6.00 livestock per m^3) cantered near Gauteng Province and the highest being in Luvuvhu /Letaba water management area in the Limpopo Province. The WUE per livestock, as presented in Figure 2.9, suggests that Pig production as the least WUE production system, compared to Sheep with the overall high water productivity. This value might be different when number of livestock is compared with their consumptive water use.

The consumptive water use will form part of the next report, and might indicate more specific water use instead of the total water use by the livestock industry. The difference in water productivity between the different livestock, and across country, suggests there is a considerable scope for improvement. An integrated livestock and water management planning and development will have the potential to increase production and reduce pressure on scarce resources.

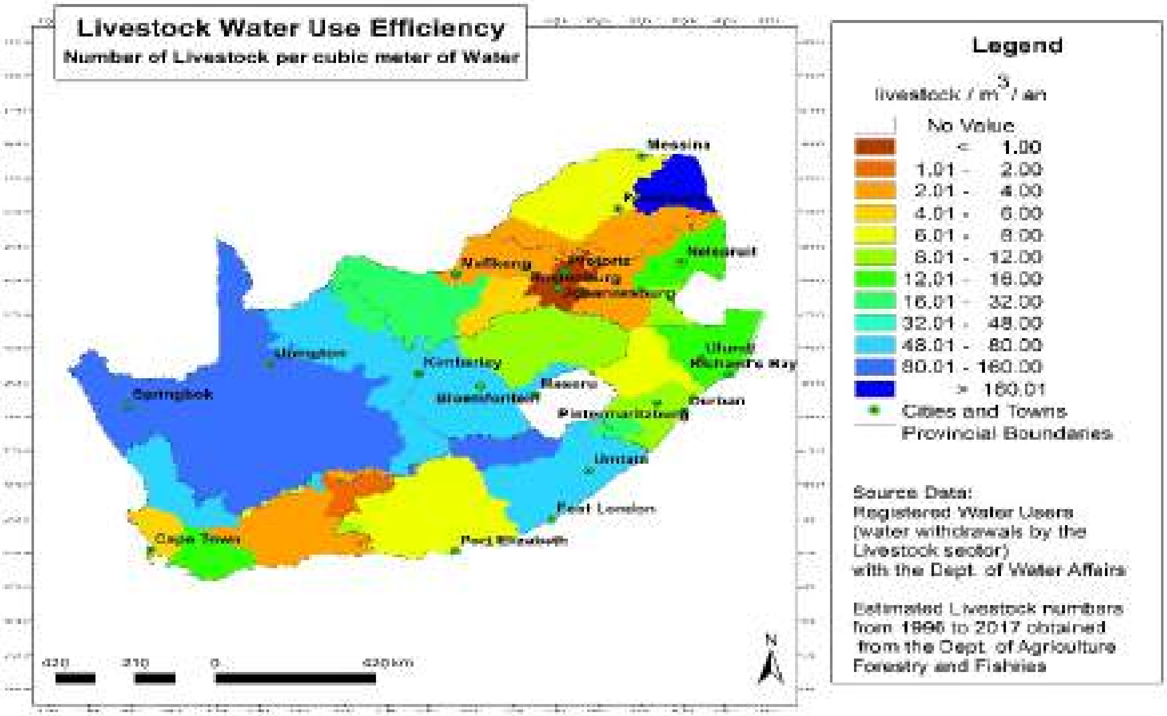
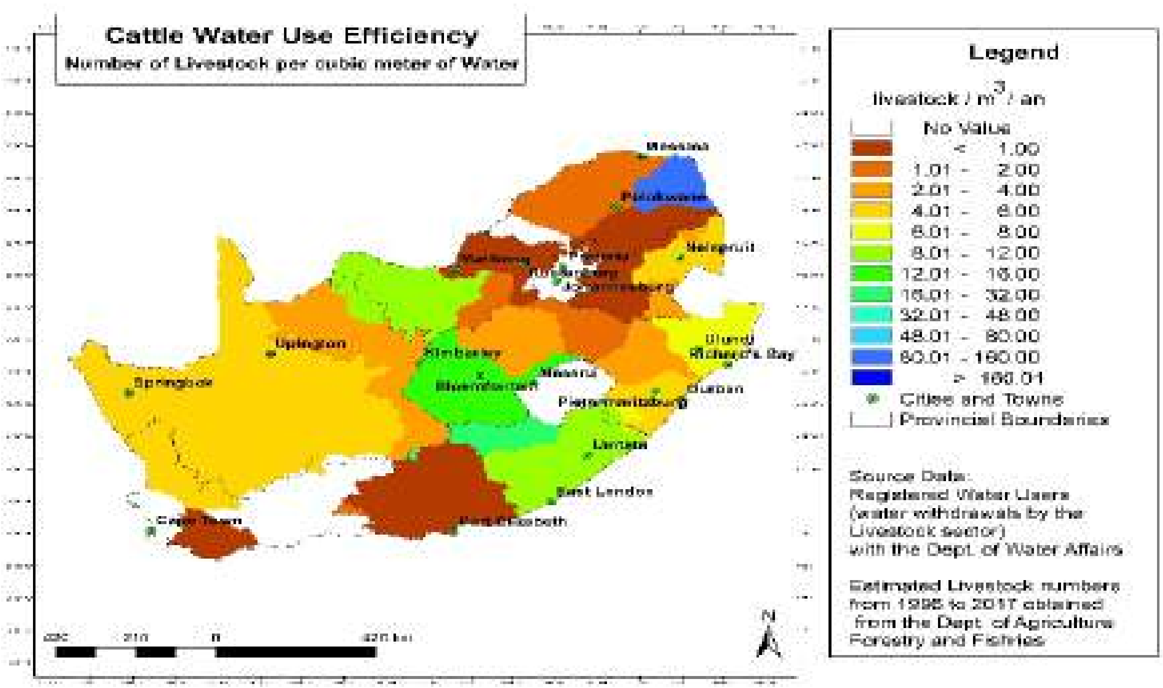
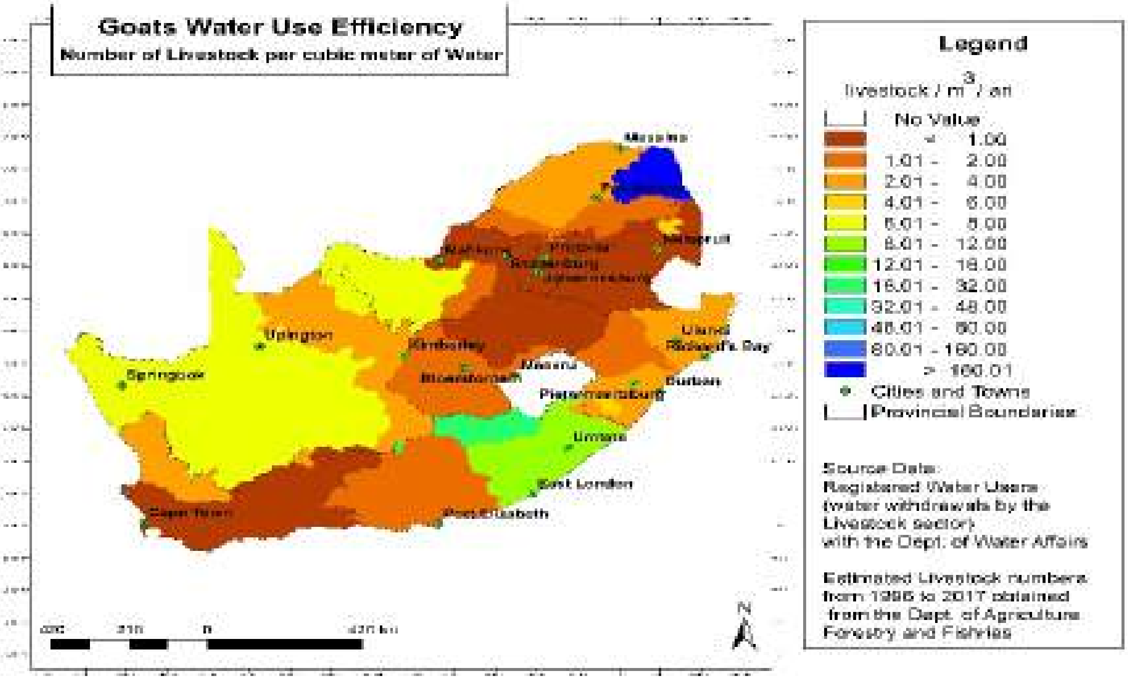
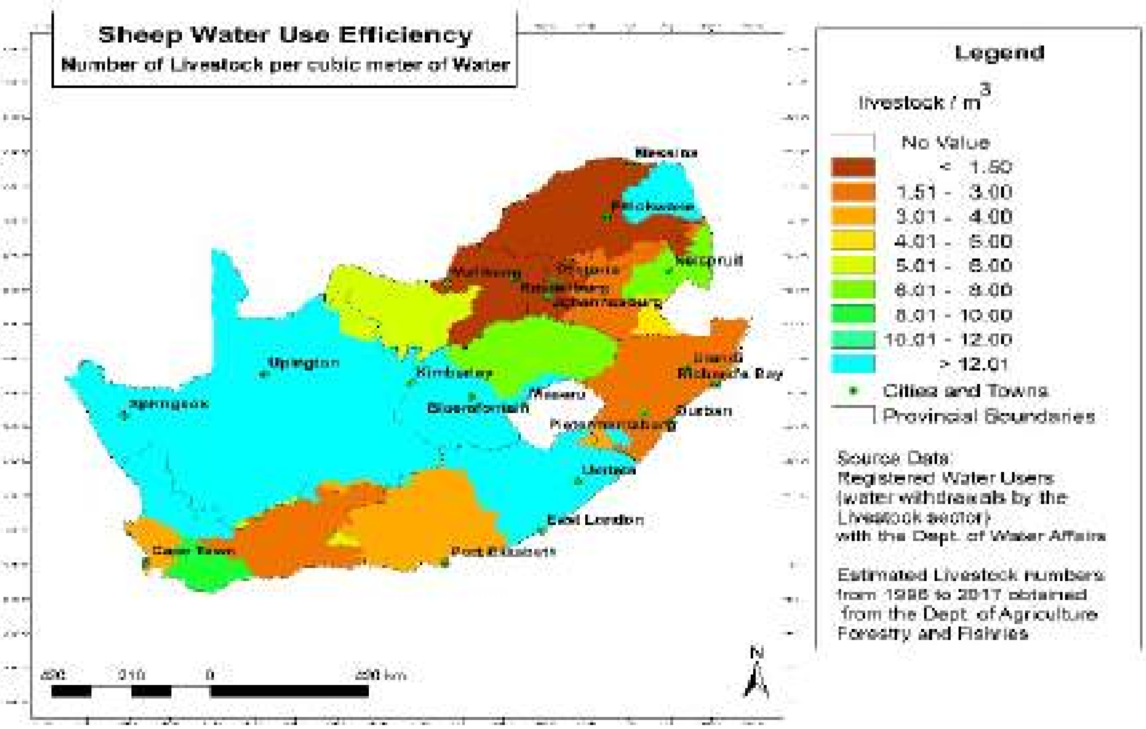


Figure 2.8. **Livestock water use efficiency**




Goats Water Use Efficiency
Number of Livestock per cubic meter of Water
Legend
livestock / m3 / an
No Value
< 1.00
1.01 - 2.00
2.01 - 4.00
4.01 - 6.00
6.01 - 8.00
8.01 - 12.00
12.01 - 16.00
16.01 - 32.00
32.01 - 48.00
48.01 - 80.00
80.01 - 160.00
> 160.01
Cities and Towns
Provincial Boundaries
Source Data:
Registered Water Users
(water withdrawals by the
Livestock sector)
with the Dept. of Water Affairs
Estimated Livestock numbers
from 1996 to 2017 obtained
from the Dept. of Agriculture
Forestry and Fishries
Messina
Nelspruit
Pretoria
Johannesburg
Upington
Kimberley
Bloemfontein
Maseru
Ulundi
Richard's Bay
Springbok
Durban
Pietermaritzburg
Umtata
East London
Cape Town
Port Elizabeth
N


Sheep Water Use Efficiency
Number of Livestock per cubic meter of Water
Legend
livestock / m3
No Value
< 1.50
1.51 - 3.00
3.01 - 4.00
4.01 - 5.00
5.01 - 6.00
6.01 - 8.00
8.01 - 10.00
10.01 - 12.00
> 12.01
Cities and Towns
Provincial Boundaries
Source Data:
Registered Water Users
(water withdrawals by the
Livestock sector)
with the Dept. of Water Affairs
Estimated Livestock numbers
from 1996 to 2017 obtained
from the Dept. of Agriculture
Forestry and Fishries
Messina
Pietersburg
Nelspruit
Pretoria
Johannesburg
Upington
Kimberley
Bloemfontein
Maseru
Ulundi
Richard's Bay
Springbok
Durban
Pietermaritzburg
Umtata
East London
Cape Town
Port Elizabeth
N

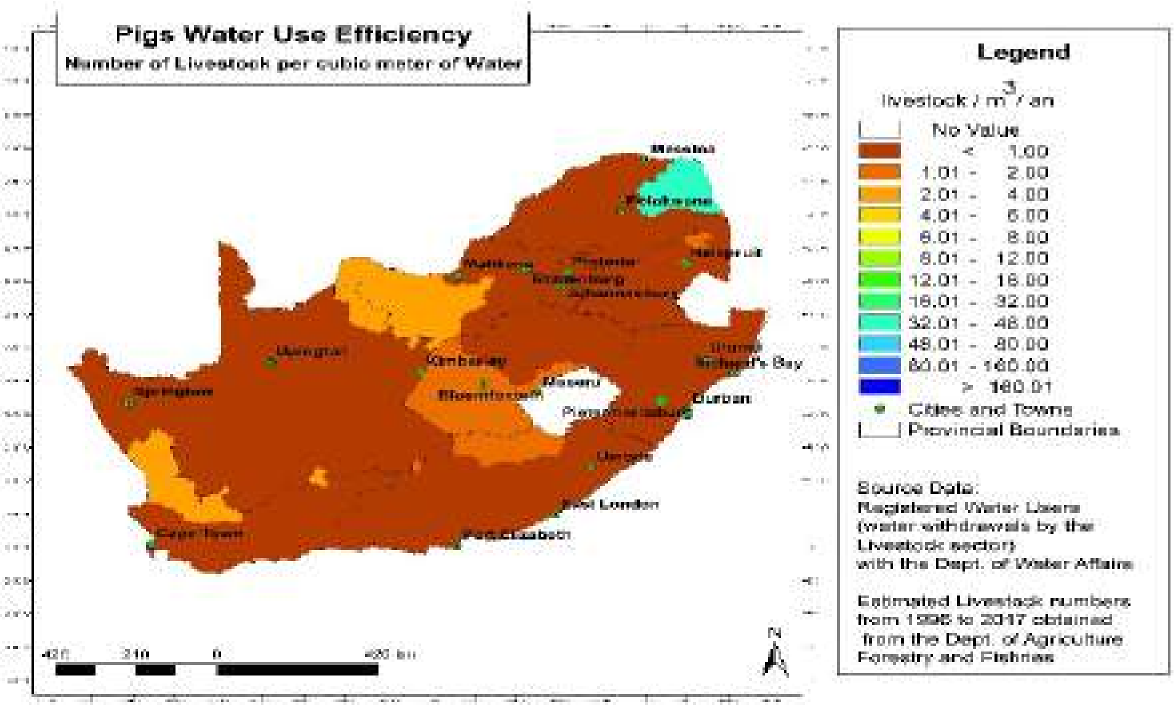


Figure 2.9. **Water Use Efficiency of Cattle, Goats, Sheep, and Pigs, over South Africa**

2.6 REFERENCES

Bekele Awulachew, S., V. Smakhtin, D. Molden and D. Peden (eds.) 2012. The Nile River basin: Water, Agriculture, Governance and Livelihoods. London: Routledge.

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Easterling, D. R., Meehl, G.A., Parmesan, C., Changnon, S.A., Thomas R.K. and Mearns, L.O. 2000. Climate Extremes: Observations, Modelling, and Impacts, Science. VOL 289 SCIENCE www.sciencemag.org.

Harrington, L.W., F. Gichuki, B.A.M. Bouman, N. Johnson, C. Ringler, V. Sugunan, K. Geheb and J. Woolley 2006. CGIAR Challenge Program on Water and Food, Changing the way we manage water for food, livelihoods, health and the environment: Synthesis 2005. CPWF Synthesis Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

HarvestChoice, 2010. "Agro-ecological Zones of sub-Saharan Africa." International Food Policy Research Institute, Washington, DC., and University of Minnesota, St. Paul, MN. Available online at http://harvestchoice.org/node/8853.

Mader, T.L. 2003. Environmental stress in confined beef cattle. Journal of Animal Science 81, 110–119.

Marcogliese, D.J. 2001) Implications of climate change for parasitism of animals in the aquatic environment. Canadian Journal of Zoology 79, 1331–1352. doi:10.1139/z01-067.

Leclère, D., Havlík, P., Fuss, S., Schmid, E., Mosnier, A., Walsh, B., Valin, H., Herrero, M., Khabarov, N. and Obersteiner, M. 2014. Climate change induced transformations of agricultural systems: insights from a global model. *Environ. Res. Lett*. 9 (): 1 – 14.

Kebebe, E.G., Oosting, S.J.1., Haileslassie, A., Duncan, A.J., de Boer, I.J.1. 2015. Strategies for improving water use efficiency of livestock production in rain-fed systems. Animal, 9(5): 908-916. doi: 10.1017/S1751731114003115.

Peden, D. et al. 2009. Nile basin livestock water productivity. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3927 Tags: PN37; Nile Livestock Water Productivity

Peden, D., T. Amede, A. Haileslassie and G. Taddesse 2008. Strategies for improving livestock water productivity. In: Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food, Vol.1, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 29-33. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. van Breugel, P., M. Herrero, J. van de Steeg and D. Peden 2010. Livestock water use and productivity in the Nile basin. Ecosystems, **13**, 205-221.

Pelling, M. 2011. Adaptation to climate change from resilience to transformation. Routledge. Abingdon, Oxon. ISBN 978-0-415-47751-2

Rojas-Downing. M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A. 2017 .Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16: 145-163.

Rust, J.M. and Rust, T. 2013. Climate Change and Livestock Production: A Review with Emphasis on Africa. *South Africa Journal of Animal Science*. *S. Afr. j. anim. sci.* 43 (3):256:267. ISSN 2221-4062.

Sutherst, R.W. 2001. The vulnerability of animal and human health to parasites under global change. International Journal for Parasitology 31, 933–948. doi:10.1016/S0020-7519(01)00203-X.

Spear, D., Haimbili, E., Angula, M., Baudoin1, M., Hegga1, s., Zaroug, M,.Okeyo, A. 2015. Vulnerability and Adaptation to Climate Change in Semi-Arid Areas in Southern Africa. Collaborative Adaptation Research Initiative in Africa and Asia c/o International Development Research Centre. Ottawa, Canada.aviable from: www.assar.uct.ac.za/.../SAFRICA/Southern%20Africa%20RDS%20full%20report.pdf.

Tabachnick, W.J. 2010. Challenges in predicting climate and environmental effects on vector-borne disease episystems in a changing world. The Journal of Experimental Biology 213, 946–954. doi:10.1242/jeb.037564

Weindl, I.,Bodirsky, L.B., Rolinskia, S., Biewald, A., Lotze-Campen, H., Müller, C., Dietrich, J.P., Humpenöder, F., Stevanović, M., Schaphoff, S. and Poppa, A. 2017. Livestock production and the water challenge of future food supply: Implications of agricultural management and dietary choices. Global Environmental Change, 47: 121-132. https://doi.org/10.1016/j.gloenvcha.2017.09.010.

CHAPTER 3: LIVESTOCK FARMER DEMOGRAPHY AND ADAPTIVE CAPACITY TO CLIMATE CHANGE AND VARIABILITY IN LIMPOPO AND MPUMALANGA PROVINCE OF SOUTH AFRICA

Abstract

The study investigated the demographic characteristics of smallholder livestock farmers in Limpopo and Mpumalanga Province of South Africa and their effect on the capacity of the farmers to adapt to climate change and variability. Respondents were mainly heads (58.7%) and parents (25.7%) to heads of households and were mostly male (63.4%) with good health (97.8%) associated with high adaptive capacity to climate change and variability. Regarding socio-economic status, four in five (81.5%) of the livestock farmers had only secondary education at most, and incomes were generally low, probably associated with low capacity to adapt to climate change and variability. To the contrary, the quality of housing for the livestock farmers was either top (48.5% of farmers) or medium (47.4%). Some 45.9% of farmers owned 4 to 5 rooms, 44.5% owned six or more rooms, with 88.5% of them having financed their houses. Almost all the respondents (97.3%) had access to electricity, and these suggest the high capacity to adapt to climate change and variability. With regards to aspects of livestock farming, one male (40.1% of households) and female (39.3%) member was fit to work in farming, livestock was owned by heads (52.9% of the households) and by children (29.0%), affirming the high capacity to adapt to climate change and variability. Almost all respondents (99.2%) used communal land, had fewer livestock, lacked training (99.5%), never belonged to a farmers' union (99.7%) or a producer organisation (100.0%), and had no access to financial support from government (99.2%) associated with low adaptive capacity. The findings of the study revealed that 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. This was true for all the three types of demographic factors studied, namely: personal characteristics, economic status, and aspects of livestock farming.

3.1 INTRODUCTION

3.1.1 Effect of climate change

The change in climate may involve gradual changes in long-term average conditions of climate, greater variability in normal conditions; or changes in the frequency, magnitude, and distribution of extreme events (Smit et al., 2000). Climate change and variability have adverse effects both environmentally and socio-economically (Scholze, Knorr, Arnell, & Prentice, 2006). Agriculture is dependent on environmental conditions such as temperature, nutrient availability and water accessibility (Rosenzweig and Hillel 2008; Lobell et al. 2011; Lin et al., 2007) and is hence vulnerable to climate change.

In South Africa, climate change is predicted to result not only in higher temperatures, but also in sporadic rainfall patterns and frequent droughts (Turpie and Visser, 2013). These severe weather events, coupled with the country's already scarce water resources, are expected to have a significant effect on the forestry and agricultural sectors, which are substantial components of the country's rural livelihoods and economies (Quinn et al., 2011; Turpie & Visser, 2013). Climate change manifestations in the form of rising temperatures, changes in water availability and increased levels of carbon dioxide are expected to affect farming and forest based livelihoods in various ways (Sonwa et al., 2012). Rural communities are believed to be particularly vulnerable to climate change (Holmes, 2007; Turpie and Visser, 2013) resulting from the effect of climate change on social and economic factors (David et al., 2007). It may therefore be affirmed that climate change poses social and economic challenges for rural communities with high dependence on natural resources (Fairbanks and Scholes, 1999; Turpie and Visser, 2013), and these include farmers, especially smallholder farmers estimated at 450-500 million or 85% farms globally (Nagayet, 2005). In affirmation of the occurrence of adverse effects induced by climate change in agriculture, O'Brien et al. (2004) revealed that smallholder farmers in the tropics already face numerous risks to their production, including pest and disease outbreaks, extreme weather events and market shocks. Smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks. Resultantly, any reduction in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (McDowell & Hess, 2012).

3.1.2 Vulnerability to climate change

Ncube et al. (2016) defines 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 an external side with risks, shocks and stress to which an individual is subject and an internal side with 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) conceptualised 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). 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, the vulnerability can be summarized as a function of three attributes, exposure, sensitivity, and adaptive capacity.

(a) 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., temperature, precipitation, extreme weather events). 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 socioecological systems (Gallopín 2006).

(b) 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 socioeconomic 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 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).

(c) 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 a 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 socioecological 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 a 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 organisational 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 adaptation 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 research was to conduct a demographic study on the livestock farmers in Limpopo and Mpumalanga Provinces of South Africa and to subsequently assess their capacity to adapt from the adverse effects of climate change and climate variability.

3.2. RESEARCH METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim to create independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

3.2.1. Sampling frame and procedure

3.2.1.1. Sampling frame

A sampling frame refers to a list of all units in a population from which a sample is drawn. In practice, not all units in a population might be available for sampling for one reason or another. The importance of a sampling frame in scientific research was shown by Welman *et al.* (2005) who revealed that it is impossible to properly judge the representativeness of the obtained sample unless a sampling frame is borne in mind. A representative sample is a requirement for subsequent research results to be credible and trustworthy (Leedy and Ormrod, 2010). In Limpopo Province, the sampling frame consisted of a database of village households owning livestock in the Vhembe District municipality in 2013. All four local municipalities of the Vhembe district were considered, i.e. Makhado, Musina, Collins Chabane and Thulamela. The population of interest included 23 283 households owning livestock from 362 villages.

In the Mpumalanga Province, the sampling frame consisted of a database of village households owning livestock in Gert Sibande District Municipality in 2016 (StatsSA, 2018). All seven local municipalities of Gert Sibande District were considered i.e. Chief Albert Luthuli, Msukaligwa, Mkhondo, Dr Pixley Ka Isaka Seme, Lekwa, Dispalesing and Govan Mbeki. The population of interest included 27 706 (57 962 including chicken production) households owning livestock from 183 villages. In all the provinces, only the total number of households owning livestock in a particular village was available and not the individual household identities. For sampling, a household list was ordered from 1 *to* n_k where n_k is the total number of households owning livestock in a village.

3.2.1.2. Sampling procedure

At least 400 smallholder livestock farmer households were sampled for interviews to elicit responses on demographic issues that would in one way or the other influence the adaptive capacity of the livestock farmers to adverse effects of climate change and climate variability. Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and within four such zones in Mpumalanga Province (Figure 3.1). An effort was made to have a minimum of 10 randomly sampled farmers per village.

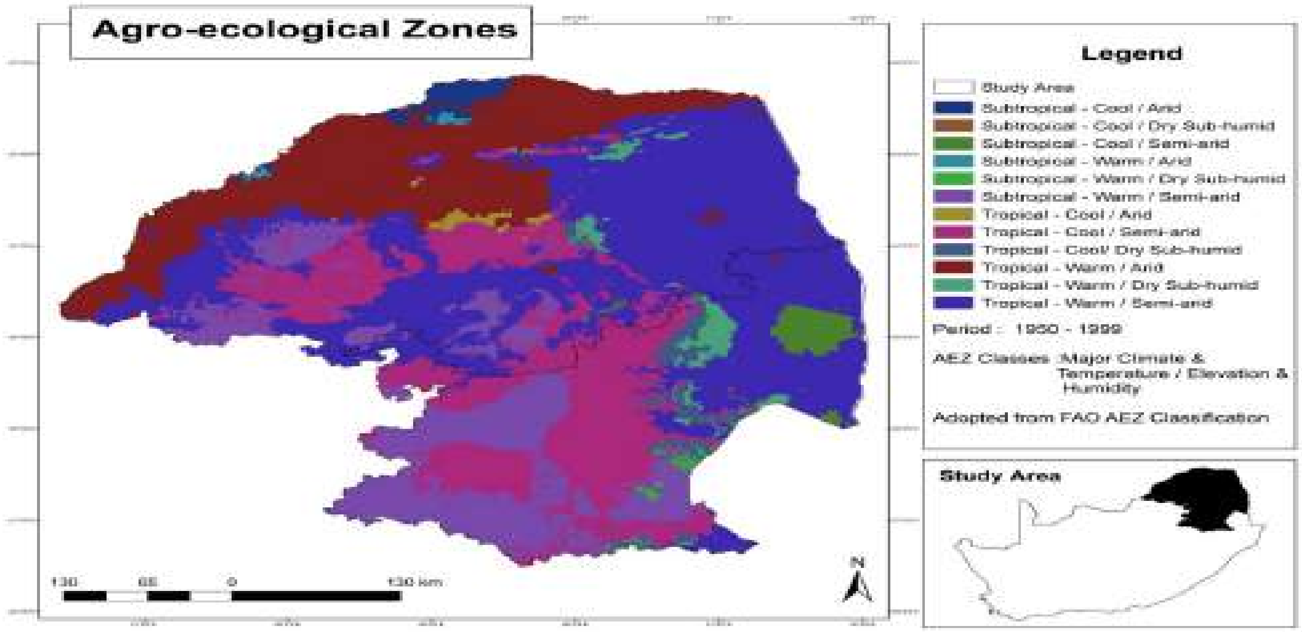


Figure 3.1. Agro-ecological zones, derived from FAO (1978)

Stratified sampling was used to obtain a representative sample of villages and households for interview (Figure3.2). A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The *PROC SUREVEYSELECT* allows selection of probability-based random sampling, where sampling in different categories or class depends on the number of units within that class. It is appropriate for handling selection bias.

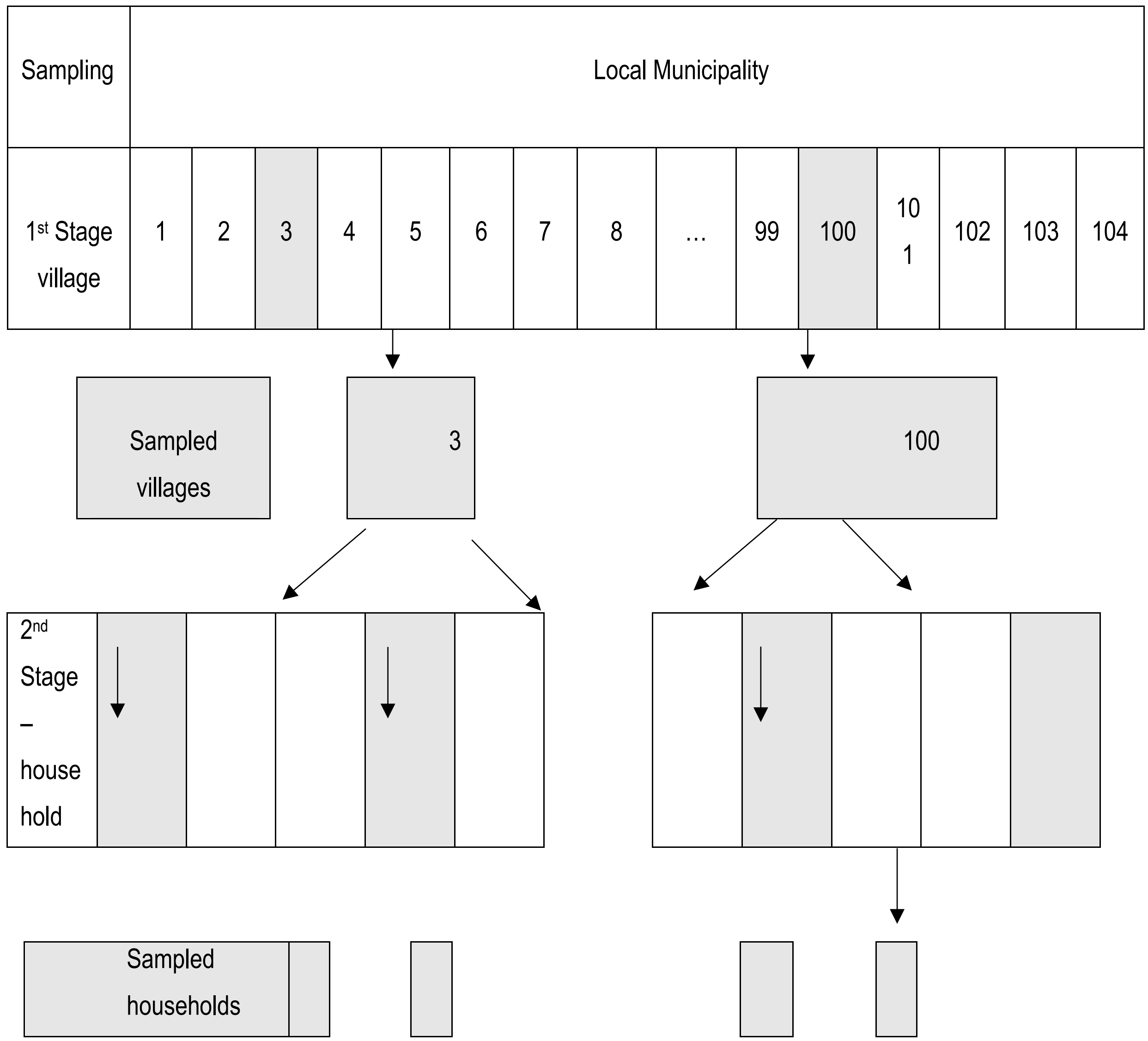


Figure 3.2. An illustration of the two-stage sampling process as used in the study

3.2.2 Data collection

Data and pertinent information for the study was mainly collected through interviews of the sampled respondents (smallholder livestock farmers) and through the study of relevant literature.

3.2.2.1 Respondent interviews

A semi structured questionnaire was used to interview the smallholder livestock farmers. Among the issues included in the questionnaire were demographic and economic household characteristics as well as livestock production issues. The focus was on investigating the demographic factors and hence describing the adaptive capacity of interviewed smallholder livestock farmers to climate change and variability.

Primary data were collected from the sampled respondents through interviews which were conducted by trained enumerators using a semi structured questionnaire. The questionnaire contained both open- and closed-ended questions which included demographic factors such as gender, and education. The closed-ended questions collected quantitative data while the open-ended questions recorded qualitative data (Leedy and Ormrod, 2010). Qualitative techniques were directed towards improved understanding of the demographic factors and their possible influence on the capacity of respondents to adapt to adverse effects of climate change and climate variability. This research method that combines the collection and analysis of quantitative data with that of qualitative data is referred to as a mixed study (Hurmerinta-Peltomaki and Nummela, 2006).

3.2.2.2 Literature review

A review of literature is an exercise where the researcher works from a 'sample' of texts that he / she reads in order to come to a proper understanding of a specific domain of knowledge. As a result, the sources of the literature must be representative to achieve good quality review (Mouton, 2001). In this study, local, national and international literature was reviewed based on the objectives of the study. An effort was made to include as much as possible of pertinent and latest articles from peer reviewed journals in the literature review. The literature review was conducted with a focus on identifying thematic issues.

3.2.3 Guiding model

Before proposing the guiding model of this study, it is perhaps necessary to attempt to define the concept 'model'. Although there is wide agreement that models are important elements in scientific practice, no unique definition of models has been established. Even scientists who consider models to be central to their research have different meanings of these models (Van der Valk *et al.,* 2007).

A model may be defined as an interpretative description of a phenomenon (Bailer-Jones, 2003). As stated by Bailer-Jones (2003), the word 'description' in this definition includes various forms of representation. The ability of a model to describe a specific phenomenon depends on the interpretation that goes beyond pure phenomenological reality (Bulle, 2009). The phrase 'interpretive description' is therefore key in this definition.

Also, a model may be regarded a representation of how some aspect of the world works (Windschitl and Thompson, 2006). There is a great variance in what can be represented by a model, and this includes the different descriptors of the modelled world, e.g. targets and systems (Oh & Oh, 2011). A model is a representation of some target in the sense that it stands for that target as its substitute. Instead of obtaining information about the target by examining it directly, one may therefore examine the properties of the model and indirectly acquire information about the target (Grune-Yanoff, 2011). The guiding model for this study, also referred to as a framework, was described by Lindoso (2011) and presents adaptive capacity as one of the three attributes of vulnerability and enlists the indicators for each attribute (Table 3.1).

Table 3.1. Framework for vulnerability of small-scale farmers (Lindoso, 2011)

Vulnerability attribute	Indicator
Exposure	Aridity Index (AI)
	Annual Distribution of rainfall
Sensitivity	Municipal population occupied by smallholder agriculture (%)
	Establishments with access to water (%)
	Establishments with rain-fed farming (%)
Adaptive capacity	Smallholder system product diversification (%)
	Establishments in which the producer is the land-owner (%)
	Establishments in which the administrator can read and write (%)
	Establishments in which a producer is a member of the association or union (%)
	Establishments that receives technical assistance (%)
	Agricultural establishments with access to electricity (%)

The investigation focussed on demography and adaptive capacity and hence the indicators (for adaptive capacity) as presented by Lindoso (2011) received thorough consideration. Also, considering McCarthy et al. (2008, p. 8)'s definition of adaptive capacity, Lindoso (2011) model seemed rather deficient. Resultantly, the Lindoso (2011) was adapted and not adopted in its original form. The adapted model used in this study enlists up to 16 indicators that influence the adaptive capacity of smallholder livestock farmers to adverse effects of climate change and variability. The expanded list of indicators are all in percent and are categorised under three thematic areas, namely:

(a) Personal characteristics (five indicators): Position of respondent in household, gender, age, health, and educational status;

(b) Economic status (five indicators): Employment status, household income, quality of housing, size of housing, and household energy supply;

(c) Aspects of livestock farming (eight indicators): Fitness to work in agriculture, land ownership, livestock ownership, farming status, number of livestock owned, livestock ranking, exposure to capacity building, and number of dependent household members staying off farm.

This study adopted the adapted model with the expanded list of indicators for livestock farmer adaptive capacity to climate change and climate variability.

3.3 DISCUSSION OF RESULTS

Studies addressing the demographics such as personal factors, decision-making, access to agricultural information, socio-economic variables and the sociocultural milieu of small-scale farmers have been limited (Bembridge & Tshikolomo, 1998). While seeking to describe the adaptive capacity of livestock farmers to adverse effects of climate change and variability, the demographic study will be based on (a) personal characteristics of respondents, (b) economic status, and (c) various aspects of their involvement in livestock farming.

3.3.1 Personal characteristics

3.3.1.1 Position of respondent in the household

For any demographic study, the position of the respondent in the household has a huge influence on the quality of information provided. According to Bembridge and Tshikolomo (1998), heads of household are the main decision makers in rural farming households and as a result the information they provide is more likely to reflect on farming and other developmental decisions of the household. It was evident in this study that three in five (58.7%) respondents were heads of household, suggesting that the information provided by the majority of respondents highly likely reflected the decisions of livestock farming households (Table 3.2).

Table 3.2. Position of respondents in surveyed livestock farming households in Limpopo and Mpumalanga provinces of South Africa

Category	Frequency	Percent
Head	215	58,7
Spouse	11	3,0
Mother	65	17,8
Father	29	7,9
Son	19	5,2
Daughter	9	2,5
Niece/ Nephew	1	,3
Grandpa	12	3,3
Other	5	1,4
Total	366	100,0

It is interesting to note that following the heads of household, the next largest categories of respondents were the mother (17.8%) and father (7.9%) to the head. In a rural set up, the parents to the (often male) head of household usually stay in the same homestead as their son’s family and are often consulted (or at least informed) when major decisions are made. As a result, one in four respondents (25.7% - 17.8% mothers and 7.9% fathers) who were parents to the heads of household could also have provided valuable information that would accurately reflect on the adaptive capacity of the small holder livestock farmers to adverse effects of climate change and variability.

3.3.1.2 Gender, age, and health status

Personal characteristics of farmers such as gender, age, and health status have some influence on farming decision making and indeed the profitability of a farming enterprise. In a society, there is inequity among different groups (Malakar and Misha, 2017), populations belonging to lower castes, old age, disability, and illiterates are assumed to be the weaker sections of the society who either have less access to resources or restricted by their physical incapability.

(a) Gender

It is necessary to establish the differences in the roles played by males and females in farm households since this gender differences are likely to influence their capacity to adapt to climate change as well as their choices of climate change adaptation strategies (IFPRI, 2015). Most of the livestock smallholder's farmers in the current study were males (63%), while 37% were females (Table 3.3), which implies that livestock farming is dominated by males.

Similar observations were made in a study of youth agricultural projects in Limpopo Province, Maele *et al.* (2015) revealed that majority of farmers (74%) were male. The finding that men were majority owners of agricultural projects was also affirmed by Bembridge and Tshikolomo (1998) who revealed that 90% of fruit growers in the Phaswana area of the Limpopo Province were males. Also, Ijatuyi *et al.* (2017) revealed that up to three in four (75%) of Nguni producers in the North-West Province of South Africa were men, further affirming the dominance of men in livestock production compared to their female counterparts.

With majority ownership of agricultural projects, men are probably able to make appropriate farming decisions that reflect improved adaptive capacity to challenges such as climate change and variability. Despite the effort of the democratic government to promote women empowerment and their equal participation in socio-economic activities (Maele *et al.,* 2015), men constituted the majority of respondents on livestock projects, further affirming the dominance of men in livestock farming.

Table 3.3 Gender, age and health status of livestock owners in Limpopo and Mpumalanga provinces of South Africa

		Frequency	Percent
Gender			
	Male	232	63.4
	Female	134	36.6
	Total	366	100
Age			
	<18 years	2	0.55
	18-35 years	25	6.87
	36-54 years	98	26.92
	55-65 years	102	28.02
	>65 years	137	37.64
	Total	364	100
Health status			
	Good	348	97.8
	Infrequently sick	8	2.2
	Total	356	100

(b) Age

In the current study, the participation of youth in livestock farming is very frightening, with only 7.4 % of the livestock farmers aged 35 years or less (Table 3.3). Mulinyac, (2017) reported that farmers within the ages of 30-34 years are likely to understand well issues involved in farming and therefore are armed with necessary information regarding climate change adaptation strategies that can be well achieved and adhered to. Two in three (65,7%) of farmers were aged 55 years and above of which almost two in five (37,6%) were aged >65 years. This observation agrees with Simotwo et al. (2018) who revealed that farmers were aging. Older farmers could be resistant to change and thus may not see the need of employing new technologies and would prefer the traditional models of farming that they are familiar with other than adopting new methods (Fussel and Klein, 2006). Farm productivity has been shown to deteriorate with the farmers' age, especially among the smallholders who largely rely on their own physical labour to execute many farming responsibilities (Uddin et al., 2014, Labbe et al., 2016). However, Hassan & Nhemachena (2008) in determining farmers‟ strategies for adapting to climate change reveals that for farmer's age, in particular older farmers are more experienced and expect older farmers to adapt to climate change better than farmers whose age are lesser. However, they also assumed younger farmers to have a longer planning horizon and to take up long term measures that will influence their decision to increase production levels.

Deressa et al. (2010) report that age has a positive influence on the choice of the livestock sale as an adaptation strategy by farmers during extreme climatic events.

(c) Health status

Almost all (97.8%) the livestock owners in the study area had good health (Table 3.3). The health status of a farmer has a strong influence on his / her productivity and adaptive capacity to adverse effects of environmental factors such as climate change and variability to the success of the farming enterprise. This was affirmed by Ajani and Ugwu (2008) who revealed that good health is related to better production and can enhance farmer`s income and economic growth. As stated by Ajani and Ugwu (2008), poor health will result in loss of work days or decrease worker capacity, decrease innovation ability and ability to explore diverse farming practices. The livestock farmers would therefore be expected to have more work days, increased work capacity, increased innovativeness and more ability to explore diverse farming practices. As a result, the livestock farmers may be expected to have the relatively better adaptive capacity to adverse effects of climate change and vulnerability.

3.3.1.3 Educational status

The importance of education in successful developmental activities such as farming cannot be overemphasized. The level of education has a strong influence on the extent to which a farmer is able to 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. Citing Appleton and Balihuta (1996), Oduro-Ofori *et al.* (2014) described the effect of education on agricultural productivity as cognitive and non-cognitive.

Cognitive effects reportedly emphasise basic literacy and numeracy that farmers achieve from education while non-cognitive effects emphasize the change in the attitude of farmers who attended school due to improved discipline introduced by formal schooling. Better education may therefore be associated with the improved adaptive capacity to adverse effects of climate change and variability.

Table 3.4. Educational status (highest education) of livestock owners in Limpopo and Mpumalanga provinces of South Africa.

	Frequency	Percent
Educational information		
Illiterate	53	18,2
Some primary school	87	29,9
Completed primary school	22	7,6
Some secondary school	23	7,9
Completed basic secondary school	27	9,3
Completed high school	25	8,6
Professional college certificate	33	11,3
University education	18	6,2
Adult education	3	1,0
Total	291	100
Currently going to school?		
Yes	15	4,1
No	11	3,0
Not applicable	340	92,9
Total	366	100
If not scholar, reasons		
Lack of finance	1	20,0
Health	3	60,0
Work	1	20,0
Total	5	100
If scholar, who is your sponsor (N=8)		
Government	2	25,0
Parents	6	75,0
Total	8	100

One in six (18.2%) smallholder livestock farmers was 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 (Table 3.4). 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).

Uddin et. al. (2014) found that education level of farmers also positively and significantly affect climate change adaptation. The level of education of the livestock farmers in the current study proved to be generally low, a situation that may be associated with the reduced adaptive capacity to adverse effects of climate change and variability. The development of human assets in terms of education and skills enhances proper utilization of existing other assets and internalization of information related to early warning systems and community preparedness plans, which may help them and the communities in districts prepare for extreme weather events (Hahn et al., 2009). Unfortunately, only 4.1% of the farmers reported that they were improving their education (attending school) at the time of the survey, and reasons for non-improvement of education were revealed to be a lack of funding and poor health. Resulting from the lack of improvement of education, there may therefore be no expectation for improvement of the adaptive capacity of the current group of farmers.

3.3.2 Economic status

Economic status of livestock farmers has a huge influence on their capacity to adapt to adverse effects of environmental factors such as climate change and variability. Among the important economic factors influencing the ability of livestock farmers to adapt to adverse effects of climate change are employment status, income, type and size of housing, sources of energy, and ownership of various household equipment (radio, television, stoves, tele- / cell phone, computer, etc.). As stated by Ijatuyi *et al.* (2017), income is a potential proxy for livelihood. As highlighted, literature is explicit about the five pillars of livelihood which includes financial capital (stocks of money or assets in liquid form), natural capital (land, water, and biological resources), social capital (rights or claim derived from group membership), physical capital (infrastructure, resources created through economic production), and human capital (Ijatuyi *et al.,* 2017).

3.3.2.1 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. Smallholder livestock farmers may need to be employed elsewhere in order to supplement the farming income and be able to buy required inputs to mitigate the adverse effects of climate change and variability.

Such inputs may include feeds and provision of water during droughts, and vaccines and medication to treat livestock parasites and diseases associated with changing climatic conditions. For these smallholder livestock farmers, involvement in additional employment increases their adaptive capacity to the adverse effects of climate change and enables their livestock enterprises to recover faster when hit by climate-related disasters.

Table 3.5. Employment status of livestock farmers in Limpopo and Mpumalanga provinces of South Africa.

Employment status	Frequency	Percent
Unemployed	143	49,5
Homemaker/ Not applicable	17	5,9
Subsistence farmer	12	4,2
Artisan/ Skilled tradesman/ woman	24	8,3
Petty trade	12	4,2
Formal employment	77	26,6
Harvesting natural resources	4	1,4
Total	289	100,0

For large-scale livestock farmers often characterized by being highly profitable, additional employment may not be necessary as it may in fact deprive them of the much required time to monitor their livestock and make prompt decisions to mitigate the adverse effects of climate change and variability. For these livestock enterprises, the farmer is able to afford inputs and other production factors without having to resort to additional employment and resultantly, acceptance of additional employment may reduce the farmers' capacity to adapt to adverse effects of climate change and variability. Depending on the profitability of the livestock farming enterprise, half (49.5%) of the respondents would have more (for non-profitable, often smallholders) or less (for profitable, often large scale farmers) adaptive capacity to adverse effects of climate change and variability (Table 3.5).

About half (50.5%) of the livestock farmers were involved in various types of employment, and these would somehow influence the adaptive capacity of their enterprises to adverse effects of climate change and variability, depending on the level of income from the employment activities, e.g. livestock farmers with formal employment would use their funds to purchase livestock feeds in times of need.

3.3.2.2 Household income of livestock farmers

Income tends to be an important determinant of the economic status of any household, including livestock farming households. High income households are able to afford their needs much more than low income households. 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.

Table 3.6. Household incomes of livestock farmers in Limpopo and Mpumalanga provinces of South Africa

	Income category	Frequency	Percent
Monthly			
	Less than or equal to R1000	18	4,9
	R1001-R3000	95	26,0
	R3001-R5000	106	29,0
	R5001-R10 000	79	21,6
	R10 001 and above	68	18,6
	Total	366	100
Annual			
	Less than or equal to R5000	33	9,1
	R5001-R20 000	183	50,4
	R20 001-R40 000	90	24,8
	R40 001-R60 000	41	11,3
	R60 001 and above	16	4,4
	Total	363	100

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. As a result, high income, livestock farming households will be better adapted to adverse effects of climate change and variability when compared to their low income counterparts. 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 where one in five (18.6%) who earned R10 001 and above per month and 4.4% who earned R60 001 and above per annum (Table 3.6). Based on the said discussion, higher income earners would be expected to have relatively higher adaptive capacity to adverse effects of climate change and variability compared to their low income counterparts. Farmers with higher incomes are likely to embrace, and will be interested in adapting by changing practice and modern methods such as irrigation to cope with the changing climate (Gbetibou, 2009). Generally, the income levels of the smallholder livestock farmers were at best adequate for basic household needs and would not significantly increase the adaptive capacity of the farmers to the negative effects of climate change and variability on the livestock enterprises.

3.3.2.3 Quality of housing

The quality of a house owned by a farmer tends to be positively influenced by the amount of income earned and may positively influence the adaptive capacity of the farmer to adverse effects of climate change and variability. Farmers earning higher incomes are expected to afford better quality houses compared to their lower income counterparts. Accordingly, livestock farmers with higher incomes are expected to reside in better quality houses than their lower income counterparts. Livestock farmers and other members of the community may, however, be the beneficiaries of the government housing scheme and own higher quality houses, even if their income levels are low, hence the interest on source of funding for house construction. Almost half (48.5%) of the livestock farmers stayed in top quality houses with cement brick walls and corrugated irons or tile roofs (Table 3.7). About the same number (47.4%) of livestock farmers dwelled in medium quality houses, of which one in eight (12.5%) stayed in mud brick wall and corrugated iron / tile roof houses with one in three (34.9%) staying in cement brick wall and thatch roof houses.

Table 3.7. Quality of housing owned by livestock farmers in selected areas of the Limpopo and Mpumalanga provinces of South Africa.

	Frequency	Percent
Type of housing		
Mud brick wall & thatch roof	15	4,2
Mud brick wall & corrugated iron/ tile roof	45	12,5
Cement brick wall & thatch roof	126	34,9
Cement brick wall & corrugated iron/ tile roof	175	48,5
Total	361	100
Source of funding		
Own finance	323	88,5
RDP (government fund)	35	9,6
Family owned (inherited)	7	1,9
Total	365	100

Only 4.2% of the livestock farmers lived in houses of a mud brick wall and thatch roof that could be regarded to be of poor quality. Up to 88.5% of the livestock farmers revealed that their houses were built through their own finance with 9.6% funded by government and 1.9 % inherited. The 9.6% government funded houses would most certainly be part of the top quality category, and so could be the case with the 1.9% inherited houses, implying that livestock farmers themselves could have funded some 37.0% (and not the reported 48.5%) of houses in this category. Assuming that the 4.2% completely poor quality houses were part of those funded by livestock farmers

themselves, it may be inferred that some 37.0% of the farmers could afford top quality houses while about 47.4% would have funded their medium quality houses.

Considering the quality of housing, some 37.0% of farmers would likely possess the high adaptive capacity to adverse effects of climate change and variability affecting their livestock enterprises. About 47.4% of the livestock farmers would possess the medium adaptive capacity while only 4.2% would likely have a complete lack of adaptive capacity. However, when considering the fairly low income levels for the livestock farmers, it could be assumed that they prioritize the housing and had to sacrifice some of the basic needs to fund the construction of the houses. The same sacrifice could be made to invest in building the adaptive capacity to climate change and variability affecting the livestock enterprises.

3.3.2.4 Size of housing

As is the case with the quality of the house, the size of a house owned by a farmer tends to have some influence on the extent to which he / she is able to adapt to adverse effects of climate change and variability. Considering the total number of rooms, one in ten (9.6%) households had between one and three rooms, and these were probably the poorest. Some 45.9% of livestock farmers lived in 4-5 roomed houses and could be regarded to be of medium wealth, status while the remaining 44.5% lived in 6 or more roomed houses and could be categorized wealthy (Table 3.8).

The livestock farmers with six or more roomed houses would most likely possess the highest adaptive capacity to the adverse effects of climate change and variability compared to those with four to five roomed houses. Similarly, the farmers staying in four to five roomed houses were likely to possess higher adaptive capacity to adverse effects of climate change and variability than those in one to three rooms. The number of bedrooms owned by livestock farmers may also be expected to be associated with the wealth status of the household and the ability of their farming enterprises to withstand the adverse effects of climate change and variability.

Table 3.8. Size of houses owned by livestock farmers in Limpopo and Mpumalanga provinces of South Africa.

	Frequency	Percent
Size of house		
Total number of rooms		
Total up to 3 rooms	35	9,6
Total of 4-5 rooms	167	45,9
6 or more rooms	162	44,5
Total	364	100
Number of bedrooms		
0	1	0,3
1-2	88	24,2
3-5	255	70,1
>5	20	5,5
Total	364	100

Regarding wealth status, livestock owners with more than five bedrooms would be regarded wealthiest with the highest adaptive capacity, followed by those with three to five bedrooms who would in turn be followed by those with one to two bedrooms.

3.3.2.5 Household energy supply

The type of energy supply to a livestock farming household is also associated with the wealth status of the family and the capacity of the farmer to adapt to adverse effects of climate change and variability.

Table 3.9. Energy supply to households of livestock farmers in Limpopo and Mpumalanga provinces of South Africa

Energy supply	Frequency	Percent
Access to electricity in the house?		
No	10	2,7
Yes	355	97,3
Total	365	100
Source of energy for cooking		
Electricity	320	87,4

Gas	2	,5
Wood	43	11,7
Other	1	0,3
Total	366	100
Alternative source of energy for cooking		
Electricity	1	0,5
Gas	1	0,5
Wood	217	99,0
Total	219	100
Sources of energy for lighting		
Electricity	358	99,7
Wood	1	0,3
Total	359	100

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 (Table 3.9). 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 change and variability. Electricity allows access to information through TV media and telephone. Adaptive capacity is highly dependent on the capacity of farmers and their families to access key information and to collectively self-organize (Jones and Boyd, 2011). The 11.7% of livestock farming households who depend on firewood for cooking would likely spend some time collecting firewood and have less time for farming activities, except for households who rely on buying and not collecting the firewood. Considering energy supply, the livestock farmers in the study area would be expected to be adaptive to adverse effects of climate change and variability.

3.3.3 Aspects of livestock farming

The situation regarding livestock farming and types of farming activities practiced have some influence on the adaptive capacity of the farmers to adverse effects caused by climate change and variability. Among the important issues likely to influence the adaptive capacity of livestock farmers to negative effects of climate change are the fitness of farming households to work in agriculture, land ownership, livestock ownership, amount of time committed to farming (full time, part time), and number of livestock.

3.3.3.1 Fitness of livestock farmers to work in agriculture

The extent of fitness of livestock farmers to work in agriculture has some influence not only on the productivity of the farming enterprise, but also on the degree to which the farmer is able to adapt to the negative effects of climate change and variability. The findings of the study revealed that fewer livestock farming households (4.7%) totally lacked a male member who was fit for farming compared to those (36.3%) who totally lacked a female member. The majority of the livestock farming households had one member who was fit to work in farming. For this category, two in five households had one member who was fit for farming, for both male (40.1%) and female (39.3%) household members (Table 3.10). Two in five (38.4%) of households had two male members compared to one in five (19.9%) households with the same number of female members who were fit for farming. More households (13.8%) had three male members compared to only 1.8% of households with the same number of female members who were fit for farming.

The analysis of household member fitness to work in farming suggests that male members were generally fit to work in livestock farming than their female counterparts. Total lack of a household member who is fit for farming would render a livestock farming household deficient in capacity to adapt to adverse effects of climate change and variability. It is therefore hoped that none of the livestock farming households in the area under study had totally nobody fit for farming, i.e. households without a single male member fit for livestock farming should have some female member(s) fit to work in the farming enterprise and vice versa. Generally, livestock farming households had some members who were fit to work in farming and would accordingly have higher adaptive capacity to the adverse effects of climate change and variability.

Table 3.10. Fitness of smallholder livestock farming households of Limpopo and Mpumalanga provinces of South Africa to work in farming.

Gender	No. of members	Frequency	Percent
Male			
	0	17	4,7
	1	145	40,1
	2	139	38,4
	3	50	13,8
	4	8	2,2
	5	2	0,6
	8	1	0,3
	Total	362	100
Female			
	0	120	36,3
	1	130	39,3
	2	66	19,9
	3	6	1,8
	4	4	1,2
	5	3	0,9

7	2	0,6
Total	325	100

3.3.3.2 Land ownership

Ownership of land is a strong determinant of the success of farming in general and livestock farming in particular. Farmers owning land for livestock farming would have the possibility of dividing it into camps, managing their stocking rate and consequently their grazing. Resultantly, the livestock farmers would possess the capacity to adapt to droughts and other negative effects of climate change and variability, and this may not be the case with farmers operating on communal land.

Table 3.11. Land ownership for smallholder livestock farming in Limpopo and Mpumalanga provinces of South Africa.

Land ownership category	Frequency	Percent
Own	2	0,5
Communal	362	99,2
Other	1	0,3
Total	365	100

Almost all the livestock farmers (99.2%) were farming under communal land. Livestock farming in this condition tends to be characterized by overstocking and subsequent overgrazing. With the overgrazing under normal rainfall conditions, an occurrence of a climate change associated disaster such as drought would highly exacerbate the issue of lack of grazing. Considering the issue of land ownership, it could be inferred that the livestock farmers in the study area had a serious dearth of capacity to adapt to adverse effects of climate change and variability.

When drought occurs, the livestock farmers would likely lean back on their positive personal and economic characteristics that would promote their capacity to adapt to the adverse effects of climate change and variability. Such characteristics would include good incomes that would enable the farmers to buy fodder from outside their areas, but often this works better when the herd has been reduced so as to manage the spending on the fodder. Livestock farmers with some education may be better positioned to source information, both for avoiding and for managing the adverse effects while those with formal employment may qualify for loans to buy fodder and other feeds.

3.3.3.3 Livestock ownership

The member of the household owning livestock tends to have some influence on the adaptive capacity of the livestock enterprise to adverse conditions caused by climate change and variability. Where the livestock is owned by a well-resourced, knowledgeable and experienced member of the household, the enterprises tend to possess more adaptive capacity to adverse effects of climate change and variability, and vice versa. Livestock in the study area was owned by heads of households in the majority (52.9%) of families. Heads of household tend to be the major decision-makers; therefore, the fact that they constituted the majority of livestock owners could be advantageous for appropriate farming decision making. The second largest owners of livestock comprised one in three (29.0%) and were children of heads of household, the sons (21.1%) and daughters (7.9%) (Table 3.12).

Table 3.12. Livestock ownership by members of households in Limpopo and Mpumalanga provinces of South Africa

Livestock owners in respondents households	Frequency	Percent
Head of family	193	52,9
Other member	172	47,1
Total	*365*	*100*
Other member, specify		
Daughter	*29*	*7,9*
Family	*9*	*2,5*
Grandfather	*7*	*1,9*
Grandmother	*9*	*2,5*
Nephew	*8*	*2,2*
Relatives	*23*	*6,3*
Sister	*9*	*2,5*
Son	*77*	*21,1*
Uncle	*1*	*0,3*
Total	*172*	*100*

The children of the respondents would likely be relatively more educated than their parents and the rest of their predecessors and would likely have better access to modern information and would hence make better informed decisions. In fact, the participation of children of the heads of household in livestock farming demonstrates some succession in farming and is a positive development. In cases where heads of household and their children made appropriate and better informed decisions on livestock farming, their enterprises would possess more adaptive capacity to adverse effects of climate change, and vice versa.

3.3.3.4 Farming status

The farming status of livestock owners may determine the length of time invested by farmers in their livestock enterprises and, hence the capacity of the enterprises to successfully adapt to the adverse effects of climate change and variability. Livestock owners who are full-time farmers are likely to make timely decisions for their enterprises, hence the adverse effects of climate change and variability will be promptly mitigated. The benefits of full-time farming may, however, be lost if the agricultural enterprise is not profitable. In that situation, the advantage of full-time availability of the livestock owner to his / her business will be counteracted by a lack of income necessary to procure inputs critically required to mitigate the adverse effects of climate change and variability.

Table 3.13. Farming status of smallholder livestock owners in respondents' households in Limpopo and Mpumalanga provinces of South Africa

Farming Status	Frequency	Percent
Head of household - Full time	295	82,2
Head of household - Part time	48	13,4
Other member - Full time	16	4,5
Total	359	100,0

Some 86.7% of livestock owners were full time, and of those, four in five (82.2%) were heads of household while 4.5% were other household members (Table 3.13). Only 13.4% of livestock farmers in the area under study were part time. Based on the type of farming practiced (full-time vs part-time), the smallholder livestock farmers in the study area would mostly possess the capacity to adapt to the adverse effects of climate change and variability.

3. 3.3.5 Number of livestock owned

Livestock occupies a cogent position in assisting households to cope with difficulties since farmers can easily trade their animals for cash (Imai, 2003:271, cited by Ijatuyi et al., 2017).

Table 3.14. Number of livestock owned by smallholder farmers in Limpopo and Mpumalanga provinces of South Africa

Stats for No. of livestock	Cattle (N=364)	Sheep (N=24)	Goats (N=176)	Chickens (N=101)	Pigs (N=46)	Donkeys (N=6)
Mean	16,63	10,38	14,50	18,80	10,65	7,33
Median	14,00	10,00	14,00	14,00	10,00	6,50
Mode	15	4	15	10	17	0
Std. Dev	13,743	5,388	9,702	17,416	8,014	7,090
Range	97	20	73	100	48	20

Min	1	0	0	0	0	0
Max	98	20	73	100	48	20

Cattle, in particular, are known for many products such as being reared for meat production, milk production, hides and skins, cash income, and the source of draught power on farm lands (ploughing, traction, and irrigation) (Traore, 2010, cited by Ijatuyi *et al.,* 2017).

The number of livestock owned has an influence on the capacity of the farming enterprise to adapt to the adverse effects of climate change and variability. Farmers with more livestock tend to benefit from the asset value of the large number of the livestock and often possess more capacity to adapt to adverse effects of climate change. The benefit of large numbers of livestock is more realized when the farmer is able to take appropriate decisions regarding the livestock management and the time to sell some of the animals to generate income for procuring required inputs and for other uses. Livestock farmers in the study area owned a mean of 16.63 cattle, 10.38 sheep, 14.50 goats, 18.80 chickens, 10.65 pigs, and 7.33 donkeys (Table 3.14). The livestock numbers seem rather small to adequately capacitate the farmers to adapt to the negative effects of climate change and variability.

3.3.3.6 Livestock ranking

The ranking of livestock by farmers indicates the extent to which the farmers regard the type of livestock to be important and the level to which they would want to keep the type of livestock. Consequently, the ranking of livestock by farmers reveals the degree to which the farmers are likely to invest resources to mitigate the adverse effects of climate change and variability on the enterprise of the ranked livestock type. The livestock farmers in the study areas were requested to rank their various livestock as Very important (ranked 3), Important (ranked 2), and less important (ranked 1).

Cattle, sheep, and goats were regarded very important by the majority of livestock farmers in the area under study. As revealed under Table 3.5, almost all (96.6%) the livestock farmers regarded cattle very important. This ranking was probably informed by the socio-economic value of these animals. Other than the fact that cattle are priced highly when sold, they sometimes also provide draught power, be it for the ploughing of fields or pulling of trail wagon. In these ways, cattle contribute to the household food production and to the provision of transport service for basic household chores such as fetching water and distribution of firewood. Although this is now often handled through cash transactions, cattle used to be the currency for payment of lobola, a payment by a bridegroom to the parents of the bride who would traditionally relocate from the family of her parents to join that of her husband. The livestock owners probably considered these multiple uses of cattle when deciding on the ranking of these animals.

Although sheep may not have similar multiple uses as cattle, they were ranked to be ‘very important’ by about the same number (95.8%) of livestock farmers as those (96.6%) who regarded cattle ‘very important’. Goats were ranked ‘very important’ by seven in ten (69.0%) of livestock farmers. All these three types of ruminant animals (cattle, sheep and goats) were ranked by the majority of livestock owners to be ‘very important’.

Table 3.15. Ranking of livestock by owners in Limpopo and Mpumalanga provinces of South Africa

Livestock type	Rank	Frequency	Percent
Cattle (N=358)	1	5	1,4%
	2	7	2,0%
	3	346	96,6%
Sheep (N=24)	2	1	4,2%
	3	23	95,8%
Goats (N=174)	1	1	,6%
	2	53	30,5%
	3	120	69,0%
Chickens (N=98)	1	12	12,2%
	2	44	44,9%
	3	42	42,9%
Pigs (N=42)	1	5	11,9%
	2	29	69,0%
	3	8	19,0%
Donkeys (N=4)	2	3	75,0%
	3	1	25,0%

Contrary to the above, majority of livestock farmers ranked chickens, pigs, and donkeys rather ‘important’ and did not regard these animals ‘very important’. Accordingly, 44.9% regarded chickens ‘important’, 69% of them ranked pigs ‘important’, while three in four (75%) of them revealed that donkeys were ‘important’. For chickens, the majority ranking was probably informed by their size and subsequent economic value per unit. Although pigs would be expected to be ranked by majority of livestock owners as ‘very important’, their ultimate ranking was probably influenced by the fact that some religious groups do not consume pork as they regard it a sin to do so. The religion issue probably had a negative effect on the demand for pork and hence the ranking of pigs by majority of livestock farmers.

Based on the majority ranking of the different livestock types by farmers in the study area, the farmers were more likely to invest resources to mitigate the adverse effects of climate change and variability on cattle, sheep, and goats. The ranking of these animals probably reveals the extent to which they would capacitate the livestock farmers to respond to household socio-economic demands. The animals would therefore likely capacitate the farmers also to adapt to negative effects of climate change and variability.

3.3.3.7 Exposure to capacity building

The level of exposure to capacity building activities on livestock issues tends to influence the depth of knowledge the farmer possesses on livestock enterprise issues and the access to resources for effective livestock farming. Farmers with more exposure are likely to possess more knowledge and to make better decisions for their livestock enterprises to be more adaptable to adverse effects of climate change and variability.

Table 3.16. Exposure of livestock farmers in Limpopo and Mpumalanga provinces of South Africa to capacity-building activities

Aspect of capacity building	Frequency	Percent
Receipt of training in livestock farming		
No	364	99,5
Yes	2	,5
Belonging to any farmers union		
No	365	99,7
Yes	1	,3
Belonging to a producers organisation		
No	366	100,0
Financial support from government		
No	362	99,2
Yes	3	0,8

It was disappointing to note that almost all the livestock farmers in the area under study had not received any training in livestock farming (99.5%), and neither belonged to a farmers' union (99.7%) nor to a producer organization (100%), and these suggest that they had no exposure to knowledge. Also, the farmers did not have access to financial support from government (99.2%) (Table 3.16). Based on exposure to capacity building activities, the livestock farmers in the areas under study seemed to have a dearth of capacity to adapt to the undesirable effects of climate change and variability.

3.3.3.8 Household members staying off farm

The number of household members who stay off farm while still relying on the farming household is an indication of the contribution of the livestock farming enterprise to the economy of the broader community. Livestock farming households supporting more members staying off farm tend to make an impact to the economy of the broader community than those limited to supporting the core farming household.

Table 3.17 Household members staying off farm and supported by livestock farming households in Limpopo and Mpumalanga provinces of South Africa

Number of members		Frequency	Percent
Males	0	214	70,6
	1	67	22,1
	2	19	6,3
	3	1	0,3
	6	2	0,7
Total		303	100
Females	0	234	78,3
	1	47	15,7
	2	12	4,0
	3	4	1,3
	6	2	0,7
Total		299	100

Livestock farming households in the study area had the majority of their dependent members not staying off - farm, and that was true for both male (70.6%) and female (78.3%) members (Table 3.17). As revealed by respondents, about one in five (22.1%) farming households had one dependent male member each staying off-farm compared to one in six (15,7%) households with one dependent female members staying off-farm. Fewer households had two or more dependent members staying off-farm, both male and female members.

The dependent members staying off-farm were most probably the children of livestock farming households who were either attending school or seeking employment away from home. Should this be the case, the livestock farming households may be regarded to be empowering their members to improve their adaptive capacity to the undesirable effects of climate change and variability. Probably, some of the farming households may be having children and other family members, schooling locally and staying on-farm, hence the adaptive capacity being built could be more.

3.4. CONCLUSIONS AND RECOMMENDATIONS

3.4.1 Conclusions

The findings of the study revealed that 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. This was true for all the three types of demographic factors studied, namely: personal characteristics, economic status, and aspects of livestock farming.

3.4.1.1 Personal characteristics

On the basis of our analysis and literature, factors that enable smallholder livestock farmers to be highly vulnerable to extreme situations of droughts and floods include; the age of the farmer, gender, formal education, income and access to information. The position of respondents in households comprised 58.7% heads and 25.7% parents to heads all of whom probably provided accurate information on household decisions. The respondents were mostly male (63.4%) with good health (97.8%) associated with high adaptive capacity to climate change and variability. The older the farmers are, the more they get exposed to an increase in vulnerability. It is suggested that the introduction of new technologies targets young farmers instead of adult farmers. When young farmers take-up an adaptation strategy, they will consider and use it for a number of years before they abandon it. Assessment of the educational status revealed that four in five (81.5%) of the livestock farmers had only secondary education at most, probably associated with low capacity to adapt to climate change and variability.

3.4.1.2 Economic status

While no definite conclusions could be drawn based on employment status, household incomes seemed low and could be associated with low capacity to adapt to the negative effects of climate change and variability. To the contrary, the quality of housing for the livestock farmers was described as either top (48.5% of farmers) or medium (47.4%) associated with high adaptive capacity to climate change and variability. Similar conclusions could be drawn to the size of housing with 45.9% owning 4 to 5 rooms and 44.5% owning six or more rooms, especially considering the fact that 88.5% of the respondents financed their houses. The probability of high adaptive capacity was perhaps affirmed by that almost all the respondents (97.3%) had access to electricity.

3.4.1.3 Aspects of livestock farming

The fact that the majority of households had members who were fit to work in farming (one male and female member for 40.1% and 39.3% of the families respectively; 19.9% of two members for each gender category) suggested high capacity to adapt to climate change and variability. Livestock was owned by heads in 52.9% of the households and by children to heads in 29.0% (sons in 21.1% and daughters in 7.9%) of the households, affirming the high capacity to adapt to climate change and variability.

To the contrary, almost all respondents (99.2%) used communal land, had fewer livestock owned (for various types), suggesting low capacity to adapt to climate change and variability. The dearth of adaptive capacity was perhaps exacerbated by lack of exposure to capacity building as the respondents had no training (99.5%), never belonged to a farmers' union (99.7%) or a producer organization (100.0%), and had no access to financial support from government (99.2%). Full-time farming by majority (86.7%) of farmers and the fact that fewer of their dependents (22.1% male and 15.7% female) stayed off-farm could be positive or negative for adaptive capacity development.

3.4.2 Recommendations

Following the research on demographic factors and their influence on the capacity of smallholder livestock farmers to adapt to adverse effects of climate change and variability, it is recommended that:

a) Research be conducted as a follow-up using the principles derived from the sustainable livelihoods approach (SLA) to investigate how that may have some influence on the smallholder farmer capacity to adapt to climate change and variability, be it livestock or crop farmers. The idea being that is it one of a number of conceptual approaches that take an asset/vulnerability approach to analyse the vulnerability of the poor. This way of approaching recognizes that livelihoods are multi-sectorial, that all aspects of people's lives will impact on the livelihood choices that they make and that livelihoods are embedded within institutional context.

b) The results of the research be shared with government and related agencies to inform policies on farmer support for improved response to adverse effects of climate change and variability.

3.5. REFERENCES

Abbé, J., Ford, J.D. Berrang-Ford, L., Donnelly, B. Lwasa, S. and Namanya, D.B., 2016. Vulnerability to the health effects of climate variability in rural southwestern Uganda. Mitigation and Adaptation Strategies for Global Change 21 (6): 931–953. https://doi.org/10.1007/s11027-015-9635-2.

Adger W, Dessai S, Goulden M et al (2009) Are there social limits to adaptation to climate change? Clim Chang 93:335–354

Adger, W.N., Brooks, N., Bentham, G., Agnew, M., Eriksen, S., 2004. New indicators of vulnerability and adaptive capacity (on-line). Tyndall Centre for Climate Research, Norwich, Technical Report 7, /http://www.tyndall.ac.uk/research/theme3/ final_reports/it1_11.pdfS.

Adger, W.N., Vincent, K., 2005. Uncertainty in adaptive capacity. Comptes Rendu Geosciences 337, 399–410.

Ajani, O.I.Y. and Ugwu, P.C., 2008. Impact of Adverse Health on Agricultural Stochastic Production Frontier Approach. Trends in Agricultural Economics, 1: 1-7.

Bailer-Jones, D.M., 2003. When scientific models represent. International Studies in the Philosophy of Science, 17(1): 59-74.

Bembridge, T.J. and Tshikolomo, K.A., 1998. Communication and decision making among fruit growers in the Phaswana area of Northern Province. South African Journal of Agricultural Extension, 27: 19-29.

Birkman, J., 2006, Measuring vulnerability to natural hazards: Towards disaster resilient societies, United Nations University Press, New York.

Brooks N, Adger WN, Kelly PM, 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang 15(2):151–163

Bulle, N., 2009. Under what conditions can formal models of social action claim explanatory power? International Studies in the Philosophy of Science, 23(1): 47-64.

Cutter, S.L., J.T. Mitchell, and M.S. Scott. 2000. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina." Annals of the Association of American Geographers no. 90 (4):713-737.

David, S.G.T., Twyman, C., Osbahr, H. and Hewitson, B. 2007. “Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa”, Climatic Change, Vol. 83 No. 3, pp. 301-322.

Dietz T, Ostrom E, Stern P., 2003. The struggle to govern the commons. Science (New York, NY) 302: 1907–1912.

Eakin H, Lemos M.C., 2010. Institutions and change: the challenge of building adaptive capacity in Latin America. Glob Environ Chang 20:1–3

Fairbanks, D.H.K. and Scholes, R.J., 1999. South African Country Study on Climate Change: Vulnerability and Adaptation Assessment for Plantation Forestry, National Research Facility, Pretoria.

Finan T, Nelson D., 2001. Making rain, making roads, making do: public and private adaptations to drought in Ceará, Northeast Brazil. Clim Res 19:97–108.

Füssel, H-M., and Klein, R.J.T., 2006. Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. Climate Change 75: 301-329.

Gallopi´n, G.C., 2003. Box 1. A systemic synthesis of the relations between vulnerability, hazard, exposure and impact, aimed at policy identification. In: Economic Commission for Latin American and the Caribbean (ECLAC). Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters. ECLAC, LC/MEX/G.S., Mexico, D.F., pp. 2–5.

Gallopín G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Glob Environ Chan Hum policy Dimens 16(3):293–303.

Gbetibouo, G.A, & Ringler, C., 2009, 'Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment', IFPRI Discussion Paper 00885, IFPRI, Washington, DC.

Grune-Yanoff, T., 2011. Isolation is not characteristic of models. International Studies in the Philosophy of Science, 25(2): 119-137.

Hahn MB, Riederer AM, Foster S.O., 2009. The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. Glob Environ Chang 19(1):74–88

Holling C.S., Meffe G.K., 1996. Command and control and the pathology of natural resource management. Conserv Biol 10:328–337.

Holmes, T.N., 2007. "Contribution of the Participatory Forest Management (PFM) intervention to the socio-economic development in the Southern Cape Forests: a retrospective approach", PhD thesis, University of Stellenbosch, Stellenbosch.

Hurmerinta-Peltomaki, L. and Nummela, N., 2006. Mixed methods in international business research: A value-added perspective. Management International Review, 46 (4): 439-459.

IFPRI, International Food Policy Research Institute, 2009. Washington, D.C. Climate Change Impact on Agriculture and Costs of Adaptation, Gerald C. Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R. Sulser, T. Zhu, T., Ringler, C. SiwaMsangi, A.P. Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M. and Lee, D.

Ijatuyi, E.J., Omotayo, A.O. and Mabe, L.K., 2017. Effect of extension service(s) and socio-economic characteristics on the livelihood of Nguni Cattle development project beneficiaries in North West Province: a TOBIT-OLS Regression Approach. South African Journal of Agricultural Extension, 45(1): 64-77. DOI: http://dx.doi.org/10.17159/2413-3221/2017/v45n1a427 (Copyright).

Intergovernmental Panel on Climate Change (IPCC), 2007. Impacts, adaptations and vulnerability. Fourth Assessment Report. Cambridge University Press, Cambridge, UK.

IPCC, 2001. Climate change: Synthesis report. Contribution of working groups I, II and III to the third assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press.

Jones L. and Boyd E., 2011. Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Leedy P.D. and Ormrod J.E., 2010. Practical Research, Planning and Design, 9th Ed. Pearson Merrill Prentice Hall, New Jersey, USA.

Lin, E., Yinlong, X., Shaohong, W., Hui, J., Shiming, M., 2007. China's National Assessment Report on Climate Change (II): Climate Change Impacts and Adaptation. – Science Press, 182-200.

Lindoso, D.P. et al., 2011. Smallholder farming and climate change: Assessing the vulnerability to drought in the semiarid region of the northeast regions of Brazil.

Lobell D.B., Banziger M., Magorokosho C et al., 2011. Nonlinear heat effects on African maize as evidenced by historical yield trials. Nat Clim Chang 1:42–45.

Luers, A.L., Lovell, D.B., Sklar, L.S., Addams, C.L., Matson, P.A., 2005. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change 13, 255–267.

Maele, L.M., Nesamvuni, A.E., Tshikolomo, K.A., Afful, D.B. and Norris, D., 2015. Characterization of Youth Agricultural Projects in Limpopo Province of South Africa. Journal of Agricultural Science, 7(7): 42 – 52.

Malakar, K., and Mishra, T., 2017. Assessing socio economic vulnerability to climate change: a city-level index- based approach. Climate and Development, 9 (4) 348-363.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge.

McDowell, J. Z., Hess J. J., 2012. Accessing Adaptation: Multiple Stressors on Livelihoods in the Bolivian Highlands under a Changing Climate. – Global Environmental Change 22: 342-352.

Morton, J.F., 2007. The impacts of climate change on smallholder and subsistence agriculture. Proc. Natl Acad. Sci. USA 104, 19680: 19 685.

Mouton, J., 2001. How to succeed in your Master's and Doctoral Studies. A South African Guide and Resource Book. Van Schaik Publishers, Hatfield, Pretoria.

Mulinya, C., 2017. Factors Affecting Small Scale Farmers Coping Strategies To Climate Change In Kakamega County In Kenya. Journal of Humanities and Social Science, 22 (2), 100-109

Nagayet O., 2005. Small farms: current status and key trends. In The future of small farms: proceedings of a research workshop (ed. IFPRI), pp. 355–367. Washington, DC: International Food Policy Research Institute.

Ncube, M., Madubula, N., Ngwenya, H., Zinyengere, N., Zhou, L., Francis, J., Mthunzi, T., Olivier, C. and Madzivhandila T., 2016. 'Climate change, household vulnerability and smart agriculture: The case of two South African provinces', Jàmbá: Journal of Disaster Risk Studies 8(2), Art. #182, 14 pages. http://dx.doi.org/10.4102/jamba.v8i2.182.

Nouman, M., Siddiqi, M.F., Asim, S.M. and Hussain, Z., 2013. Impact of socio-economic characteristics of farmers on access to agricultural credit. Sarhad Journal of Agriculture, 29(3): 469-476

O'Briena, K., Leichenkob, R., Kelkarc, U., Venemad, H., Aandahla, G., Tompkinsa, H., Javedc, A., Bhadwalc, S., Bargd,S., Nygaarda, L. and West, J., 2004. Mapping vulnerability to multiple stressors:

climate change and globalization in India. Glob. Environ. Change 14, 303:313. (doi:10.1016/j.gloenvcha.2004.01.001).

Oduro-Ofori E., Aboagye A.P. and Acquaye N.A.E., 2014. Effects of education on the agricultural productivity of farmers in the Offinso Municipality. International Journal of Development Research, 4(9): 1951-1960.

Oh, P.S., and Oh, S.J., 2011. What teachers of science need to know about models: An overview. International Journal of Science Education, 33(8): 1109-1130.

Quinn, C.H., Ziervogel, G., Taylor, A., Takama, T. and Thomalla, F., 2011. “Coping with multiple stresses in rural South Africa”, Ecology and Society, Vol. 16 No. 3, pp. 1-20.

Rosenzweig C, Hillel D. 2008. Climate variability and the global harvest impacts of El Nino and other oscillations on agro-ecosystems. Oxford University Press, USA.

Scholze, M., Knorr, W., Arnell, N. W., & Prentice, I. C., 2006. A climate change risk analysis for world ecosystems. Proceedings of the National Academy of Sciences, 103(35), 13116e13120.

SEI (Stockholm Environment Institute), 2004. Choosing methods in assessments of vulnerable food systems. Risk and Vulnerability Programme, SEI Briefing Note, Stockholm: SEI.

Simotwo, H.K., Mikalitsa S.M. and Wambua B.N., 2018. Climate change adaptive capacity and smallholder farming in Tras-Mara East sub-Country, Kenya. Geoenvironmental Disasters, 5:5.

Smit B, Burton I, Klein RJ, Wandel, J., 2000. An anatomy of adaptation to climate change and variability. Clim Chang 45:223–251

Smit B, Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob Environ Chang Hum Policy Dimens 16:282

Smith, J., and S. S. Lenhart. , 1996. Climate change adaptation policy options. Climate Research 6(2): 193–201.

Smithers J, Smit B., 1997. Human adaptation to climatic variability and change. Glob Environ Chang 7:129–146

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y. and Nkem, J., 2012. “Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon”, Forest Policy and Economics, Vol. 23, pp. 1-9.

Stats SA, 2018. Provincial profile: Mpumalanga Community Survey 2016, Statistics South Africa, Pretoria. Report Number 03-01-13, 112pp. ISBN: 978-0-621-44985-3.

Turner B, Kasperson R, Matson P et al., 2003. A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci U S A 100:8074–8079.

Turpie, J. and Visser, M., 2013. "The impact of climate change on South Africa's Rural areas", Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.

Uddin, M., Bokelmann, W., and Entsminger J., 2014. Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. Climate Retrieved from http://www.mdpi.com/2225-1154/2/4/223/htm.

Van der Valk, T., van Driel, J.H. and de Vos, W., 2007. Common characteristics of models in present-day scientific practice. Research in Science Education, 37: 469-488.

Vyas, S., and L. Kumaranayake. 2006. Constructing socio-economic status indices: How to use principal component analysis. Health Policy and Planning 21(6): 459–468.

Welman, C., Kruger, F. and Mitchell, B., 2005. Research Methodology, 3rd Edition. Oxford, Cape Town, South Africa.

Windschitl, M. and Thompson, J., 2006. Transcending simple forms of school science investigation: The impact of pre-service instruction on teachers' understanding of model-based inquiry. American Educational Research Journal, 43(4): 783-835.

Yohe, G., Tol, R.S.J., 2002. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global Environmental Change 12, 25–40.

CHAPTER 4: AGRO-ECOLOGICAL CHARACTERISATION OF SMALLHOLDER LIVESTOCK FARMING SYSTEM IN LIMPOPO AND MPUMALANGA PROVINCES

Abstract

A study to characterise the agro-ecological attributes of smallholder livestock farming areas was carried out in Limpopo and Mpumalanga Provinces. The aim of the investigation was to differentiate the geophysical and climatic variables that may have an effect on the smallholder livestock farmers' vulnerability to climate extremes such high temperatures, drought, and floods. For purposes of this study the Geographic Information System’s coordinates, were collected to match the geographic location of each farmer to the agro-ecological area, village, municipality, towns and district. Thematic maps (GPS) were developed to show major geophysical and climatic attributes in each village such as rainfall, temperature, aridity and water sources. Water resources were also mapped showing location of water sources and their types (springs, pans, dams, boreholes, wells and waterholes. The study adopted the Vulnerability Framework and or system by Lindoso (2011). Classification of the study area was based on FAO frame-work of 1978 of agro-ecological zones (AEZs), based on major climate zones, moisture zones (water availability) and highland-lowland (cool or warm based on elevation). The assumption was made to the effect that AEZs are said to be influenced by latitude, elevation, and temperature, seasonality, and rainfall & distribution during varying seasons. The factoring in of elevation provided more information to the local conditions and its usual zonation for the classification of the various livestock production system and determination of their likely climate-related risks, as well as vulnerability. The results showed that over 90% of the present study experiencing lower rainfall to the global average of 860mmpa. There were localized microclimate zones that were arranged in a north-south areas that experience in excess of 1000 mmpa. The temperatures within the study region were generally warmer with the temperatures in excess of 24°C especially to the north eastern parts. The aridity index values in the study area were categorized into three discrete subsections; namely the arid, semi-arid and, dry sub-humid. The arid areas in the Musina Municipality were found to be the hottest regions in the study area while it is also amongst the driest regions with serious lack of water resources. Smallholder farmers suffer great losses during the drought years 1980s, 1990s, 2002, 2003, 2007 and recently 2013. The lowest mean annual rainfall and erratic precipitation pattern are the main factors that hinder farming, especially when natural grazing becomes scarce in the semi-arid regions. The dry sub-humid areas constituted about 5% of the entire study area. The study region was found to be a risk area, owing to changing environmental conditions, mostly as a result of the rain-fed and/or unsecure source water upon which the livestock production systems are dependent. Based on the findings of the study, it was recommended that: (1) early warning system be enhanced to rapidly provide smallholder farmers with weekly, monthly weather forecasts; (2) smallholder farmers be encouraged in their mixed farming to grow fodder crops for their animals and (3) that indigenous breeds and their crosses of small-stock especially of goats and sheep be promoted.

4.1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC, 2007) highlighted that Africa will be one of the continents that will be hard hit by the impacts of climate change due to the increased temperature and water scarcity. According to Mzezewa *et al*., (2010) climate is a critical role player in biomass production. On the other hand, harsh climatic conditions have negative impacts on-farm production (Li *et al*., 2006). The amount of rainfall that a particular area experience plays a principal role in the spatial allocation of agricultural systems. Lazaro *et al*., (2001) suggests the analysis of climatic records for the establishment of the land use planning. Climate change manifests in different forms that incorporate rising temperatures, changes in water availability, increase in levels of carbon dioxide, alteration of the precipitation frequency and amount (Sonwa *et al*., 2012). Turpie and Visser, (2013) predicted that the impacts of climate change in South Africa to highly manifests in the form of the amplified temperature, sporadic rainfall patterns, and higher drought frequency. These severe weather events, coupled with the country's already scarce water resources, are expected to have a significant effect on the forestry and agricultural sectors, which are substantial components of the country's rural livelihoods and economies (Quinn *et al*., 2011; Turpie and Visser, 2013).

Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien *et al*., 2004). Climate extremes can be placed into two broad groups:

a) Those based on simple climate statistics, which include extremes such as a very low or very high daily temperature, or heavy daily or monthly rainfall amount, that occur every year; and
b) More complex event-driven extremes, examples of which include drought, floods, or hurricanes, which do not necessarily occur every year at a given location. (Easterling et. al., 2000).

Smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with climate change induced shock, any reductions in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (McDowell and Hess, 2012). In the context of South Africa, the impacts of climate change are highly correlated with the increase in temperature, erratic rainfall patterns and increase drought frequency (Turpie and Visser, 2013). In order to mitigate the impacts of such climate extremes an in-depth a study of agro-ecological zones becomes critical. Central to such investigations is the type, magnitude and frequency of the climate stimuli and or external property of socio-ecological systems (Gallopín 2006) to guide the smallholder livestock & and or crop farmers to cope with climate induced shock. The study is on *exposure* as an attribute of the vulnerability of smallholder livestock farming systems within agro-ecological zones for potential adaptive measures.

4.2 METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim to create independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

4.2.1 Study area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having Small Holder Livestock Farmers that are organized and within reach to the investigators. A map of the two provinces is attached as Figure 4.1.

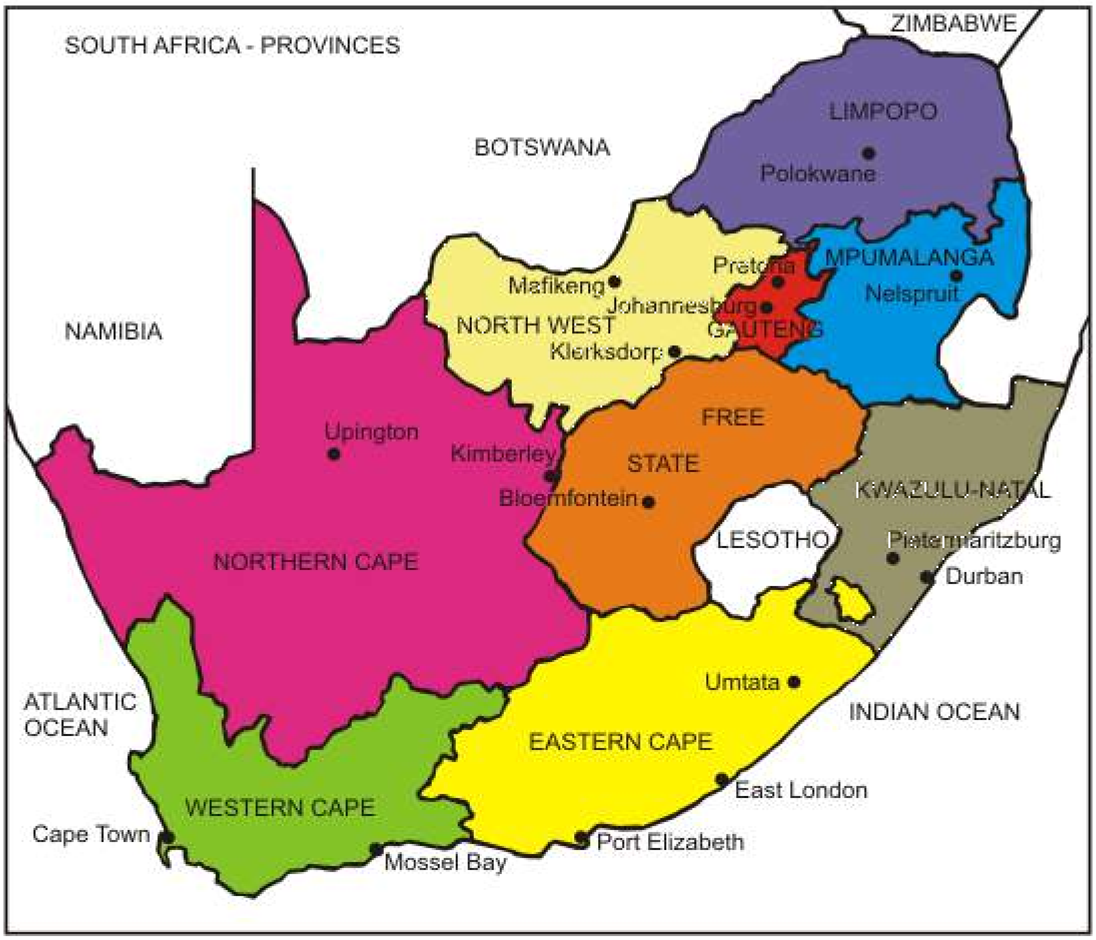


Figure 4.1. Political Map of South Africa with provinces

4.2.2 Data collection

Data was collected through a descriptive survey using structured questionnaires, observations and interviews from 469 individual's smallholder farmers. A semi-structured questionnaire was developed where respondents were interviewed each being asked a standard set of questions posed in the same way each time. For purposes of this study the Geographic Information System's coordinates were collected to match the geographic location of each farmer to the agro-ecological area, village, municipality, towns and district (Ormsby et al., 2001). Thematic maps (GPS) were developed to show major geo-physical and climatic attributes in each villages such as rainfall, temperature, aridity and water sources. Water resources were also mapped showing location of water sources and their types (springs, pans, dams, boreholes, wells and waterholes. The study adopted the Framework and or system by Lindoso (2011).

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.

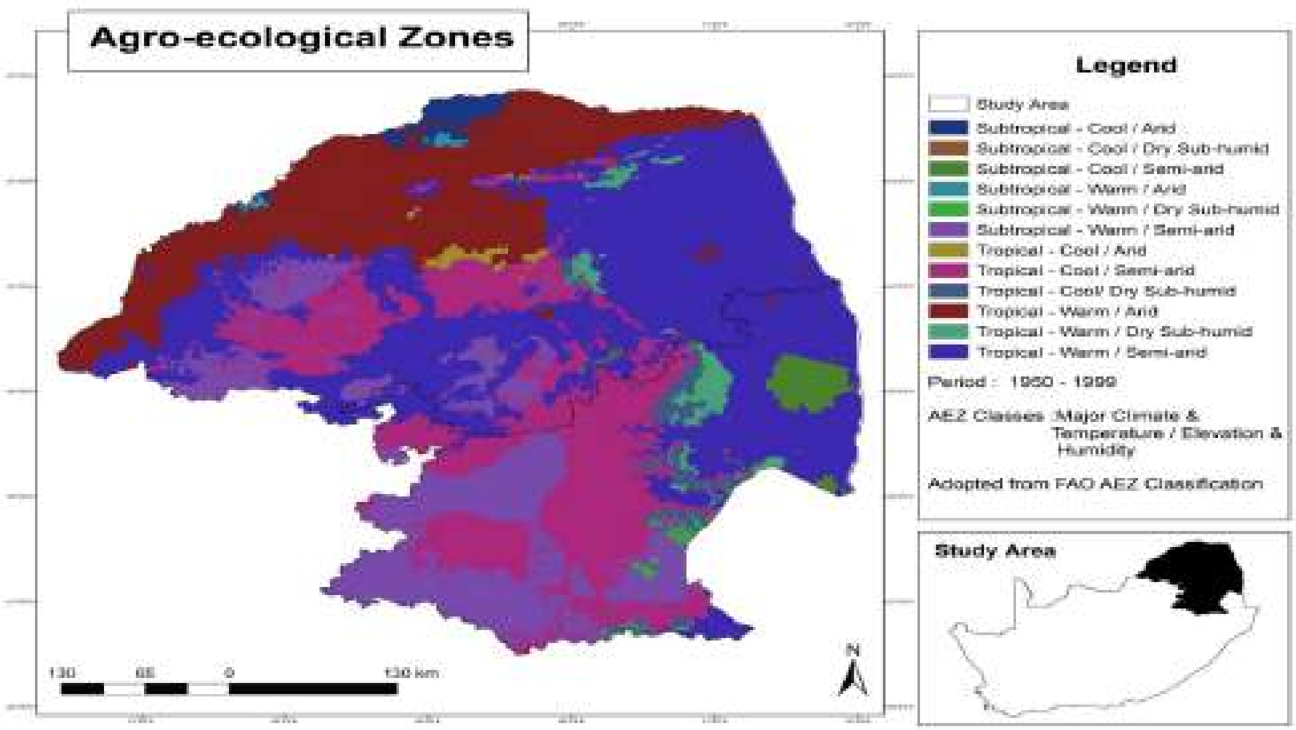


Figure 4.2. Agro-ecological zones, derived from FAO (1978) definition

For the purposes of determining livestock water use efficiencies, focus was on the sensitivity attributes. The main water related indicators were around 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 5 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.

4.2.3 Sampling Procedure and Data Analysis

4.2.3.1 Sampling

Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and about four in Mpumalanga. An effort was made to have a minimum of at least 10 farmers per village out of the random 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 selection of probability-based random sampling, where sampling in different categories or class 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.

4.2.3.2 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.

4.2.3.3 Data analysis

Quantitative data were transcribed into the MS Excel Package and analysed 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 an Excel Spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents mainly the qualitative data.

4.3 RESULTS AND DISCUSSIONS

4.3.1 Rainfall patterns within agro-ecological zones

According to Kotir (2011), precipitation is one of the key determining factors for livestock production in Sub-Saharan Africa because it is a 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 experiences, dictates the natures of the agro-ecological setting that shall prevail. If an area obtains, a high amount of the rainfall (in excess of 2500 mmpa) a rain forest is probably going to occur (Butler, 2005). On the other hand, if an area receives little rainfall that barely exceeds 400 mmpa, the area will be dry (Butler, 2005). Furthermore, rainfall serves as an instrument for decision making as to which livestock to pursue. It also translates to the water availability and the nature of pastures and its respective recovery during the wet season (Kotchoni, 2019). In South Africa, pastures are hardly irrigated, these imply that they rely on rain-fed irrigation (Kotir, 2011).

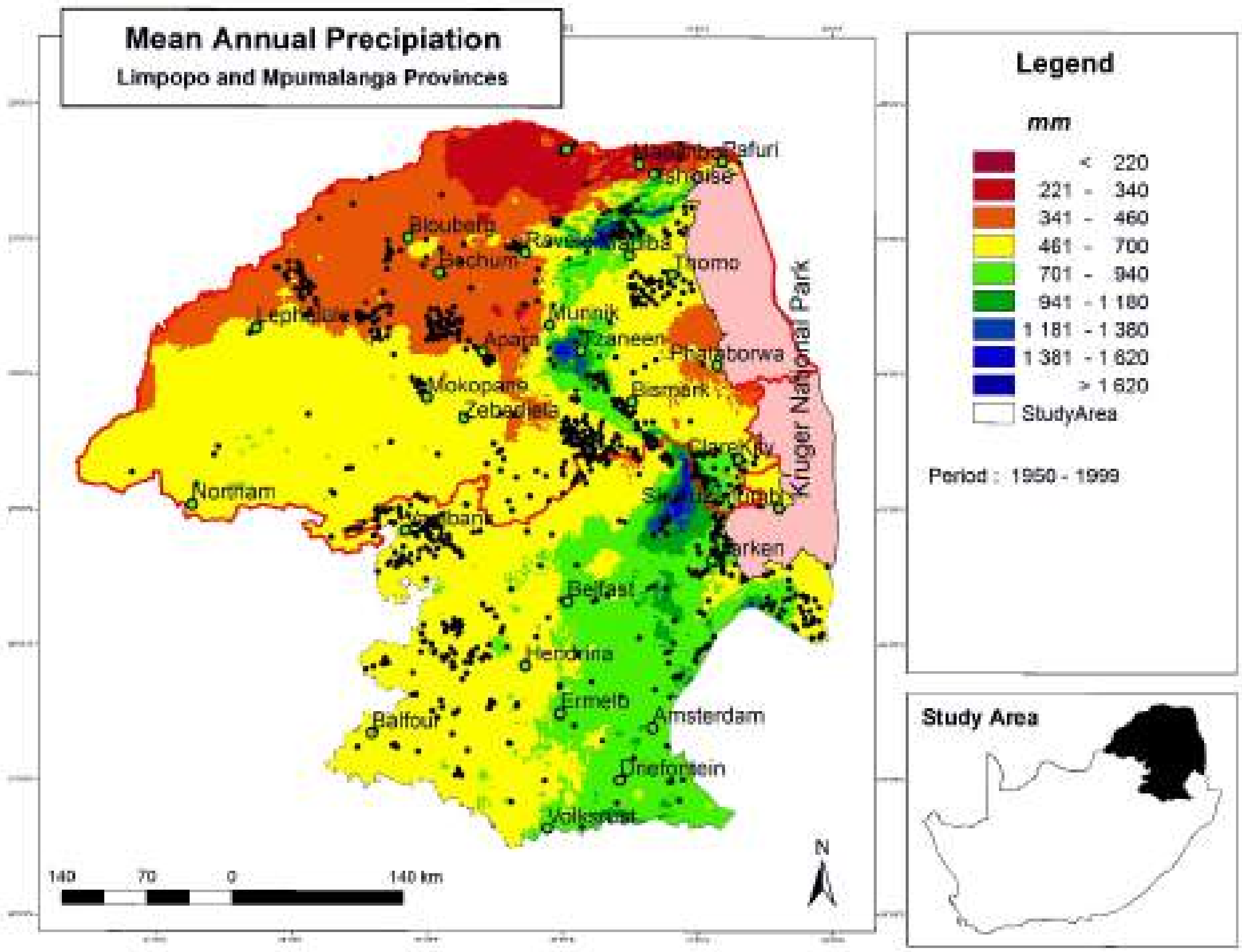


Figure 4.3. Mean annual rainfall for Limpopo and Mpumalanga

Figure 4.3 shows a map of the mean annual precipitation for the Limpopo and Mpumalanga Province. The map portrays that there is spatial variability in the precipitation that is experienced throughout the aforementioned areas. The trend is denoted with a decrease with southward advancement. The driest part occurs in the most northern part of the Limpopo province enticing the Limpopo River. This area experiences about 200 millimetre per annum (mmpa). There are localized microclimate zones that are arranged in a north-south direction that experience in excess of 1000 mmpa. The segments instituting these localized climatic zones in the two provinces include Dzimauli, Tshipise, Valdezia, Tzaneen, and Gateway. The eastern hemisphere of the area is divided into the upper segment and the lower segment. The former as presented by the light brown colour reflects the drier area, whereas, the latter that is symbolized by the yellow colour signifies comparatively wet area. The global average rainfall is 860 mmpa (Ingrin and Rainier, 2012), over 90% of the present study experiences lower rainfall to the global average (Ingrin and Rainier, 2012). The low rainfall deprives the development of the surface water resources, from this point of view, the smallholder livestock is highly exposed to the impacts of climate change. According to SA Explorer (2017), Mpumalanga normally receives about 610mm of rain per year, with most rainfall occurring mainly during midsummer. It receives the lowest rainfall (8mm) in June and the highest (89mm) in January.

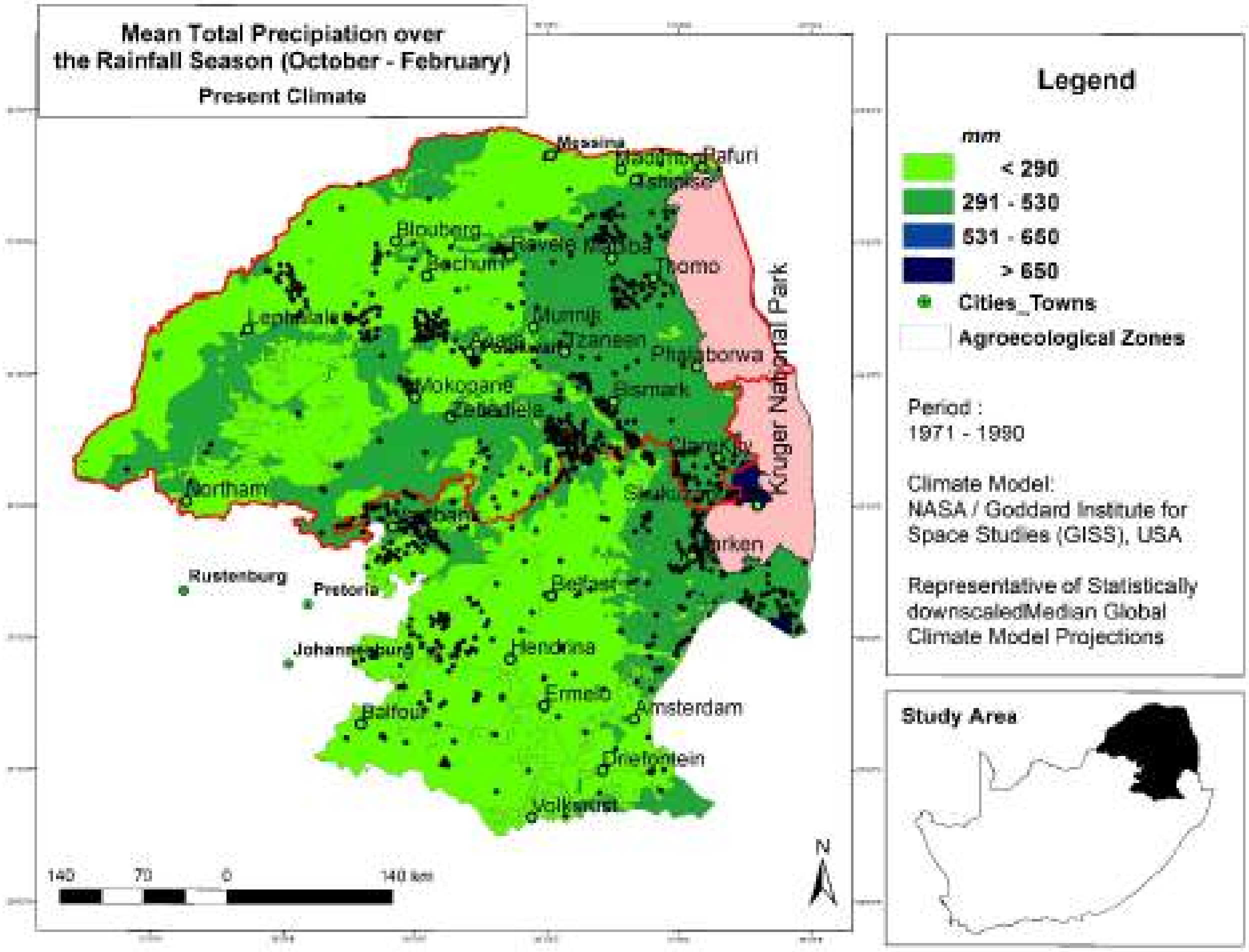


Figure 4.4 Mean total precipitation for the wet season

The mean total precipitation is the average rainfall that the area gets during the wet season. In the context of the study area, this period is between October and February. According to a map in Figure 4.4, there are four rainfall classes. The microclimate areas Dzimauli, Tshakhuma and Tzaneen) are highly localized and in-extensive, but relishes the average precipitation in excess of 650 mm. The farmers are clustered around these localities in order to get reliable water provision. Skukuza in Mpumalanga also receives considerable rainfall in excess of 530 mm. Surprisingly, Mpumalanga is predominated by the low rainfall, although the mean annual precipitation suggests otherwise. The precipitation in this part barely reaches 290 mm. Similar rainfall occurs in the northern margin of the Limpopo that stretches from Madimbo through Tshipise to Northam on the westerly part of the province. The mid precipitation of between 290 and 530mm occurs in the east, extending from the Kruger National Park covers a significant of the area.

4.3.2 Temperature variability within agro-ecological zones

There are spatial conformities between the precipitation and the mean annual temperatures. The eastern side is generally warmer with the temperatures in excess of 24°C (Figure 4.5). These temperatures cover the entirety of the Kruger National Park. They also incorporate the towns that are a bit far from the National Park which incorporate Musina, The lost City, and Bismark. The westward progression correlates with a decline in temperatures, the temperatures in this part range between 20-22°C. The segments comprising these temperatures also stretch from the west of Musina to Northam, through Lephalale, Swartwater, and Alldays (covering the whole of the Limpopo Catchment). The temperatures in the range of 18-20°C occurs throughout the middle of the Limpopo Province, including Vaalwater, Bochum, Tzaneen, and Elim. The coolest part of the area conforms to the microclimate throughout the two provinces. The lowest mean temperatures occur throughout the Mpumalanga Province (Figure 5). In spite of the hot summer, the mean temperatures of lower than 10°C are common. These imply that the livestock that is sensitive to heat stress (such as dairy, beef cattle and chicken) is highly probable in this region.

The mean maximum temperatures along Mpumalanga is comparatively cooler than the Limpopo Province. The mean maxim temperatures of up to 38°C are spatially in extensive (Figure 4.5). The overall average temperatures in these regions are around the margin of 32°C. These imply that a diverse array of livestock can be farmed without subjecting the livestock to heat stress. On the other hand, a major part of the Limpopo Province experiences higher mean temperatures.

This asserts a view that the province is ideal for drought resistance and cold intolerant livestock. This claim can be supported by the emergence of goat farming in many parts of the province and use of donkeys for ploughing and a decline in the farming of the cattle's. There is common agreement that climate change is causing an increase in temperatures and in the frequency of extreme weather events (Easterling *et al*., 2000; Seneviratne *et al*., 2012). A map in Figure 4.4 depicts the spatial distribution of the mean maximum temperature in Limpopo and Mpumalanga. The map depicts that there is a general decline in temperatures from the east to the west. The overall temperature ranges from just below 30°C to over 44°C.

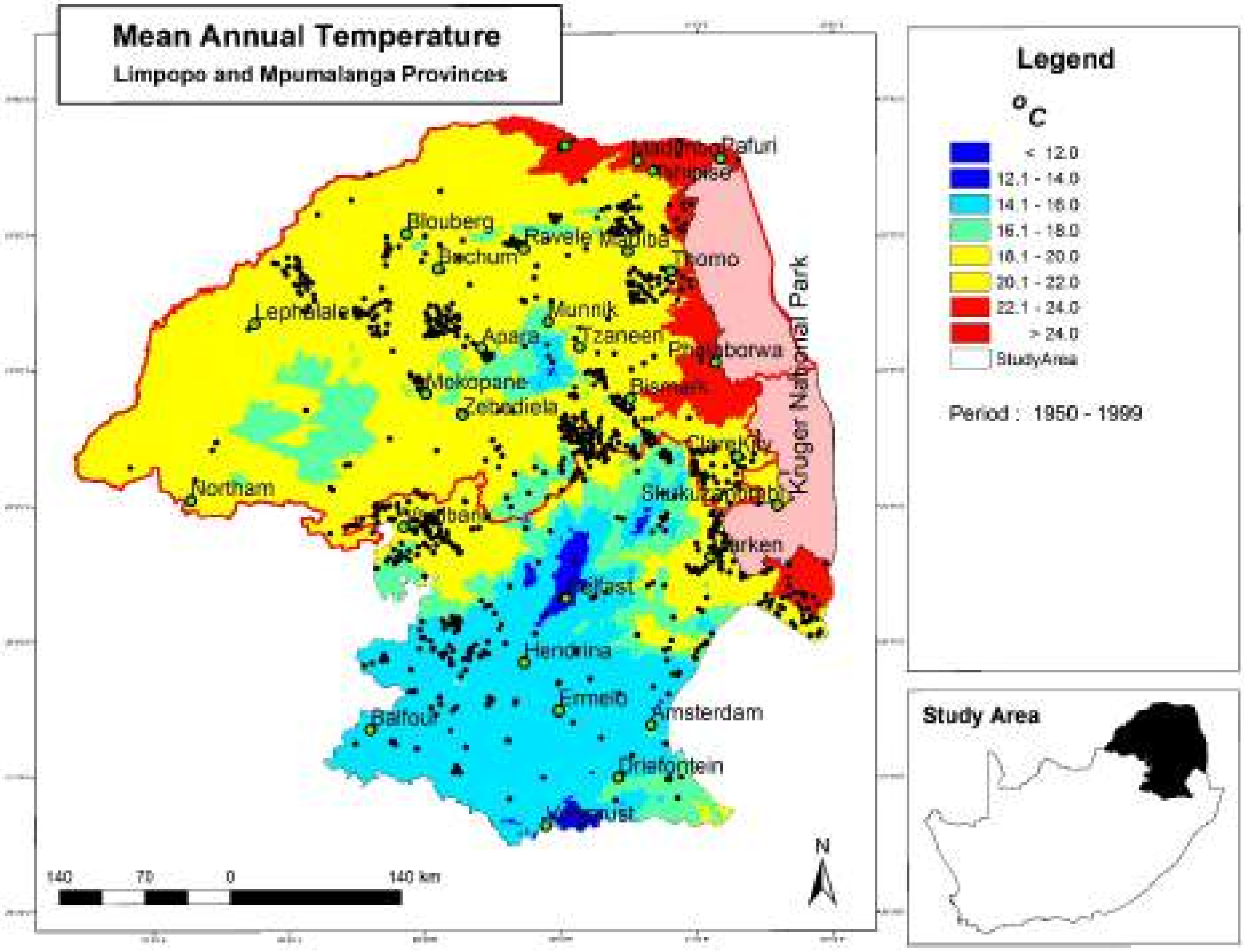


Figure 4.5. Spatial distribution of the mean maximum temperature in Limpopo and Mpumalanga Provinces of South Africa

Climate change will have far-reaching consequences for dairy, meat and wool production mainly via impacts on grass and range productivity. Heat distress in animals will reduce the rate of animal feed intake and causes poor performance growth (Rowlinson, 2008). According to Alkire (2009), livestock (cattle) relishes the temperatures between 10 and 26 °C.

Surprisingly, in spite of cattle being the most dominant smallholder farming practice, almost the entire Limpopo Province does not possess optimal conditions to support them. This is rather unfortunate because cattle are by far the most practiced livestock farming. This is in response to the high returns that are associated with this farming. It is also a traditional instrument for measuring wealth. The summer exhibits excessive temperatures that impact on the productivity of the livestock. However, such conditions are ideal for the farming of goats and donkeys. Although the latter does not have a strong market.

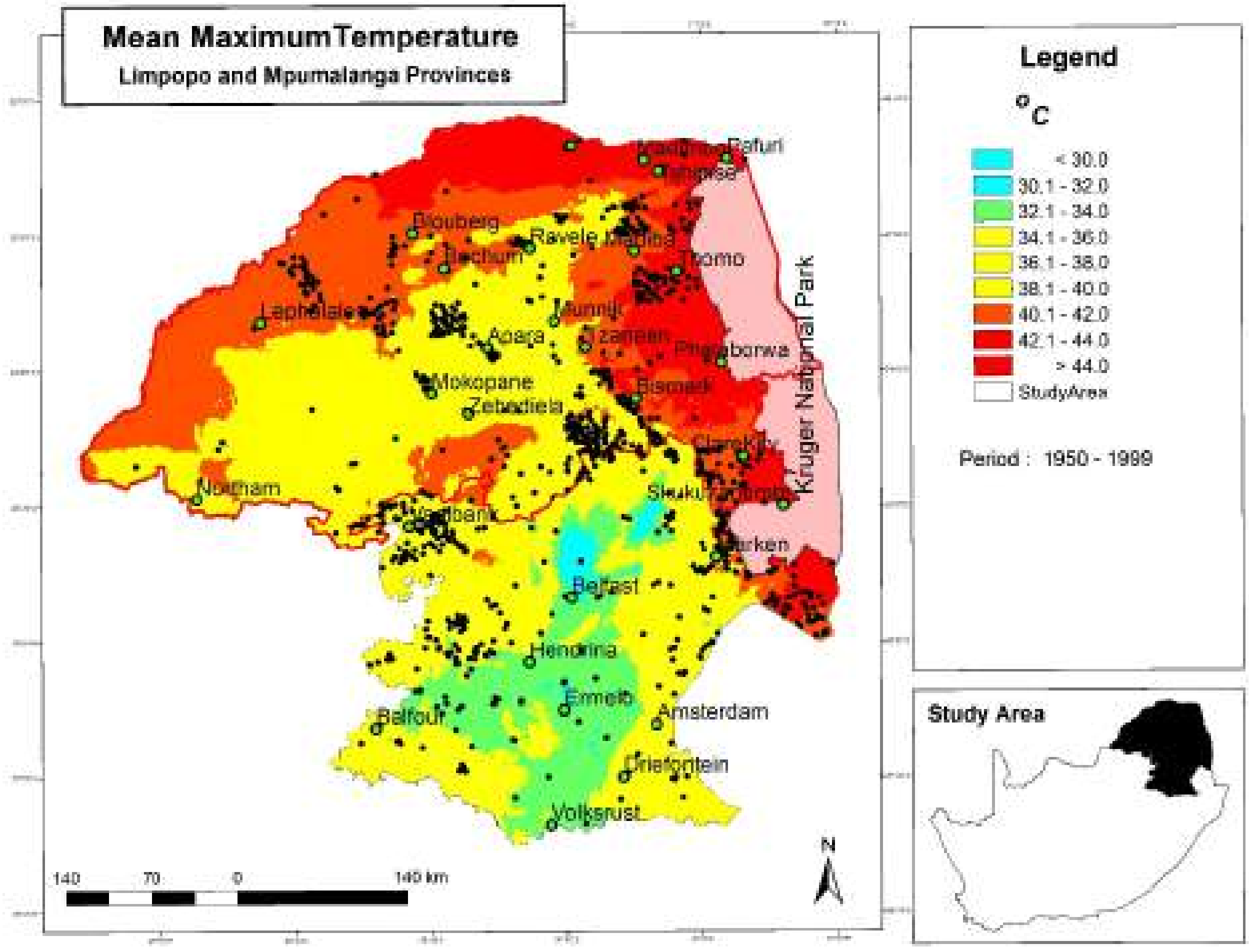


Figure 4.6. Mean maximum temperatures of Limpopo and Mpumalanga Provinces of South Africa

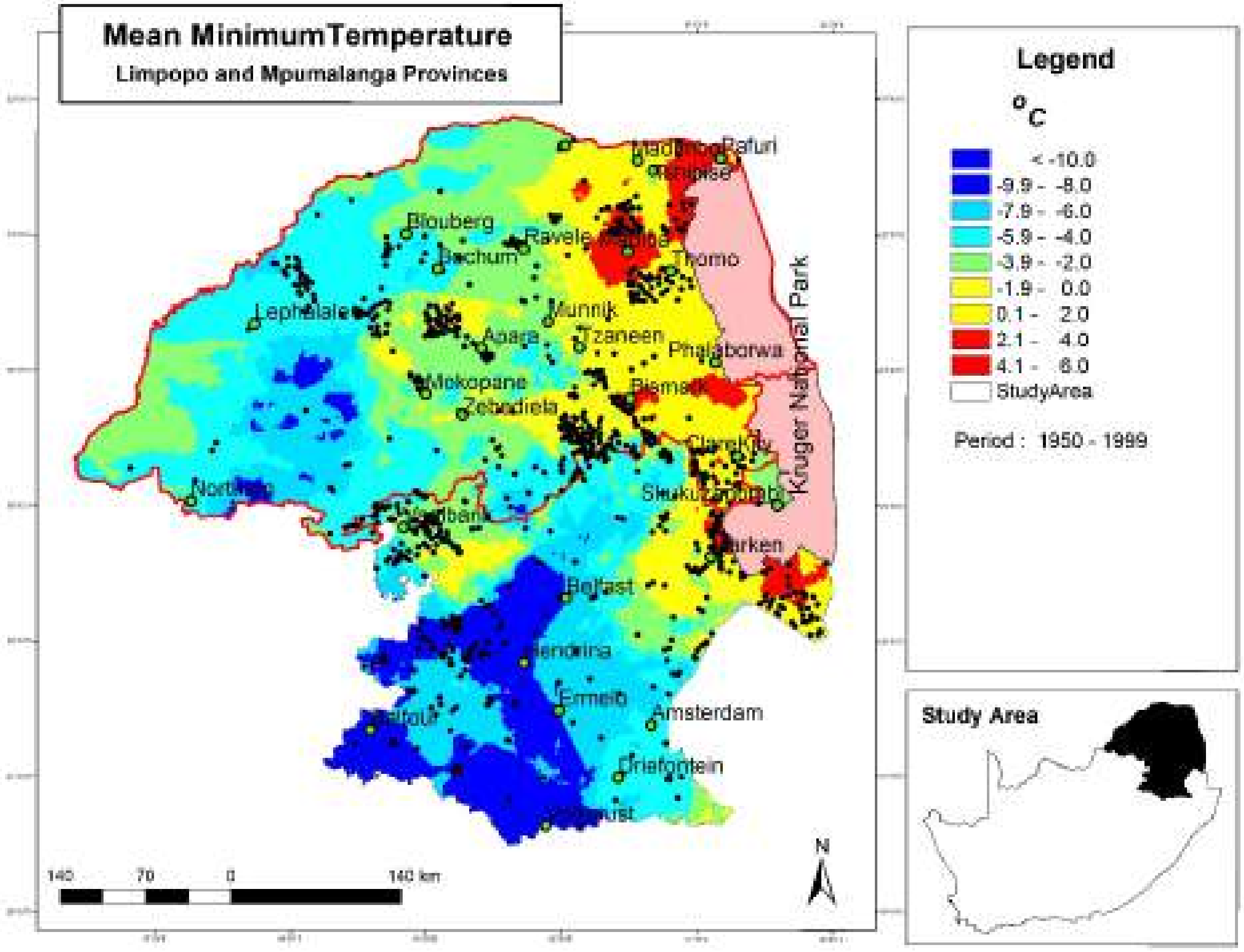


Figure 4.7. Mean minimum temperatures of Limpopo and Mpumalanga Provinces of South Africa

4.3.3 Aridity Index within Agro-ecological areas

Aridity index is a numerical indicator, which denotes the degree of the dryness at a particular location based on the ratio of the evapotranspiration to the precipitation (Derya, *et al*., 2009). Maliva and Missimer (2012) define 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. The aridity indexes that are based on temperature and precipitation are commonly used in all over the world (Baltas 2007; Deniz *et al*., 2011; Croitoru *et al*., 2013; Hrnjak *et al*., 2013; Moral *et al*., 2015). A map in Figure 4.8 portrays the aridity index of the study area.

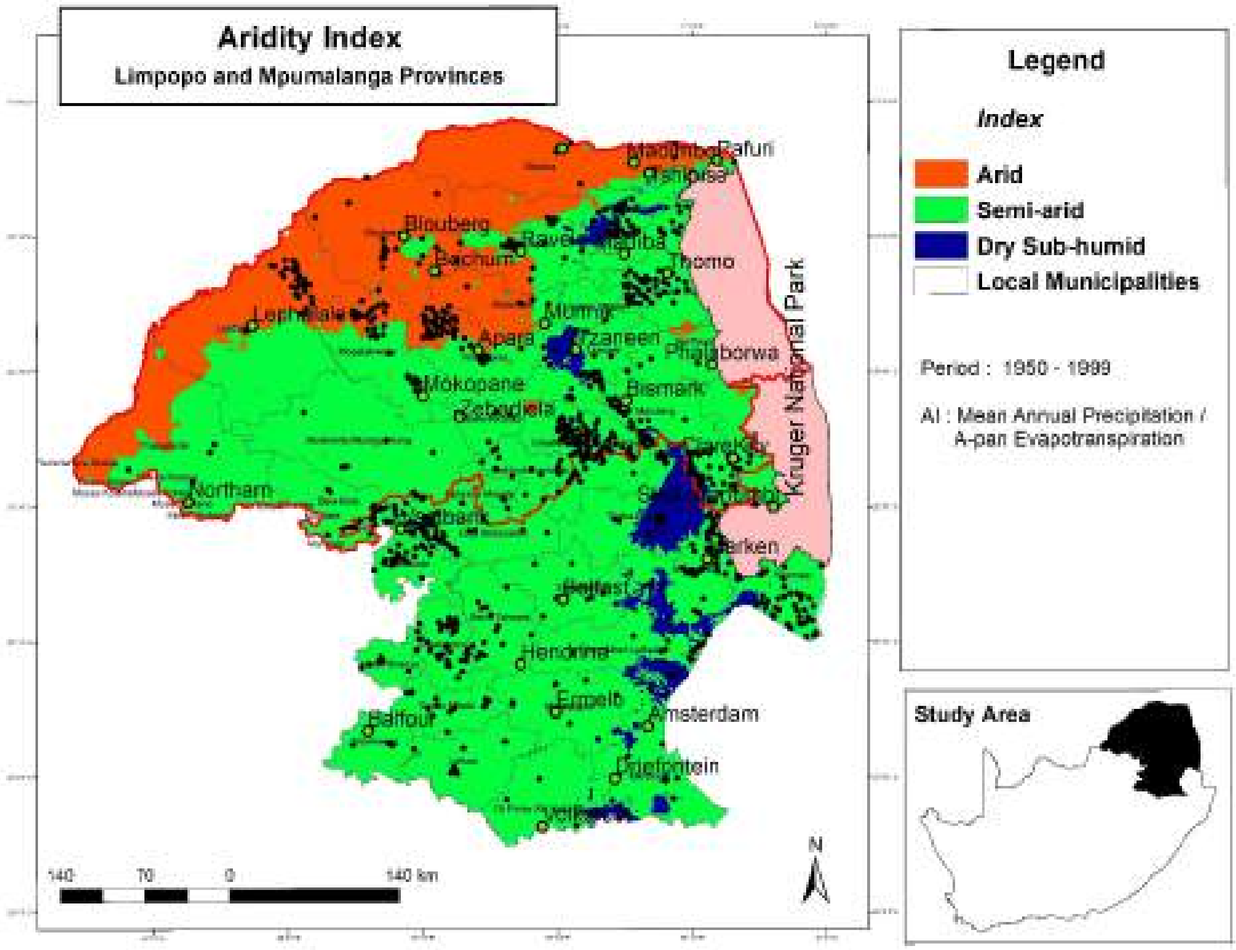


Figure 4.8. Spatial variability of the aridity index in Limpopo and Mpumalanga Provinces of South Africa.

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.

4.3.3.1 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), an arid area is characterized by a severe lack of water resources to the extent of hindering the development of plants and vegetation. Such a lack is brought forth by the predominance of the evapotranspiration to the rate of the precipitation (Derya, et al., 2009). Agricultural production in this category is impossible with the exception where there is irrigation. With irrigation being an exception, the recharge of water resource 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 very much political than hydrological. Furthermore, cattle as the main livestock production, cannot tolerate high heat stress that the area displeasures. In order to lower heat production, farm animals reduce their physical activity as well (Collin *et al*., 2001) and spend less time eating (Brown-Brandl *et al*., 2001). Feed refusal increases with body weight at high ambient temperatures (Quiniou *et al*., 2000). Higher temperatures tend to reduce animal feed intake and lower feed conversion rates (Rowlinson, 2008). Voluntary feed intake decreases curvilinearly with increasing environmental temperature resulting in reduced animal performance (Collin *et al*., 2001). In these regards, cattle farming in this region is highly exposed to the detrimental effects of climate change.

4.3.3.2 Semi-arid area

Over 85% of the study area is recognised as the semi-arid area. The lowest mean annual rainfall and erratic precipitation pattern are the main factors that hinder farming in the semi-arid regions (Aydın, 1995). Griffins (1985), 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 of 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 these 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 that are practicing cattle farming are somehow exposed to the impacts of climate change.

4.3.3.3 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 with relatively warm temperatures in comparison with the surrounding environment and comparably higher precipitation. The rainfall becomes a significant contributing factor towards 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, in most part it runs out in response to the over-grazing as grazing capacity is often exceeded.

4.3.4 Distribution of ground- and surface water resources within agro-ecological zones

Adams (2014) conducted an intensive review on the underutilisation of the groundwater resources in South Africa. The review established that current groundwater abstraction ranges between 2-4 billion M^3/a, which is less than half the optimal potential of 10 billion M^3/a, which is slightly reduced to 7.5 billion M^3/a during drought conditions (Adams, 2014). Groundwater use review asserts the notion that there was sufficient groundwater resource to sustain the livestock sector. On the contrary, the groundwater resource potential is spatially variable. The two provinces comprise the aquifers that are heterogeneous in hydrogeological parameters. These imply that the groundwater availability was differentiable throughout the two provinces.

The variability in the borehole density between the two provinces indirectly signifies the variance in the surface water resource (Figure 4.9). The arid nature of most parts of the Limpopo Province compels the farmers and other water users to turn their focus to groundwater resources. The abundance of the groundwater resources indirectly suggests that the farmers are to a particular level not exposed to the impacts of climate change. However, all sectors of the economy are now turning to groundwater resources. The majority of the existing boreholes were developed without borehole testing. Hence the Department of Water and Sanitation reported a high borehole failure rate in some part of the Limpopo Province. This translates to the improper aquifer management due to unsustainable abstractions that exceed the sustainable yields, boreholes subsequently fail. In the unfortunate event when this unfolds, the farmers will be exposed to the predicament impacts of climate change.

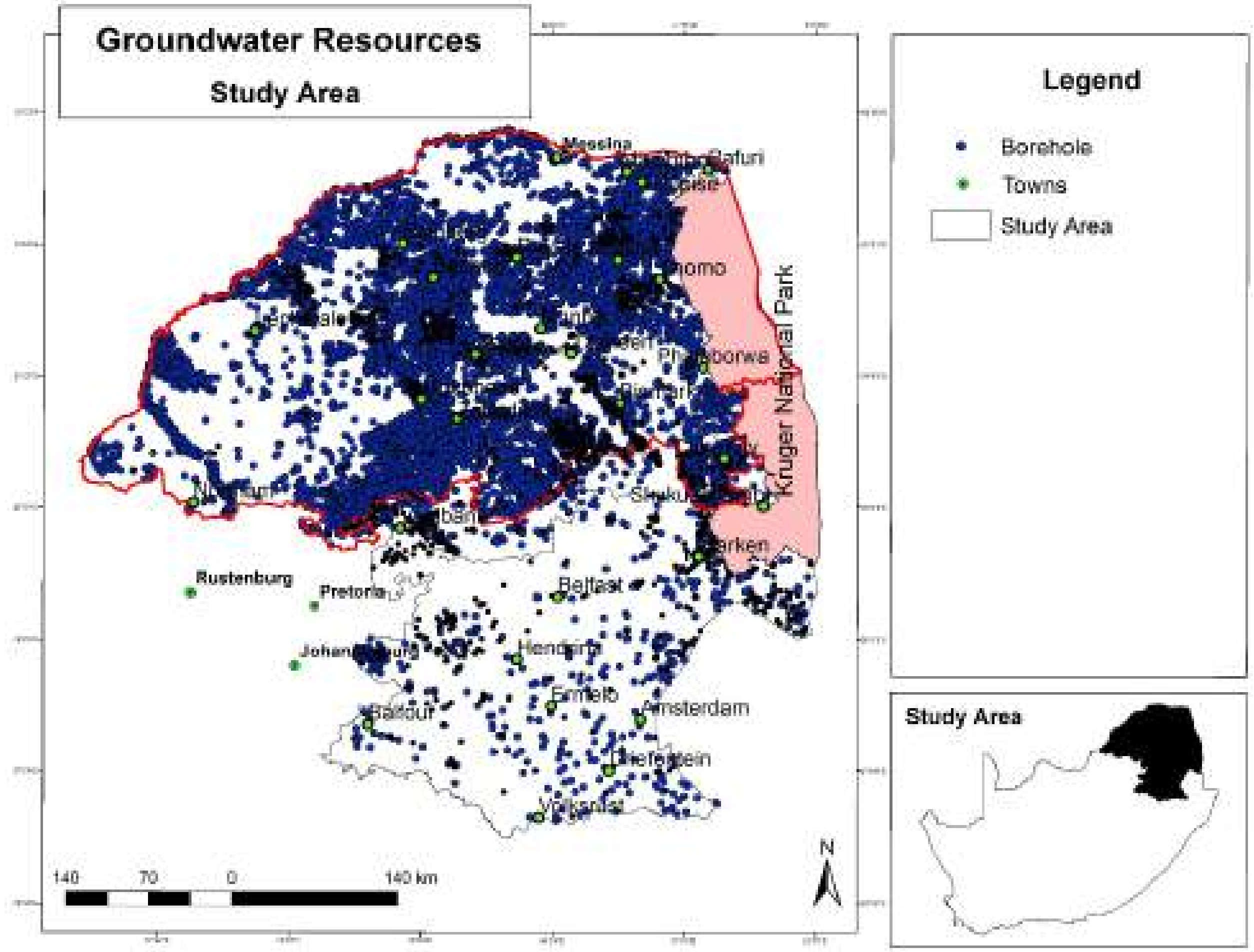


Figure 4.9. Groundwater resources in use in the Limpopo and Mpumalanga provinces of South Africa

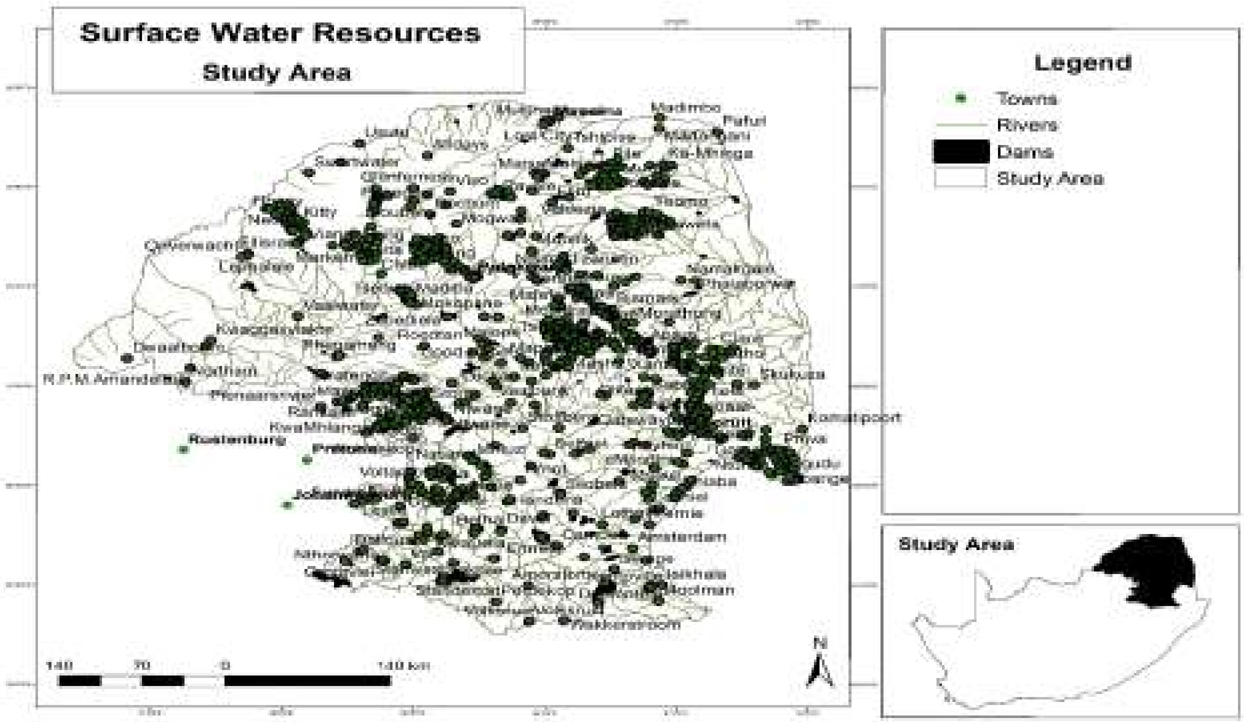


Figure 4.10. Surface water resources in settlement areas of the Limpopo and Mpumalanga Provinces of South Africa

The livestock farmers are distributed throughout the two provinces, however, their density is variable. High farmers clustering throughout conforms to the microclimatic regions that experience high rainfall (Figure 4.10). The reason for this being, a considerable amount of water is lost through evapotranspiration. Subsequently, livestock farming is reliant on the streams. The livestock farmers are exposed to the impacts of climate change in spite of their close proximity to the streams. This is particularly because the majority of the streams are periodic in nature, meaning they only flow water during summer and shortly after that. Furthermore, one of the most prominent impacts of climate change in the context of South Africa is the increasing frequency of drought and floods. These imply that some prevalence of the periodic streams is likely to increase. On the other hand, the proximity to the streams implies that they are prone to wash ways during floods.

4.3.5 The frequency of the climatic extremes

Table 4.1 reflects the views of the farmers on climate trends. Notable changes in climatic trends was experienced by 92.9 percent of farmers who also explored the nature of such variabilities. Out of the 340 farmers, (86 percent) indicated that there was a considerable decline in rainfall. Their views conform to the outcomes of Maponya and Mpandeli (2014). Only a tenth (11.8%) indicated an increment in the rainfall, while 1.2% believe there was no change. According to three-quarters of the farmers, (76.74%) there was a decline in the rainfall for the past 5 years. This decline in rainfall was also observed over the past 5 years. These observations corroborate the findings of Lekalakala (2017) who revealed that the precipitation on the eastern side of South Africa (where this study was conducted) was declining and expected to retain this trend.

Table 4.1. Frequencies and associated percentages of the changes in climatic conditions that include rainfall trend and variations in the rainfall in the past 5 years.

Changes in climatic patterns	Frequency	Percent
Yes	26	7.1
No	340	92.9
Total	366	100
The direction of rainfall change		
Increase	40	11.76
Decrease	293	86.18
No Change	4	1.18
Total	340	100
Rainfall pattern in the past 5 years		
Increase	16	4.65
Decrease	264	76.74
No change	7	2.03
Not observed any change	57	16.57
Total	**344**	**100**

Table 4.2 indicates the perceptions of the livestock farmers on the temperature trends. The majority of the livestock farmers (78.24 percent) observed an increase in the temperatures. Similarly, 73 percent of the entirety also reported similar observations for the prior two years. Moreover, The Department of Environmental Affairs (DEA 2017a, 72) reported similar observations for the countrywide observations.

Table 4.2. Frequencies and associated percentages of the temperature trends and the temperature variations in the past 5 years

Direction of Temperature	Frequency	Percent
Increase	266	78.24
Decrease	61	17.94
No change	10	2.94
Total	340	100
Temperatures in the past 5 years		
Increase	252	73.04
Decrease	24	6.96
No change	7	2.03
Not observed any change	62	17.97
Total	**345**	**100**

In addition, Maponya and Mpandeli (2012); established an increase in temperatures, meanwhile, Turpie and Visser, (2013), probed on the prospect of the increased drought frequency due to the decline of the rainfall. The solidarity on the confirmation of the rising temperatures and reduction of the precipitation provide the undisputed evidence pointing towards the down of the climate change. These imply that the farmers are much likely to be exposed to the multidimensional impacts of climate change. Table 4.3 indicates the frequencies and percent of the variation in the occurrence of the flood, wind, and, drought between 2006 and 2010.

Precisely 346 respondents answered to these questions. About three quarters (70.81%) reported that there has been a decline in flood occurrence between 2006 and 2010. While only 2.89% indicated an increase. Another 25% could neither confirm nor refute to the change in the frequency of the drought. The wind reflects a similar trend to the floods. While a third (29.48%) hints to the increase in wind frequency, a little less than half (46.24%) hinted a decline in wind occurrences and a further quarter (24,28%) reflected that there is no change in the wind occurrences. About 80.92% of the smallholder farmers revealed that the frequency of drought occurrence has increased over the years. According to Turpie and Visser, (2013), the frequency of drought is expected to rise in response to climate change.

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Table 4.3. Frequencies & associated percentages of the temperature trends and variations in the past 5 years

Climatic Extremes	Frequency	Percent
Floods between 2006-2010		
Floods Increase	10	2.89
Floods Decrease	245	70.81
No change in Floods	12	3.47
Not observed any change	79	22.83
Total	**346**	**100**
Wind between 2006-2010		
Increase in Wind	102	29.48
Wind Decrease	160	46.24
No change in Wind	84	24.28
Total	**346**	**100**
Drought between 2006 and 2010		
Drought increase	280	80.92
Drought decrease	8	2.31
No change in Drought	5	1.45
Not observed any change	53	15.32
Total	**346**	**100**
The Weather between 2006-2010		
Weather Increase	166	50.61
Weather Decrease	54	16.46
Weather No change	44	13.41
Not observed any change in Weather	64	19.51
Total	**328**	**100**

Limpopo and Mpumalanga are located within the arid to semi-arid conditions. The temperatures in these regions are already high with limited water resources. Therefore, the intensification of the drought periods threatens the productivity of the livestock. Only a mere 2.1% suggested that the drought frequency decrease and 15.32% could not establish any trend. Another 28.9% agreed to the increments in drought events; while 11.4%, could neither confirm nor refute.

There has been an overall increase in climatic extremes between 2006 and 2010, 50.61% of smallholder farmers reported an increase in the occurrences of such predicaments. About 16.46% outlined a declining trend and the remaining 32.92% could not establish any climatic trend. The increase in climate extremes could be easily correlated to the impacts of climate change (Turpie and Visser, 2013). The increase in climatic extreme frequency suggests that the farmers are bound to be exposed to the impacts of climate change at some point because their means are also limited.

4.3.6 The environmental factors

In addition to the climatological parameters, there are environmental phenomenon’s that equally affects the exposure of the livestock to the impacts of climate change. The environment is a reflective factor to the extent of climate change. It indirectly quantifies the extent of climate change as well as the ability of the environment to support agricultural activities. Livestock farming thrives when there is sufficient grazing together with the conducive climatic setting. Table 4.4 shows the frequencies and the percent of the environmental parameters that affect livestock productivity. About 340 livestock farmers expressed their views on the environmental variability that is associated with climate change.

Table 4.4. Frequencies and associated percentages of the environmental parameters that affect livestock farmers

Environmental Factors	Frequency	Percent
High temperatures	39	11.47
Floods	4	1.18
Environmental	7	2.06
Drought related	288	84.71
Not affected	2	0.59
Total	**340**	**100**

The majority (84%) of the livestock farmers revealed that the most imperative environmental challenge was the incorporation of drought, heat, and fires. Excessive temperatures were also a key issue at 11.47%. Environmental (erosion and land degradation) and floods contributed 2.06 and 1.18% respectively. Only 0.59 outlined that environmental issues do not affect them. These views laments that the environment is bound to fail to support the livestock farming more especially under the smallholder farmers as they lack basic infrastructure, resources, and capital to condition the environment for edifying the production. 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 suboptimal potential area that is already water strained.

4.3.7 Adaptations

Smallholder farmers are entirely reliant on agriculture for their livelihood. With the uncertainty, affecting this component of the sector, their food security, nutrition, and income are at stake (McDowell and Hess, 2012). Table 4.5 indicates the frequencies and percent of farmers to the early warning signs. Almost all (99.45%) of the farmers outlined that upon identifying the signs for a potential climatic extreme event, they pray to God, in other words, they do not have any measure to either prepare their livestock or fields for when the actual event strikes. The response was split almost evenly on whether they trust the meteorological forecasting of the weather; 43% indicated it is not reliable, while 54% believe in forecasting.

Table 4.5. Frequencies and associated percentages of the farmers and their use of indigenous responses to the early warning signs of drought

Indigenous Response to early warning signs of drought		Frequency	Percent
Indigenous Response to early warning signs of drought	Pray to God	363	99.45
	Pray to ancestors	2	0.55
	Total	**365**	**100.00**
To what extent do you trust meteorological predictions	Not reliable	157	43.13
	Reliable	200	54.95
	Very reliable	7	1.92
	Total	**364**	**100.00**
To what extent do you trust indigenous predictions	Not reliable	151	41.94
	Reliable	206	57.22
	Very reliable	3	0.83
	Total	**360**	**100.00**
Have you ever discussed climate change adaptation issues with someone	No	161	44.11
	Yes	199	54.52
	Total	**365**	**100.00**

Adaptive capacity is highly dependent on the capacity of farmers and their families to access key information and to collectively self-organise (Smit and Wandel 2006; Jones and Boyd 2011; Abdul-razak et.al. 2017). Cooperatives are relevant for adaptive capacity since they facilitate access to public policies and to the production scale necessary to be inserted in the market (Jones and Boyd 2011; O'Brien *et al*., 2004a).

4.4 CONCLUSIONS

The agro-ecological attributes of smallholder livestock farming areas of Limpopo and Mpumalanga provinces are classified as 85 percent semi-arid region. The area experiences extended spells of the dry season and shorter wet periods. The arid area is characterised by a severe lack of water resources to the extent of hindering of plants and vegetation. There are localised microclimate zones that are arranged in a north-south direction that experience in excess of 1000 mmpa in the five percent sub-humid component of the study areas. Based on the geo-physical and climatic attributes animals that graze are likely to suffer the negative impacts of climate change while those that browse are likely to survive. It is highly recommended that (1) early warning system be enhanced to rapidly provide smallholder farmers with weekly, monthly weather forecasts; (2) smallholder farmers be encouraged in their mixed farming to grow fodder crops for their animals and (3) that indigenous breeds and their crosses of small-stock especially of goats and sheep be preferred farming species as they are drought-tolerant.

4.5 REFERENCES

Abdul-Razak, M. and Kruse, S (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. Climate Risk Management, 17:104-122.

Adams, S. (2013). WRC – leading the charge on groundwater research. Water Wheel. Groundwater Special Edition. 2013.

Alkire, D. (2009). Protecting against summer temperatures. Retrieved from Farm Progress: https://www.farmprogress.com/livestock/protecting-cattle-against-summer-temperatures

Aydın, M. (1995). Water: Key ingredient in Turkish farming. Forum for applied research and public policy. A Quarterly Journal of the University of Tennessee. 10: 68-70.

Baltas, E.,(2007) Spatial distribution of climatic indices in northern Greece. Meteorol Appl 14:69–78.

Brown-Brandl T M; Eigenberg R A; Hahn G L; Nienaber J A. (2001). Correlations of respiration rate, core body temperatures, and temperatures for shaded and non-shaded cattle. Proceedings, Sixth International Livestock. Environment Symposium, pp 448–454. American Society Agricultural Engineers, Louisville, Kentucky

Butler, R. A. (2005) A Place Out of Time: Tropical Rainforests and the Perils They Face. Published online: Rainforests.mongabay.com

Collin, A., van Milgen, J., Dubois, S. and Noblet, J. (2001). Effect of high temperature on feeding behaviour and heat production in group-housed young pigs. British Journal of Nutrition, Vol.86, pp. 63-70. ISSN: 0007-1145

Croitoru, A.E, Piticar. A., Imbroane AM., Burada, D, C., (2013) Spatio-temporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania. Theor Appl Climatol 112:597–607

Deniz A, Toros H, Incecik S (2011). Spatial variations of climate indices in Turkey. Int. J. Climatology 31(3):394–403

Derya, Ö., Mehmet, A., Süha, B., Sermet, Ö., and Tomohisa, Y. (2009). The use of aridity index to assess implications of climatic change for land cover in Turkey. Turk J Agric For(33), 305-314. doi:doi:10.3906/tar-0810-21

Easterling, D. R., Meehl, G.A., Parmesan, C., Changnon, S.A., Thomas R.K. and Mearns, L.O. 2000. Climate Extremes: Observations, Modelling, and Impacts, Science. VOL 289 SCIENCE www.sciencemag.org.

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Griffins, J. (1985). Handbook of applied Meteorology. (D. D. Houghton, and J. W. Sons, Eds.)

Hrnjak I, Lukić T, Gavrilov MB, Marković SB, Unkašević M, Tošić I (2013) Aridity in Vojvodina, Serbia. Theor Appl Climatol 115(1–2):323–332

Ingrin. D., and Rainier., D (2012). Climate change vulnerability index for South African aquifers. http://www.scielo.org.za/pdf/wsa/v38n3/08.pdf

Intergovernmental Panel on Climate Change (IPCC) (2007). Impacts, adaptations and vulnerability. Fourth Assessment Report. Cambridge University Press, Cambridge, UK.

Jones L. & Boyd E (2011) Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Kala, N., Kurukulasuriya, P., and Mendelsohn, R. (2012). The impact of climate change on agro-ecological zones: Evidence from Africa. Environment and Development Economics, 17(6), 663-687. Retrieved from http://www.jstor.org/stable/26265545

Kotchoni, D.O.V., Vouillamoz, JM., Lawson, F.M.A. et al. Hydrogeol J (2019) 27: 447. https://doi.org/10.1007/s10040-018-1806-2

Kotir, J. (2011) "Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security," Environment, Development, and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 13(3), pages 587- 605, June.

Lazaro R, Rodrigo FS, Gutierrez l, Domingo F and Puigdefafregas J. (2001). Analysis of a 30-year rainfall record (1967-1997) in semi-arid SE Spain for implications on vegetation. J. Arid Environ. 48 373-395.

Lekalakala, (2017). Options for Managing Climate Risk and Climate Change Adaptation in Smallholder Farming Systems of the Limpopo Province, South Africa. Doctoral Thesis. Goettingen (IPAG), Faculty of Agricultural Sciences, Georg-August-University Goettingen, Germany

Li x-y, Shi, P-J, Sun Y-l, Tang J and Yang Z-P (2006). Influence of various in-situ rainwater harvesting methods on soil moisture and growth of Tamarix Ramosissima in the semiarid loess region of China. For. Ecol. Manage. 23 (1) 143-148.

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2012) Indicators for Assessing the Vulnerability of Smallholder Farming to Climate Change: the Case of Brazil's Semi-Arid Northeastern Region. Poverty Practice, Bureau for Development Policy, UNDP Esplanada dos Ministérios, Bloco O, 7º andar, 70052-900 Brasilia, DF - Brazil

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2014). Integrated assessment of smallholder farmings vulnerability to drought in the Brazilian Semiarid: a case study in Ceará. Climatic Change, https://www.researchgate.net/publication/262485038. DOI 10.1007/s10584-014-1116-1

Mader TL (2003) Environmental stress in confined beef cattle. Journal of Animal Science 81, 110–119.

Maliva RG, Missimer TM (2012). Arid lands water evaluation and management. Environ Sci Eng 3(1948):806.

McDowell, J. Z., Hess J. J. (2012): Accessing Adaptation: Multiple Stressors on Livelihoods in the Bolivian Highlands under a Changing Climate. – Global Environmental Change 22: 342-352.

Moral FJ, Rebollo FJ, Paniagua LL, García-Martín A, Honorio F (2015) Spatial distribution and comparison of aridity indices in Extremadura, southwestern Spain. Theor Appl Climatol. https :// doi.org/10.1007/s0070 4-015-1615-7

Mpandeli, S. and Maponya, P. (2014). Constraints and Challenges Facing the Small Scale Farmers in Limpopo Province, South Africa. Journal of Agricultural Science; Vol. 6, No. 4

Mzezewa, J., Misi, T., and van Rensburg, L. D. (2010, January). Characterisation of rainfall at a semi-arid ecotype in the Limpopo Province (South Africa) and its implications for sustainable crop production. Water SA, Vol. 36 (No. 1). doi:ISSN 0378-4738

O'Brien, K., Leichenkob, R., Kelkarc, U., Venemad, H., Aandahla, G., Tompkinsa, H., Javedc, A., Bhadwalc, S., Bargd, S., Nygaarda, L., and Westa, J. (2004a). Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change 14 (2004) 303–313

Omokanye, Akim and Yoder, Calvin and Sreekumar, Lekshmi and Vihvelin, Liisa and Benoit, Monika. (2018). On-farm Assessments of Pasture Rejuvenation Methods on Soil Quality Indicators in Northern Alberta (Canada). Sustainable Agriculture Research. 7. 74. 10.5539/sar.v7n2p74.

Ormsby, T.; Napoleon, E.; Burke, R.; Groessl, C.; Feaster, L. 2001. Getting to know ArcGIS desktop. Basics of ArcView, ArcEditor and ArcInfo. Redlands, Ca. ESRI Press.

Quiniou, N., Dubois, S. and Noblet, J. (2000.) Voluntary feed intake and feeding behaviour of group-housed growing pigs are affected by ambient temperature and body weight. Livestock Production Science, Vol. 63, No. 3 (May 2000) pp. 245–253. ISSN: 0301-6226

Rowlinson, P., 2008. Adapting Livestock Production Systems to Climate Change – Temperate Zones. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Seneviratne, S., Nichols, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M., Sorteberg, A., Vera, C., and Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment, chapter 3 in IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation Cambridge University Press, Cambridge, UK, New York, NY, USA (2012)

Smit B. and Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Chang Hum Policy Dimens 16:282

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y. and Nkem, J. (2012), "Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon", Forest Policy and Economics, Vol. 23, pp. 1-9.

Turpie, J. and Visser, M. (2013), "The impact of climate change on South Africa's Rural areas", Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.

CHAPTER 5: SMALLHOLDER FARMERS' PERCEPTIONS ON THE IMPACT OF CLIMATE VARIABILITY & EXTREMES ON LIVESTOCK PRODUCTION IN LIMPOPO AND MPUMALANGA PROVINCES

Abstract

A study was carried out to investigate the perception of smallholder farmers about the impact of climatic variability and extremes on livestock production in Limpopo and Mpumalanga Provinces. The purpose of the study was to investigate the level of awareness and knowledge of farmers on climate change due to its imperative prerequisite in their exposure to the impacts of climate change. Data was collected through a descriptive survey using structured questionnaires, observations, and interviews from individuals and focus groups. At least 469 smallholder farmers were interviewed using a semi-structured questionnaire to elicit responses on vulnerability. Almost all the farmers (96 %) have heard about climate change, with only a few farmers (4%) not knowing about climate change. The medium for the conveyance of climate change information was mainly radio (94.32%). Newspaper and television were also efficient media in the conveyance of this information, each with the outreach of 16.76% and 32.67%, respectively. In terms of the impact of climate change on livestock production, the majority of farmers (77.87%) experienced a dip in rainfall quantity and frequency. Similarly, (80.87%) of the farmers outlined that the most imperative predicament that is correlated to climate change was drought. Central to the impact of drought was the fact that 90% of the farmers confirmed that there was a change in grass availability. Over half of the farmers (55.19%) attested to major livestock fatalities due to a lack of natural pastures. It was therefore important to evaluate the content of the awareness campaigns. The study found that 86.67% of the farmers who attended awareness meetings indicated that the discussions prioritised the importance of adapting to climate change. However, most of the farmers (80.77%) did not have an early warning system. This was coupled with a lack of any contingency plans by 84.36% of the farmers to deal with the impact of the said drought on their farms. Farmers (19%) who had facilitated contingency plans indicated that improved aspects of the plan should incorporate the provision of feeds, drilling of boreholes, and erection of dams. The study, based on smallholder farmers' perception, 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 specialised business. Also, there is a need for a shift to small stock farming based on agro-ecological analysis. The government should intervene by providing facilitated water and small-scale feedlot infrastructure for smallholder farmers. For farmers to cope and adapt to climate change, there is a great need for an early warning system. Early warning and disaster-related matters have not been fully assimilated into 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.

5.1. INTRODUCTION

Climate change refers to a long-term (over a decade) change in climate patterns that can be identified by changes in the mean and/or the variability of its properties, whether due to natural variability or as a result of human activity. It may involve a gradual change in long-term average conditions of climate, greater variability in normal conditions, or changes in the frequency, magnitude, and distribution of extreme events (Smit *et al*., 2000). The adverse effects of climate change and variability have become an environmental and socio-economic problem which is increasingly causing climate-driven hazards to people around the world (Scholze, Knorr, Arnell, and Prentice, 2006). Climate change is also expected to alter pest and disease outbreaks, increase the frequency and severity of droughts and floods, and increase the likelihood of poor yields, crop failure and livestock mortality (Morton, 2007).

Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien *et al.*, 2004). Climate change impacts livestock production in two ways, direct and indirect. The most significant direct impact of climate change on livestock production comes from heat stress. (Sejian et. al., 2016), while most of the production losses are incurred via indirect impacts of climate change, largely through reductions or non-availability of feed and water resources. It is believed that livestock production and productivity will be one of the most susceptible sectors to climate change due to changes in the hydrological cycle, temperature balance and rainfall patterns, which harm livestock production and productivity (Mwiturubani, 2010). Climate change is affecting rains, an increase in the frequency of droughts and a rise in temperatures, threatening the availability of freshwater for agricultural production and other uses (Kotir, 2010). Impacts facing the agricultural sector include a reduction of land that is suitable for arable and pastoral agriculture, a shortened growing season and a decrease in yields, particularly along the margins of semiarid areas (Turpie *et al*., 2002). Notenbaert *et al*. (2010) observed climatic trends that included reduced productivity of animal feed, higher disease prevalence, and reduced freshwater availability. This was due to the negative effects of lower rainfall and more droughts on crops and on pasture growth, and to the direct effects of high temperature and solar radiation on animals.

5.2 RESEARCH METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim of creating independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

5.2.1 Study area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers who are organised and within reach of the investigators. A map of the two provinces is attached as Figure 5.1.

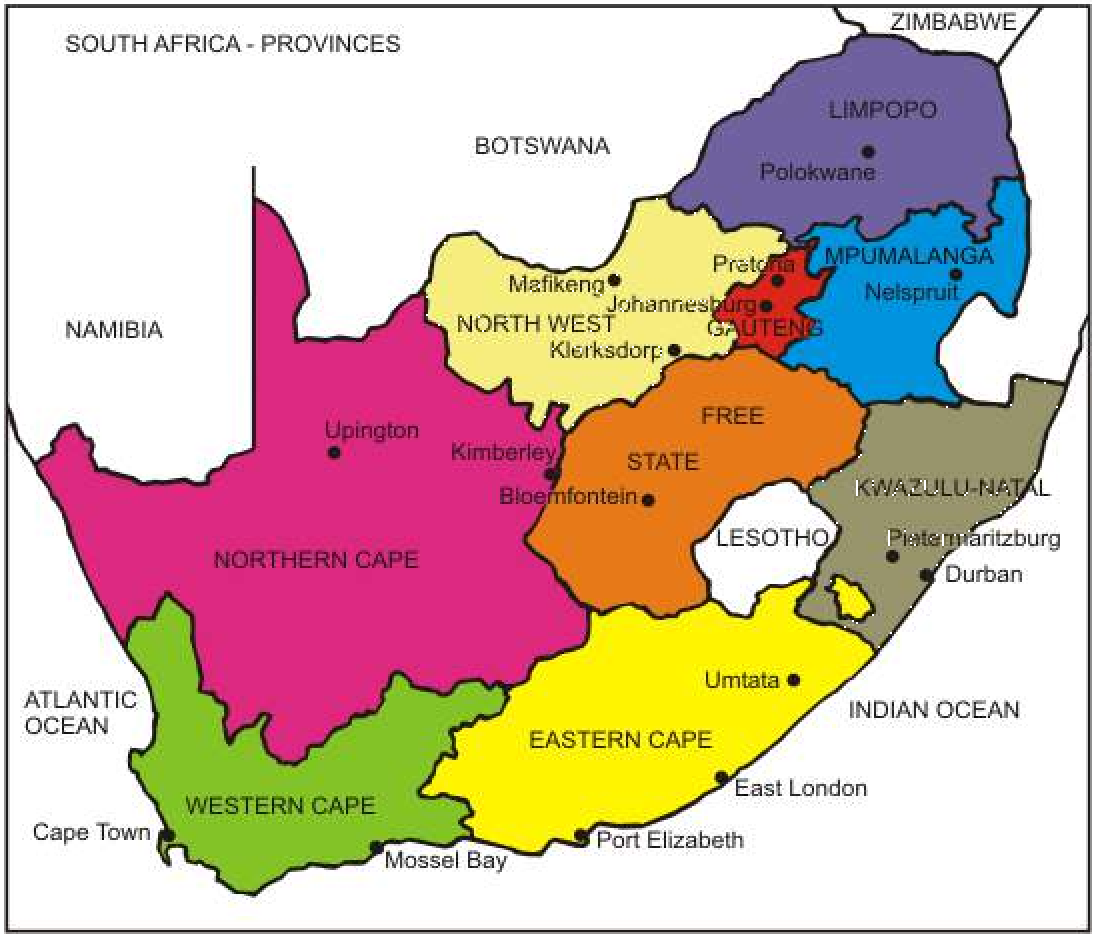


Figure 5.1. Political map of South Africa with provinces

5.2.2 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 interacting with the interviewee (Schulze, 2002). The structured questionnaire contained both open and closed-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 questionnaire included, among others, demographic and economic household characteristics; livestock and crop production; access to extension services; credit access;

hazards occurrence; adaptation strategies pursued; coping strategies; the level of resilience and other information as indicated in the methodology. The study adopted the Framework and or system by Lindoso (2011).

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, the 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 was also 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.

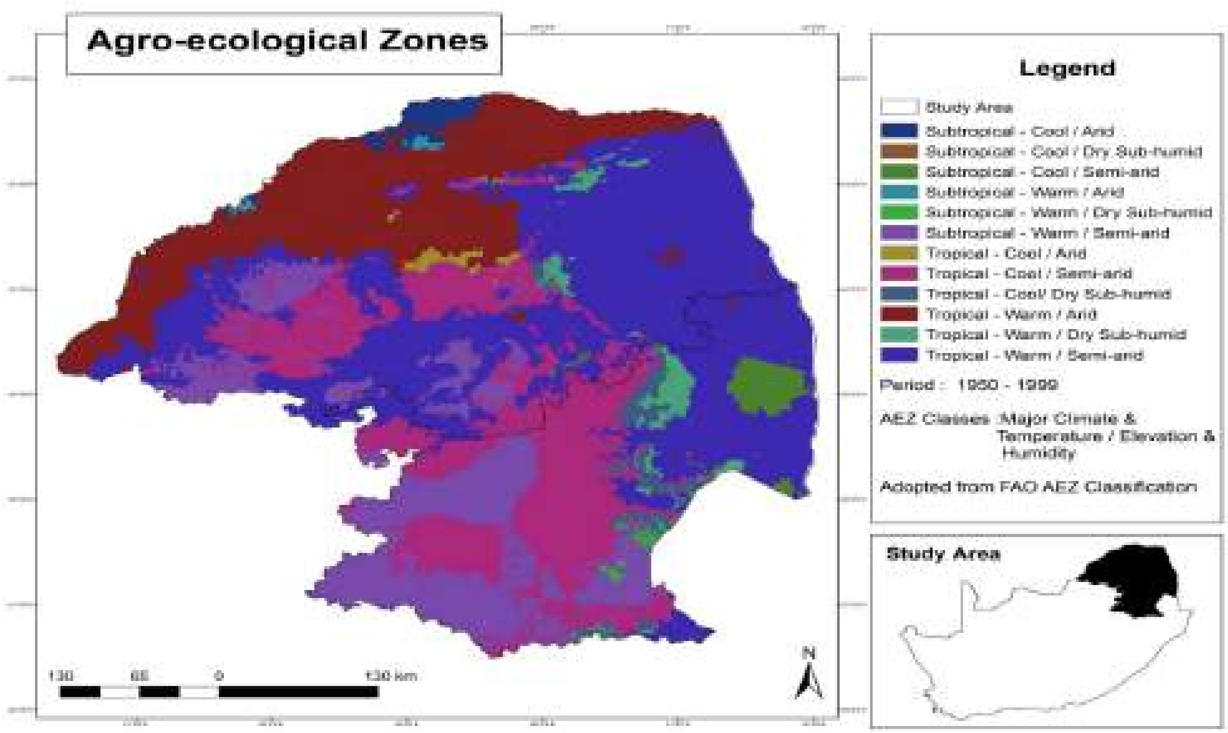


Figure 5.2. Agro-ecological zones of Limpopo and Mpumalanga provinces of South Africa (FAO, 1978)

It was assumed that water sources exceeding a 5 km radius are beyond realistic reach for domestic water supplies, and hence are only available for livestock. The 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.

5.2.3 Sampling procedure and data analysis

5.2.3.1 Sampling

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 5.2). An effort was made to have a minimum of at least 10 farmers per village out of the randomly sampled households. We used stratified sampling to obtain a representative sample of villages and households for the interview. A two-stage random sampling process was conducted using SURVEYSELECT procedure of SAS. The PROC SUREVEYSELECT allows 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.

5.2.3.2 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 was 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.

5.2.3.3 Data analysis

Quantitative data were transcribed into the MS Excel Package and analysed 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 summarised in an Excel Spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents, mainly the qualitative data.

5.3 RESULTS AND DISCUSSIONS

This section summarises and synthesises the results of the smallholder livestock farmers' exposure to the impacts of climate change. The exposure was expressed in terms of the following parameters: access to information, water resource availability and source, aridity index, precipitation, and temperature variability.

5.3.1 Access to climate change information

5.3.1.1 Farmers' awareness of climate change

Climate change is arguably the foremost human and environmental crisis of the 21st century (Tadesse, 2010). Throughout the world, this phenomenon imposes adverse impacts on livelihood activities such as agriculture and water provision through recurring extreme events that include floods, cyclones, droughts, and unpredictable rainfall patterns (Urama and Ozor, 2010).

The variations in climatic setting (changes in temperature and rainfall patterns) affect the agricultural practices and subsequent production in tropical regions (FAO, 2008). The exposure of farmers to the impacts of climate change is proportionate to the degree of awareness on this subject. If farmers are equipped and capacitated in the aspects of climate change, their operations are less likely to be exposed to the impacts of climate change.
Their awareness and knowledge of climate change underlay an imperative prerequisite in their exposure to the impacts of climate change (Maddison, 2007). Without knowledge, the minor impacts of climate change are stretched beyond their actual extent. Table 5.1 shows the frequency and percentage of farmers who are familiar with the concept of climate change and different and the different sources of such information. Almost all the farmers (96.17%) have heard about climate change, but only a few (3.83%). According to Maddison (2007), such a high proportion with some knowledge of climate change is critical for the adaptation of the measures to use in response to climate challenges. While having heard about climate change will not provide a meaningful basis to rate the farmers' exposure, the relative exposure can only be measured based on the comprehension of the farmers to this phenomenon.

The farmers who were familiar with the concept of climate change provided where they learned about this subject. According to Table 1, multiple stakeholders capacitated farmers with climate change information. Unexpectedly, almost all livestock farmers (98.58%) have not heard about this topic from the government. This is rather unexpected, as there are multiple climate change awareness programs in different spheres of the government. At a more relevant level, the Department of Agriculture initiated the climate change adaptation program for livestock farmers, yet the farmers nullified the role of the government in the dissemination of climate information.

On the other end of the spectrum, radio was the most imperative medium for the conveyance of climate change information. Almost all farmers (94.32%) receive climate change-related information through this medium. This is because, in rural areas, radios are used for entertainment and the reception of current affairs. Its wider audience base is influenced by its mobility, accessibility, cost efficiency, ease of operation, and wide reception coverage. Newspaper and television were also efficient media in the conveyance of this information, each with the outreach of 16.76% and 32.67% respectively. Very few farmers (6.82%) heard about climate change from their friends. The contribution of the NGOs and churches was close to nothing; the two contributed a little less than 1% and 1.99% respectively. A low figure of 4.26% heard this topic at the village meetings. Therefore, it is imperative to use radio to convey climate information and educate farmers on climate change issues. These have the potential to marginalise the exposure of the farmers to the impacts of climate change.

Table 5.1. Frequencies and respective percentages of smallholder farmers and access to climate change information

Climate change information		**Frequency**	**Percent**
Have you heard of climate change	No	14	3.83
	Yes	352	96.17
	Total	**366**	**100**
From what source of information			
Government Source	No	347	98.58
	Yes	5	1.42
	Total	**352**	**100**
Friend	No	328	93.18
	Yes	24	6.82
	Total	**352**	**100**
Radio	No	20	5.68
	Yes	332	94.32
	Total	**352**	**100**
Newspapers	No	293	83.24
	Yes	59	16.76
	Total	**352**	**100**
NGOs	No	351	99.72
	Yes	1	0.28
	Total	**352**	**100**
Church group	No	345	98.01
	Yes	7	1.99
	Total	**352**	**100**
Television	No	237	67.33

	Yes	115	32.67
	Total	**352**	**100**
Village meetings	No	337	95.74
	Yes	15	4.26
	Total	**352**	**100**

5.3.1.2 Observable impacts of climate change

Climate change manifests in different forms, including rising temperatures, changes in water availability, floods, droughts, etc. (Sonwa et al., 2012). However, these outcomes hardly occur concurrently. This section attempts to appraise the prevalent impacts that haunt the smallholder livestock farmers. Table 5.2 portrays the prevailing impacts of climate change that are affecting their farming.

The majority of the farmers (77.87%) expressed a dip in rainfall quantity and frequency as the major visual evidence of the decline due to climate change. These results are in accord with the remarks of Maluleke and Mokwena (2017) that Limpopo province is branded as a drought-prone province. After this, there is a shortage of water resources and a shortage of pastures (Maluleke & Mokwena, 2017). This is rather unfortunate because climatic regions of the country are dominated by the intercalations of the arid to semi-arid climatic zone, which is strained with limited water resources (Mpandeli and Maponya, 2014).

Beyond the scope of climate change at a generalised level, the farmers expressed some of the impacts of climate change that are experienced in their communities. Table 5.2 shows the visual impacts of climate change that are experienced within the localities of the farmers. The majority (80.87%) outlined that the most imperative predicament that is correlated to climate change is the drought. These findings are in congruence with the findings of Maluleke and Mokwena (2017), which indicate that the Limpopo is prone to drought. Moreover, Kotir (2010), also establishes that climate change affects rains, an increase in the frequency of drought, and rising temperatures. Drought could be easily correlated with the reduction of rainfall.

Table 5.2. Frequencies & respective percentages of smallholder farmers' beliefs on factors that influence climate change

Factors Influencing Farmers' Beliefs		Frequency	Percent
Low rainfall	No	81	22.13
	Yes	285	77.87
	Total	**366**	**100**
Rainy season starting late	No	300	81.97
	Yes	66	18.03
	Total	**366**	**100**
Heavy rains that bring floods	No	323	88.25
	Yes	43	11.75
	Total	**366**	**100**
Very hot summer	No	234	63.93
	Yes	132	36.07
	Total	**366**	**100**

According to Table 5.3, the farmers did not correlate the occurrence of the following climatic phenomena to climate change: tropical cyclones/ wind change, land erosion and degradation, destruction of buildings, and unpredictable seasons. The following percentage of farmers indicated that each of these factors does not conform to climate change: tropical cyclones, 95.63%, land erosion/degradation, 93.17%, destruction of buildings, 98.91%, and unpredictable seasons (short or long rainy season), 96.17%, even though these factors generally correlate with climate change, especially in South Africa. In addition, Turpie and Visser (2013) reveal that climate change in South Africa manifests in various ways that incorporate higher temperatures, sporadic rainfall patterns, and frequent droughts.

Beyond the point of mere awareness, it all comes down to how equipped the individual is to deal with the impacts of climate change. Table 5.3 shows the frequencies and percentages of the farmers who have attended a climate change workshop and the topics that were discussed. It is rather unfortunate that almost none of the farmers (4.11%) had attended any climate change workshop. Workshops are of paramount significance in equipping the attendees with the necessary knowledge on the subject matter. Lack of training is an imperative indicator to portray high exposure of livestock farming to the impacts of climate change.

According to Maddison (2007), knowledge of climate change is critical for the adaptation of the measures to use in response to climate challenges. The farmers do not have experience with such gatherings on climate change, making them highly exposed to the impacts of climate change.

Table 5.3. Frequencies and respective percentages of smallholder farmers and their perceptions on changes that may be due to climate change

Perceived impacts & changes due to climate change		Frequency	Percent
Changes	No	326	89.07
	Yes	40	10.93
	Total	**366**	**100**
Drought	No	70	19.13
	Yes	296	80.87
	Total	366	100
Flooding	No	353	96.45
	Yes	13	3.55
	Total	**366**	**100**
Hurricanes/ wing change	No	350	95.63
	Yes	16	4.37
	Total	**366**	**100**
Soil erosion/ land degradation	No	341	93.17
	Yes	25	6.83
	Total	**366**	**100**
Destruction of buildings	No	362	98.91
	Yes	4	1.09
	Total	**366**	**100**
Unpredictable seasons (short or long rainy season)	No	352	96.17
	Yes	14	3.83
	Total	**366**	**100**

Table 5.4 shows the frequencies and percentage of the farmers who have attended a climate change workshop and the topics that were discussed. Almost no farmers (4%) have attended a workshop on climate change. According to Fata and Falazo (2016), a workshop is a great way for someone to learn about a particular subject, learn new projects, and methods to be equipped, thus to say without attending workshops, you are deprived of new techniques and new knowledge that is rather critical for your operations.

Table 5.4. Frequencies and respective percentages of smallholder farmers who have attended facilitated climate change workshops

Climate change workshop facilitations		Frequency	Percent
Have you ever attended any climate change meeting or training programs?	No	350	95.89
	Yes	15	4.11
	Total	**365**	**100.00**
If yes, Where?	At school meetings	3	30.00
	Chief place	5	50.00
	In the Royal Place	1	10.00
	Village meetings	1	10.00
What topics were discussed?			
Causes and effects of climate change	No	10	66.67
	Yes	5	33.33
	Total	**15**	**100.00**
How to adapt to climate change	No	4	26.67
	Yes	11	73.33
	Total	**15**	**100.00**
Importance of adapting to climate change	No	13	86.67
	Yes	2	13.33
	Total	**15**	**100.00**
Community participation in climate adaptation	No	9	60.00
	Yes	6	40.00
	Total	**15**	**100.00**
Awareness	No	14	93.33
	Yes	1	6.67
	Total	**15**	**100.00**
Ways of mitigation and adaptation	No	6	40.00
	Yes	9	60.00
	Total	**16**	**106.67**
Have you talked about climate change with your neighbours	No	155	42.47
	Yes	210	57.53
	Total	**365**	**100.00**

It is unfortunate that most of the farmers are deprived of the opportunity to attend many such climate change-focused events. Attending such events would equip them in such a way that their exposure to the impacts of climate change would certainly be reduced.

The few farmers who have attended climate change workshops commented that these events were held at the following premises: at school meetings (30%), the residence of the chief (60%), and village meetings (10%). The supremacy of the chief palace as the meeting gathering point and information dissemination point reflects how well the rural communities uphold their traditional leaders. The farmers reflected that the following issues were discussed in the meetings: a third (33.33%) indicated the discussions were on the causes of climate change, the widely covered aspect (73.33%) was on how to adapt to climate change. However, 86.67% outlined that the discussions were on the importance of adapting to climate change. More than half (60.00%) indicated that there were no issues of community participation in climate change. The dominance of the topics on the adaptation serves to instill that those who attend such gatherings are less exposed to the impacts of climate change. It is unfortunate that those who attend such gatherings are in the minority, which implies that their impact would be marginal.

Surprisingly, the majority (93.33%) had no awareness of climate change. This explains why the majority of farmers are not familiar with this phenomenon. Although 60.00% affirm that the mitigation and adaptation were prioritised. The minority composition of the farmers has attended the workshops on climate change. Though the assumption that the farmers are blank on this subject matter could not be totally true, the workshops are ideal for capacity building more especially because they hold the fate of farming, since the majority of the farmers are only relying on farming for a livelihood. Given these issues, the sector is highly exposed to the impacts of climate change.

5.3.1.3 Feed resources variability

The smallholder livestock farmers almost entirely rely on the natural feed system. Feeding is an important aspect of livestock farming. Without it, this type of farming is not possible. The livestock feed types and availability respond directly to the variations in the rainfall pattern and amount. Given these, Table 5.5 shows the frequency and percentage of livestock feed changes in response to climate change. It is logical to pre-assume a dip in feed availability in response to the decline in rainfall.

Almost all farmers (90%) confirmed that there is a change in grass availability. Considering that the majority of the livestock farmers participate in cattle farming, this is a critical impact as such animals rely mostly on grazing. Grass has a short lifespan and usually picks up after the rainy season. According to Turpie *et al.* (2002), there is a significant reduction in land for grazing. Notenbaert *et al.,* (2010) also observed climatic trends that incorporated reduced productivity of animal feed, higher disease prevalence, and reduced fresh water availability. Correspondingly, almost all the respondents deny the emergence of the new grass species.

Table 5.5. Frequencies & respective percentages of smallholder farmers on the change of feeds available subsequent to the climate change

Change in livestock feeds		**Frequency**	**Percent**
Less grass in pastures	No	34	9.29
	Yes	332	90.71
	Total	**366**	**100**
Less shrubs in pastures	No	257	70.22
	Yes	109	29.78
	Total	**366**	**100**
New grass species	No	363	99.18
	Yes	3	0.82
	Total	**366**	**100**
New shrubs invasion of pastures	No	358	97.81
	Yes	8	2.19
	Total	**366**	**100**
Raising of exotic breeds	No	352	96.17
	Yes	14	3.83
	Total	**366**	**100**

The majority of the respondents (70.22%) also outlined that the shrubs dominate the pasture. This implies that the pasture is threatening the existence of livestock farming. The pasture available at any given point in time has specific grazing support for a particular number of livestock. Any excess would deem the pasture insufficient. Often, the smallholder livestock farmers are not aware of this, as it requires scientific studies to do. Consequently, livestock fatality is likely to escalate. In order to sustain their practice, the farmers have to turn to supplementary feeding with forage and Lucerne. However, they may not have the financial muscles to feed their livestock, and the strain intensifies if the feeding has to be for a prolonged period. Consequently, livestock fatality is very likely. Because of these, livestock farmers are highly exposed to the impacts of climate change.

Ibrahim et.al. (2013) in their book with co-authors indicated that natural pasture degradation leads to a decline of the natural resource base, i.e., decreased biodiversity, soil and water quality; more rapid runoff and hence higher peak flows and sedimentation of rivers; and lower productivity, increased rural poverty and vulnerability, and further land-use pressure. In smallholder setups, it manifests in overgrazing, which is also related to a significant reduction in soil carbon stocks and is one of the main reasons for the large carbon footprint associated with cattle farming in the world.

It therefore can be concluded based on studies by Ibrahim (1994) that improved grasses and legume pastures can fix similar amounts of Carbon to that of forest systems, and that can improve animal productivity.

5.3.1.4 Livestock fatality

The profitability of livestock farming is highly affected by the mortality of animals. Table 5.6 indicates the frequency and percentage of livestock fatalities in relation to different causes. Over half of the farmers (55.19%) asserted that the main contributing factor to the livestock fatality is the lack of pastures. This is in congruence with Table 5.6 where 90% of the farmers outlined that there is a tremendous decline in pastures available. This view is in accord with Turpie et al. (2002) and Notenbaert et al. (2010), who established that there is a decline in pastures for livestock. The lack of drinking water follows suit with 39.89%, however, 60.11% do not consider drinking water that important. Heat stress/ cold, unknown disease, and floods accounted for 34.70% and 29.23% and 20.22% out of a hundred respectively, but the 65.30%, 70.77%, and 79.18% suggested otherwise.

Table 5.6. Frequencies and respective percentages of smallholder farmers' livestock fatality

Factors contributing to the loss of livestock		Frequency	Percent
Heat stress/ cold	No	239	65.3
	Yes	127	34.7
	Total	**366**	**100**
Lack of feed	No	164	44.81
	Yes	202	55.19
	Total	**366**	**100**
Lack of drinking water	No	220	60.11
	Yes	146	39.89
	Total	**366**	**100**
Unknown diseases	No	259	70.77
	Yes	107	29.23
	Total	**366**	**100**
Floods	No	292	79.78
	Yes	74	20.22
	Total	**366**	**100**

DEA (2017a) supports the claim that the temperature increase is affecting livestock with an issuing of the general increase in temperature over the past century. The potential impacts on livestock include changes in production and quality of feed crop and forage (Polley *et al*., 2013). Because of these, the smallholder livestock farmers are highly exposed to the climate change impacts.

5.3.2 Early warning system

Wigmore (2019) 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 disasters prior to their 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 interpretation of the early warning signs: 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 5.7 shows the frequencies and the percentage of the availability of the early warning system and operational level in Limpopo and Mpumalanga smallholder farmers. The majority of the smallholder livestock farmers (80.77%) do not have any mode of early warning system. A further 16.76% are not aware of any early warning system. Only 2.47% were aware of early warning systems. Out of those aware of the early warning system, they classified the system into the key stakeholders responsible. The disaster management was reported to be the most well-known early warning system provider, with 57.14%. Secondly, the dryness of streams was also an imperative indicator of the severity of the drought by 28.57%. Lastly, 14.29% are reliant on the local radio for weather forecasting. The District Municipality also offers the early warning system in the form of weather forecasting at 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 have to absorb the entire shock 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 is informative. Only 2.03% believe that the early warning is an effective tool to get them prepared for the onset of the drought. In order 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 the majority of the smallholder farmers are caught off guard when such events unfold.

Subsequently, they have to absorb the total impacts of the extreme event due to their unpreparedness. These, therefore, indicate that the smallholder farmers are highly exposed to the impacts of the climate extremes that are subsequent to climate change.

Table 5.7. Frequencies and respective percentages of smallholder farmers' perception of the availability of the early warning system

Availability of Early Warning Systems		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 consultations with key agricultural advisors, the early warning system of the government is operational and effective at a level of less than 30%. 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 Forecasts 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 into 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.

5.3.3 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 them. Table 5.8 shows the frequencies and the percentage of the contingency to curb the impacts of climate change on livestock.

Table 5.8. 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**

In spite of the absence of an early warning system, 84.36% of the smallholder livestock 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 it strikes. This translates to financial losses in the form of livestock death when there is a disaster, impeding for a serious need for disaster preparedness seminars. The respondents who confirmed the existence of the contingency plan also revealed the intrusive aspects of the plan. Table 5.9 indicates the evolution that the contingency plan has 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 transformed within the past 5-10 years. This illustrates an attempt to stay relevant in an attempt 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 integrated into their existing models. 4.44 and 2.22% indicated that there was the provision of the water resource and the erection of a dam, respectively.

Table 5.9. Frequencies and respective percentages of smallholder farmers' perceptions of 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 has 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
Does 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 adjustments 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, Food security was not part of the contingency (96.64%), while 3.36% suggests otherwise.

5.4 CONCLUSIONS

The study of the perception of smallholder farmers on the impact of climate change has shown the level of exposure that affects their daily choices for their livelihood. Their awareness and knowledge of climate change underlie an imperative prerequisite in their exposure to the impacts of climate change. Though multiple stakeholders capacitated farmers with climate change information, their level of education impedes their understanding of this phenomenon in their livestock business ventures. Unexpectedly, almost all livestock farmers (98.58%) have not heard about climate change from the government. On the other end of the spectrum, radio was the most imperative medium for the conveyance of climate change information. Almost all farmers (94.32%) receive climate change-related information through the radio. It may also be a consequence of the language being used by the radio, which is mostly their indigenous languages. The intervention that could empower the farmers will be regular workshops within commodity groups on climate change. Unfortunately, 95.89 % of the farmers have not attended a workshop on climate change.

The manifestation of climate change to smallholder farmers is identified through drought. The majority of the farmers (77.87%) identified a dip in rainfall quantity and frequency as the major visual evidence of the decline due to climate change. The other evidence is the loss of natural grazing, almost all farmers (90%) confirmed that there is a change in grass availability. With the consideration that the majority of the livestock farmers participate in cattle farming, this is a critical impact as animals rely on grazing. The majority of the respondents (70.22%) also outlined that the shrubs dominate the pasture, which is symptomatic of overgrazing. Consequently, over half of the farmers (55.19%) asserted that the main contributing factor to the livestock fatality is the lack of pastures. When smallholder farmers were exposed to extreme weather, they did not comprehend the events as part of the climate change phenomenon. The following percentage of the farmers indicated that each of these factors does not conform to climate change: tropical cyclones 95.63%; land erosion/degradation 93.17%, destruction of buildings 98.91 and unpredictable seasons (short or long rainy season) 96.17%.

It can be concluded from the study that the early warning system of the government is operational and effective at a 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 Forecasts 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 into 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' perception, 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 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.

5.5 REFERENCES

FAO, 2007. Adaptation to climate change in agriculture, forestry, and fisheries: perspective, framework and priorities. FAO, Rome

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Ibrahim,M., Guerra, L., Casasola, F., and Neely, C. 2013. Importance of silvopastoral systems for mitigation of climate change and harnessing of environmental benefits. In: Integrated Crop Management - Policy Support Guidelines for the Promotion of Sustainable Production Intensification and Ecosystem Services, Chapter X - Grassland Carbon Sequestration: Management, Policy and Economics. 189 – 196

Ibrahim, M.A. 1994. Compatibility, persistence and productivity of grass-legume mixtures for sustainable animal production in the Atlantic zone of Costa Rica. Ph.D. – Thesis Wageningen, Netherlands, Wageningen Agricultural University.

Kala, N., Kurukulasuriya, P., and Mendelsohn, R. (2012). The impact of climate change on agro-ecological zones: Evidence from Africa. Environment and Development Economics, 17(6), 663-687. Retrieved from http://www.jstor.org/stable/26265545

Kotir, J. (2011) "Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security," Environment, Development, and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 13(3), pages 587-605, June.

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2012) Indicators for Assessing the Vulnerability of Smallholder Farming to Climate Change: the Case of Brazil's Semi-Arid North-eastern Region. Poverty Practice, Bureau for Development Policy, UNDP Esplanada dos Ministérios, Bloco O, 7º andar, 70052-900 Brasilia, DF - Brazil

Maddison, D. (2007). The Perception of and Adaptation to Climate Change in Africa. Policy Research Working Paper 4308

Maluleke WI; Mokwena R. J. (2014). The effect of climate change on rural livestock farming: case study of Giyani Policing Area, Republic of South Africa. S Afr. Jnl. Agric. Ext. vol.45: 26-40

Morton JF. 2007 The impacts of climate change on smallholder and subsistence agriculture. Proc. Natl Acad. Sci. USA 104, 19 680–19 685. (doi:10.1073/ pnas.0701855104)

Mpandeli, S. and Maponya, P. (2014). Constraints and Challenges Facing the Small Scale Farmers in Limpopo Province, South Africa. Journal of Agricultural Science; Vol. 6, No. 4

Mwituribani, D. A. and van Wyk, J. 2010. Climate Change & Natural Resources Conflicts. Monograph 170. Institute for Security Studies.

Ormsby, T.; Napoleon, E.; Burke, R.; Groessl, C.; Feaster, L. 2001. Getting to know ArcGIS desktop. Basics of ArcView, ArcEditor and ArcInfo. Redlands, Ca. ESRI Press.

Polley, H.W., Briske, D.D., Morgan, J.A., Wolter, K., Bailey, D.W., Brown, J.R., 2013. Climate change and North American rangelands: trends, projections, and implications. Rangeland Ecol. Manage. 66, 493–511

Scholze,M, Knorr, W, Arnell, N.W and Prentice, I.C. 2006. A climate-change risk analysis for world ecosystems. PNAS vol. 103no. 35 www.pnas.orgcgidoi10.1073pnas.0601816103

Smit, B., Burton, I., Klein, R., Wandel, J., 2000. An anatomy of adaptation to climate change and variability. Climatic Change 45, 223–251.

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y. and Nkem, J. (2012), “Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon”, Forest Policy and Economics, Vol. 23, pp. 1-9.

Tadesse, M., 2010. Living with adversity and vulnerability: Adaptive strategies and the role of trees in Konso, Southern Ethiopia. Ph.D. Thesis, Swedish University of Agricultural Sciences, Uppsala.

Turpie, J. K., Adams, J. B., Joubert, A., Harrison, T. D.,Colloty, B. M., Maree, R. C. Whitefield, A. K.,Wooldridge, T. H., Lamberth, S. J. Taljaard,S. And L. Van Niekerk 2002 — Assessment Of The Con-Servation Priority Status Of South African Estuaries For Use In Management And Water Allocation. Water Sa: 191– 206

Urama, K.C. and Ozor,N. 2010. Impacts of Climate Change on Water Resources In Africa: The Role Of Adaptation. African Technology Policy Studies Network (ATPS)

Wigmore, O., Mark, B.G., McKenzie, J., Baraer, M., Lautz, L. (2019). Sub-metre mapping of surface soil moisture in proglacial valleys of the tropical Andes using a multispectral unmanned aerial vehicle. Remote Sensing of Environment, 222:104-118

CHAPTER 6: MANAGING DISTRICT IN LIMPOPO PROVINCE, SOUTH AFRICA CLIMATE RISKS USING SEASONAL CLIMATE FORECAST INFORMATION IN VHEMBE

Abstract

In this paper, the role of climate information as a strategy to manage climate risk is outlined, including various coping and climate change adaptation strategies. Some of these strategies used to counteract climate risk are traced, drawing from various international and local case studies. The majority of small–scale farmers in the Vhembe district have been experiencing extreme climatic risk, high climate variability, and change for a very long time. The majority of these small–scale farmers are vulnerable to all types of climate risk due to their low adaptive capacity, lack of access to technology as a result of level of education, lack of financial resources, and also among other things, low level of resilience and high level of poverty amongst these farmers. However, the majority of these small – scale farmers in the Vhembe district use different adaptive strategies as a way of preserving assets for future livelihoods, including: (a) Drought resistant varieties, (b) Crop diversification, (c) Plant crops that require less water, (d) Some of these small – scale farmers use local climate indicators to monitor climate risk, (e) Adjust fertilizer input, (f) Use rainwater harvesting techniques. Different institutions in the country, including the South African Weather Services, the Agricultural Research Council, and the Limpopo Provincial Department of Agriculture, issue and disseminate the seasonal forecast information to different districts, including the Vhembe. Most of the time, the information has been disseminated to end-users in simple ways, but the need to find out more about end users' needs is still required.

6.1 INTRODUCTION

Since 1994, the South African Weather Service (SAWS) has been actively involved in research around the seasonal time-scale of climate predictions (Klopper *et al*., 1998; Landman and Manson, 1999; Tennant, 1999; O'Brien *et al*., 2000), to provide the best possible information on future climate conditions so that the risk in economic and social decisions is reduced. Climate information, even if provided in a perfect forecast, has limited value if it cannot be understood and used by the recipient to support the decision-making process (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). Most studies of the value of the seasonal forecast have been conducted in the developed world (Mjelde *et al*., 1988; Lyakhou, 1994; Mosley, 1994; Mason, 1996; Nicholls, 1996; Mjelde *et al*., 1997; Landman and Mason, 1999; Letson *et al*., 2001; Klopper and Landman, 2003; O'Brien and Vogel, 2003). This paper will add to the few studies conducted in the southern African region. Various mechanisms have been used by several organizations to disseminate climate forecast information by distributing fliers, newsletters, electronic and printed media, technical briefs, etc.

Forecasts, moreover, need to be expressed in the language of the users, providing the communities with possible appropriate alternatives to current production methods (Price, 1995; Arctic Council, 1995; Blench, 1999; Stern and Easterling, 1999; Stricherz, 1999; Letson *et al*., 2001; Valdivia and Gillies., 2003; Easton, 2004b; Hansen *et al*., 2004; Ziervogel *et al*., 2004). Blench (1999) and Finan (1999) argue that these forecasts will probably be useful only to certain types of producers, as not all farmers can equally access or use the information. It also requires that trust and communication exist between users and providers of climate forecasts (Finan, 1999).

Effective use of seasonal forecast information that is useful to farmers, however, is wider than just issuing a forecast and includes a process of examining the current needs, problems, and context in which users operate. The use of forecasts, however, provides more than just information about the forecast. The highly variable nature of rainfall in southern Africa enhances the potential use and value of reliable seasonal forecasts in the decision-making processes of different sectors. The knowledge that rainfall is so variable imparts considerable inertia on the implementation of such a process that may also often require major shifts in policy and redirection of investments (Mjelde *et al*., 1996; Nicholls, 1996). Using climate forecasts to better manage climate-sensitive sectors such as agriculture is a new frontier in climate-risk management, with potentially very significant implications for farmers (IRI, 2000). Seasonal climate forecasts also require further integration into agricultural management (Orlove and Tosteson, 1999; Wilbanks and Kates, 1999; Unganai, 2000; McGee, 2004; Ritchie *et al*., 2004).

Seasonal climate, forecast information in farming communities is increasingly becoming an option to manage risk due to the variable environment in which farmers operate, heightened by the increasing pressure of the cost of inputs such as seeds, fertilizer, and herbicides (Nicholls, 1996). As a result of lower yields, some farmers are unable to recover financial costs due to the high cost of inputs. Seasonal climate forecasts may thus help farmers to make more informed decisions for farm management based on the seasonal climate information. For the seasonal climate forecast to be useful to farmers, however, the information must be accurate, reliable, and meaningful. The user must be able to understand and interpret the information. Various institutions, such as SAWS, ARC, PDA, and various academic institutions, disseminate seasonal climate forecast information through different structures before the season starts in the form of an advisory. The objectives of this paper are: (a) to understand how farmers in the Vhembe district are managing climate risks from 1920 to the present. (b) This paper seeks to understand how farmers in Limpopo Province are managing risk and mid-season dry spells during the growing season. (c) Analyse the impact of rainfall variability during the growing season in the Vhembe district.

6.2 RESEARCH METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim of creating independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

6.2.1 Study area

According to Van Averbeke (2013:18), Vhembe borders Zimbabwe in the north and Mozambique in the east. It incorporates the territories of two former homelands of Venda and Gazankulu. The Venda homeland was created for the Venda-speaking people. Gazankulu was the territory allocated to the Tsonga-speaking people, also known as the Shangaan. Culturally, the VhaVenda are closely associated with the Shona people of Zimbabwe, whilst the cultural roots of the Shangaan are in Mozambique. The South Africa Political Map, which also depicts the Vhembe District is shown in Figure 6.1.

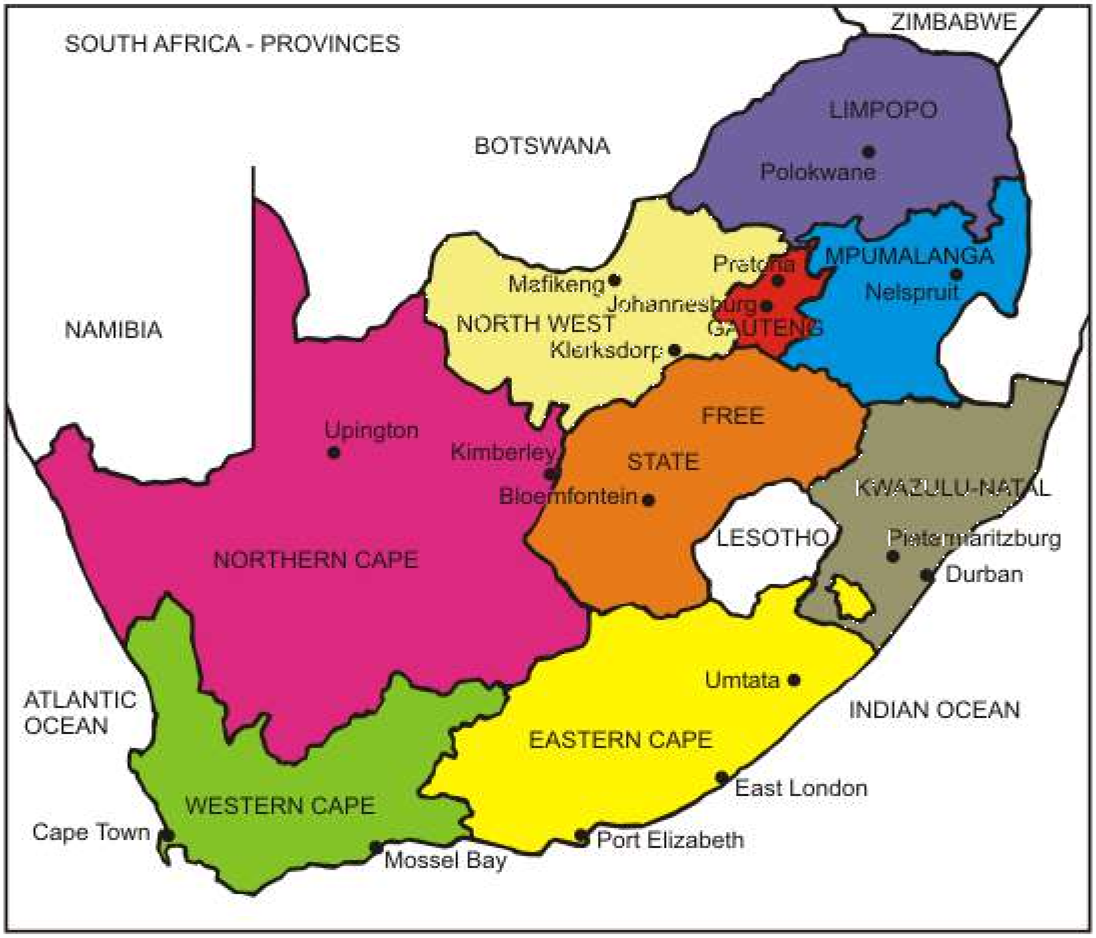


Figure 6.1. **Political map of South Africa with provinces**

6.2.2 Materials and methods

This section has been written to be a stand-alone part of each chapter with the aim of creating independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

Two methods were used to analyse the results from this paper, and these include:

(a) Mean annual rainfall map:

The rainfall data were downloaded from the AgroMet databank at the ARC-ISCW (South African Weather Service and ISCW weather stations) from 1920 – 1999 with a recording period of 10 years or more. Regression analysis and spatial modelling were utilized during the development of the surface.

(b) SPI time series:

Rainfall GIS surfaces, covering South Africa, have been produced from data within the ARC-ISCW Climate Databank. The databank holds historical data from the South African Weather Service and the ARC-ISCW. Monthly rainfall GIS surfaces are produced from the historical rainfall data over the period from 1920-2013. The rainfall surfaces are produced as follows:

- Rainfall data from between 1200 and 3000 mechanical and automatic stations are extracted.
- The long-term average rainfall for a specific month is used as a trend surface for interpolation
- Rainfall at a specific point is expressed as a percentage of the underlying rainfall trend surface
- The rainfall percentage values for a specific ten-day period are interpolated using the inverse distance weight method.

The method results in a monthly rainfall surface that is true to the points where rainfall is recorded, but follows the climatology resulting from the influence of factors such as topography or distance from the ocean. The rainfall surfaces from 2003 onward are created through a combination of the above-mentioned method and satellite rainfall estimates to supplement rainfall data over the South African plateau. The resulting monthly rainfall surfaces are summarized to the quaternary catchment (These are represented by +/- 1700 polygons in a GIS, covering the surface area of South Africa). For each catchment, the rainfall at a monthly to 48-month time scale is transformed into a Surface Precipitation Index (SPI) value for the catchment. The result is an SPI dataset for several time scales for each month since 1920. The SPI values can be used to study the time series of drought intensity classes by considering the traditional classification of the SPI ranges.

6.3 RESULTS AND DISCUSSIONS

The high rainfall variability in Limpopo Province and some other parts of the country has led some farmers to use seasonal forecast information for farm planning and decision making. Daily weather forecasts allow farmers to plan their daily activities. The daily weather forecast is provided by the SAWS through both the print and the 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 (Figure 6.2). 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 is given as probabilities and not as deterministic.

A probability forecast outlines how likely an event is to occur, as a percentage, and can assist farmers to be aware of the risks associated with weather and climate events. Seasonal climate forecasts are grouped into three categories of rainfall probability (a) above-normal (wet conditions), (b) near-normal (around average), and (c) below-normal (dry conditions) (Figure 6.2). The first category in the below normal, shows a 50 % probability of rainfall to be above normal. The second category shows a 30% probability for near-normal rainfall, and the third category shows a 20 % probability for below-normal rainfall (Figure 6.2).

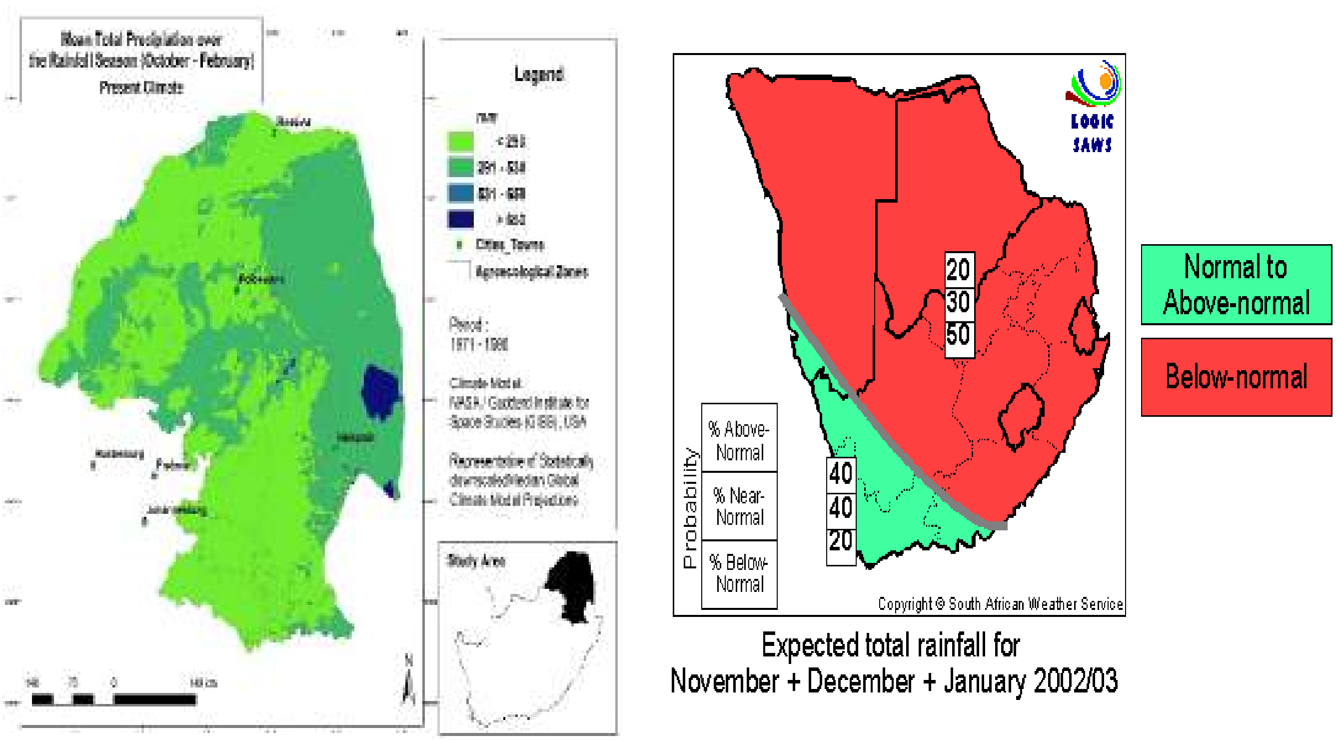


Figure 6.2. **Mean total precipitation over the rainfall season (October – February)**

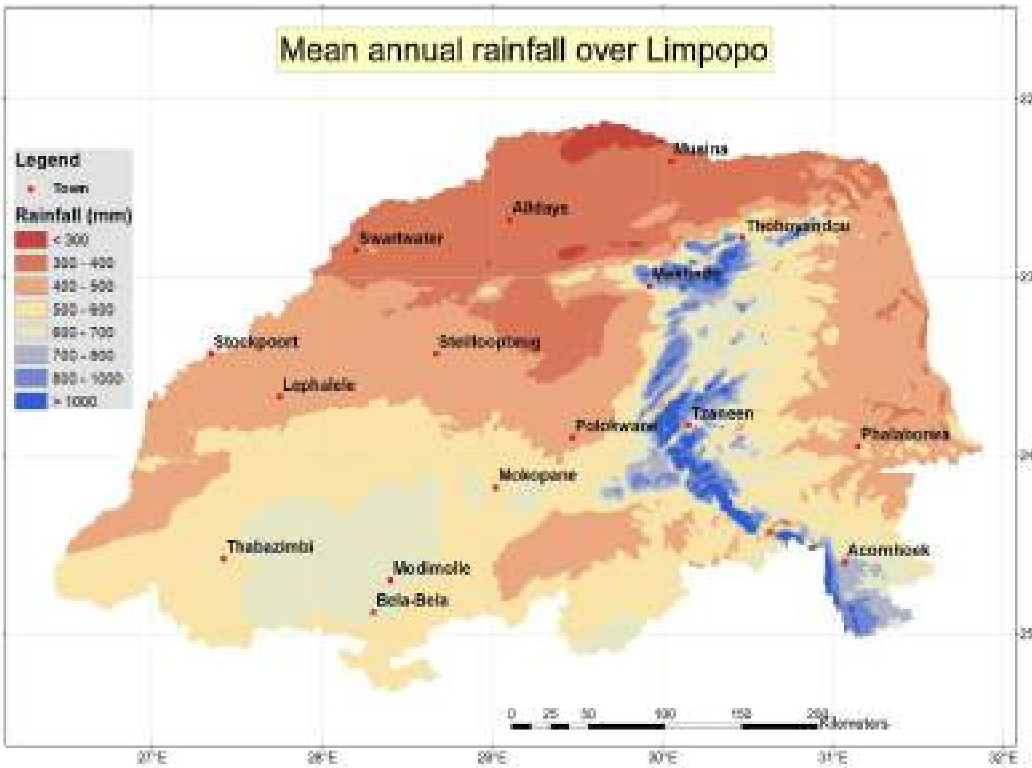


Figure 6.3 **Mean annual rainfall map for Limpopo Province: (Source: ARC-ISCW, 2014)**

The average annual rainfall in the Vhembe district is 820 mm. The rainy season starts in October in most areas of the Limpopo Province, especially in the Vhembe district. The rainfall pattern peaks in January-February months, and thus, when floods are also expected (Figure 6.3). Rainfall exceeds the potential evapotranspiration in months (December to March). It was also noted that the meteorological drought is the result of the negative deviation of rainfall from the mean and is normally the most common indicator for drought (Wilhite *et al.,* 2000; Wilhelmi & Wilhite, 2002). Limpopo Province has high climatic variability and change, and therefore, farmers need to have seasonal climate forecast information or projections in advance in order for them to be able to plan their farming calendar accordingly. Figure 6.3 shows that the Makhado and Thohoyandou areas in the Vhembe district are located in micro-climatic areas. In the Vhembe district, for example, the highest average monthly amount of rainfall received is normally from November to March every year (Mpandeli, 2006).

February usually records the highest rainfall of more than 184 mm. During the winter months, from May to August, the climate is warm during the day with dry air prevailing. The temperature can drop sharply in the evenings. During the winter period, less than 20 mm of rainfall monthly is usually received in the Vhembe district, with the average rainfall dropping to 8 mm during August in 2003 (Mpandeli, 2006).

The majority of the farmers in Limpopo Province generally start planting their summer crops during September. The mean annual rainfall figures from Figure 6.3 indicate very low rainfall, especially in areas such as Musina, Alldays, and Swartwater; therefore, the mean annual rainfall in these areas is less than 300mm. In areas such as Musina, Alldays, and Swartwater, farmers respond differently to drought and extreme climatic events. According to Mpandeli (2006), commercial farmers generally have more choices during drought than subsistence and small–scale farmers. Because the majority of the commercial farmers have strong financial backups, they could easily switch their enterprise to a safer environment or to an area where they will be able to cope and adapt easily, and most of the commercial farmers had enough reserves their activities even if they are farming in new areas. However, for subsistence and small–scale farmers, they have limited options due to the fact that these farmers do not have enough financial resources, they do not have collateral or security in case they need loans from banks, compared to the commercial farmers in the area.

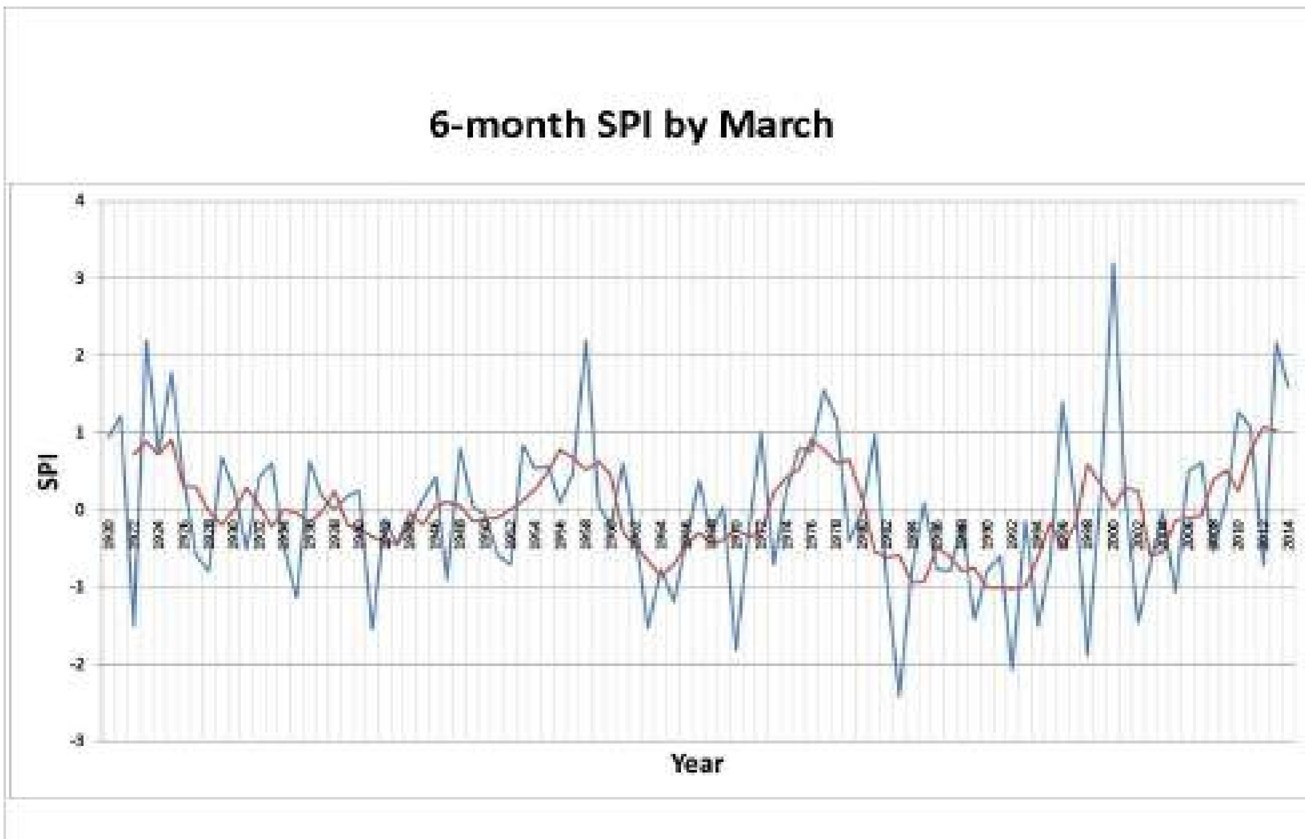


Figure 6.4. Six-month Surface Precipitation Index (SPI) for the quaternary catchment encompassing Musina, in Vhembe district of the Limpopo Province for the period 1920 to 2014.

Figure 6.4 shows the 6-month SPI for the quaternary catchment encompassing Musina from 1920 – 2014. Multi-year dry periods are indicated. The clustering of dry years exacerbates the effect of low rainfall. Figure 4 shows that the Musina area in the Vhembe district received significant Surface Precipitation Index for the following years 1924, 1958, 1977, 1986, 2000 and 2013. This area had more than 1.5 SPI above the mean.

It was noted that the serious dry spells were experienced in the following years in the Musina area 1922, 1941, 1970, 1983 and 1992. The lowest year was 1983 with – 2.45 below the mean. During the dry spells in the Musina area, the majority of farmers lost large numbers of livestock, a shortage of drinking water, low yields, and shortage of seeds for subsequent cultivation (Mpandeli and Maponya, 2014). The driest periods in the Musina area were in 1983, the majority of farmers had to seek assistance from the South African government and most of these farmers were commercial farmers (Figure 6.4). Low SPI values indicate drought conditions, and high values indicate very wet conditions.

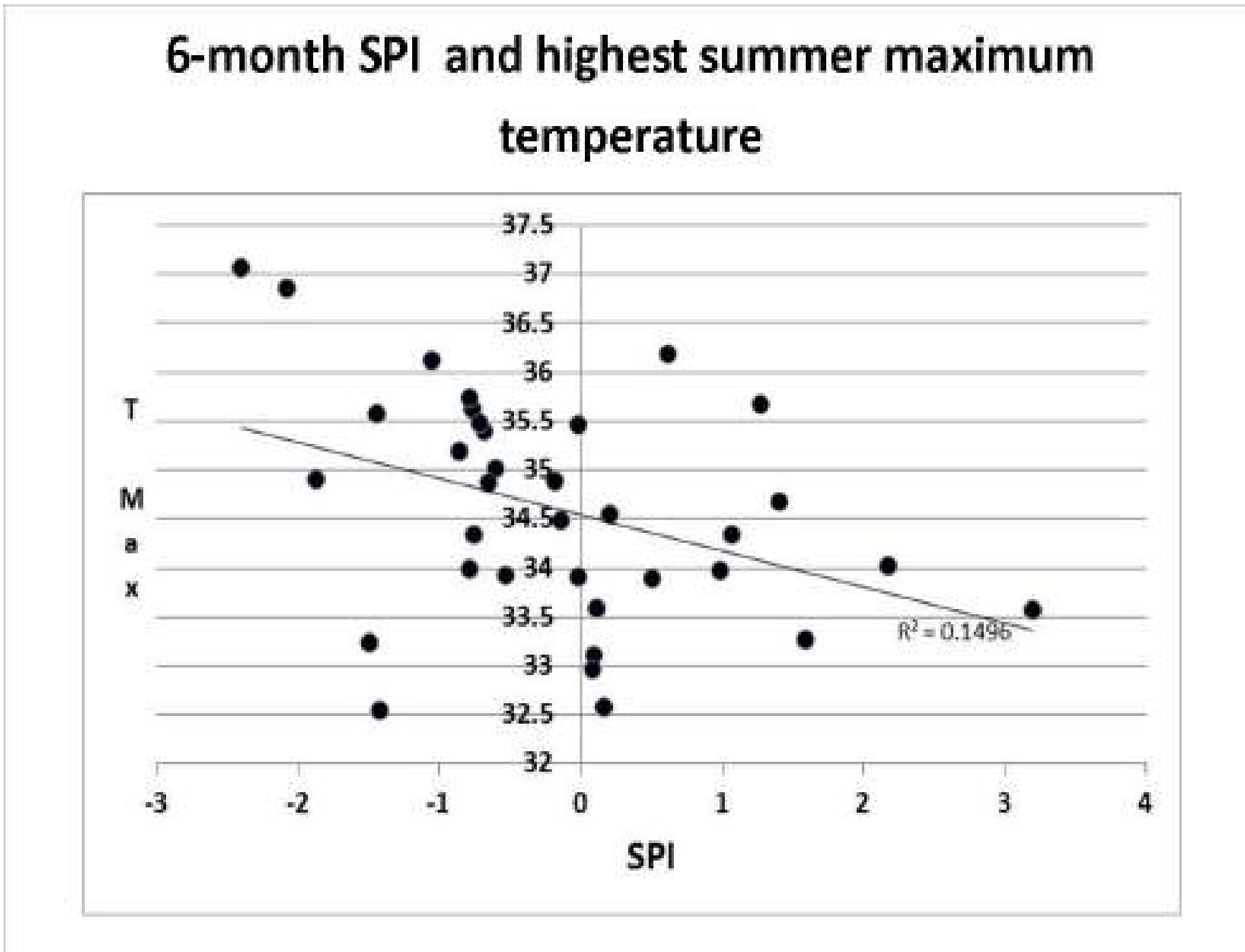


Figure 6.5. Six (6)-month SPI and summer maximum temperature in Vhembe district, Limpopo Province

Figure 6.5 shows the SPI and TMax since 1980 shows the inverse relationship between summer rainfall (6-month SPI) and the highest maximum temperatures during the summer – showing that during dry years, higher temperatures increase the negative impact of low rainfall through increased potential evapotranspiration. Vhembe district sometimes experiences extremes in temperatures. When the temperature is high, there is also a high probability of evaporation during that particular period (Figure 6.5). Temperatures, for example, can reach more than 35˚C during summer. According to Mpandeli (2006), the average monthly maximum temperature most of the time can reach more than 35˚C especially during summer (Mpandeli, 2006). Occasional frosts that may occur from early June to mid-August are a feature of the area from 1995 to 2003. During the winter months, cold fronts normally occur, and these conditions can damage crops and livestock.

It is important to note that farmers in the Vhembe district have always applied different coping and climate change adaptation strategies to increase production during drought periods, including: Adjust fertilizer inputs, (b) Practice crop diversification, (c) Food preservation, (d) Adopt destocking during uncertainty periods. Drought, for example, has also been a recurrent phenomenon occurring in the 1960s, 1980s, 1990s, 2002 and 2003 (Tyson and Dyer, 1978; Vogel *et al*., 2000; Adger et al., 2002; Kihupi *et al*., 2003; Mpandeli, 2006). Drought frequently adversely affects agricultural production in various provinces, including Limpopo, Free State, and Northern Cape (e.g., *Sowetan*, 2003).

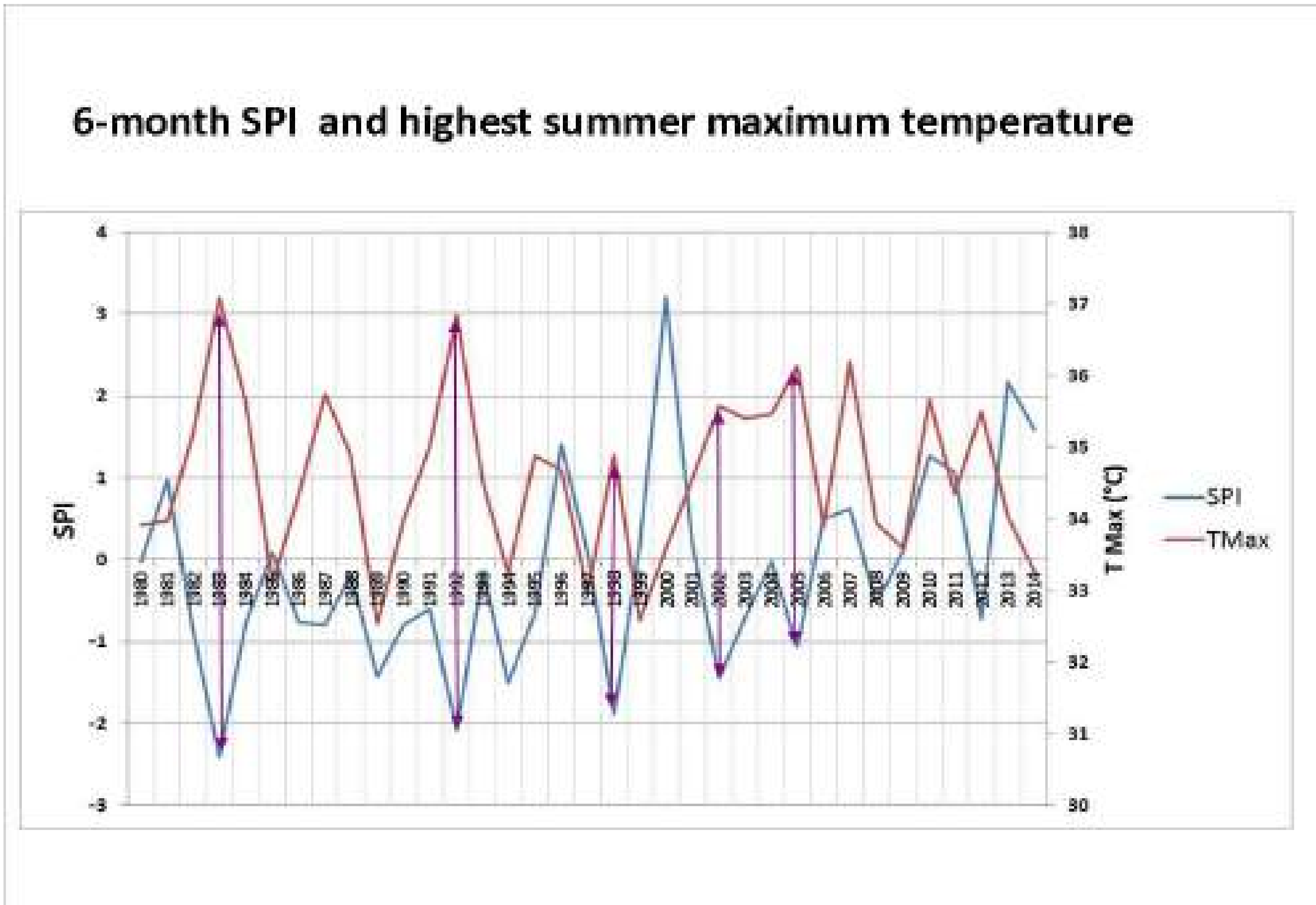


Figure 6.6. Surface Precipitation Index and summer maximum temperature in Vhembe district, Limpopo Province for the period 1980 to 2014

Figure 6 shows that the SPI and TMax since 1980 shows the inverse relationship between summer rainfall (6-month SPI) and the highest maximum temperatures during the summer – showing that during dry years, higher temperatures increase the negative impact of low rainfall through increased potential evapotranspiration. Vhembe district sometimes experiences extremes in temperatures.

When the temperature is high, there is also a high probability of evaporation during that particular period (Figure 6.6). Temperatures, for example, can reach more than 35˚C during summer. The average yearly maximum temperature from 1980 to 2014 during summer was 37˚C. Figure 6.7 shows that the highest maximum temperature was experienced in 1983, 1992, 2005 and 2007. Farmers in this area need to come up with varying coping and climate change adaptation strategies, including: (a) Use of drought resistant seeds, (b) Use early matured crop varieties, (c) Practice crop diversification system (e) Changing farming practices, (f) Use seasonal climate forecasting etc. According to Sivakumar (2000), climate information is very useful because it assists farmers to be able to plan their agricultural calendar accordingly.

For example, if farmers can access climate information in advance on issues such as early warning of drought, farmers can counteract any threats posed by drought impacts on time as long as the information is reliable, accurate, and also simple to interpret and understand. Problems and constraints that might come as a result of climate change include high temperatures, decreased precipitation, incidence of fungal crop diseases such as army worm, destruction of habitats, environmental degradation, and extinction of plants and animal species (Matarira et al., 2004).

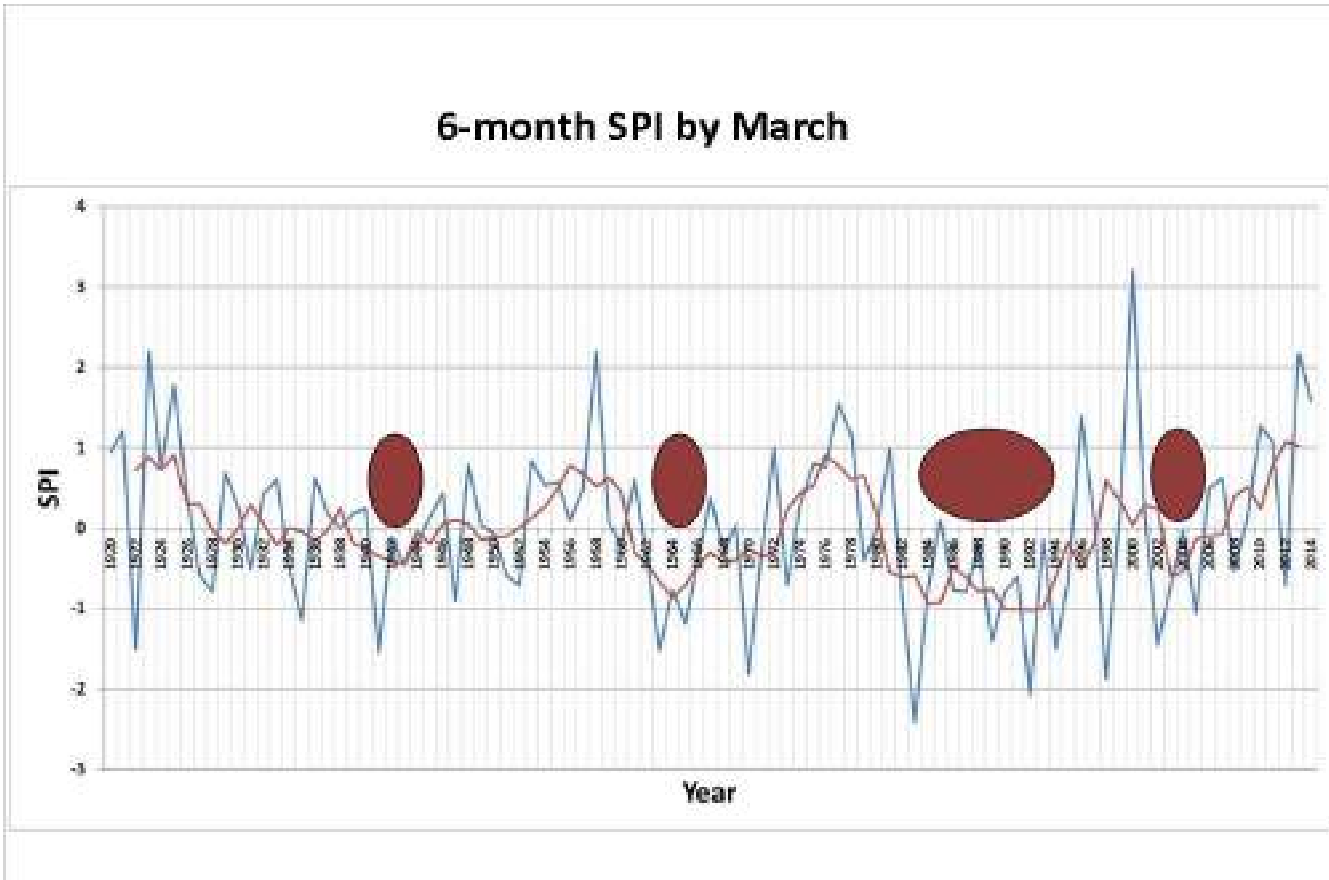


Figure 6.7. Surface Precipitation Index from 1920 to 2014 in Vhembe district, Limpopo Province for the period 1920 to 2014

Climate information, including seasonal climate forecasts, has been heralded as a promising tool for early-warning systems and agricultural risk management in Southern Africa (Vogel, 2000 and Vogel et al., 2000). The climate of the Limpopo Province, as indicated previously, is usually hot and is characterised by hot summers and dry winters. Rainfall can vary markedly over time (Figure 6.7). The highest annual average rainfall recorded in 2000, for example, was 1612 mm (Mpandeli, 2006). According to Mpandeli (2006), heavy rain in the year 2000 resulted in flooding, loss of properties, loss of human life and loss of agricultural production. The lowest average annual rainfall recorded was 438 mm in 1992.

Limpopo Province has been characterised by low rainfall and recurrent drought problems, especially in 1981/84, 1988/89, 1991/92, and 2004, and these hinder agricultural production in the province. The majority of farmers in 1992 lost high volumes of crops and livestock due to shortages of water and because of drought problems during that year (Mpandeli, 2006).

6.3.1 Living with drought in the Vhembe district

According to Mpandeli and Maponya (2014), Limpopo Province is characterised by high climatic variability. This is a serious problem in Limpopo Province, considering the fact that the province is in a semi-arid area with low, unreliable rainfall. The rainfall distribution pattern, for example, in the Vhembe district is characterized by wet and dry periods depending on the geographical location. In the Vhembe district, high rainfall is usually experienced in the Tshakhuma and Levubu areas. Most of the rainfall received in the Vhembe district is in the form of thunderstorms and showers, and this makes rainfall in the district vary considerably (Mpandeli and Maponya, 2014). The impact of lower rainfall has negative effects on the agricultural sector, low rainfall resulting in decreases in agricultural activities, loss of livestock, shortage of drinking water, low yields, and shortage of seeds for subsequent cultivation (Mpandeli and Maponya, 2014).

6.3.2 Vegetation characteristics and drought impacts in the Vhembe district

In the Limpopo Province, the condition of the vegetation is a major concern for livestock farmers. The Limpopo Province is characterized by different kinds of veld types; the kind of veld type differs especially in the morphology, palatability, and the nutritive value. Sweet veld grass is found around the Thohoyandou area in the Vhembe district, and the sweet veld grows in frost-free and low-lying areas (Acocks, 1998). Sourveld grows mostly in the Tshakhuma area; these types of grass usually grow in a high rainfall area. The quality and status of vegetation can be severely impacted by drought periods. One way to monitor the condition of the vegetation is to use the Normalized Difference Vegetation Index (NDVI). A relationship between rainfall and vegetation status exists, usually expressed as an index the NDVI. This index generally shows the presence and absence of green vegetation (Figure 6.8). Since green vegetation reflects more infrared radiation than visible radiation, the higher the value of NDVI, the higher the vegetation activity. An example of the relationship between periods of drought and vegetation can be observed in Figure 6.8.

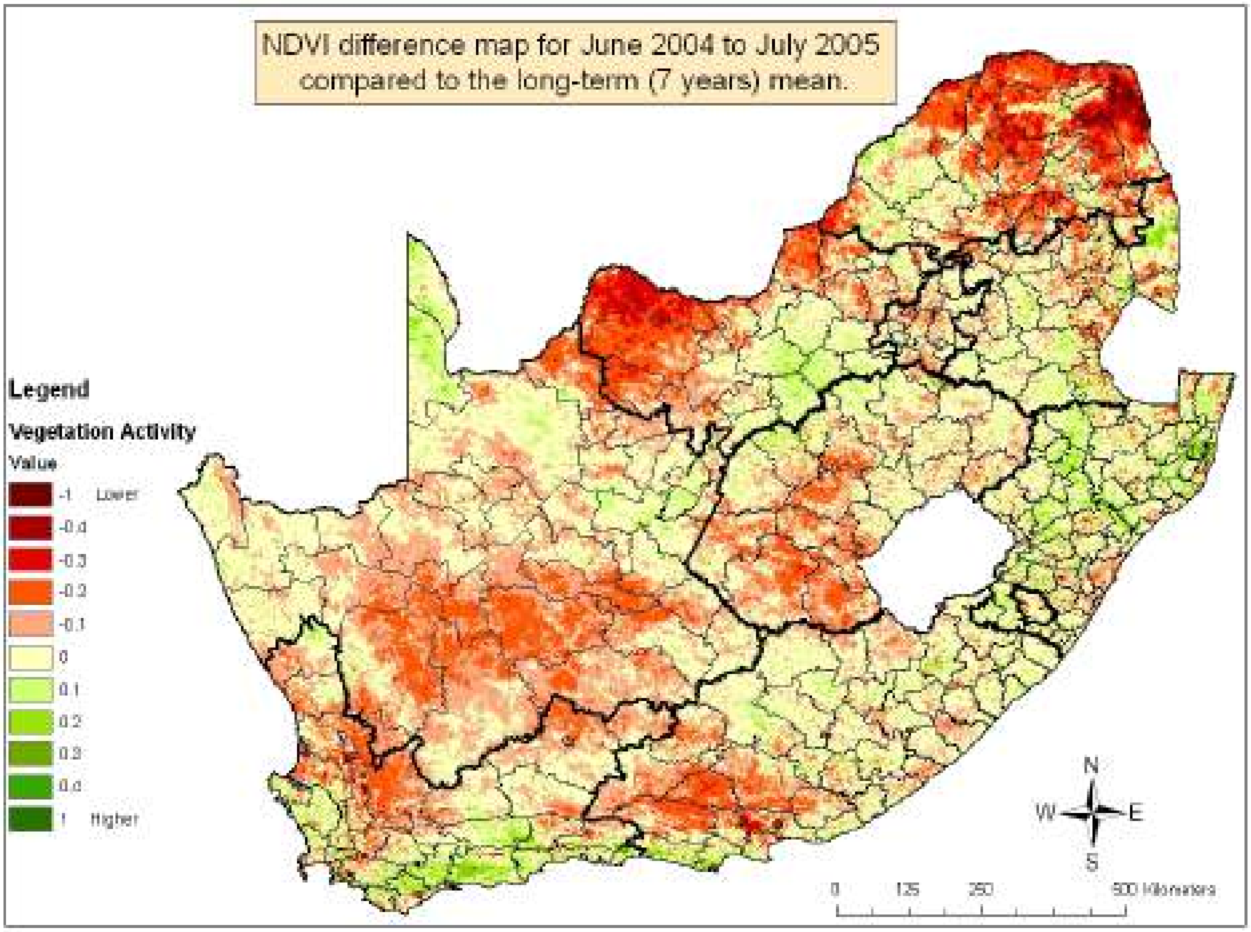


Figure 6.8 Normalised Difference Vegetation Index for June 2004 to July 2005, compared to the long-term mean for seven years: (Source, ARC-ISCW, 2005)

NDVI can thus be displayed and interpreted spatially over time. For example, from Figure 6.8, one can infer that the rainfall distribution was very low in Limpopo Province compared to other parts of the country for the period June 2004 to July 2005. The red colour in most parts of Limpopo Province shows that the vegetation activity was lower than normal over this period. The green colour shows that there was higher vegetation than normal. In areas where the green colour dominates, there was a good rainfall distribution (Figure 6.8). The combination of these factors, for example, low rainfall, poor vegetation condition, and a range of other constraints, heightened during droughts, unfortunately, produces a range of additional stress for farmers in the area. Poor vegetation usually means poor grazing and, therefore, poor cattle condition. This can further translate into loss of livelihoods as poor cattle often receive poor market prices.

Older farmers in the Vhembe district indicated that drought has been a recurring process since the 1950s, and this was confirmed by results from Figure 6.6. Some farmers stated that in 1992, they had severe drought problems resulting in a shortage of grazing and crop failures in many parts of the district (Bakali, pers. comm., 2004). Livestock was slaughtered, and farmers had to sell their livestock at prices as low as R5 per unit. The drought impacts in 1992 increased farming debt and affected food exports in the province (Koch, pers. comm., 2005 and Mpandeli, 2006). According to Mpandeli (2006), farmers in the Vhembe district describe drought based on the following factors: food and feed shortages, low rainfall, decrease in water availability, dying vegetation and animals etc. These factors were also highlighted by O' Farrell et al. (2009). According to O' Farrell et al. (2009), farmers described drought in terms of the way it affected the agricultural systems.

6.4 CONCLUSIONS AND RECOMMENDATIONS

Farmers have used a variety of information sources to help them manage climate risk. These farmers, for example, have been exposed to scientific climate forecasting, with some starting to use the information as a guide during the decision-making process. The rainfall distribution patterns in the Vhembe district various from area to area and small-scale farmers are using various coping and climate change adaptation strategies, including: (a) Crop diversification, (b) Early planting strategies, (c) Plant crops that require less water, (d) Some farmers use local climate indicators, for example cloud formation as part of the decision making tool, (e) Changing farming practices. If small–scale farmers in the Vhembe district are planning to obtain higher yields, they should use several climate change adaptation strategies in order to have good agricultural production and be able to sustain their livelihoods. The fact that these small–scale farmers are situated in a semi–arid area with high climatic variability and poor rainfall distribution makes farming very difficult to manage.

6.5 REFERENCES

Adger, W. N., Huq, S., Brown, K., Conway, D and Hulme, M., 2002: Adaptation to climate change: Setting the Agenda for Development Policy and Research, Progress in Development Studies, 3(3), 179-195.

Arctic Leaders' Summit Declaration, 1995. The Declaration on its establishment recognized 'the traditional knowledge", Arctic Council Press release. Ottawa, Canada.

Bakali, agricultural scientist, personal communication, 2004.

Blench, R., 1999: Seasonal Climate Forecasting: Who can use it and how it should be disseminated? Natural Resource Perspectives, No. 47, November. 25, Overseas Development Institute. UK, Available: http://www. Oneworld.org/odi/nrp/47.html.

Chagnon, S. A., 1992: Gender and Migration in the Developing countries. London: Belhaven Press.

Eakin, H., 2002: Seasonal climate forecasting and the relevance of local knowledge, Physical Geography, 20, 447-460.

Easton, P., 2004b: West African languages: medium and message. In: Indigenous knowledge: local pathways to global development, The World Bank, 64-167.

Finan, T. J., 1999: Drought and Demagognemy: A Political Ecology of Climate Variability in Northeast Brazil, Workshop Proceedings from Public Philosophy, Environment, and Social Justice: October, 21-22, 1999, Carnegie Council on Ethics and International Affairs. New York, USA.

Finan, T. J, Nelson, and D. R., 2001: Making rain, making roads, making do: public and private adaptations to drought in Ceará, Northeast Brazil, Climate Research, 19, 97-108.

Glantz, M. H., 1977: The value of long-range weather forecasting for the West African Sahel, Bulletin of the American Meteorological Society, 58,150-158.

Hansen, J. W., Marx, S., Weber, E., 2004: The role of climate perceptions, expectations and forecasts in farmer decision making: the Argentine Pampas and South Florida, International Research Institute for Climate Predictions Technical Report, 04-01, Palisades, New York.

Huber, T. and Pedersen, P., 1998: Meteorological knowledge and environmental ideas in traditional and modern societies: the case of Tibet, Journal of the Royal Anthropological Institute, 3, 577-598.

IRI (International Research Institute for Climate Prediction)., 2000, Proceedings of a conference held on 20 July 1992 at IDS, Sussex, UK. Internet site: http: //iri. Ucsd. Edu/forecast/ sup/index. Html, accessed June 14, 2000.

Kihupi, N., Kingamkono, R., Dihenga, H., Kingamkono, M., Rwamugira, W., 2003: Integrating indigenous knowledge and climate forecasts in Tanzania. In: Vogel C, O'Brien K (eds). Coping with climate variability: the use of seasonal climate forecasts in Southern Africa, Ashgate, Burlington, Vermont, 155-169.

Klopper, E., Landman, W. A. and Van Heerden, J., 1998: The predictability of seasonal maximum temperature in South Africa, International Journal Climatology. 18, 741-758.

Klopper, E. and Landman, W.A., 2003: A simple approach for combining seasonal forecasts for southern Africa, Meteorological Applications, 10, 319-327.

Koch, agricultural project manager, personal communication, 2005.

Landman, W. A. and Manson, S. J., 1999: Change in the association between Indian Ocean sea-surface temperature and summer rainfall over South Africa and Namibia. International Journal Climatology, 19, 1477-1492.

Letson, D., Llovet, I., Podestá, G. P., Royce, F., Brescia, V., Lema, D., Parellada, G., 2001: User perspectives of climate forecasts: crop producers in Pergamino, Argentina, Climate Research. 19, 57-67.

Luseno, W. K., McPeak, J. G., Barrett, C. B., Little, P. D. and Gebru, G., 2000: Assessing the value of climate forecast information for pastoralists: Evidence from Southern Ethiopia and Northern Kenya, World Development, 31, 1477-1494.

Lyakhou, A. A., 1994: Analysis of economic benefits of short term, medium term and long term forecast. WMO/TD-No 630, Geneva, 278-280.

Mason, B. J., 1996: The role of meteorology in the national economy, Weather document (November), 382-393.

Matarira, C.H., Makadho, J.C. and Mukahanana-Sangarwe, M. Edited by Zhakata, W. (2004). Vulnerability and Adaptation of Maize Production to Climate change in Zimbabwe. Government of the Republic of Zimbabwe, Ministry of Environment and Tourism. Harare.

McGee, R., 2004: Unpacking policy: actors, knowledge and spaces. In: Brock K, McGee R, Gaventa J. Unpacking policy: knowledge, actors, and spaces in poverty reduction in Uganda and Nigeria. Fountain Publishers, Kampala, 1-26.

Mjelde, J. W., Sonka, S. T., Dixon, B. L. and Lamb, P. J., 1988: Valuing Forecast Characteristics in a Dynamic Agricultural Production System, American Journal of Agricultural Economics, 70, 674-684.

Mjelde, J. W., Thompson, T. N., Nixon, C. J. and Lamb, P. J., 1997: Utilising a farm-level decision model to help prioritise future climate prediction research needs, Meteorology Applied Journal, 4, 161-170.

Mosley, M. P., 1994: Economic and social benefits of climatological information and services, A review of existing assessments. WCASP-38, WMO/TD, 78, 38.

Mpandeli, N. S. (2006). Coping with climate variability in Limpopo Province. Unpublished PhD thesis, University of Witwatersrand.

Mpandeli, N.S and Maponya, P.I., 2014: Constraints and challenges facing the small scale farmers in Limpopo Province. Journal of Agricultural Science, Vol. 6, No. 4, April, 2014.

Mutiso, S. K., 1997: Indigenous knowledge in drought and famine forecasting in Machakos District, Kenya. In: Adams WM, Slikkerveer LJ (eds.) Indigenous knowledge and change in African agriculture, Ames IA, Center for Indigenous Knowledge for Agriculture and Rural Development, 67-86.

Nicholls, J. M., 1996: Economic and social effects of climatological information and services: Are view of existing assessments, WOASP-38, WMO/TD: 78, 38.

O'Brien, K. and Vogel, C., 2003: A future for forecasts? In: Vogel C, O'Brien K (eds) Coping with climate variability: the use of seasonal climate forecasts in Southern Africa, Ashgate, Burlington, Vermont, 197-211.

O' Farrell, P., Anderson, P., Milton, S & Dean, W., 2009: Human response and response to drought in the arid zone: lessons from southern Africa: South African Journal of Science, 105 (1 – 2): 34 -39.

Osunade, M. A. A., 1994: "Indigenous Climate Knowledge and Agricultural Practices in South-western Nigeria", Malayasian Journal of Tropical Geography, 1, 21-28.

Orlove, B. and Tosteson, J., 1999: The application of seasonal to interannual climate forecasts based on EL Nino-Southern Oscillation (ENSO) events: Lesson from Australia, Brazil, Ethiopia, Peru and Zimbabwe: WP 99-3. Institute of International Studies, University of California, Berkeley.

Tennant, W. J., 1999: Numerical forecasting of monthly climate in Southern Africa. International Journal of Climatology, 19, 1319-1336.

Tyson, P. D. and Dyer, T. G. J., 1978: The predicted above-normal rainfall of the seventies and the likelihood of droughts in the eighties in South Africa, South African Journal of Science, 74, 372-377.

Unganai, L. S., 2000: Application of long range rainfall forecasts in agricultural management: a review of Africa's experience, Proceedings of the International Forum on Climate Prediction, Agriculture and Development, International Research Institute for Climate Prediction.

Ritchie, J. W., Zammit, C. and Beal, C., 2004: Can seasonal forecasting assist in catchment water management decision-making? A case study of the Border Rivers catchment in Australia. Agriculture, Ecosystem, and Environment, 104, 553-565.

Roncoli, C. S., Bahadio, S and Boena, S., 1999: The role of rainfall information in farmers decisions: Ethnographic research in the Central Plateau (Burkina Faso), Technical Report 1, Climate Forecasting and Agricultural Resources Project, University of Georgia, Athens.

Sivakumar M.V.K. 2000. Climate prediction and agriculture. Proceedings of START/WMO International Workshop, Geneva, Switzerland, 27–29 September 1999. International START Secretariat, Washington, DC.

Sowetan. 2003: Drought takes its toll in Limpopo Province. 5 May 2003, Sowetan, Gauteng, 23.

Stern, P. and Easterling, W. (eds)., 1999: Making Climate Forecasts Matter: Panel on the Human Dimensions of Seasonal- to- Interannual Climate Variability. Committee on the Human Dimensions of Global Change. Commission of Behavioural and Social Sciences and Education. National Research Council. National Academy Press, Washington, D. C.

Stricherz, V., 1999: Long-Term Forecast Cold Give Nations Tools to Survive Climate Change. "January 23. Online Internet. November"1999. Available http://www.euralert. Org/releases/ ww-/fno1 1999. Html.

Roncoli, C., Ingram, K. and Kirshen, P., 2001a: The costs and risks of coping: Household impacts and farmer responses to drought in Burkina Faso, Climate Resources, 19(2), 119-132.

Roncoli, C., Ingram, K., Kirshen, P. and Jost, C., 2001b: Modernity meets marginality: Impacts of seasonal rainfall forecasts on rural livelihoods in Burkina Faso, Paper presented at the Society for Applied Anthropology Meetings, Merida, Mexico.

Roncoli, C., Ingram, K., Kirshen, P. and Jost, C., 2004: Meteorological meanings: understandings of seasonal rainfall forecasts by farmers of Burkina Faso. In: Strauss S, Orlove B (eds). Weather, climate and culture, Berg, Oxford, 181-202.

Valdivia, C. and Gilles, J. L., 2003: Coping and adapting to climate variability in the Andes: strategies and local knowledge, Paper presented at the Open Meeting of the Global Environmental Change Research Community, Montreal, Canada, 16-18 October 2003.

Van Averbeke, W., 2013: Improving Plot Holder Livelihood and Scheme Productivity on Smallholder Canal Irrigation Schemes in the Vhembe District of Limpopo Province.

Vogel, C., Laing, M. and Munnik, C., 2000: Drought in South Africa, in Wilhite, D (ed). Drought Volume 1, A Global Assessment, Routledge Hazards and Disasters Series, London, 348-366.

Vogel C., 2000: Usable science: an assessment of long-term seasonal forecasts among farmers in rural areas of South Africa, South African Geographical Journal, and 82,107-116.

Wilhite, D. (2000). Drought Preparedness in the sub-Saharan Africa context (Vol. I & II). London: Routledge.

Wilhite, D., 2000: Drought as a natural hazard: Concepts and definitions. Drought Volume 1: A Global Assessment, D. A. Wilhite, Ed., Routledge Hazards and Disasters Series, Vol. 1, Routledge, 3–18.

Wilhelmi, O.V. and Wilhite, D.A. (2002). Assessing Vulnerability to Agricultural Drought: A Nebraska Case Study. Natural Hazards (25), 37-58.

Wilbanks, T. J and Kates R. W., 1999: “Global change in local places: How scales matters”, Climate Change, 43 (3), 601-628.

Ziervogel, G., Bithell, M., Washington, R., Downing, T. E., 2004: Agent-based social simulation: a method for assessing the impact of seasonal climate forecast application among smallholder farmers. Agricultural Systems, 83, 1-26. (doi:10.1016/j.agsy.2004.02.009).

CHAPTER 7: CLIMATE VULNERABILITY AND SMALLHOLDER LIVESTOCK WATER AND FODDER USE ANALYSES

Abstract

Farmer understanding of the impact of climate variability and extremes on water supply and grazing production is critical for them to develop adaptive practices necessary for resilience against adverse climatic conditions. Smallholder farmers often make a critical contribution to food security and are more vulnerable to adverse climatic conditions. The purpose of this study was to investigate the perceptions of smallholder farmers about the impact of climatic variability and extremes of livestock water and fodder use in Limpopo and Mpumalanga Provinces. Based on the results, recommendations were made for adaptive management of the water and grazing resources by smallholder farmers for sustained livestock production. Data was collected through descriptive surveys using a semi-structured questionnaire for interviews of individual farmers, while some data was obtained from observations and focus group discussions. Based on the semi-structured questionnaire, 366 small-scale livestock farmers were interviewed, each being asked a standard set of questions posed in the same way each time. Spatial mapping of the smallholder farmers indicated that they were located in agro-ecological zones where surface (rivers and dams) and groundwater were available. The main sources of water for smallholder farmers were perceived to be rivers (41%), municipal/piped water (40%) and boreholes (33%). Only 3% and 7% of the farmers were believed to have used wells and dams/ponds, respectively, as water sources for livestock. Adult women older than 18 years (47.3%) and teenage women between 10 and 18 years (25.4%) were thought to be the main carriers of water from the water sources. The main water uses by households were regarded to be cooking (84%), washing (46.7%), and drinking (44.1%). Municipal piped water to farmers' households was reported to be critical to supply sheep and goats within homesteads. Cattle were perceived to have obtained water from a distance of 1-10 km, mainly from rivers. The majority of smallholder livestock farmers (97%) were believed to have accessed fodder from communal grazing. Even with the use of crop residues (59%) and own crop harvest (35%), inadequate grazing was perceived to be the biggest challenge for large stock (cattle) and small stock (sheep). Based on the findings of the study, it was recommended that: (1) early warning information be interpreted and regularly presented to farmers for them to be timeously aware of pending weather patterns, (2) livestock reduction be encouraged for seasons when adverse climate is anticipated (especially droughts in which both water and grazing tend to be scarce), (3) earth dams were constructed to harvest flood water at strategic catchment points (access to livestock farming villages) for use in times of scarcity.

7.1 INTRODUCTION

Water use and availability within the livestock production sector have been poorly studied, especially under small-scale production systems. The small-scale livestock production system water use becomes confounded with competition with other uses, alternative uses, multiple uses and benefits of a certain resource in a specific location (Rojas-Downing et al., 2017). This limitation in knowledge would lead to maladaptation, and hence might contribute to increasing pressure on the finite water resources. The sector is estimated to be consuming 8% of the global water supply, through the industry's intensive feed-based production. Weindl et al. (2017) projected that water usage in livestock production would increase by 19 to 36% compared to present consumption levels from surface water resources (i.e., rivers, lakes and dams). In this study, water usage in livestock production is put as an important component of the agricultural water resource management, therefore making the development and adoption of water-smart agricultural strategies for sustaining livestock production demands and improving water management in agriculture, in light of the recent climate projection studies and growing demand for water. In this analysis, we present current water use and efficiency of the livestock sector. The purpose was to create a foundation for management scenario simulations and climate projections of water usage and likely water use efficiencies within the smallholder livestock sector.

7.2 METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim of creating independent papers addressing specific areas of the project and objectives. Each Research Method section will only vary depending on the approach used in data collection and analysis.

7.2.1 Study area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having Small Holder Livestock Farmers that are organized and within reach to the investigators. A political map of South Africa with the provinces is shown in Figure 7.1.

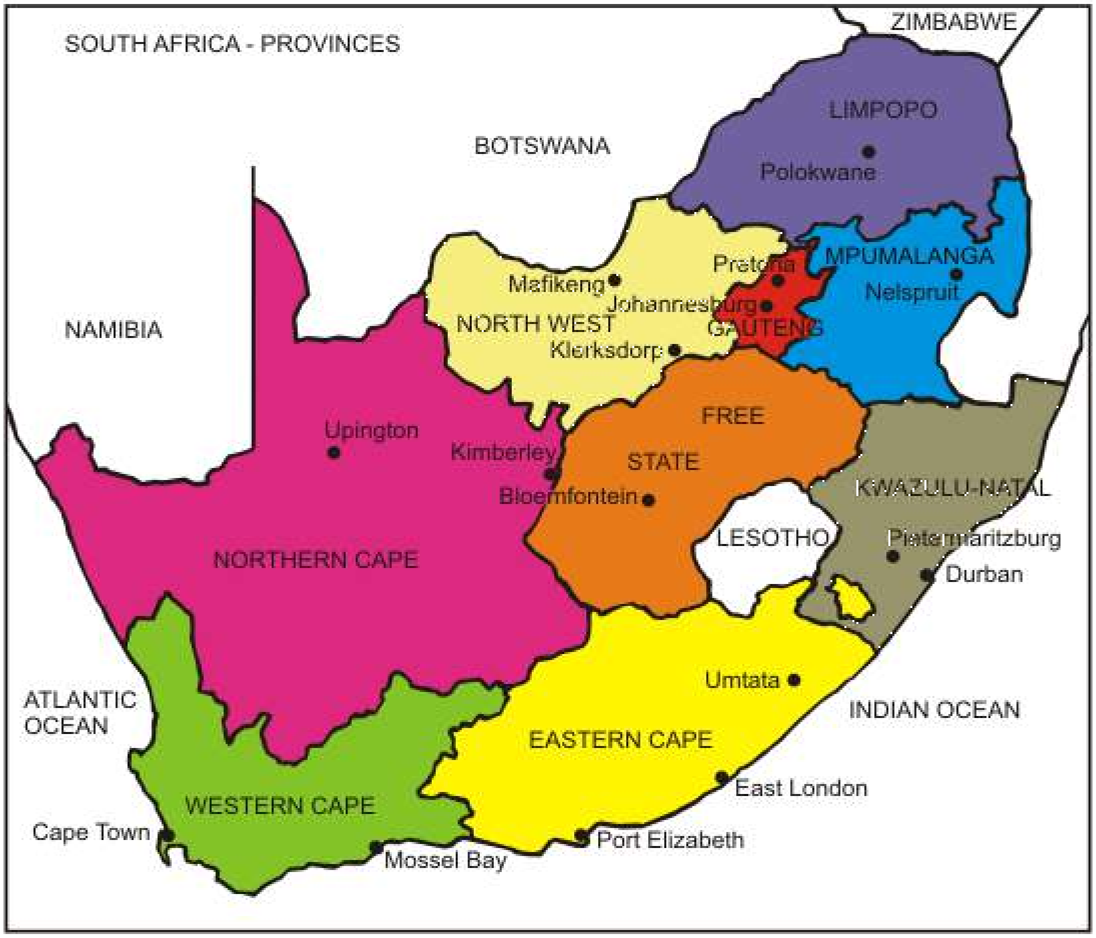


Figure 7.1. Political map of South Africa showing the nine provinces

7.2.2 Data collection

Data was collected through a descriptive survey using 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. Spontaneous questions were also developed for interacting with the interviewee (Schulze, 2002). The structured questionnaire contained both open and closed-ended questions. Closed-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 percent. The questionnaire included, among others, demographic and economic household characteristics; livestock and crop production; access to extension services; credit access; hazard occurrence; adaptation strategies pursued; coping strategies; level of resilience and other information as indicated in the methodology. The study adopted the Framework and or system by Lindoso (2011).

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.

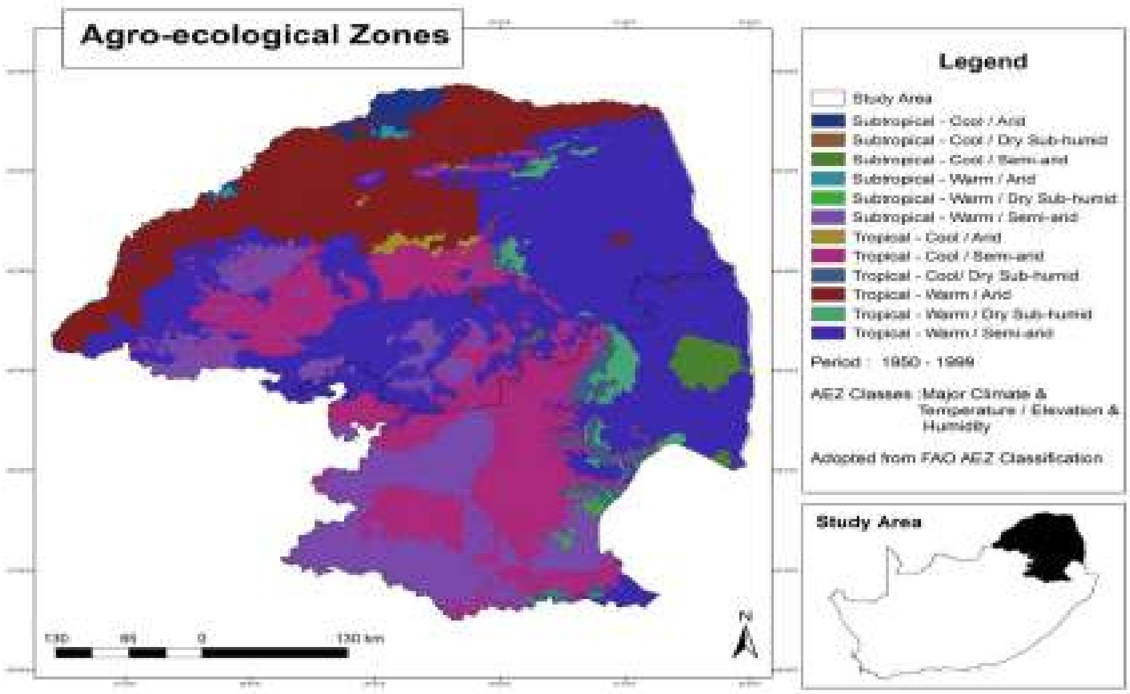


Figure 7.2. Agro-ecological zones of the Limpopo and Mpumalanga Provinces of South Africa (FAO, 1978)

To determine livestock water use efficiencies, focus was on the sensitivity attributes. The main water-related indicators were around 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 5 km radius are beyond realistic reach for domestic water supplies, and hence are only available for livestock. The 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 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.

7.2.2.1 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.

7.2.2.2 Sampling procedure

Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and about four in Mpumalanga. An effort was made to have a minimum of at least 10 farmers per village out of the random sampled households. We used stratified sampling to obtain a representative sample of villages and households for the interview. A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The *PROC SUREVEYSELECT* allows 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.

7.2.3 Data analysis

Quantitative data were transcribed into the MS Excel Package and analysed 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 summarised in an Excel Spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents, mainly the qualitative data.

7.3 RESULTS AND DISCUSSIONS

Water is the most important nutrient in a living organism. It serves as a body solvent and constitutes about 80% of the weight of the body. Water is a critical requirement for agricultural production, especially for livestock production. This resource is obtained from various sources, some, which appear favourable to livestock while others are not. In this section, sources of water are discussed, which are predominantly used by the livestock farming sector. For the study to have mitigating factors to improve access to water and use by livestock farmers, the status per agro-ecological regions was evaluated

7.3.1 Major resources of water

In Figure 7.3, the two main sources of water supply for the sector are shown, which are surface (rivers and dams) and sub-surface (groundwater accessed mainly by boreholes) water resources. These water sources are mostly for multiple uses, i.e. shared with other water users, which indicates the existing competition for both water resources. The scarce and limited water resources in the predominantly semi-arid region, South Africa present challenges in the production and sustainability of the agriculture sector. The main determinants of access to surface water sources are location, availability of resources for allocation and the reliability of supply of the source, whether it's a perennial or non-perennial source. In most farming areas within the study area, groundwater resources serve as either an alternative or main water supply. The diversification of sources of water supply ensures a sustained water supply. Another source of water supply, mostly recently gaining popularity, is the adoption of rainwater harvesting in response to dry spells. It is worth noting that this water used for livestock production might be of lower quality than that consumed by other crop production, industries and domestic use. Factoring in the issue of water quality, the competition with other water users might be as significant.

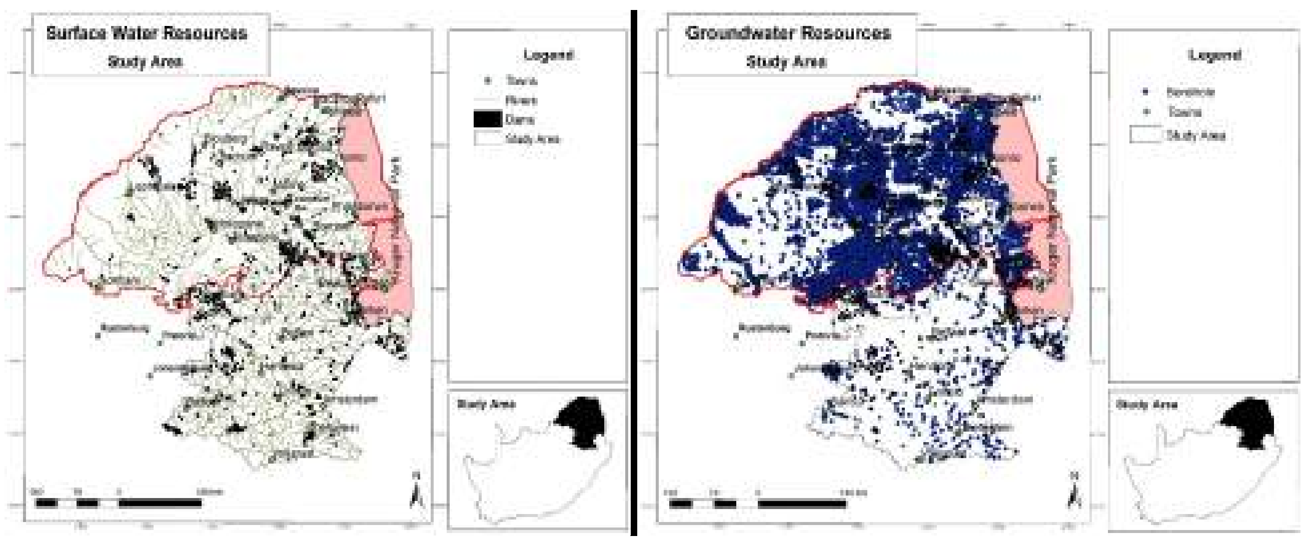


Figure 7.3. Sources of water resources used in the livestock sector, with surface water from rivers and dams (left) and groundwater accessed through boreholes (right)

7.3.2 Agro-ecological evaluation

An evaluation of the location of smallholder farmers concerning the three major resources of water, mainly rivers, boreholes and piped municipal water, can help improve access and use. Figure 7.4 shows the availability of streams throughout the province. The livestock farmers are distributed throughout the two provinces; however, their density is variable. The areas where farmers are clustered conform to the microclimatic regions that experience high rainfall. The reason for this is that a considerable amount of water is lost through evapotranspiration.

Subsequently, livestock farming is reliant on the streams. The livestock farmers are exposed to the impacts of climate change in spite of their proximity to the streams. This is particularly because the majority of the streams are periodic, meaning they only flow water during summer and shortly after that. Furthermore, one of the most prominent impacts of climate change in the context of South Africa is the increasing frequency of drought and floods. These imply that the prevalence of the periodic streams is likely to increase. On the other hand, the proximity to the streams implies that they are prone to being washed away during floods.

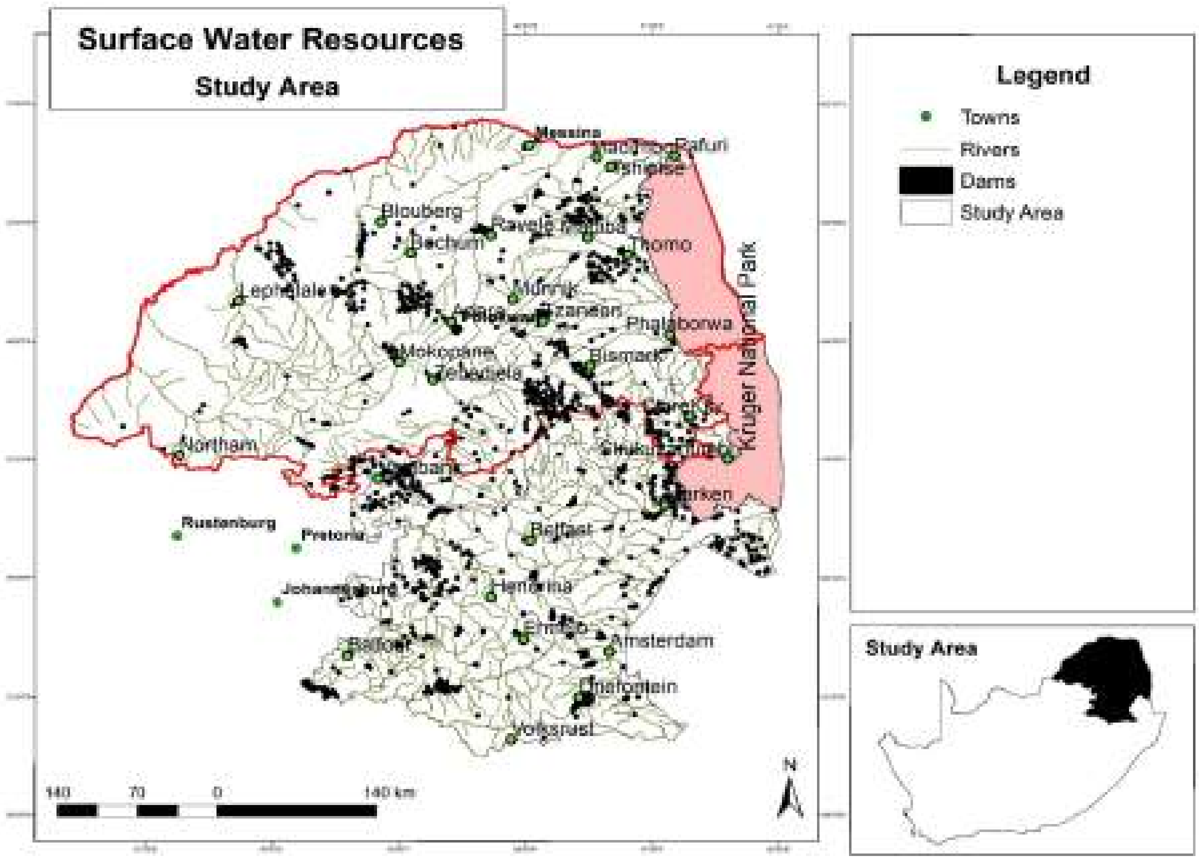


Figure 7.4. Map of surface water resources in farmer settlement areas in Limpopo and Mpumalanga Provinces of South Africa

The map in Figure 7.5 indicates the groundwater resources throughout the province and the locations of smallholder farmers. The variability in the borehole density between the two provinces indirectly signifies the variance in the surface water resource. The arid nature of most parts of the Limpopo Province compels the farmers and other water users to turn their focus to groundwater resources. The abundance of the groundwater resources indirectly suggests that the farmers are to a particular level, are not exposed to the impacts of climate change. However, all sectors of the economy may also hypothetically be turning to groundwater resources. Exposure to livestock farmers may also be the unsustainable management of the underground aquifer. In the unfortunate event that this unfolds, the farmers will be exposed to the predicament of climate change.

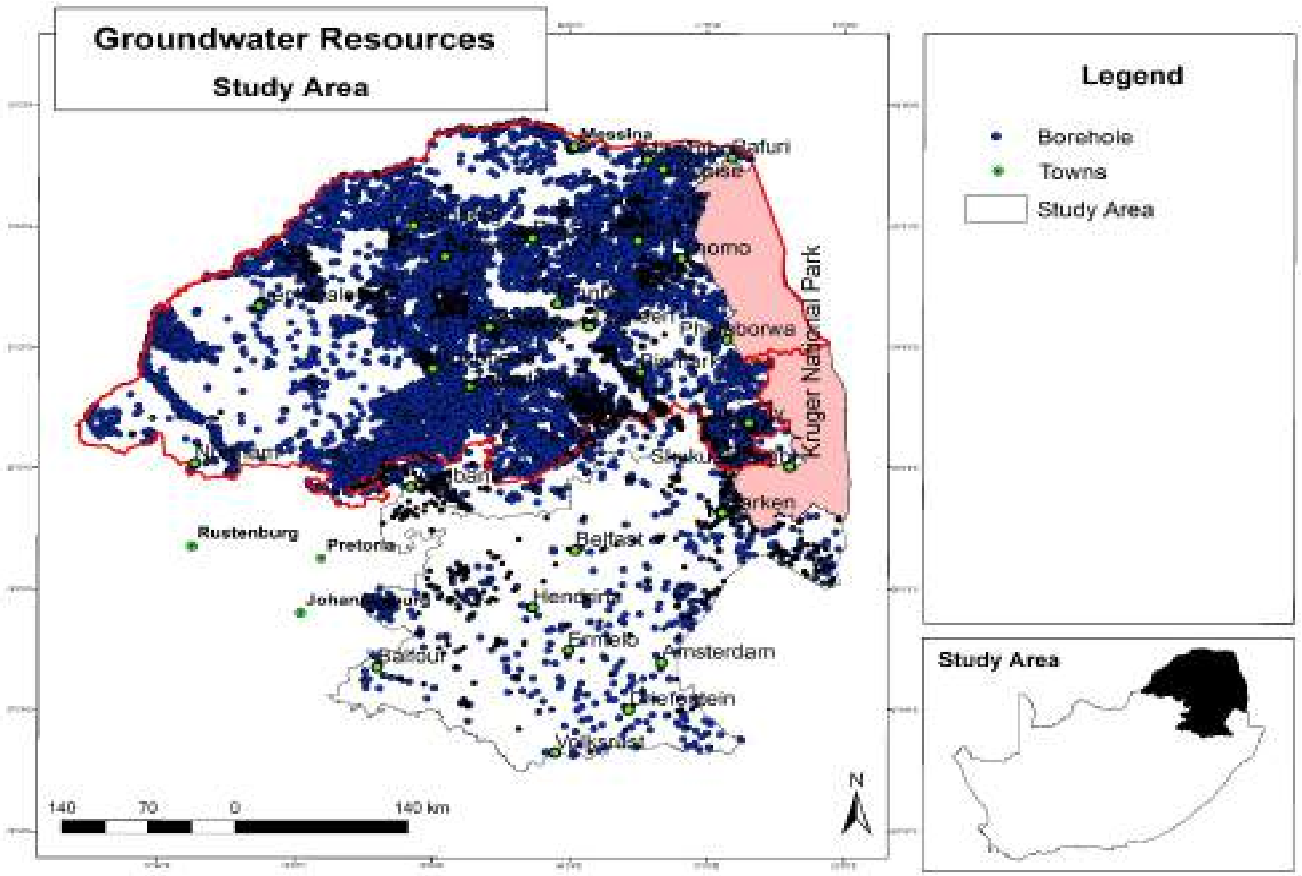


Figure 7.5. Map of groundwater resources used in farmer settlement areas in Limpopo and Mpumalanga Provinces of South Africa

Adams (2014) conducted an intensive review of the underutilisation of the groundwater resources in South Africa. The review established that current groundwater abstraction ranges between 2-4 billion M^3/a, which is less than half the optimal potential of 10 billion M^3/a, which is slightly reduced to 7.5 billion M^3/a during drought conditions (Adams, 2014). Groundwater use review asserts the notion that there is sufficient groundwater resource to sustain the livestock sector. On the contrary, the groundwater resource potential is spatially variable. The two provinces comprise the aquifers that are heterogeneous in hydrogeological parameters. These imply that the groundwater availability is differentiable throughout the two provinces.

The variability in the borehole density between the two provinces indirectly signifies the variance in the surface water resource. The arid nature of most parts of the Limpopo Province compels the farmers and other water users to turn their focus to groundwater resources. The abundance of the groundwater resources indirectly suggests that the farmers are to a particular level, not exposed to the impacts of climate change. However, all sectors of the economy are now turning to groundwater resources. The majority of the existing boreholes were developed without borehole testing. Hence, the Department of Water and Sanitation reported a high borehole failure rate in some part of the Limpopo Province. This translates to improper aquifer management due to unsustainable abstractions that exceed the sustainable yields, boreholes subsequently fail. In the unfortunate event when this unfolds, the farmers will be exposed to the predicament impacts of climate change.

7.3.3 Farmers' experience and perceptions of water sources

Table 7.1 shows the percentage of farmers who access water from dams, rivers, water wells, boreholes and municipal piped water. According to Table 7.1, the main source of water is the river system (41.3%). This may be mainly attributed to the grazing fields that are outside the residential area. The municipal/piped water (40.4%) closely follows the streams. Boreholes were found to be the third-level stream for farmers to access water. 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 the climatic extremes. This is partly because the Limpopo and Mpumalanga provinces are spatially confined to the arid to semi-arid climatic configurations (Mpandeli and Maponya, 2014).
These zones receive low rainfall that is exclusively experienced in summer and endure the dry winter (Mpandeli and Maponya, 2014). Subsequently, there are minor perennial streams. This implies that the livestock is highly exposed to the climatic extremes, especially during extended spells of dry season. On the other hand, the municipal water is insufficient for the sustenance of the domestic needs and often interrupted by mechanical failures and breakdowns. Moreover, the installation of the prepaid water system will make water unaffordable for livestock feeding. Furthermore, the municipal systems are often reliant on surface water supply; during drought spells, they are also compromised.

The results of Table 7.1 are consistent with Figure 7.1, which indicates the location of rivers and dams but also the distribution of boreholes. Percentage and frequencies of the main source of water for each type of livestock are illustrated in Table 7.2, where the majority of farmers indicated river as the main source of water for cattle and donkeys. Whereas tap water and borehole were equally shared by sheep and goats as sources of water. 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, sheep, goats, pigs and chickens had access to the dam as the source of water. The change in rainfall frequency and amount, and subsequent depletion of the water resources, are some of the classical impacts of climate change. The results are corroborated by similar work in Kenya by Bake (1993) and Rosegrant et.al. (2000).

Table 7.1. Frequencies and associated percentages of smallholder farmers accessing water from different water Sources

Water Sources		**frequency**	**Percent**
Dam/pond	Yes	27	7.40
	No	337	92.60
River	Yes	150	41.30
	No	214	58.70
Water well	Yes	9	2.50
	No	355	97.50
Borehole	Yes	119	32.80
	No	245	67.20
Municipal/piped water	Yes	147	40.40
	No	217	59.60

Table 7.2. Frequency and respective percentages of smallholder livestock farmers using different sources of water for livestock types

Source of Water	**Cattle**		**Goats**		**Chickens**		**Pig**	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	%
Dam	35	9.7	3	1.9	3	3.1	3	7.1
River	237	65.4	12	7.2	2	2.1	1	2.4
Tap water	23	6.4	82	49.4	59	60.8	28	66.6
Borehole	65	18.0	68	41	31	32.0	8	19.1
Other	1	0.3	1	0.5	2	2.1	1	2.4
TOTAL	**361**	**100**	**166**	**100**	**95**	**100**	**41**	**100**

Table 7.3 depicts the frequency and percentage of the drying of the streams. Two-thirds of the farmers (66%) indicated that they have not observed anything along with the drying of the streams in the last decade, and a third (33%) affirmed the depletion of the water in the streams.

Table 7.3. Frequency and respective percent on the perception of the smallholder livestock farmers towards the drying of the streams

Are the streams drying?	Frequency	Percent
No	243	66.39
Yes	123	33.61
TOTAL	**366**	**100**

While this is logical as climate change do not only yield to water deficiency, but a diverse array of climatic impacts that were not common. The spatial variability in the sampling points may also explain contradictions in the views of the farmers towards the drying of the streams. The impacts of climate change are variable in different geographical locations, hence the mixed assessments. The variabilities on the opinions can be interpreted in terms of the spatial variance in the manifestations of the impacts of climate change. Moreover, climate change encompasses a diverse array of impacts, including rising temperatures, changes in water availability, an increase in levels of carbon dioxide, and alterations of the precipitation frequency and amount (Sonwa *et al*., 2012). Turpie and Visser (2013) predicted that the impacts of climate change in South Africa to highly manifest in the form of amplified temperature, sporadic rainfall patterns, and higher drought frequency. The erratic rainfall could mean an increase or decline in rainfall, which will translate to either depletion, steady an increase in stream water.

7.3.4 Livestock farmers' access, use and distance to water sources

Table 7.4 shows the age and gender differentiation associated with the person power to carry water from sources to households. Most women older than 18 years (53.6 %) are tasked with the responsibility of fetching water. On the contrary, fewer (25.4%) Adult Men older than 18 years had the responsibility to fetch water. Logically, the cultural succession to the responsibility showed that teenage girls between 10-18 years (9.6%) had the responsibility to fetch water.

Table 7.4. Frequencies and respective percentages of gender by age categories and task to fetch water

Gender X Age Categories	Number	%
Women older than 18 years	173	53.6
Girls aged 10-18 years	35	10.8
Girls aged < 10 years	4	0.01
Men older than 18	93	28.8
Boys aged 10-18 years	14	0.04

Percentage and frequencies on the distance travelled by livestock to drink water are presented in Table 7.5. Livestock drank water at the household (35%) and some travelled < 1 km (27%), 1-5 km (36%) and 6-10 km (2%)

for water. Sources of water for livestock are shown in Table 7.5, where 41.3%, 40.4% and 32.8 % of the livestock farmers used river, municipal/piped water and boreholes, respectively, as the sources of water for their livestock. Only 2.5 % and 7.4 % of the farmers used water wells and dam/ponds, respectively, as the water sources for livestock.

Table 7.5. Frequencies and respective percentages on the distance travelled to the furthest water Source

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

Table 7.6 shows the percentage of enterprises per household that travelled a distance to a water source. When farmers were asked to give the distance to a water source for each enterprise (Table 7.6), the majority of farmers (>79%) indicated that sheep, goats, chickens, and pigs drank water at the household. Cattle seemed to get water at the household and travelled 1 -10 km.

Pratt and Gwynne (1977) recommended 4 km for cattle without stress. The maximum distance for small livestock was 15 km, and 30 km was the maximum distance for livestock at stress levels. Although 30 km is the distance livestock have to walk during water scarcity periods, cattle and small stock will normally graze up to 10-15 km away from a water source (MoA&LD 2002).

Table 7.6. Frequency and respective percentages of livestock enterprise & corresponding distance to water source

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

The distances the smallholder farmers travel to access water and other water-related resources are indicated in Table 7.7. There were only a few farmers (16%) who travelled less than a kilometre to the river. More farmers (53%) travel between a kilometres to five kilometres to the river resource. Thirty one percent travel between 6 to 10 kilometres to the river. Access to water was also provided through a community tap or borehole, which was accessed outside the household. The majority of farmers accessed the community tap within a kilometre, whereas 17% had to travel between one and five kilometres. The indoor tap (93%), pumped water (100%) and harvested rainwater (95%) were all accessed by the majority of households within less than a kilometre.

Table 7.7. Distance (kilometres) covered by smallholder farmers to water resources

Water Source	Frequencies (N) & respective percentages (%) of smallholder farmers and distance (km) covered to the water source							
	<1		1-5		6-10		>11	
	N	%	N	%	N	%	N	%
Indoor Tap	25	92.6	2	7.4	0	0	0	0
Tap In Yard	33	94.3	2	5.7	0	0	0	0
Pumped Water Tank	40	100	0	0	0	0	0	0
Rain Harvest / Water Tank	35	94.6	1	2.7	1	2.7	0	0
Communal Tap / Borehole	246	80.9	53	17.4	5	1.6	0	0
River	39	15.8	131	53.0	76	30.8	1	0.4

The frequency at which water is available also determines the level of access by the farming households. Table 7.8 shows the frequency with which the farmers access water from different sources. Most farmers (219), which is 72% of the households, access water more often from the communal tap and compared to 211 (84%) who use the river. Fewer numbers of households access water more often from pumping water (38), taps in the yard (36), indoor taps and communal wells (7), respectively. The numbers reflect more the availability of the said resources than the level of frequency to access the water resources.

Table 7.8. Frequencies and respective percentages on the rate of water availability to smallholder farmers per source used.

Water Source	Rate Of Water Availability					
	Often (%)		Once / Week (%)		Once / Month (%)	
	Number	%	Number	%	Number	%
Indoor Tap	26	100	0	0	0	0
Tap In Yard	36	94.7	1	2.6	1	2.6
Pumped Water Tank	38	95.0	0	0	2	5.0
Communal Tap / Borehole	219	72.0	85	28.0	0	0
Earth dam	8	88.9	1	11.1	0	0
River	211	84.4	27	10.8	12	4.8
Communal Well	7	63.6	4	36.4	0	0

The frequencies and associated percentages of farmers' household water consumption (in litres per water use) are reflected in Table 7.9. The majority of farmers indicated that their main use of water was cooking (84.0), washing (46.5), drinking (44.1), livestock (37.8) and irrigation (17.3), respectively. Water used for cooking and drinking was between 11 to 30 litres, whereas that of washing, irrigation and livestock drinking was within the range of 101 to 300 litres per family. Storage of water seems to be the driver of the quantity of water used, as indicated by the decrease in the percentage of households and or farmers within each category of quantity range. It may also be speculated that the quality of water for drinking and cooking may be affected by the length of time in storage.

Table 7.9. Frequencies (N) and respective percentages (%) of smallholder farmers' households to water consumption (litres) according to water use.

	Water Consumption in (*l*) by Smallholder Farmers' Households									
Water Use	**<10**		**11-30**		**31-60**		**61-90**		**>90**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Drinking		40.5		44.1		13.9		2.5		0.3
Cooking		12.4		84.0		1.6		0		1.7
	<100		**101-300**		**301-600**		**601-900**		**>900**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Washing		37.0		46.5		12.0		8.8		2.4
Irrigation		13.6		17.3		2.2		0		1.1
Livestock		5.5		37.8		18.8		1.1		35

The results of this study are similar in quantity and type of water use to recent work done by van Koppen, et. al., (2019) in the Sekhukhune and Vhembe Districts of Limpopo Province, South Africa.

7.3.5 Livestock water use

The water used by the livestock sector was determined by computing registered water uses by livestock farmers in South Africa, registered in line with the Department of Water Affairs, Figure 7.6. The water used in the Livestock sector is associated with stock watering, feedlots, dairy, pastures and other on-farm needs. According to the 2014 National State of Water Resources report by the Department of Water and Sanitation, livestock watering accounted for only 0.25 % of the total registered water users in South Africa. The water usage across South Africa varies, with the least recorded use, less than 80 000 m^3, in the Luvuvhu /Letaba water management area, and over 1 447 0000 M^3 water use along the parts of the Western and Eastern Cape Provinces, and the North-West Province, as shown in Figure 7.4. Within the Study area, i.e. Limpopo and Mpumalanga Provinces, the water use ranges from 80 000 to 1 080 000 m^3.

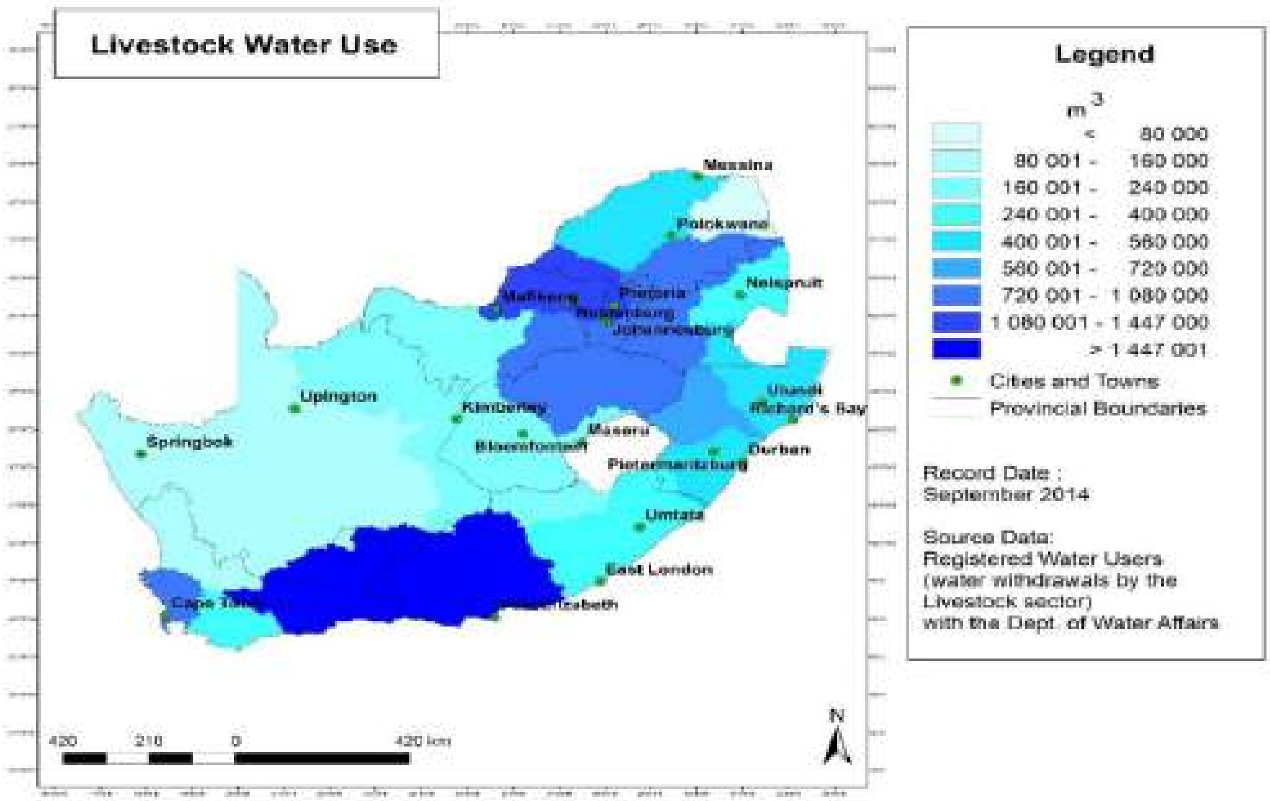


Figure 7.6 Livestock water use in South Africa, determined from the water user registry by the Department of Water and Sanitation of 2014

From the perspective of the smallholder farmers (97.5%) indicated in Table 7.10, livestock water use at their level was mainly for animal drinking. Because our smallholder farmers were mainly cattle farmers, only 2% of farmers indicated water for livestock washing, cleaning of houses and product processing, which could most likely be pig farmers.

Table 7.10 The frequencies and respective percentages of smallholder farmers' livestock water use

Livestock Water Use	Number	%
Livestock Drinking	358	98.1
Livestock Washing	5	1.4
Cleaning of Livestock Housing	1	0.3
Livestock & Product Processing	1	0.3
TOTAL	**364**	**100**

7.3.6 Livestock water use efficiency

The livestock WUE over South Africa, in Figure 7.7, shows the estimated livestock water productivity with the least water efficient production indicated by yellow to brown (<6.00 livestock per m^3) centred near Gauteng Province and the highest being in Luvuvhu /Letaba water management area in the Limpopo Province. The WUE per livestock, as presented in Figures 7.8, 7.9, and 7.10, suggests that Pig production is the least water-use efficient production system, compared to ruminants, with the overall high water productivity. This value might be different when the number of livestock is compared with their consumptive water use. The growing demand for livestock products influences the already limited water resources. The improvement of the livestock water use efficiency (WUE) will, therefore, contribute towards the agricultural water use efficiency and thus reduce competition with other water users (Kebebe et al., 2015). The livestock WUEs computed below were based on livestock numbers as estimated by the Department of Agriculture and registered water user withdrawals. The difference in water productivity between the different livestock and across country suggests there is a considerable scope for improvement. An integrated livestock and water management, planning and development will have the potential to increase production and reduce pressure on scarce resources.

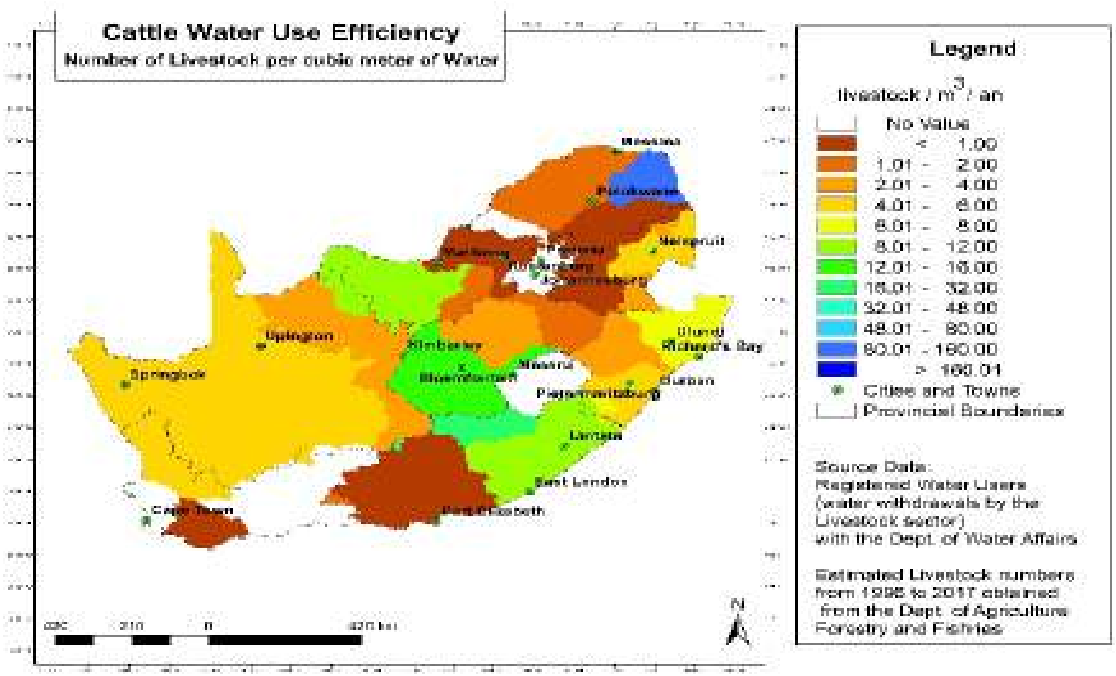


Figure 7.8. Cattle's water use efficiency over South Africa (DWS - DAFF, 2017)

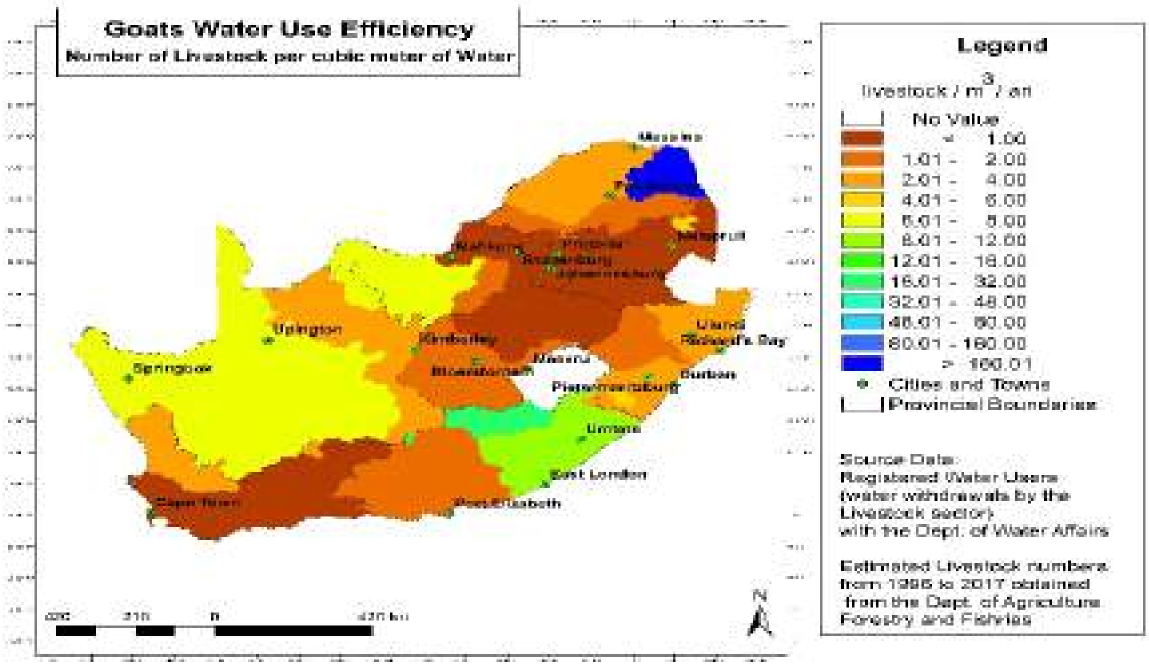


Figure 7.9. Goats' water use efficiency over South Africa (DWS - DAFF, 2017)

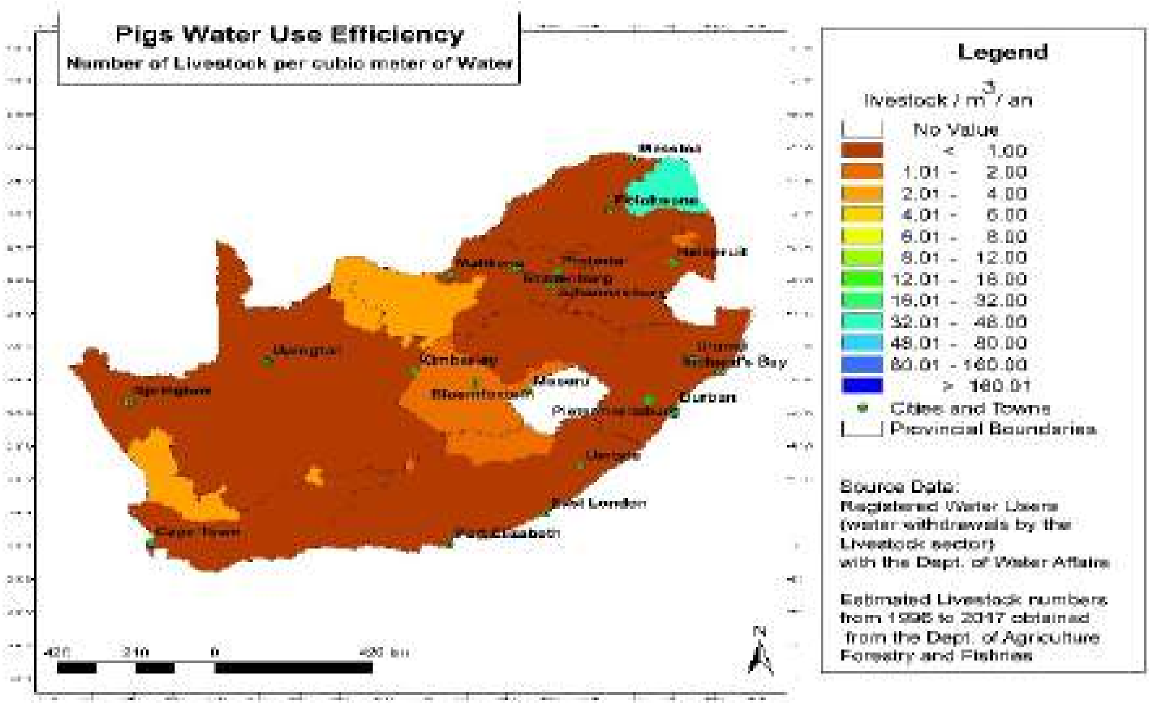


Figure 7.10. Pigs' Water Use Efficiency over South Africa (DWS - DAFF, 2017)

The four strategies, along with the Livestock Water Production Efficiency assessment framework, underpin the research undertaken on a basin-wide and country-specific basis in Uganda, Sudan and Ethiopia. The framework identified the following four strategies to increase Livestock Water Production Efficiency: (a) Selection of feeds that require relatively little water and produce enough quality dry matter and nutrients; (b) Integration of animal science knowledge (e.g. veterinary science) into water development; (c) Water conservation associated with livestock keeping; and (d) Optimally distributing livestock: feed and drinking water resources over large areas to maximise animal production through access to underutilised pasture far from water while preventing overgrazing and water degradation near watering points.

7.3.7 Smallholder farmers' experience and perceptions on sustainable and effective water use

Table 7.11 shows the frequencies of smallholder farmers' perceptions of the sustainability of the water system in the ecosystem. The majority of farmers (59.8%) thought that water use was moderately managed for long-term sustainability. Only 10.9% of the farmers were of the view that water use in their communities was sustainably managed. On the other hand, 13.1% of the farmers had a view that water resources were very poorly managed for long-term sustainability.

Table 7.11 Frequencies and respective percentages of smallholder farmers and livestock water use

Sustainability of Water Use	Number	%
Very Poor	48	13.1
Poor	57	15.6
Moderate	219	59.8
High	40	10.9
TOTAL	**364**	**100**

Table 7.12 shows the major constraints to effective water use. The major constraint identified was salinity by 61.2% of the farmers. The cost of accessing water was identified as a constraint by 15.3% of the farmers.

Table 7.12. Frequencies and respective percentages of smallholder farmers' perceptions of constraints on effective water use

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

7.3.8 Farmers' experiences and perceptions on fodder access and use

Smallholder sources of livestock grazing and or fodder are presented in Table 7.13. Due to the historic and dichotomous economy of South Africa, the majority of smallholder livestock farmers (97%) access fodder from communal grazing. It follows logically then that the exposure to climate change leads them to buy in feeds when the grazing becomes scarce. Crop residues are used by 59%, whereas 35% use their own crop harvest. Studies done by Mati (2002) and Mati et. al. (2005) also showed similar results in their work on assessing water availability under pastoral livestock systems in the drought-prone Isiolo District, Kenya.

Table 7.13 Frequencies and respective percentages of smallholder farmers' access and sources of grazing or feed for livestock

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

The main geo-environmental challenges affecting livestock production are indicated in Table 7.14. The size of cattle as large stock in relation to small stock creates the challenge of the volume of feed that needs to be ingested per day. Over 77% of the farmers indicated that grazing is the biggest challenge to cattle. The same trend was reported in sheep (67%) and goats (71%), respectively. The greatest challenge for poultry farmers (32%) were temperature, whereas for pigs it was pests and diseases (43%).

Table 7.14. Percentage and frequency of the main environmental challenges affecting livestock production

	Cattle		Goats		Chickens		Pig	
	Number	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
Rainfall	11	3.0	8	4.8	5	5.2	2	4.8
Temperature	38	10.4	31	18.7	31	32.0	11	26.2
Grazing	279	76.9	118	71.1	18	18.6	2	4.8
Pests and diseases	27	7.4	6	3.6	1	1.0	18	42.9
Lack of water	8	2.2	3	1.8	0	0	0	21.4

Environmental challenges by themselves give part of the bigger challenge of smallholder farmers. Table 7.15 shows the socio-economic challenges faced by livestock farmers. Lack of feed seems to be consistently the main socio-economic challenge faced by smallholder farmers for cattle (91%), goats (92%), and chicken (44%), respectively. It was interesting to note that the pig small enterprises mentioned poor extension as their main socio-economic challenge, though lack of feed (24%) was their second challenge. Corroborating the environmental challenge of chicken mentioned as temperature in Table 7.13, the second socio-economic challenge for poultry farmers was shelter (17%). It is important to note that beyond the mention of feed as the main socio-economic challenge for most of the livestock, the number of farmers associated with other challenges was extremely small.

Table 7.15. Frequencies (N) and respective percentages (%) of main socio-economic challenges faced by farmers for each enterprise

Challenges	Cattle		Goats		Chickens		Pig	
	N	%	N	%	N	%	N	%
Lack of feed	330	90.9	151	92.1	43	44.3	10	27.0
Lack of shelter	3	0.8	8	4.9	16	16.5	5	13.5
Poor extension	9	2.5	1	0.6	12	12.4	15	40.5
Theft	12	3.6	2	1.2	3	3.1	3	8.1
Lack of knowledge	8	2.2	2	1.2	15	15.5	3	8.1
No labour for husbandry	0	0	0	0	7	7.2		0
Other	0	0	0	0	1	1.0	1	2.7
TOTAL	**362**	**100**	**164**	**100**	**97**	**100**	**37**	**100**

7.4 CONCLUSIONS

Smallholder farmers are located in areas that conform to the microclimatic regions that experience high rainfall. The main source of water in these locations is the river system. The municipal/piped water, together with boreholes, were found to be the second and third level streams for farmers to access water. Municipal piped water to farmers' households was critical to supply small stock, chickens and pigs within homesteads. Cattle seemed to get water within 1 -10 km, mainly to the river sources which are within the recommended 30 km distance for livestock to avoid stress levels. The majority of smallholder livestock farmers accessed fodder from communal grazing. It follows logically that the exposure to climate change led them to buy feeds when the grazing becomes scarce. Even with the use of crop residues and own crop harvest, grazing was found to be the biggest challenge for large stock (cattle) and small stock (sheep). The greatest challenge for poultry farmers was the increase in temperatures, whereas for pigs it was pests and diseases. For the sustainable socio-economic well-being of smallholder farmers and to adapt to changes in geo-climatic conditions, intensive production systems are proposed. Based on the findings of the study, it is recommended that: (1) early warning information be interpreted and regularly presented to farmers for them to be timeously aware of pending weather patterns, (2) livestock reduction be encouraged for seasons when adverse climate is anticipated (especially droughts in which both water and grazing tend to be scarce), (3) earth dams be constructed to harvest flood water at strategic catchment points (accessible to livestock farming villages) for use in times of scarcity, (4) heat and drought tolerant breeds of livestock be promoted especially for areas that have high aridity indexes.

7.5 REFERENCES

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Kebebe, E.G., Oosting, S.J.1., Haileslassie, A., Duncan, A.J., de Boer, I.J.1. 2015. Strategies for improving water use efficiency of livestock production in rain-fed systems. Animal, 9(5): 908-916.

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2012) Indicators for Assessing the Vulnerability of Smallholder Farming to Climate Change: the Case of Brazil's Semi-Arid North-eastern Region. Poverty Practice, Bureau for Development Policy, UNDP Esplanada dos Ministérios, Bloco O, 7º andar, 70052-900 Brasilia, DF - Brazil

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2014). Integrated assessment of smallholder farming's vulnerability to drought in the Brazilian Semiarid: a case study in Ceará. Climatic Change, https://www.researchgate.net/publication/262485038. DOI 10.1007/s10584-014-1116-1

Mati, B. M. 2002. Community water developments through rainwater harvesting in Laikipia, Isiolo and Garissa Districts of Kenya. Project notes. Kenya Rainwater Association, Nairobi, Republic of Kenya.

Mati, B. M.; Muchiri, J. M.; Njenga, K.; Penning de Vries, F.; Merrey, D. J. 2005. Assessing water availability under pastoral livestock systems in drought-prone Isiolo District, Kenya. Working Paper 106. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Mpandeli, S. and Maponya, P. (2014). Constraints and Challenges Facing the Small Scale Farmers in Limpopo Province, South Africa. Journal of Agricultural Science; Vol. 6, No. 4

MoA&LD (Ministry of Agriculture and Livestock Development). 2002. Report of Agriculture and Livestock Development. Isiolo District Livestock Division. Isiolo. MoA&LD.

Ormsby, T.; Napoleon, E.; Burke, R.; Groessl, C.; Feaster, L. 2001. Getting to know ArcGIS desktop. Basics of ArcView, ArcEditor and ArcInfo. Redlands, Ca. ESRI Press.

Rosegrant, M. W.; Ringler, C.; McKinney, D. C.; Cai, X.; Keller, A.; Donoso, G. 2000. Integrated economic hydrologic water modelling at the basin scale. The Maipo River Basin. EPTD Discussion Paper No. 63. Washington DC.: International Food Policy Research Institute.

Rojas-Downing. M.M., Nejadhashemi, A.P., Harrigan, T. and Woznicki, S.A. 2017 .Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16: 145-163.

Schulze, S. (2002). Research Methodology. Department of Further Teacher Education. Pretoria: University of South Africa.

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y. and Nkem, J. (2012), "Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon", Forest Policy and Economics, Vol. 23, pp. 1-9.

Turpie, J. and Visser, M. (2013), "The impact of climate change on South Africa's Rural areas", Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.

Weindl, I., Bodirsky, L.B., Rolinskia, S., Biewald, A., Lotze-Campen, H., Müller, C., Dietrich, J.P., Humpenöder, F., Stevanović, M., Schaphoff, S. and Poppa, A. 2017. Livestock production and the water challenge of future food supply: Implications of agricultural management and dietary choices. Global Environmental Change, 47: 121-132. https://doi.org/10.1016/j.gloenvcha.2017.09.010.

CHAPTER 8: ADAPTIVE CAPACITY OF SMALLHOLDER LIVESTOCK FARMERS TO THE IMPACTS OF CLIMATE CHANGE

Abstract

The study was conducted to determine the adaptive capacity of smallholder livestock farmers to climate change in Limpopo and Mpumalanga provinces of South Africa. The study was conducted in both the Limpopo and Mpumalanga provinces. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having livestock smallholder farmers who are organised and within reach of the investigators. The sampling frame consisted of a database of village households owning livestock in Vhembe (4 municipalities) and Gert Sibande (7 municipalities) districts. The majority of the livestock perceived that there are notable changes in climate patterns (93%), decreased rainfall (87%), increases in temperature (79%), and they agree that the frequency of droughts has increased over the years (88%). Smallholder farmers believed that there is an impact of climate change on their livestock production. Perceptions of the impact of climate change on livestock production were based on observations of less grass in pastures, drying streams, outbreaks of diseases, death of livestock due to excessive heat or cold, shortage of feeds, drinking water and unknown disease and floods. The majority of livestock farmers practice a communal backyard production system (80%) under small-scale production, and their livestock are directly and indirectly affected by climate change. It was observed that livestock farmers do not own the land (99%), and their livestock grazed/browsed on communal land. The use of communal grazing by livestock farmers makes them more vulnerable to climate change, with less adaptive capacity. The majority (97%) of farmers had access to electricity in their houses. Most of the livestock farmers had cattle (98%), followed by goats (15%), chickens (8%), pigs (6%) and sheep (3%). On average, livestock farmers had 16 years of farming experience, with the minimum and maximum of farming experience of 3 and 70 years, respectively. Farmers on average kept 16.70, 12.50, 14.82, 19.07, 7.0 and 11.53 of cattle, sheep, goats, fowls, donkeys and pigs, respectively. Males were mentioned as the main members of the household responsible for selling/slaughtering (74%), animal health (72%), purchasing (69%), breeding decisions (67%), herding (56%), and feeding (56%) activities. The majority of livestock farmers indicated the river as the main source of water for their cattle and donkeys, and their cattle travelled 1 -10 km to access water (proxy to water stock), especially from the river. Grazing (> 66%) was mentioned as the main environmental challenge, affecting cattle, sheep, goats and donkeys, followed by temperature, pests and diseases, rainfall and water. Smallholder farmers reported taking different types of adaptation measures to deal with climate change, such as the provision of water, allowing livestock to graze near the river, water storage, and the provision of feed supplements and the selling of livestock to buy feeds. Livestock farmers are highly vulnerable to climate change, with less adaptive capacity, and need financial and political support to improve their adaptive capacity of the government.

8.1 INTRODUCTION

It has been observed in South Africa that livestock farming has the potential to become a micro business, particularly in the rural areas. Smallholder farmers own these biological assets, such as cattle, goats, sheep, donkeys and mules. Livestock is also a major contributor of fertilizer in the rural areas (Usmani 2006). Livestock is a financial, as well as a social capital. It is a financial capital in the shape of insurance, cash, savings, credit, and gifts. It is a social capital as it symbolises wealth and prestige, while also being linked to tradition, identity, friendship, respect, and festivity. Livestock provide high-quality proteins to the poorest households, particularly for pregnant females and for improving the cognitive skills and mental growth of children (Sidahmed 2010). It is practically a feature for rural households to have livestock because it contributes to income, food supply, soil productivity, agricultural traction, community and family employment, ritual purposes, and social stratification (Bettencourt, et al. 2013). Unfortunately, livestock is highly vulnerable to climate variability and extremes (Easterling *et. al*., 2007; FAO, 2007; Thornton *et. al*., 2007; IFAD, 2010). The impact of climate change is expected to heighten the vulnerability of livestock systems and reinforce existing factors affecting livestock production systems (Gill & Smith, 2008). In South Africa, climate change is predicted to result not only in higher temperatures but also in sporadic rainfall patterns and frequent droughts (Turpie and Visser, 2013). These severe weather events, coupled with the country's already scarce water resources, are expected to have a significant effect on the forestry and agricultural sectors, which are substantial components of the country's rural livelihoods and economies (Turpie and Visser, 2013; Quinn *et al*., 2011).

Climate change will affect animal production in four ways: the impact of changes in livestock feed grain availability and price; the impact on livestock pastures and forage crop production and quality; changes in livestock diseases and pests; and the direct effects of weather and extreme events on animal health, growth and reproduction (Smith *et. al*., 1996). Vulnerability has two sides, namely an external side with risks, shocks and stress to which an individual is subject and an internal side or being defenceless, meaning a lack of means with which to cope when facing loss (Ncube *et al*., 2016). Vulnerability can be summarised as a function of three attributes, namely exposure, sensitivity and adaptive capacity. Adaptation has been floated as the only immediate option for cushioning smallholders, among other vulnerable groups (Field, 2012; Opiyo *et. al*., 2015), and the ecosystem against the imminent impacts of climate change. Successful implementation of desired adaptation is largely associated with a number of socio-economic dynamics, which include the smallholder's age, marital status, his/her well-being, educational levels, farm size and diversity of livelihood streams (Le Dang *et al*., 2014; Silvestri *et al*., 2015).

Livestock smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks; any reductions in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (Hertel and Rosch, 2010]. Information on vulnerability-adaptive capacity of small-scale livestock farmers to the impacts of climate change in South Africa is very limited.

The current study focused on the adaptive capacity of smallholder livestock farmers to climate change in Limpopo and Mpumalanga provinces of South Africa.

8.2 METHODS AND MATERIALS

This section has been written to be a stand-alone part of each chapter with the aim of creating independent papers addressing specific areas of the project and objectives. Each research method section will only vary depending on the approach used in data collection and analysis.

8.2.1 Study area

The study was conducted in both the Limpopo and Mpumalanga provinces. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers who are organised and within reach of the investigators. A political map showing the provinces is attached as Figure 8.1.

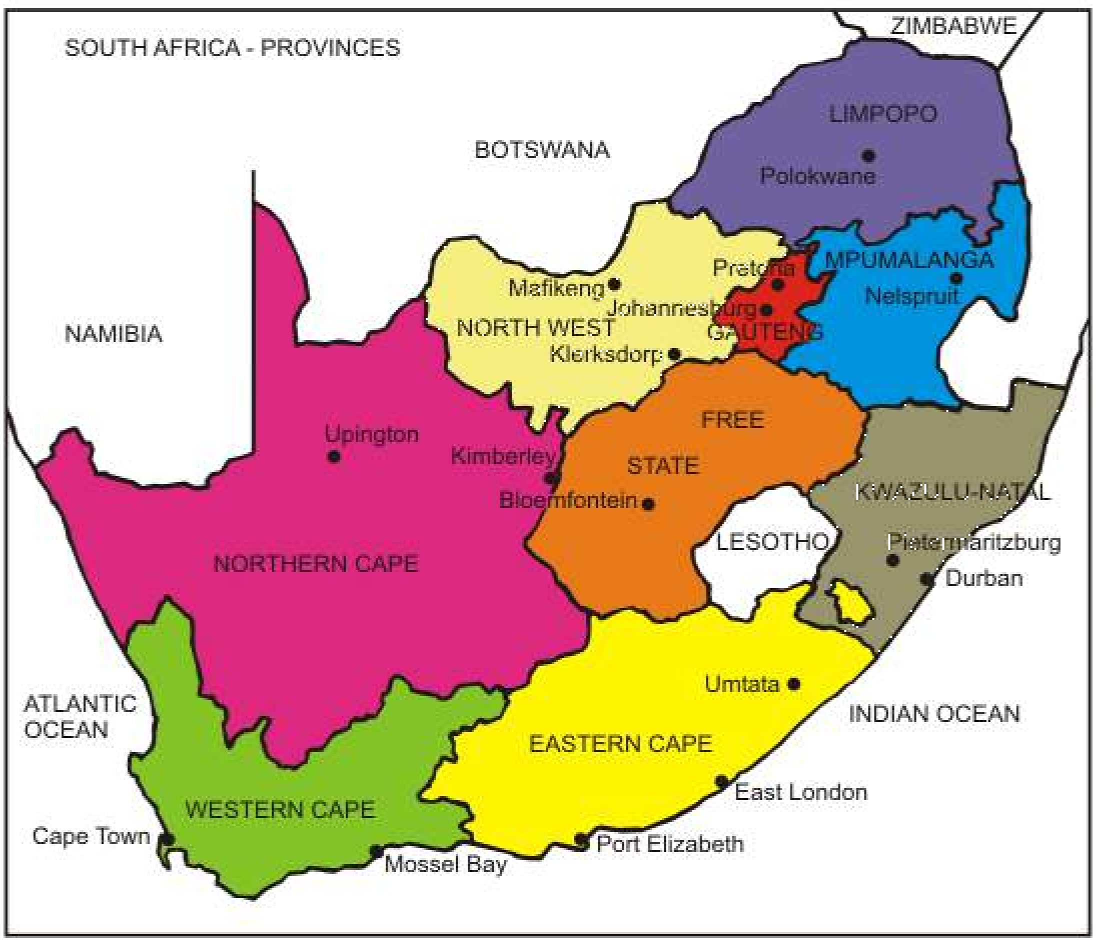


Figure 8.1. Political map of South Africa with provinces

8.2.2 Sampling

The sampling frame consisted of a database of village households owning livestock in Vhembe (four municipalities) and Gert Sibande (7 municipalities) districts. For sampling, a household list was ordered from 1 to nk where nk is the total number of households owning livestock in a village. 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 8.2).

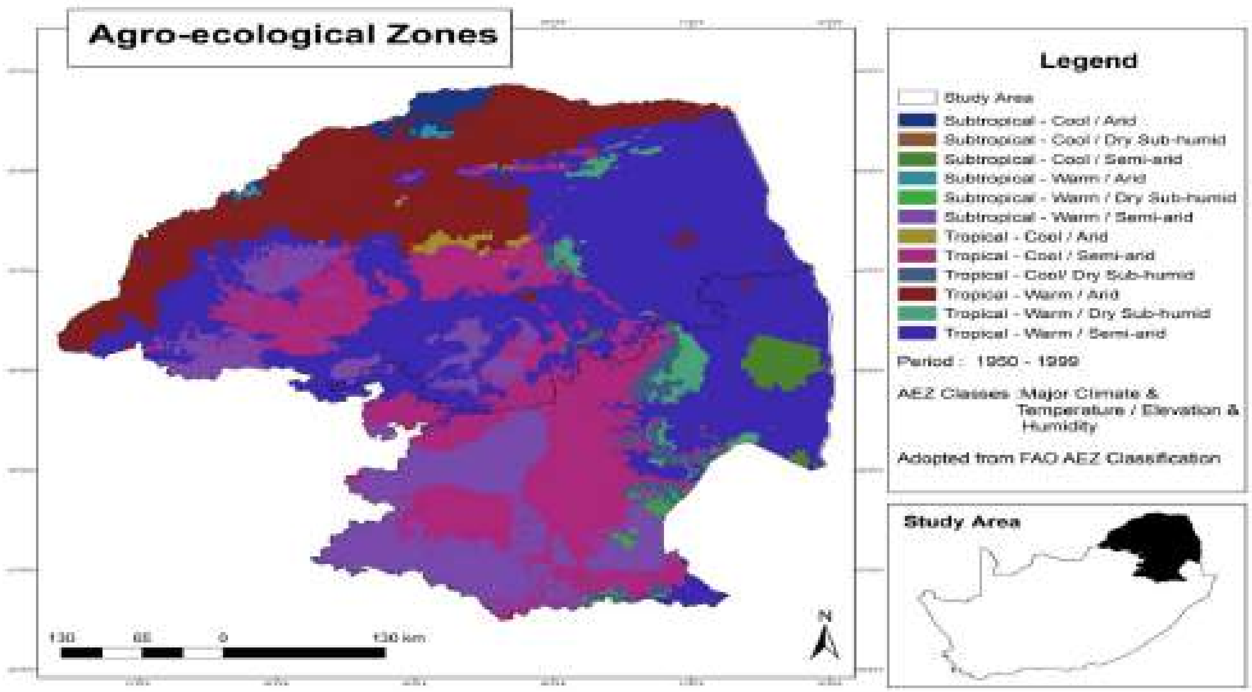


Figure 8.2. Agro-ecological zones of Limpopo and Mpumalanga Provinces of South Africa (FAO, 1978)

The stratified sampling to obtain a representative sample of villages and households for the interview was used. A two-stage random sampling process was conducted using *SURVEYSELECT* procedure of SAS. The two-stage sampling was conducted as follows: Stage 1: 10% of the villages from the four local municipalities were randomly sampled, 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

8.2.3 Data collection

Data were collected through a descriptive survey using structured questionnaires, observations and interviews from individuals and focus groups. The structured questionnaire contained both open and closed-ended questions. Closed-ended questions will collect quantitative data more structured with less flexibility. A total of three hundred and sixty-six (366) farmers were interviewed in Vhembe (251) and Gert Sibande (115) districts. Quantitative data were transcribed into the MS Excel Package and analysed statistically using the SAS Package (SAS, 2009). The

Procedure FREQ of SAS was used to generate simple frequency tables for variables of interest. The Procedure Means of SAS was used to generate means, min, and max.

8.3 RESULTS AND DISCUSSION

8.3.1. Household socio-economic characteristics

In this section, the profile of smallholder farmers is summarised, as this was discussed and reported in detail in Chapter 3:

- ***Heads of households***: It was evident in this study that three in five (58.7%) respondents were heads of household, suggesting that the information provided by the majority of respondents was highly likely to reflect the decisions of livestock farming households. It is interesting to note that following the heads of household, the next largest categories of respondents were the mother (17.8%) and father (7.9%) of the head.
- ***Gender***: Most of the livestock smallholder farmers in the study were males (63%), while 37% were females, which implies that livestock farming is dominated by males. Similar observations were made in a study of youth agricultural projects in Limpopo Province. Maele *et al.* (2015) revealed that the majority of farmers (74%) were male. Ijatuyi *et al.* (2017) revealed that up to three in four (75%) of Nguni producers in the North-West Province of South Africa were men, further affirming the dominance of men in livestock production compared to their female counterparts.
- ***Age***: In the study, the participation of youth in livestock farming is frightening, with only 7.4 % of the livestock farmers aged 35 years or less. Mulinyac, (2017) reported that farmers within the ages of 30-34 years are likely to understand well the issues involved in farming and therefore are armed with the necessary information regarding climate change adaptation strategies that can be well achieved and adhered to. Two in three (65,7%) of farmers were aged 55 years and above, of which almost two in five (37,6%), were aged >65 years. This observation agrees with Simotwo et al. (2018), who revealed that farmers were aging.
- ***Education***: 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 a 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).
- ***Employment*:** About half (50.5%) of the livestock farmers were involved in various types of employment, and these would somehow influence the adaptive capacity of their enterprises to adverse effects of climate change and variability, depending on the level of income from the employment activities, e.g. livestock farmers with formal employment would use their funds to purchase livestock feeds at times of need.

- ***Income***: 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. Only 4.2% of the livestock farmers lived in houses of a mud brick wall and thatch roof that could be regarded to be of poor quality.
- ***Quality of housing***: Up to 88.5% of the livestock farmers revealed that their houses were built through their finances, with 9.6% funded by the government and 1.9 % inherited. The 9.6% government-funded houses would most certainly be part of the top quality category, and so could be the case with the 1.9% inherited houses, implying that livestock farmers themselves could have funded some 37.0% (and not the reported 48.5%) of houses in this category. Assuming that the 4.2% completely poor quality houses were part of those funded by livestock farmers themselves, it may be inferred that some 37.0% of the farmers could afford top quality houses, while about 47.4% would have funded their medium quality houses. Considering the quality of housing, some 37.0% of farmers would likely possess a high adaptive capacity to the adverse effects of climate change and variability affecting their livestock enterprises. About 47.4% of the livestock farmers would possess the medium adaptive capacity, while only 4.2% would likely have a complete lack of adaptive capacity.

8.3.2. Scale of farming, land ownership, and access to electricity

The majority of the livestock farmers practiced small-scale farming (99%) (Table 8.1). The percentage of the population devoted to smallholder farming is a good sensitivity indicator (Lindoso *et al*., 2014). The specific socio-political situation in South Africa, where past agricultural policies persistently marginalized small-scale black farmers by curtailing their access to resources such as land, water, credit and technical knowhow (Coetzee and Van Zyl, 1992; Kirsten and Van Zyl, 1998), is a further indication of increased sensitivity of South Africa's smallholders to climate change. Smallholder farming is a special case within the agriculture sector since it produces more than food, it also preserves specific cultural and social traits (Adger *et. al*., 2009; Lemos *et al*., 2002). However, its adaptive capacity is compromised, especially when compared to large-scale agriculture, for which access to funding and productive infrastructure is easier (Morton 2007). Small farms can switch more easily from temperate animals to heat-tolerant animals and from crops to livestock (Seo & Mendelsohn, 2006b). For small farmers, livestock provides some protection against the effects of warming, as crops become less desirable (SEO & Mendelsohn, 2006a)

Table 8.1. Frequencies and percentages of farm type, land ownership and electricity on the farm

	Frequency	Percent
Farm type		
Small scale	361	98.9
Large scale	4	1.1
Total	365	100
Land ownership where livestock graze/browse		
Own	2	0.6
Lease	1	0.3
Communal	362	99.2
Total		
Access to electricity in the house?		
No	10	2.7
Yes	355	97.3
Total	365	100
Access to electricity in the farm		
Yes	53	15.3
No	293	84.7
Total	346	100

With regards to land ownership, it was observed that livestock farmers do not own the land (99%) and their livestock grazed/browsed on communal land. Land ownership allows farmers to partition portions of the land into different livestock enterprises like planting pastures. Legal land ownership also allows one access to agricultural credit. Proving legal ownership of the land accelerates the process of obtaining public credits and acts as a guarantee for personal credits (Lindoso *et. al*., 2014). Farmers with large landholdings stand a better chance of diversifying their farming practice to adapt to climate change than those with small landholdings. Landless households are mostly affected by climatic shocks (Senbeta and Olsson, 2009). Livestock farmers in the current study have low adaptive capacity due to a lack of land ownership.

The use of communal grazing by livestock farmers makes them more vulnerable to climate change, with less adaptive capacity because of their dependence on climatic conditions and the natural resource base. Wani *et al*., (2009) reported that rainfed agricultural systems dominate much of tropical agriculture, and are extremely vulnerable to climate change. Rovere *et. al*., (2009) observed that agricultural systems that depend entirely on crops are at great risk of collapse.

Livestock are more likely to experience a shortage of feed due to exposure to drought and a shortage of rainfall. The majority (97%) of farmers had access to electricity in their houses and however, most of the livestock farmers (85%) indicated non-electrification in their farms since their livestock graze or browse on communal land. Electricity allows access to information through TV media and the telephone. Adaptive capacity is highly dependent on the capacity of farmers and their families to access key information and to collectively self-organize (Jones and Boyd, 2011).

8.3.3 Production systems

Smallholder livestock farming systems

Indigenous cattle have roles to play in the traditional subsistence style of farming. Milk production for sale and household consumption is of overriding importance. Draft and dung power is of major concern to farmers. Meat production may have to be considered as a by-product until such time as marketing and price infrastructure develop to increase the economic motivation to produce meat for its own sake. In the recent past, lobola was a system used to move cattle from one herd to another, thus avoiding inbreeding. Cattle are also used as some form of living savings account and as an insurance against unforeseen events. The introduction of new breeds in an attempt to improve the indigenous breeds in the past has created crossbred animals that have indirectly become more common in rural areas. This has resulted in a dramatic decrease in the number of pure indigenous cattle. A common sight in rural areas today is the Nguni-type crossbred, Brahman type, and mixed breed that are a variant of the indigenous Sanga cattle breeds of South Africa. The Afrikaner characters also feature prominently in certain herds due to the historic introduction of the breed in the early 1970s. The prominence of the Bonsmara breed also plays a role in stallholder farmers crossing the breed with Nguni or Nguni Crosses. Central to the said random crossing has always been the desire of smallholder farmers to breed bigger-sized animals, whilst in the context of a lack of resources for proper management in a vulnerable environment. It must also be stated that commercial beef producers are showing renewed interest in the indigenous breeds, especially Nguni, owing to growth and favourable reproduction characteristics under adverse conditions such as drought, worm and tick burdens. In the context of this study, it has always been the observation that the larger-framed breed types suffer greater mortality during drought. The large-framed breeds will include not only the *Bos Taurus* but also the large-framed *Bos Indicus* (Brahman) type breeds. The small-framed Sanga-type breeds are bred from the foundation stock of Nguni cattle. survive better under extreme weather events of drought and insufficient natural grazing.

It is our contention that unconsciously, smallholder farmers have been breeding random crosses for decades to develop what today we call a breed in transition – the Nguni-type, Brahman-type, Bonsmara-type, Sanga and Bos Taurus crossed that change in composition in relation to changes in extreme climates over the years. Whatever the cross ideally, the breed-type should have medium-term improvement in productivity and have similar or better resistance to environmental stress than indigenous breeds.

The importance and popularity of indigenous livestock rest on their adaptive ability and availability. Among the characteristics attributed to the popularity of indigenous cattle and their derivatives are their tolerance to climatic stresses. Traits such as their genetic adaptation to poor quality forages and resistance to pest and diseases contribute to their popularity. Therefore, evaluation of beef cattle productivity should consider fertility and adaptability as the factors of importance, affecting the profitability of the smallholder livestock enterprise.

Objectives of keeping animals

The objectives of keeping animals by farmers are presented in Table 8.3. The majority of farmers kept livestock for meat (98%), followed by cultural (52%), ceremonies (45%), cash or sales (41%) and manure (40%). Similar reasons for keeping livestock were also reported by Nthakeni (2006), Musenwa *et al*. (2007); and Goni *et al*. (2018). It was noted that only 19% of the farmers kept livestock as an investment. Households with livestock were more resilient to climate change (Nkonde *et al*., 2014), since they would sell them in the event of financial shock and food shortage, thereby reducing vulnerability.

Table 8.3. Percentages and frequencies of the objectives of keeping livestock by smallholder farmers

Objective	Responses			
	Yes	%	No	%
Meat	98.4 (360)	98.4	1.6 (6)	1.6
Milk	1.1 (4)	1.1	98.9 (362)	98.9
Eggs	0.5 (2)	05	99.5 (364)	99.5
Manure	40.4 (148)	40.4	59.6 (218)	59.6
Hide	0.3 (1)	0.3	99.7 (365)	99.7
Cash/sales	41.3 (151)	41.3	58.7 (215)	58.7
Investment	19.4 (71)	19.4	80.6 (295)	80.6
Ceremonies	44.8 (164)	44.8	55.2 (202)	55.2
Cultural	52.2 (191)	52.2	47.8 (175)	47.8
Cashmere	8.5 (31)	8.5	91.5 (335)	91.5

Animal activities

The present study found that adult males were mentioned as the main member of the household responsible for selling/slaughtering (74%), animal health (72%), purchasing (69%), breeding decisions (67%), herding (56%), and feeding (56%) activities (Table 8.3). Boys under 15 years were more involved in animal activities such as purchasing, selling/slaughtering, herding, breeding decisions and feeding than girls under 15 years. It was evident in this study that males, irrespective of age, are generally responsible for all animal activities. This was supported by Mulinyac, (2017), who reported that in most African countries, most decisions regarding agricultural activities and planning are made by men, who mainly focus on the end products from agriculture and not the processes.

Table 8.3. Frequencies and associated percentages of members of households responsible for animal activities

	Adult males	Adult female	Boys (<15 yrs.)	Girls (<15 yrs.)	Hired labour
Animal Activities					
Purchasing	252 (68.9)	70 (19.1)	26 (7.1)	1 (0.3)	13 (3.6)
Selling/ slaughtering	269 (73.5)	56 (15.3)	43 (11.7)	1 (0.3)	16 (4.4)
Herding	206 (56.3)	25 (6.8)	33 (9)	1.1 (4)	36 (9.8)
Breeding decisions	246 (67.2)	45 (12.3)	38 (10.4)	1 (0.3)	41 (11.2)
Feeding	206 (56.3)	30 (8.2)	41 (11.2)	1 (0.3)	52 (14.2)
Milking	14 (3.8)	0	1 (0.3)	1 (0.3))	2 (0.5)
Making dairy products	0	0	1 (0.3)	0	2 (0.5)
Selling dairy products	2 (0.5)	3 (0.8)	0	0	1 (0.3)
Animal health	262 (71.6)	31 (8.5)	42 (11.5)	6 (1.6)	48 (13.1)

Percentages and frequencies of livestock farmers' production systems are presented in Table 8.4. Climatic extremes and seasonal fluctuations in herbage quantity and quality will affect the well-being of livestock and will lead to declines in production and reproduction efficiency (Sejian, 2013). The majority of livestock farmers practice a communal production system (80%), and their livestock are directly and indirectly affected by climate change. These livestock are exposed to direct and indirect effects of climate change. Direct effects of air temperature, humidity, wind speed, and other climate factors influence animal performance: growth, milk production, wool production and reproduction (Houghton, 2001). While indirectly, feed resources can have a significant impact on livestock productivity, the carrying capacity of rangelands, the buffering ability of ecosystems, and their sustainability, and the distribution of livestock diseases and parasites (Thornton et *al*., 2007).

Generally, the communal production system is more vulnerable to climate change with low adaptive capacity. Only 1.6% of livestock farmers were farming under the intensive production system. Confined livestock production systems that have more control over climate exposure will be less affected by climate change (Rotter and van de Geijn, 1999).

Table 8.4. Percentages and frequencies of livestock farmers' production systems

	Yes	%	No	%	Total
Industrial/Intensive	6.0	1.6	360	98.4	100 (366)
Semi-intensive	48.0	13.1	318	86.9	100 (366)
Extensive/Communal	296	83.6	70	0.191	100 (366)

Livestock type

Most of the livestock farmers had cattle (98%), followed by goats (15%), chicken (8%), pigs (6%) and sheep (3%) (Table 8.5). African farmers are known to keep cattle as an insurance policy for when droughts ruin annual crops (Swinton, 1988; Fafchamps et al., 1998).

Table 8.5. Percentages and frequencies of livestock farmers by major species

	YES		**NO**		
	Frequencies	%	Frequencies	%	Total
Cattle	360	98.4	6	1.6	100 (366)
Sheep	10	2.7	356	97.3	100 (366)
Goats	53	14.5	313	85.5	100 (366)
Pig	20	5.5	346	94.5	100 (366)
Chicken	30	8.2	336	91.8	100 (366)

Years of farming experience

Farming experience is an important aspect of agriculture (Mulinyac, 2017). It was revealed that, on average, livestock farmers had 16 years of farming experience, with a minimum and maximum of farming experience of 3 and 70 years, respectively. It was reported that the number of years of experience in farming is highly correlated with the level of knowledge and skill related to adapting to climate change and climate variability using technology (Abdul-Razak and Kruse, 2017).

Total number of livestock owned by farmers

The number of livestock owned, ownership of a radio, and quality of residential homes are commonly used as indicators of wealth in rural African communities (Vyas and Kumaranayake, 2006). Wealth enables communities to absorb and recover from losses more quickly (Cutter *et al*., 2000). Table 8.6 indicates the total number of livestock owned by farmers in recently and ten years ago where, on average, in recent years, farmers kept a total number of 16.70, 12.50, 14.82, 19.07, 7.0 and 11.53 of cattle, sheep, goats, fowls, donkeys and pigs, respectively. The average number of cattle owned reported in this study is more than the findings of Stroebel (2004) in Sub

Saharan Africa, Moorosi (2009) in Thaba Nchu of South Africa, Stroebel *et. al*. (2008) in the Venda region of South Africa, and Goni *et al*. (2018) in Majali Community, Peelton of South Africa. Whereas 10-20 years ago, on average, farmers kept a total number of 17.04, 9.27, 12.53, 15.07, 14.75, 6.74 of cattle, sheep, goats, fowls, donkeys, and pigs, respectively. There were no changes observed in the average total number of cattle between recent years and 10-20 years ago. As of now, livestock farmers have slightly more sheep, goats, fowls and pigs than 10-20 years ago, an improvement was noted. Rust and Rust (2013) indicated that the probability of choosing goats and sheep becomes greater as temperatures rise. Currently, on average, the total number of donkeys are low as compared to 10-20 years ago.

Table 8.6. The total number of livestock owned by farmers recently and 10 years ago

	Recent			10-20 years ago		
	Mean	Min	Max	Mean	Min	Max
Cattle	16.70	1	98	17.04	1	120
Sheep	12.50	4	40	9.27	1	20
Goats	14.82	2	73	12.53	1	50
Fowls	19.07	3	100	15.07	1	55
Donkeys	7.0	5	20	14.75	1	50
Pig	11.53	2	48	6.74	1	25

Reasons for the increase and decreases in herd sizes in the last two years

Most of the livestock farmers (82%) indicated a natural increase (calving, lambing, or farrowing) as the main reason for the increase in the recent two years (Table 8.7). Other reasons cited by a few farmers for the increase were purchases (buy in), donations, and received from lobola.

The main reason for the decrease in livestock (50-70%) indicated by livestock farmers was selling or slaughtering. Few livestock farmers (48%) reported that their fowl decrease was due to disease-related deaths. Less than 3% of the livestock farmers observed theft as the reason for the decrease in cattle and goats. Only 26% of the livestock farmers reported drought as the reason for the decrease in cattle. Paid lobola, predation and weather were not stated by livestock farmers as reasons for the decrease in herd size in the recent 2 years.

Table 8.7. Frequencies & associated percentages of reasons for increase and decrease in herd size in the last 2 years

	Cattle	Sheep	Goats	Pigs	Donkeys	Fowls
Increase						
Purchased (buy in)	21 (11.9)	0	7 (7.7)	2 (6.1)	0	9 (22.0)
Natural increase (calving/lambing/farrowing)	144 (81.8)	11(100)	80 (87.9)	30 (90.9)	3 (100)	28 (68.3)
Donations/gifts	3 (1.7)	0	1 (1.1)	0	0	2 (4.9)
Received from lobola	2 (1.1)	0	0	0	0	0
Good management	5 (2.8)	0	1 (3.0)	1 (3.0)	0	2 (4.9)
Other	1 (0.6)	0	0	0	0	0
Decrease						
Disease related death	21 (15.22)	0	3 (9.1)	2 (22.2)	1 (100)	10 (47.6)
Drought related death	36 (26.1)	1 (50)	4 (12.1)	1 (11.1)	0	3 (14.3)
Sold/slaughtered	75 (54.3)	1 (50)	24 (72.7)	6 (66.7)	0	8 (38.1)
Theft	3 (2.2)	0	1 (3.0)	0	0	0
Paid lobola	2 (1.4)	0	0	0	0	0
Predation	1 (0.7)	0	0	0	0	0
Weather	0	0	0	0	0	0

Natural increase (calving, lambing, or farrowing) was mentioned by the majority of farmers as the reason for the increase in livestock (except pigs) 10-20 years ago (Table 8.8). Purchased or buy-in was reported by the majority of farmers as the reason for the increase in pigs 10-20 years ago.

Smaller fractions of farmers cited purchased, donations or gifts, lobola and good management in cattle, sheep. Goats, donkeys and fowls as some of the reasons for the increase 10-20 years ago. Sold/slaughtered was mentioned as the reason for the decrease in cattle (55%), goats (57%) and pigs (73%) herd size for the last 10-20 years. Livestock farmers probably sell their livestock to meet family demands like food and education for children. Disease and drought related deaths were mentioned by few livestock farmers as reasons for the decrease in livestock herd sizes for the past 10-20 years.

Table 8.8. Frequencies and associated percentages of reasons for increase and decrease in herd size for the last 10-20 years

	Cattle	Sheep	Goats	Pigs	Donkeys	Fowls
Increase						
Purchased (buy in)	7 (5.0)	1 (12.5)	4 (6.2)	17(85.0)	0	2 (7.4)
Natural increase (calving/lambing/farrowing)	121(85.8)	6 (75.0)	55 (84.6)	0	4 (100.0)	25 (92.6)
Donations/gifts	4 (2.8)	0	1 (1.5)	2 (10.0)	0	0
Received from lobola	1 (0.7)	0	1 (1.5)	0	0	0
Good management	8 (5.7)	1 (12.5)	4 (6.2)	1(5.0)	0	0
Decrease						
Disease related death	20 (15.7)	1 (20.0)	9 (20.5)	2 (13.3)	1 (100)	6 (24.0)
Drought related death	28 (22.0)	2 (40.0)	9 (20.5)	2 (13.3)	0	6 (24.0)
Sold/slaughtered	70 (55.1)	2 (40.0)	25 (56.8)	11 (73.3)	0	9 (36.0)
Theft	3 (2.4)	0	0	0	0	0
Paid lobola	0	0	1 (2.3)	0	0	4 (16.0)
Predation	4 (3.1)	0	0	0	0	0
Weather	2 (1.6)	0	0	0	0	0

Livestock housing materials

Livestock housing plays a role in protecting animals from extreme climatic conditions. It was observed that almost all livestock farmers used treated wood (92%), and wire (99%) for their livestock housing. Livestock housing had no floor or roof. Livestock require some form of shelter where they can rest and ruminate. Shelter is also important for protection against extreme weather conditions. Most importantly, animals may need shelter from the hot sun and extreme cold and wet conditions. It has also been projected that in the intermediate to long term, there will be a need for sheltered cattle, goats, sheep housing towards intensive farming to avoid extreme weather patterns of heat and floods.

Pig or poultry supplementation

Over 91% of the livestock farmers did not supplement poultry or pig with either kitchen waste, bought complete ration, home-made ration, crushed or whole grain Table 9.9. Pigs and poultry in the study area are free range wherein they search for food around the household during the day.

Table 8.9. Frequencies and associated percentages on poultry/ pig supplementation regimes

	Yes	%	No	%
Kitchen waste	31	8.5	335	91.5
Bought complete ration	3	0.8	363	99.2
Home-made ration	5	1.4	361	98.6
Crushed grain	1	0.3	365	99.7
Whole grain	12	3.3	354	96.7

Farm records

Keeping records of livestock production is useful for monitoring the success of farming activities and to inform future veld management decisions. The majority of livestock farmers kept records (67%) and the type of records kept were mostly production (87%). Essential farm records include production and financial records. It was noted that the majority of livestock farmers kept no sales (76%) or marketing (100) records. Record keeping can help the livestock farmer to understand how climate extremes and certain weather patterns affect farming practices and livelihoods. These records are also useful when planning for livestock farming in a changing climate.

Causes of livestock death

Small margins of livestock farmers reported disease and lack of feeds/rainfall (45%) and 41% respectively) as the main causes of livestock death. Changes in the primary productivity of crops, forages and rangelands are probably the most visible effect of climate change on feed resources for ruminants with the end result, for livestock production, a change in the quantity of grains, stover and rangelands available for dry season feeding (Thornton et al., 2007). Changes in species composition in rangelands and some managed grasslands will have significant impact on the types of animal species that can graze them, and may alter the dietary patterns of the communities dependent on them (Thornton et al., 2007).

Alterations in temperature and rainfall may result in the spread of disease and parasites into new regions or produce an increase in the incidence to which a particular disease is already prevalent, which will lead to a decrease in animal productivity and increase in animal mortality (Baker & Viglizzo, 1998).

Access to veterinary services

Disease surveillance and vaccination services seemed not to be working efficiently. About 53% of the livestock farmers had no access to veterinary services. While those livestock farmers that had access to veterinary services received it from the government (26%), private veterinarians (18%) and extension services (15%). The majority (85%) of the livestock farmers undertook control of external parasites when the need arose. Methods of controlling external parasites used by farmers included dipping (62%) and spraying (44%). Drench (69%) and traditional methods (13%) were used as methods for controlling internal parasites by livestock farmers. Only 17% of the livestock farmers did not control internal parasites.

Environmental factors

The main environmental challenges greatly affecting livestock production are listed in Table 8.10, where grazing (> 66%) was mentioned as the main environmental challenge, affecting cattle, sheep, goats and donkeys, followed by temperature, pests and diseases, rainfall and water. The forage quality and quantity available for grazing livestock in the current study seemed to be affected by the combination of increased temperature and lack of rainfall (water). Temperature affects most of the critical factors for livestock production, such as water availability, animal production, reproduction and health (Rojas-Downing et. al., 2017). An increase in temperature between 1 and 5°C might induce high mortality in grazing cattle (Howden et al., 2008) and, as a mitigation measure, they recommended sprinklers, shade or similar management to cool the animals. Farmers (43%) mentioned pests and diseases as the environmental challenges affecting pigs. Several livestock health problems related to climate change have been reported (Nardone et al., 2010).

Table 8.10. Frequencies and associated percentage of the main environmental challenges greatly affecting livestock production.

	Cattle	Sheep	Goats	Chickens	Turkeys	Donkeys	Pig
Rainfall	11 (3.0)	2 (11.1)	8 (4.8)	5 (5.2)	0	0	2 (4.8)
Temperature	38 (10.4)	2 (11.1)	31 (18.7)	31 (32.0)	1 (100)	1 (25)	11 (26.2)
Grazing	279 (76.9)	12 (66.7)	118 (71.1)	18 (18.6)	0	3 (75)	2 (4.8)
Pests and diseases	27 (7.4)	2 (11.1)	6 (3.6)	1 (1.0)	0	0	18 (42.9)
Lack of water	8 (2.2)	0	3 (1.8)	0	0	0	9 (21.4)

Lack of feeds was reported by the majority of farmers (>90%) as socio-economic challenges faced by cattle, sheep, goats and donkeys. Other socio-economic factors listed by livestock farmers included lack of shelter, poor extension, theft, lack of knowledge and farm labour. The sources of grazing or feed for livestock are shown in Table 8.11, where 97%, 75%, and 59 % of farmers reported communal grazing, bought in feeds and crop residues, respectively, as sources of grazing or feed for livestock. Few farmers fed their livestock agro-processing by-products (25%) and their own crop harvest (35%). Almost 100% of the livestock farmers did not receive government support in terms of feed for livestock.

Sources of grazing

Table 8.11. Frequencies and associated percentages on sources of grazing for livestock

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

Farmers reported that the assessment of the condition of rangelands status as average and bad, 55% and 43%, respectively. It was indicated that grazing pasture or veld was poor, with some grass and bush encroachment. The browse condition contained very poor, big trees, bush encroachment, little grass and no shrubs. It is clear that the feeding systems depend on natural pastures which is influenced by climatic conditions.

Livestock market

Almost all (99%) farmers sold their livestock in a live form and to the community (93%) and butchery (7%). Livestock farmers do not slaughter, nor is there any value added. Livestock farmers do not have access to larger markets. Livestock farmers negotiate farm gate prices, and their target market is rural consumers (91%).

Prices are influenced by the local community demand. It was observed that consumers/buyers are responsible for transporting livestock to the butchery. Farmers do not incur any transportation fees. Livestock farmers considered the quality of the skin as a factor when grading it. In general, livestock farmers do not sell the skin (84%), and the small margin that sell (16%) target the butchery, church and the community. Farmers were asked about the rating of trust to local markets in accessing buying and selling of livestock, availability, and favourable prices of buying and selling livestock were rated as very poor. Farmers in the current study do not have the adaptive capacity due to a lack of market and infrastructure to process livestock. The lack of resources and socio-economic limitations can impair farmers' adaptation decision-making even when they perceive high risks (Frank et. al., 2011).

Access to water

Water source

Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processing (Thornton *et al*., 2009). Agricultural water sources and accessibility to a water source are sensitive indicators, based on the principle that human populations and agro-productive systems, whose water supply is limited, are highly sensitive to severe droughts (Lindoso *et al.,* 2014). Healthy livestock require regular access to potable water. The majority of livestock farmers indicated the river as the main source of water for their cattle and donkeys (Table 8.12). Whereas tap water and boreholes were equally shared by sheep and goats as sources of water. 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, sheep, goats, pigs, and chickens had access to the dam as the source of water.

Distance to water source

When farmers were asked to give the distance to a water source for each enterprise (Table 8.13), the majority of farmers (>79%) indicated that sheep, goats, chickens and pigs accessed water at the household. The majority (76%) of livestock farmers, indicated that their cattle travelled 1 -10 km to access water (proxy to water stock), especially from the river. The shorter the distance that livestock have to move each day to get to water, the better their condition. Cattle seemed to be the most vulnerable livestock due to long distances travelled to access water. Water stress is the environmental threat to smallholder farming, which is dependent on rain-fed agriculture (Sun *et al*., 2007).

Table 8.12. Frequencies & associated percentages of the main source of water for each type of livestock

	Cattle	Sheep	Goats	Chickens	Turkeys	Donkeys	Pig
Dam	35 (9.7)	1 (5.6)	3 (1.9)	3 (3.1)	0	0	3 (7.1)
River	237 (65.4)	1 (5.6)	12 (7.2)	2 (2.1)	2 (100)	3 (75.0)	1 (2.4)
Tap water	23 (6.4)	8 (44.4)	82 (49.4)	59 (60.8)	0	1 (25.0)	28 (66.6)
Borehole	65 (18.0)	8 (44.4)	68 (41.0)	31 (32.0)	0	0	8 (19.1)
Vleis /springs	1 (0.3)	0	0	2 (2.1)	0	0	0
Other	1 (0.3)	0	1 (0.6)	0	0	0	1 (2.4)

Table 8.13. Frequencies and associated percentage of distance to water source for each type of livestock

	Cattle	Sheep	Goats	Chickens	Turkeys	Donkeys	Pig
At household	87 (23.9)	16 (88.9)	131 (78.9)	83 (88.3)	1 (100)	0	38 (92.7)
<1 km	103 (28.3)	2 (11.1)	27 (16.3)	9 (9.6)	0	2 (50)	1 (2.4)
1-5 km	107 (29.4)	0	8 (4.8)	2 (2.1)	0	2 (50)	2 (4.9)
6-10 km	65 (17.9)	0	0	0	0	0	0
>10 km	2 (0.5)	0	0	0	0	0	0

Other livestock production issues

Livestock farmers' capacity

Only a few (<4%) of the livestock farmers received technical support from the Limpopo Department of Agriculture (LDARD) and private institutions, belonged to farmers' or producers' unions, and received financial support from the government (Table 13). It was observed that there is poor support for livestock farmers by Extension Officers. Such situations impede the penetration and subsequent adoption of tangible adaptation measures among smallholders (Silvestri *et al.,* 2015; Mutunga *et. al*., 2017). Abdul-Razak and Kruse (2017) reported that access to agricultural extension services enhances farmers' knowledge and skills in climate change and adaptation-related practices and technologies. Participation by rural workers in associations and unions also plays a key role in their accessing benefits, such as retirement payments and agricultural insurance (Lindoso *et. al*., 2014). Jones and Boyd (2011) reported that participation in unions and associations also has an impact on the creation of social networks based on solidarity, something vital to the process of resistance and to the material and psychological recovery during and after climatic damages.

Families that are isolated and seldom visited by technical experts usually have less access to financing mechanisms. Adaptive capacity also relies on the availability of technical support to implement adaptation 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-organise (Smit and Wandel 2006; Jones and Boyd 2011). Acceptance of climate change and the need to adapt is an important step to adapting to climate change and thus enhances the adaptive capacity (Abdul-Razak and Kruse, 2017). 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). Cooperatives are relevant for adaptive capacity since they facilitate access to public policies and to the production scale necessary to be inserted in the market (Jones and Boyd 2011; O'Brien *et. al*., 2004). In general, livestock farmers in the current study did not receive training in livestock farming, climate change, and do not belong to farmers' or producers' unions and which reduces their adaptive capacity.

Table 8.14. Frequencies and associated percentages of capacity-building aspects

Aspects of capacity building	Yes		No		
	Frequencies	%	Frequencies	%	Total
Receipt of training in livestock farming?	2	0.5	364	99.5	100 (366)
Receipt of training in climate change?	15	4.1	350	95.9	100 (365)
Belonging to any farmers union?	1	0.3	365	99.7	100 (366)
Belonging to a producer's organisation?	0	0	366	100.0	100 (366)
Financial support from government?	3	0.8	362	99.2	100 (365)
Receipt of technical support?	11	3.1	344	96.9	100 (365)

Livestock farmer perceptions on climate issues

Perception on climate change

Climate change perceptions include the individuals' views and interpretations of the climate issue based on beliefs, experiences, and understanding (Wolf and Moser, 2011). Dietz (2015) indicated that if farmers do not believe in climate change, they will not consider it as a threat to their livelihoods and will not try to adapt and cope with this phenomenon. The majority of the livestock perceived that there are notable changes in climate patterns (93%), rainfall decreased (87%), the temperature increased (79%) and agree that the frequency of droughts has increased over the years (88%).

Tropical countries have large populations of poor smallholders who live in a complex, diverse and risk-prone system, which adds to their vulnerability (Javis *et. al*., 2011). It is clear the small-scale farmers believed that they are exposed to climate change and that makes them more vulnerable. Any preparedness towards a potentially adverse situation, including climate change, has been shown to correspond to perceptions and awareness levels among the affected individuals and or groups (Le Danga *et al*., 2014). Across the tropics, smallholder farmers already face numerous risks to their agricultural production, including pest and disease outbreaks, extreme weather events and market shocks, among others, which often undermine their household food and income security (O'Brien *et al*. 2004). Smallholder farmers typically depend directly on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions in agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (McDowell & Hess, 2012).

Perception on the impact of climate change on livestock production

Climate change impacts livestock production in two ways, direct and indirect. The most significant direct impact of climate change on livestock production comes from the heat stress (Sejian *et. al*., 2016), while most of the production losses are incurred via indirect impacts of climate change, largely through reductions or non-availability of feed and water resources. The potential impacts on livestock include changes in production and quality of feed crop and forage (Polley *et al*.,2013; Thornton *et al*., 2009), water availability (Henry et al., 2012), animal growth and milk production (Henry *et al*., 2012), diseases (Nardone et al., 2010; Thornton *et al*., 2009), reproduction (Nardone *et al*., 2010), and biodiversity (Reynolds *et al*., 2010). It is believed that livestock production and productivity will be one of the most susceptible sectors to climate change due to changes in the hydrological cycle, temperature balance, and rainfall patterns, which have a negative impact on livestock production and productivity (Mwiturubani, 2010). Smallholder farmers believed that there is an impact of climate change on their livestock production, as indicated in Table 8.14.

Perceptions of the impact of climate change on livestock production were based on observation of less grass in pastures, drying streams, outbreaks of diseases, death of livestock due to excessive heat or cold, shortage of feeds, drinking water and unknown disease, and floods. Notenbaert *et al*. (2010) observed climatic trends that included reduced productivity of animal feed, higher disease prevalence, and reduced freshwater availability. This was due to the negative effects of lower rainfall and more droughts on crops and on pasture growth, and to the direct effects of high temperature and solar radiation on animals. Forage quantity and quality are affected by a combination of increases in temperature, CO_2, and precipitation variation. The majority of smallholder farmers believed that less grass in pastures (90.7%) and drying of river streams (33.6%) were due to climate change.

Table 8.15. Percentage and frequencies of the livestock smallholder farmers' perception of the impact of climate change on livestock

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

Droughts and floods have been commonly experienced in many parts of SSA especially around the Horn of Africa and the Sahel (Kotir, 2010). Only 20% of the smallholder farmers perceived that death of their livestock was due to floods, while 39.9 % of the smallholder farmers believed that their livestock died due to lack of drinking water. Water availability issues will influence the livestock sector, which uses water for animal drinking, feed crops, and product processes (Thornton *et al*., 2009). Inchaisri *et. al.* (2013) reported that the majority of livestock losses were in poultry and swine farms. Because of the unfeasibility of movement of swine during a flood, the number of swine losses was the highest of any livestock species. Droughts and floods are recurring environmental challenges in several rural communities across the country.

The capability to develop adaptations and survive extreme conditions becomes more difficult as the disturbance becomes increasingly more unpredictable and severe, as shown by both theoretical and empirical studies (Colinet *et al*., 2015; Roitberg and Mangel, 2016). So in the livestock farming sectors, it is important to identify areas that are prone to heavy flooding, as this will be crucial information for farmers to decide whether livestock farming should be continued in those areas.

Few smallholder farmers believed that there were outbreaks of diseases (24%) and death of livestock due to an unknown disease (29.2%). Increasing temperature may also increase exposure and susceptibility of animals to parasites and disease (Marcogliese 2001; Sutherst 2001), especially vector-borne diseases (Tabachnick, 2010). The effects of climate change on livestock diseases depend on the geographical region, land use type, disease characteristics, and animal susceptibility (Thornton *et al*., 2009).

8.3.6 Coping strategies to deal with climate change

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

8.3.6.1. ***Governance at village Level***: Smallholder farmers formed intra-village committees – each village has an umbrella committee, which acts like an executive committee of about eight people The Civic Committee. The subcommittee is then also formed that deal with Livestock, Rain-fed crops, Irrigation Schemes, Water, and in certain areas Land Care and Seed Multiplication. In the formation of these committees there is a greater consciousness to include women and youth, though some villages have specific Women and Youth committees. In the main the sub-committees manage and collaborate between villages all the natural resources such as natural grazing, source of water and theft. Two members of the sub-committees are nominated to represent a village in the inter-village committees on to say Livestock, Rain-fed crops, Irrigation Schemes, Water and Theft.

8.3.6.2. ***Drought coping strategies***: Smallholder farmers reported taking different types of adaptation measures to deal with climate change. During high temperature livestock farmers provide water for livestock, allow livestock to graze near the river, water stored in containers, use of borehole, provision of livestock feeds, supplements, sell livestock to buy feeds supplement and livestock stay inside when temperatures are high.

8.3.6.3. ***Flood – heavy rains strategies***: During floods livestock farmers provide medication, dip, shelter, store water using containers and dams, irrigate using river water, avoid grazing during rain and provide feed supplements.

8.3.6.4. ***Long-term strategies***: The local governance committees at village level have long term plans to deal with climate extremes. (a) Despite the gross lack knowledge, awareness, sources of funding, land and markets, there is a growing realization by smallholder farmers that they should spare part of their rain-fed land and irrigation scheme to grow their own fodder; (b) Central to these strategies is also disjointed access to weather-related information (Early Warning System) and cooperation between farmer groups and or committees with agricultural extension services;

(c) The power of many that comes with the formation of committees helps smallholder farmers to mobilise support from Traditional Leaders, Municipal Councillors and Municipal Officials on Local Economic Development projects such as roads, dams, boreholes, and other community needs related to service delivery.

8.4 CONCLUSIONS

Smallholder farmers have the potential to create thriving enterprises with rural communities. An average smallholder farmer has on average 16 years of farming experience and has enough knowledge and skills to deal with climate change and variability. The main objective of keeping livestock is for meat production, cultural ceremonies, cash and manure. Men are generally responsible for all animal activities like purchasing, selling, and breeding. There were no changes observed in the average total number of cattle between recent years and 10-20 years ago. Currently, livestock farmers have slightly more sheep, goats, fowls, and pigs than 10-20 years ago. Natural increase (calving, lambing, or farrowing) is the main reason for the increase in the recent 2 and last 10-20 years, and selling or slaughtering was the main reason for the decrease in livestock for the last 10-20 years. The main environmental challenges affecting livestock are drought, lack of grazing, heat stress, pests, diseases, and lack of water. Smallholder farmers reported taking different types of adaptation measures to deal with climate change, like the provision of water, allowing livestock to graze near the river, water storage, and provision of feed supplements and the selling of livestock to buy feeds. Empowerment programs to smallholder farmers should be directed towards activities and projects that are self-sustaining, with support for local governance structures to initiate and lead a process on service delivery within the prescripts policy and law (Disaster Management Act 2002).

8.5 REFERENCES

Abdul-Razak, M. and Kruse, S., 2017. The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. Climate Risk Management, 17:104-122.

Adger W, Dessai S, Goulden M,. 2009). Are there social limits to adaptation to climate change? Clim Chang 93:335–354

Baker, B. & Viglizzo, J.E., 1998. Rangelands and livestock. Chapter 9. In: Handbook of methods for climate change impact assessment and adaptation strategies. Eds: Feenstra, J.F., Burton, I., Smith, J.B. & Tol, R.S., IVM/UNEP Version 2.0 Accessed September 22nd 2002.

Barrett, C.B., and M.R. Carter. 2013. The economics of poverty traps and persistent poverty: Empirical and policy implications. Journal of Development Studies 49 (7): 976–990. https://doi.org/10.1080/00220388.2013.785527.

Coetzee, G.K., Van Zyl, J., 1992. An assessment of food security in South Africa. In: Csaki, C., Dams, T.J., Metzger, D., Van Zyl, J. (Eds.), Agricultural restructuring in Southern Africa. Association of Agricultural Economics of Namibia, Windhoek Printers & Publishers: Namibia: 496–504

Colinet, H., Sickair, B.J., Vernon, P., Renault, D., 2015. Insects in fluctuating thermal environments. Annu. Rev. Entomol. 60, 123–140.

Cutter, S.L., J.T. Mitchell, and M.S. Scott. 2000. "Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina." Annals of the Association of American Geographers no. 90 (4):713-737.

Dietz T, Ostrom E, Stern P 2003. The struggle to govern the commons. Science (New York, NY) 302: 1907–1912

Dietz, T., 2015. Environmental value Handbook of Value: Perspectives from Economics, Neuroscience, Philosophy, Psychology and Sociology, 329.

Eakin H, Lemos MC (2010) Institutions and change: the challenge of building adaptive capacity in Latin America. Glob Environ Chang 20:1–3

Easterling, W.E. & Aggarwal, P.K., 2007. Food, Fibre and Forest Products. In: Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Eds: Parry, M.L., Canziani, O.F., Palutikof, J.P., Van der Linden, P.J. & Hanson, C.E., Cambridge, Cambridge University Press. pp. 273-313

Fafchamps, M., Udry, C. & Czukas, K., 1998. Drought and saving in West Africa: Are livestock a buffer stock? J. Dev. Econ. 55, 273-305.

FAO, 2007. Adaptation to climate change in agriculture, forestry, and fisheries: perspective, framework and priorities. FAO, Rome

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Frank, E., Eakin, H., & López-Carr, D. (2011). Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. Global Environmental Change, 21(1), 66–76.

Gill, M. & Smith, P., 2008. Mitigating climate change: the role of livestock in agriculture. Livestock and Global Change Conference Proceeding. May 2008, Tunisia.

Goni S., Skenjana A. and Nyangiwe N., 2018. The status of livestock production in communal farming areas of the Eastern Cape: A case of Majali Community, Peelton. Applied Animal Husbandry and Rural Development, 11:34-40.

Havlík,P., H. Valin, A. Mosnier, M. Obersteiner, J.S. Baker, M. Herrero, M.C. Rufino, E. Schmid, 2013. Crop productivity and the global livestock sector: Implications for land use change and greenhouse gas emissions. Am. J. Agric. Econ., 95 (2013), pp. 442-448

Henry, B., Charmley, E., Richard, E., Gaughan, J.B. and Hegarty, R. (2012). Livestock production in a changing climate: adaptation and mitigation research in Australia. Crop & Pasture Science, 2012, 63, 191–202

Hertel, Thomas W. and Rosch, Stephanie D., Climate Change, Agriculture and Poverty (November 1, 2010). World Bank Policy Research Working Paper No. 5468. Available at SSRN: https://ssrn.com/abstract=1702130.

Houghton, J.T., 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, UK

Howden, S.M., Crimp, S.J., Stokes, C.J., 2008. Climate change and Australian livestock systems: impacts, research and policy issues. Aust. J. Exp. Agric. 48,780–788.

IFAD, 2010. Livestock and climate change. Livestock Thematic Papers. Tools for project design. www.ifad.org

Inchaisri, C., Supikulpong, P., Vannametee, E., Luengyosluechakul, S., Khanda, S., Tashnakajankorn, T., Ajariyakhajorn, K., Sasipreeyajan, J., & Techakumpu M. (2013). The effect of a catastrophic flood disaster on livestock farming in Nakhon Sawan province, Thailand. Trop Anim Health Prod (2013) 45:917–922

In-depth studies across the world. WileyInterdiscip. Rev. Clim. Change 2, 547–569.

Jones L. & Boyd E (2011) Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Kirsten, J.F., van Zyl, J., 1998. Defining small-scale farmers in the South African context. Agrekon, 37(4): 560–571.

Kotir, J. H. (2010): Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security, Journal of Environment and Sustainable Development, DOI 10.1007/s10668-010-9278-0, Springer

Le Dang, H., E. Li, J. Bruwer, and I. Nuberg. 2014. Farmers' perceptions of climate variability and barriers to adaptation: Lessons learned from an exploratory study in Vietnam. Mitigation and Adaptation Strategies Retrieved from http://link.springer.com/article/10.1007/s11027-012-9447-6.

Lemos M, Finan T, Fox R, Nelson D, Tucker J (2002) The use of seasonal climate forecasting in policymaking: lessons from Northeast Brazil. Clim Chang 55:479–507

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2014). Integrated assessment of smallholder farmings vulnerability to drought in the Brazilian Semiarid: a case study in Ceará. Climatic Change, https://www.researchgate.net/publication/262485038. DOI 10.1007/s10584-014-1116-1

Marcogliese DJ (2001) Implications of climate change for parasitism of animals in the aquatic environment. Canadian Journal of Zoology 79, 1331–1352. doi:10.1139/z01-067

McDowell, J. Z., Hess J. J. (2012): Accessing Adaptation: Multiple Stressors on Livelihoods in the Bolivian Highlands under a Changing Climate. – Global Environmental Change 22: 342-352.

Morton JF. 2007 The impacts of climate change on smallholder and subsistence agriculture. Proc. Natl Acad. Sci. USA 104, 19 680–19 685. (doi:10.1073/ pnas.0701855104)

Mulinya, C., (2017). Factors Affecting Small Scale Farmers Coping Strategies To Climate Change In Kakamega County In Kenya. Journal Of Humanities And Social Science, 22 (2), 100-109

Musemwa, L., Chagwiza, C., Sikuka, W., Fraser, G., Chimonyo, M. & Mzileni, N., 2007. Analysis of cattle marketing channels used by small scale farmers in the Eastern Cape Province, South Africa. LRRD, Paper No19 (9).

Mutunga, E., Charles, K., & Patricia, M. (2017). Smallholder farmers perceptions and adaptations to climate change and variability in Kitui County, Kenya. Retrieved from http://repository.seku.ac.ke/handle/123456789/3447.

Mwiturubani, D.A. (2010). Climate change and access to water resources in Lake Victoria basin; In; Mwiturubani Da and van Wyk JA (Ed) (2010) Climate change and natural resources conflicts in Africa, Institute for Security Studies, PO Box 1787, Brooklyn Square 0075, Pretoria, South Africa

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S., Bernabucci, U., 2010. Effects of climate change on animal production and sustainability of livestocksystems. Livest. Sci. 130, 57–69.

Ncube, M., Madubula, N., Ngwenya, H., Zinyengere, N., Zhou, L., Francis, J., Mthunzi, T., Olivier, C. and Madzivhandila T. (2016). 'Climate change, household vulnerability and smart agriculture: The case of two South African provinces', Jàmbá: Journal of Disaster Risk Studies 8(2), Art. #182, 14 pages. http://dx.doi.org/10.4102/jamba.v8i2.182.

Ndamani, F., and T. Watanabe. 2015. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. Water Retrieved from http://www.mdpi.com/2073-4441/7/9/4593/htm.

Nkondze, M.S, Masuku, M.B, & Manyatsi, A. (2014). Factors Affecting Households Vulnerability to Climate Change in Swaziland: A Case of Mpolonjeni Area Development Programme. Journal of Agricultural Science; Vol. 5, No. 10; 2013

Notenbaert, A., Mude, A., Van de Steeg, J. and Kinyangi, J. (2010). Options for adapting to climate change in livestock-dominated farming systems in the greater horn of Africa Journal of Geography and Regional Planning, 3 (9): 234-239.

Nthakheni ND (2006) A livestock production systems study amongst resource-poor livestock owners in the Vhembe District of the Limpopo Province. PhD Thesis. University of the Free State, Bloemfontein.

O'Briena, K., Leichenkob, R., Kelkarc, U., Venemad, H., Aandahla, G., Tompkinsa, H., Javedc, A., Bhadwalc, S., Bargd,S., Nygaarda, L. and West, J., 2004 Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob. Environ. Change 14, 303:313. (doi:10.1016/j.gloenvcha.2004.01.001).

Opiyo, F., O. Wasonga, M. Nyangito, J. Schilling, and R. Munang. 2015. Drought adaptation and coping strategies among the Turkana pastoralists of northern Kenya. International Journal of Disaster Risk Science 6 (3): 295–309. https://doi.org/10.1007/s13753-015-0063-4

Polley H.W., Briske, D.D.. Morgan, J.A. Wolter, K. Bailey, D.W. &. Brown, J.R. (2013) Climate change and North American rangelands: trends, projections, and implications. Rangeland Ecol. Manage., 66 (2013), pp. 493-511

Quinn, C.H., Ziervogel, G., Taylor, A., Takama, T. and Thomalla, F. (2011), "Coping with multiple stresses in rural South Africa", Ecology and Society, Vol. 16 No. 3, pp. 1-20.

Raworth, K. 2007. Adapting to climate change: What's needed in poor countries, and who should pay. Oxfam Policy and Practice: Climate Change and Resilience 3 (1): 42–88.

Reynolds, C., Crompton, L. & Mills, J. (2010). Livestock and climate change impacts in the developing world Outlook Agric., 39 (2010), pp. 245-248

Roitberg, B.D., Mangel, M., (2016). Cold snaps, heatwaves, and arthropod growth. Ecol. Entomol. 41, 653–659.

Rojas-Downing M.M, A. P. Nejadhashemi, T. Harrigan and S.A. Woznicki, 2017. Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management, 16:145-163

Rotter, R., van de Geijn, S.C., 1999. Climate change effects on plant growth, crop yield and livestock. Climatic Change 43, 651–681.

Rovere E, Avzaradel AC, Monteiro J (2009) Potential synergy between adaptation and mitigation strategies: production of vegetable oils and biodiesel in north-eastern Brazil. Clim Res 40:233–239

Rowlinson, P., M. Steele, A. Nefzaoui, 2008. Livestock and global climate change: Adaptation I and II P. Rowlinson, M. Steel, A. Nefzaoui (Eds.), Livestock and Global Climate Change Conference Proceeding, Cambridge University Press, Tunisia (2008), pp. 56-85

Rust J.M. and Rust T., 2013. Climate change and livestock production: A review with emphasis on Africa. South African Journal of Animal Science, 43 (3):255-267.

Sansoucy, Rene. 1995 Keynote paper: The contribution of livestock to food security and sustainable development. Food and Agri. Organization Pp. 2-3.

Schlatzer, Martin. 2010 Tierproduktion und Klimawandel: ein wissenschaftlicher Diskurs zum Einfluss der Ernährung auf Umwelt und Klima LIT Verlag Münster 1:Pp. 5-6.

Sejian, V. (2013). Climate change: Impact on production and reproduction, Adaptation mechanisms and mitigation strategies in small ruminants: A review. The Indian Journal of Small Ruminants, 19(1):1-21.

Sejian, V., Gaughan, J. B., Raghavendra Bhatta and Naqvi, S. M. K. (2016) Impact of climate change on livestock productivity. Broadening Horizons, www.feedipedia.org.

Senbeta, A.F., Olsson, J., 2009. In: Climate Change Impact on Livelihood, Vulnerability and Coping, Mechanisms:3 A Case Study of West-Arsi Zone. Ethiopia Lund University, Lund, pp. 54.

Seo, S.N. & Mendelsohn, R., 2006a. Climate change impacts on animal husbandry in Africa: A Ricardian analysis. CEEPA Discussion Paper No. 9, Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.

Seo, S.N. & Mendelsohn, R., 2006b. Climate change adaptation in Africa: A microeconomic analysis of livestock choice. CEEPA Discussion Paper No. 19, Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.

Sid-Ahmed. 2010 Livestock planning challenges and strategies for livestock development International Fund for Agri. Development Pp.1-2.

Silvestri, S., D. Sabine, K. Patti, F. Wiebke, R. Maren, M. Lanetta, Q. F., Carlos, H. Mario, N. Anthony, N. Nicolas, M. Joash, C. Lieven & R. M. Cristina. 2015. Households and food security: Lessons from food secure households in East Africa. Agriculture & Food Security 4 (1): 23. https://doi.org/10.1186/ s40066-015-0042-4

Smit B. and Wandel J. 2006. Adaptation, adaptive capacity and vulnerability. Glob Environ Chang Hum Policy Dimens 16:282

Smith, B., McNabb, D. & Smithers, J., 1996. Agricultural adaptation to climatic variation. Climate change 43, 7-29

Stroebel A (2004) Socio-economic complexities of smallholder resource poor ruminant livestock production systems in Sub-Saharan Africa. PhD thesis. University of the Free State, Bloemfontein.
Stroebel A., Swanepoel F.J.C., Nthakheni N.D., Nesamvuni A.E. and Taylor G., 2008, Australian Journal of Experimental Agriculture, 48, 825-828
Sutherst RW 2001. The vulnerability of animal and human health to parasites under global change. International Journal for Parasitology 31, 933–948. doi:10.1016/S0020-7519(01)00203-X
Swinton, S., 1988. Drought survival tactics of subsistence farmers in Niger. Human Ecology 16, 123-144.
Tabachnick WJ 2010. Challenges in predicting climate and environmental effects on vector-borne disease episystems in a changing world. The Journal of Experimental Biology 213, 946–954. doi:10.1242/jeb.037564
Thornton, P., Herrero, M., Freeman, A., Mwai, O., Rege, E., Jones, P. & McDermott, J., 2007. Vulnerability, climate change and livestock – Research opportunities and challenges for poverty alleviation. SAT e-Journal 4 (1), 1-23.
Thornton, P.K. Van de Steeg, J. Notenbaert, A & Herrrero, M. (2009). The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know Agric. Syst., 101 (2009), pp. 113-127
Turpie, J. and Visser, M., 2013. “The impact of climate change on South Africa’s Rural areas”, Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.
USDA (United States Department of Agriculture), 2013. Climate Change and Agriculture in the United States: Effects and Adaptation USDA technical bulletin, Washington, DC http://www.usda.gov/oce/climate_change/effects_2012/CC%20and%20Agriculture%20Report%20%2802-04-2013%29b.pdf.
Usmani, Hasnain. 2006 Livestock of Pakistan: Livestock is considered as a more secure source of income for the small poor people Population 15(16):Pp. 17-18.
Vyas, S., and L. Kumaranayake. 2006. Constructing socio-economic status indices: How to use principal component analysis. Health Policy and Planning 21(6): 459–468.
Wani, S.P.; Rockström, J.; Oweis, T.Y., 2009. International Crops Research Institute for the Semi-Arid Tropics; International Water Management Institute. Rainfed Agriculture: Unlocking the Potential; CABI: Wallingford, UK; Cambridge, MA, USA, 2009; p. 326.
Wolf, J., Moser, S.C., 2011. Individual understandings, perceptions, and engagement with climate change: insights from

CHAPTER 9: A LOCALISED FRAMEWORK TO MONITOR AND EVALUATE VULNERABILITY OF SMALLHOLDER LIVESTOCK FARMERS IN LIMPOPO AND MPUMALANGA

Abstract

A study was carried out with the aim of assessing the level of vulnerability of smallholder livestock farmers in order to provide an 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 the Limpopo and Mpumalanga provinces. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers that were organised and within reach of 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 smallholder 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, hazard occurrence, adaptation strategies pursued, coping strategies; the level of resilience, and other information as indicated in the methodology. This paper presents a theoretical and conceptual monitoring and evaluation (M&E) framework while also positing that if such a framework is mainstream, 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 involved 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 (m^3/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. The 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 the 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 cattle, have received training in the commodity value chain and not be older than 60 years.

9.1 INTRODUCTION

This chapter seeks to understand the vulnerability of smallholder farmers livelihoods at a rural environment in Limpopo and Mpumalanga considering the level of exposure, sensitivity and adaptive capacity to climate change. Climate change and variability have been considered the major issue of concern to the livelihoods of rural communities in the past decades (Maru *et al.*, 2014). Climate change has the potential to influence community livelihoods (Adger, 2003) and may disrupt smallholder and individual households' abilities to undergo their customary way of life (Artur and Hilhorst, 2012). It was then prudent following on many studies to understand how individuals and a community of livestock smallholder farmers were affected by projected climate change trends. The challenge with climate change is that is a complex phenomenon, especially when determining its impact on the socioeconomic wellbeing of individuals coupled with the uncertainty of climate variability.

Several approaches have been used to understand the socio-economic and or livelihood impacts of climate change. Some of the approaches that have been used to include, but not limited to (a) risk-based approach (Gaichas *et al.*, 2014); (b) participatory community-based strategies (Leonard *et al.*, 2013); (c) contextual approach (Gundersen *et al.*, 2016); (d) deductive, inductive and normative approaches (Hinkel, 2011); (e) role and stakeholder expert (Tonmoy *et al.*, 2014); and (f) multicriteria outranking approach (El-Zein and Tonmoy, 2015). It was of interest to the authors that the vulnerability component has been outlined as the major component (Huang *et al.*, 2012), as it was used to describe systems' exposure to the adverse effects of climate change (Füssel and Klein, 2006, IPCC, 2007). It therefore implied that that climate change has been described differently depending on the area of research being done such as resilience, marginality, susceptibility, adaptability, fragility and risk (Liverman, 1990) or exposure, sensitivity, coping capacity and robustness (Fussel, 2007). As defined vulnerability in the context of climate change is the exposure of groups or individuals in this case smallholder farmers to stress as a result of social and environmental change, with stress referring to unexpected changes and disruption to livelihoods (Adger and Kelly, 1999; Bohle *et al.*, 1994). For purposes of this study vulnerability was specifically in the manner in which we conducted the assessment targeting to understand how vulnerable smallholder livestock farmers are with the purpose of identified problems to recommend specific interventions aimed at reducing their vulnerability (Hughes *et al.*, 2012). The key to this 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.

9.1.1 Vulnerability defined

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) defines 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 an external side with risks, shocks and stress to which an individual is subject, and an internal side with 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) conceptualised 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, the vulnerability can be summarized as a function of three attributes: exposure, sensitivity, and adaptive capacity.

9.1.2 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 be associated with factors such as temperature and precipitation). Exposure as an attribute of vulnerability is linked to the type, magnitude and frequency of climate stimuli (Smithers and Smit 1997), and is sometimes considered as an external property of socio-ecological systems (Gallopín 2006).

9.1.3 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).

9.1.4 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 a 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 a 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 organisational landscapes – social capital, legislation, information flows, resources, learning capacity, and accumulated knowledge – is vital to adaptation (Dietz et al., 2003; Eakin and Lemos, 2010). Adaptive capacity also relies on the availability of technical support to implement adaptation 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-organise (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's (2011) Framework on Vulnerability. The said indicators will be established using the work on the livestock farmers in Limpopo and Mpumalanga Provinces of South Africa. The report will subsequently validate conclusions on the capacity to adapt to the adverse effects of climate change and climate variability.

9.2 MATERIALS AND METHODS

This section has been written to be a stand-alone part of each chapter with the aim to create independent papers addressing specific areas of the project and objectives. Each research method section will only vary depending on the approach used in data collection and analysis.

9.2.1 Study area

The study was conducted in both Limpopo and Mpumalanga provinces, respectively. Only Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers that are organised and within reach of the investigators. The political map of South Africa with the provinces is shown in Figure 9.1.

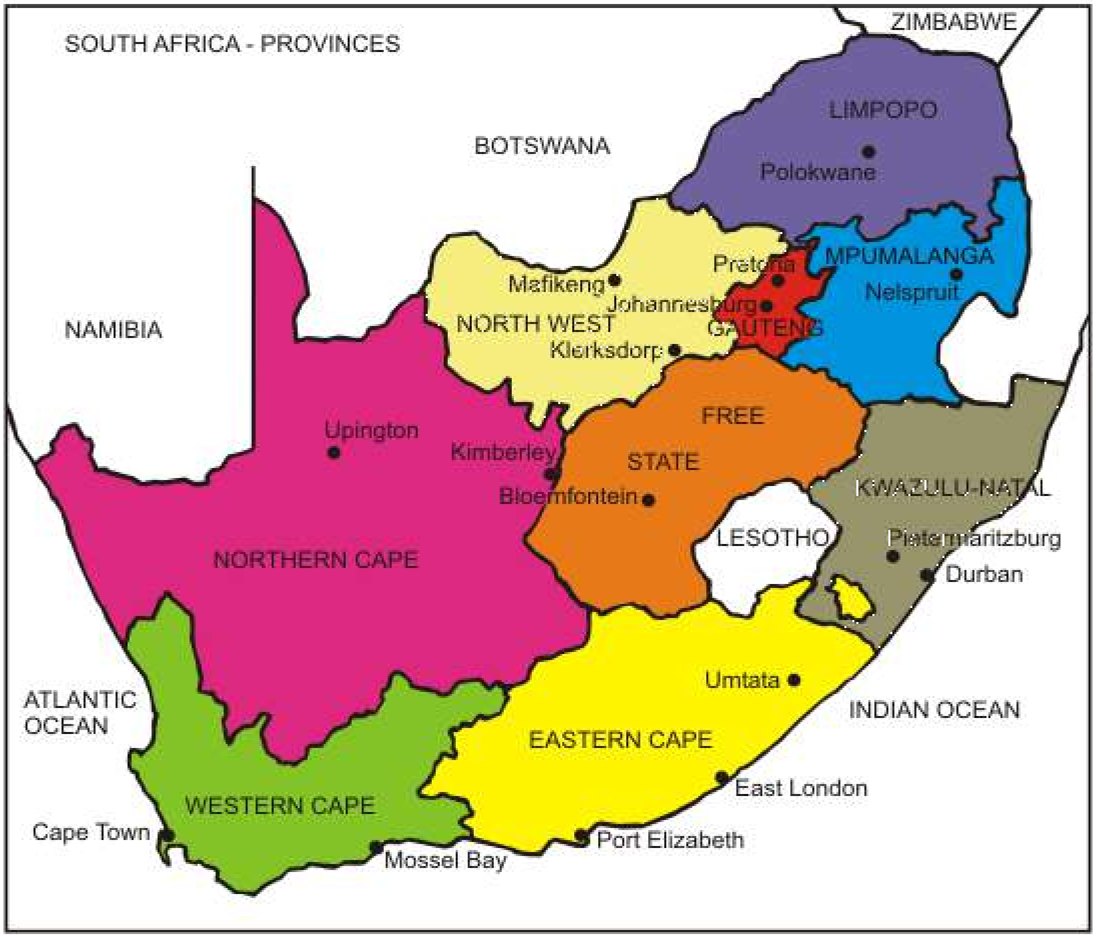


Figure 9.1. **Political map of South Africa showing the nine provinces**

9.2.2 Data collection

Data was collected through a descriptive survey using 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 interacting with the interviewee (Schulze, 2002). The structured questionnaire contained both open and closed-ended questions. Closed-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 percent. The questionnaire included, among others, demographic and economic household characteristics; livestock and crop production; access to extension services; credit access; hazard's occurrence; adaptation 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).

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.

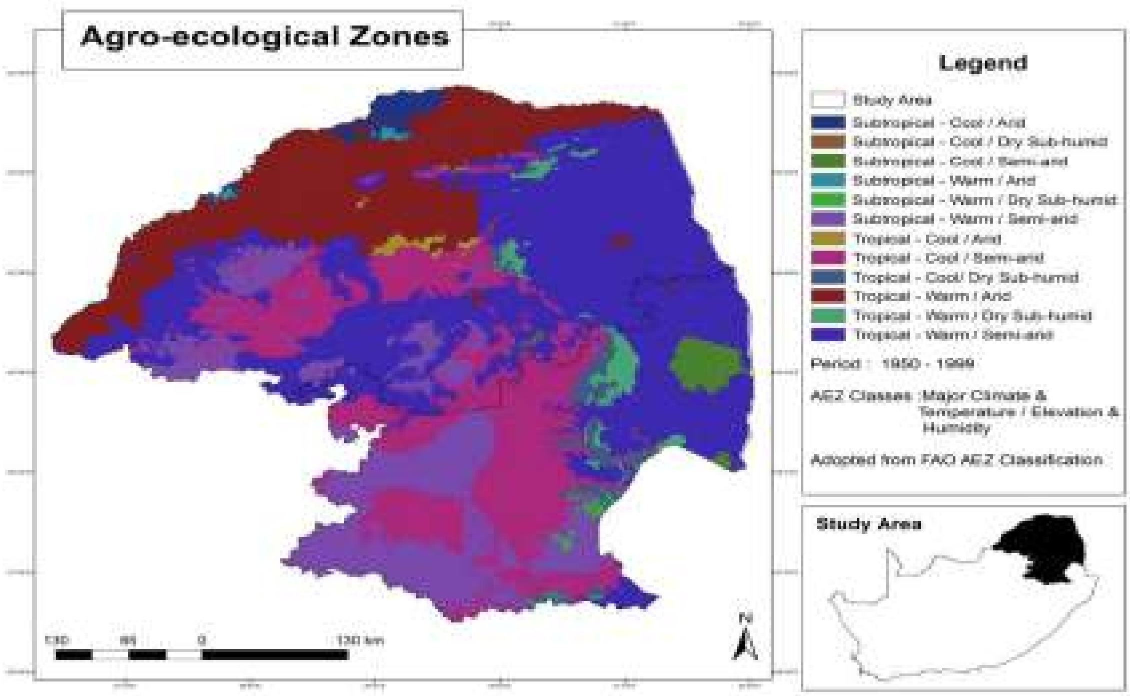


Figure 9.2. **Agro-ecological zones of the Limpopo and Mpumalanga provinces of South Africa (FAO, 1978)**

To determine livestock water use efficiencies, focus was on the sensitivity attributes. The main water-related indicators were around 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 5 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 utilise 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 the villages showing 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 village will be rainfall, land use-cover, drainage systems, hydrogeology and grazing potential.

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 was 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.

Sampling procedure

Systematic purposive sampling was used to select farmers within the five identified agro-ecological zones of Limpopo and about four in Mpumalanga. Effort was made to have a minimum of 10 farmers per village out of the randomly sampled households. We used stratified sampling to obtain a representative sample of villages and households for the interview. A two-stage random sampling process was conducted using the *SURVEYSELECT* procedure of SAS. The *PROC SUREVEYSELECT* allows 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.

9.2.3 Data analysis

Quantitative data were transcribed into the MS Excel Package and analysed 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 an Excel Spreadsheet. Descriptive analysis techniques were used in the study to capture the perceptions of respondents, mainly the qualitative data.

9.3 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.

9.3.1 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 9.1).

Table 9.1. Exposure-based thematic areas and indicators revised from the Lindoso (2011) Framework for 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)

Thematic area: Aridity and drought

(a) Aridity Index (AI)

Aridity Index (AI) is a numerical indicator which 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 recognised 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 percent of the study area was found to be in sub-humid areas, considered 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 considered arid, characterised by a severe lack of water resources to the extent of hindering the development of vegetation. Such a lack is exacerbated by the high evapotranspiration compared to the rate of precipitation (Derya, et al., 2009). Agricultural production in this category is impossible with the exception of portions with irrigation. The study area, therefore presents various levels of exposure of livestock farmers to adverse effects of aridity.

(b) Drought

A drought may be defined as an extended period of unusually dry weather with no rain or other precipitation. The majority (84%) of 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.

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 experiences dictates the nature of the agro-ecological setting that shall prevail. If an area receives a high amount of rainfall (more than 2 500mm per annum), a rainforest 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 and experience in excess of 1000mm per annum. According to SA Explorer (2017), Mpumalanga normally receives about 610mm of rain per annum, with most rainfall occurring mainly during midsummer. The Province receives the lowest rainfall (8mm) in June and the highest (89mm) in January. As shown by Tshikolomo (2012), the annual rainfall in the 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

A flood occurs when a river discharge exceeds its channel's volume, causing the river to overflow onto the area surrounding the channel, known as the floodplain. Land degradation and floods contributed 2.06% and 1.18%, respectively of exposure to the adverse effects of climate change and variability. Only 0.59% of respondents stated that 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, which makes 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 for the smallholder farmers, as they lack basic infrastructure, resources, and capital to condition the environment for supporting the production.

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 over 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 include Musina, The Lost City, and Bismark. Progression in the western 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 (THI)

Thermal heat index (THI) is an index that combines air temperature and relative humidity, in shaded areas, to posit a perceived equivalent temperature. Livestock have 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 that of the animals, is important for sustainable livestock farming.

Thematic area: Wind

(a) Wind

Among the major exposures of livestock farmers to the effects of wind are when disasters associated with the occurrence of wind occur. 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 next. The exposure of the farmers to wind disasters could result in issues such as the destruction of shelters, both for household and for livestock.

Vegetation

(a) Normalised difference vegetation index (NDVI)

The 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) suggests poor grazing for the livestock farmers. With the seasonal variation of rainfall followed by variations 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.

9.4 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. Accordingly, pertinent thematic issues and indicators were proposed for inclusion under this attribute (Table 9.2).

Table 9.2. Sensitivity based thematic areas and indicators revised from the Lindoso (2011) Framework for 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 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 *(litres/capita/day)*
	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 (%)

9.4.1 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 populations with 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.

9.4.2 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 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. Boreholes were 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 the 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 counterpart 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.

9.4.3 Thematic area: Distance to 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 5 km. 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 the 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.

9.4.4 Thematic area: Quantity and frequency of water access

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

The quantity of water accessed by a livestock farming household (litres per capita per day) also tends 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 as 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 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 pumping water sources (38%), taps in the yard (36%), indoor tap and communal well (7%), respectively.

9.4.5 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 of time and would therefore suffer more during periods 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 of time and would be less sensitive to adverse conditions associated with water scarcity.

9.4.6 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 for 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. As a result, 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 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 complementary grazing to livestock farmers. Accordingly, livestock farmers with access to crop residues for grazing tend to be less sensitive to the 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 the 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 reported using their own 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 who could afford feed 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.

9.5 ADAPTIVE CAPACITY

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). Guided by the Lindoso's (2011) Framework, pertinent thematic issues and associated indicators were proposed (Table 9.3).

Table 9.3. An 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 producer were of different age categories (%)
	c) Establishment in which producer had different levels of education (%)
	(d) Establishments in which producer had different employment status (%)
	e) Establishments in which producer had different income levels (%)
2. Product diversification	a) Establishments in which producer had diversified products (%)
3. Capacity building	a) Establishments which 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 (%)

9.5.1 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.

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

As was proposed for gender, age would also likely influence the level of the 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 to employ 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 tends 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 was 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 a 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 the producer had a different employment status (%)

The employment status of livestock farmers tends to have some influence on their adaptive capacity to the adverse effects of climate change and variability. The influence of employment status is informed by various influences, such 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 the livestock farming (negative influence). About half (50.5%) of the livestock farmers in the study area were involved in various types of employment, 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 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 the producer had different income levels (%)

High-income household 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 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 adapted to the adverse effects of climate change and variability when compared to their low-income counterparts.

9.5.2 Thematic issue: Product diversification

(a) Establishments in which the 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 the 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. The other 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.

9.5.3 Thematic issue: Capacity building

(a) Establishments which had a competent administrator (%)

The level of education has a strong influence on the extent to which a farmer is able to 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. The importance of education of a farmer in developing capacity to adapt to adverse climatic and other conditions was already discussed (Item 3.3.1(c)). 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 the producer was a member 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 higher adaptive capacity than their non-member 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 of belonged to a farmers' union (99.7%) nor to a producer organization (100%), and these suggest that they lacked exposure to knowledge and information and would possess 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 livestock farmers with the knowledge and information necessary to help them 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 low adaptive capacity to adverse conditions to which their enterprises would be sensitive.

9.5.4 Thematic issue: Access to electricity

(a) Establishments in which producers 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 his / 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 the 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 the 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).

9.5.5 Thematic issue: Receipt of support

(a) Establishments in which producers 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 producers received infrastructure support (%)

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

9.6 CONCLUSIONS AND RECOMMENDATIONS

9.6.1 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 reviewed 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 furthest water source (km); distance covered by animals to 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 (m^3/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 differing levels of education (%); establishments in which producers had a different employment status (%); establishments in which producers received financial support (%); and establishments in which producers received material infrastructure support (%).

(c) Although not necessarily critical, the introduction of thematic areas in this study allowed for categorisation of related indicators under each of the three attributes of the Lindoso (2011) Framework (exposure, sensitivity, and adaptive capacity).

9.6.2 Recommendations

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

9.7 REFERENCES

Adger W, Dessai S, and Goulden M. 2009. Are there social limits to adaptation to climate change? Clim Chang 93:335–354

Adger, W.N. 2003. Social capital, collective action and adaptation to climate change", Economic Geography, Vol. 79 No. 4, pp. 387-404.

Adger, W.N., Brooks, N., Bentham, G., Agnew, M., Eriksen, S., 2004. New indicators of vulnerability and adaptive capacity (on-line). Tyndall Centre for Climate Research, Norwich, Technical Report 7, /http://www.tyndall.ac.uk/research/theme3/ final_reports/it1_11.pdfS.

Adger, W.N., Vincent, K., 2005. Uncertainty in adaptive capacity. Comptes Rendu Geosciences 337, 399–410.

Artur, L. and Hilhorst, D. 2012. Everyday realities of climate change adaptation in Mozambique", Global Environmental Change, Vol. 22 No. 2, pp. 529-536.

Baltas, E., 2007. Spatial distribution of climatic indices in northern Greece. Meteorol Appl 14:69–78.

Birkman, J., 2006, Measuring vulnerability to natural hazards: Towards disaster resilient societies, United Nations University Press, New York.

Bohle, H.G., Downing, T.E. and Watts, M.J. 1994. Climate change and social vulnerability: toward a sociology and geography of food insecurity", Global Environmental Change, Vol. 4 No. 1, pp. 37-48.

Brooks N, Adger WN, Kelly PM, 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Chang 15(2):151–163

Butler, R. A., 2005. A Place Out of Time: Tropical Rainforests and the Perils They Face. Published online: Rainforests.mongabay.com

Creswell, J.W., 2003. Research Design: Qualitative, Quantitative and Mixed Methods Approaches (2nd Ed), Thousand Oaks, CA: Sage Publications.

Croitoru, A.E, Piticar. A., Imbroane AM., Burada, D, C., 2013. Spatio-temporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania. Theor Appl Climatol 112:597–607

Cutter, S.L., J.T. Mitchell, and M.S. Scott. 2000. Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina." Annals of the Association of American Geographers no. 90 (4):713-737.

Deniz A, Toros H, Incecik S., 2011. Spatial variations of climate indices in Turkey. Int. J. Climatology 31(3):394–403

Derya, Ö., Mehmet, A., Süha, B., Sermet, Ö., and Tomohisa, Y., 2009. The use of aridity index to assess implications of climatic change for land cover in Turkey. Turk J Agric For (33), 305-314. doi:doi:10.3906/tar-0810-21

Dietz T, Ostrom E, Stern P., 2003. The struggle to govern the commons. Science (New York, NY) 302: 1907–1912.

Eakin H, Lemos M.C., 2010. Institutions and change: the challenge of building adaptive capacity in Latin America. Glob Environ Chang 20:1–3

Egbu, A., 2007. The Impact of Land Use Planning on Urban Land Markets in sub-Saharan Africa: A case study of Nigeria. Unpublished PhD Thesis, school of Engineering and Build Environment, University of Wolverhampton, Wolverhampton – United Kingdom

El-Zein, A. and Tonmoy, F.N., 2015. Assessment of vulnerability to climate change using a multi-criteria outranking approach with application to heat stress in Sydney", Ecological Indicators, Vol. 48, pp. 207-217.

Finan T, Nelson D., 2001. Making rain, making roads, making do: public and private adaptations to drought in Ceará, Northeast Brazil. Clim Res 19:97–108.

Fussel, H.M. 2007. Vulnerability: a generally applicable conceptual framework for climate change research", Global Environmental Change, Vol. 17 No. 2, pp. 155-167.

Füssel, H-M., and Klein, R.J.T., 2006. Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. Climate Change 75: 301-329.

Gaichas, S.K., Link, J.S. and Hare, J.A. 2014. A risk-based approach to evaluating northeast US fish community vulnerability to climate change”, ICES Journal of Marine Science, Vol. 71 No. 8, pp. 2323-2342.

Gallopi´n, G.C., 2003. Box 1. A systemic synthesis of the relations between vulnerability, hazard, exposure and impact, aimed at policy identification. In: Economic Commission for Latin American and the Caribbean (ECLAC). Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters. ECLAC, LC/MEX/G.S., Mexico, D.F., pp. 2–5.

Gallopín G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Glob Environ Chan Hum policy Dimens 16(3):293–303.

Gbetibouo, G.A, & Ringler, C., 2009. Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment’, IFPRI Discussion Paper 00885, IFPRI, Washington, DC.

Gundersen, V., Kaltenborn, B.P. and Williams, D.R. 2016. A bridge over troubled water: a contextual analysis of social vulnerability to climate change in a riverine landscape in South-East Norway”, Norwegian Journal of Geography, Vol. 70 No. 4, pp. 216-229.

Hinkel, J. 2011. Indicators of vulnerability and adaptive capacity: towards a clarification of the science-policy interface”, Global Environmental Change, Vol. 21 No. 1, pp. 198-208.

Holling C.S., Meffe G.K., 1996. Command and control and the pathology of natural resource management. Conserv Biol 10:328–337.

Hrnjak I, Lukić T, Gavrilov MB, Marković SB, Unkašević M, Tošić I., 2013. Aridity in Vojvodina, Serbia. Theor Appl Climatol 115(1–2):323–332

Huang, Y., Li, F., Bai, X. and Cui, S. 2012. Comparing vulnerability of coastal communities to land use change: analytical framework and a case study in China”, Environmental Science and Policy, Vol. 23, pp. 133-143.

Hughes, S., Yau, A., Max, L., Petrovic, N., Davenport, F., Marshall, M., McClanahan, T.R., Allison, E.H. and Cinner, J.E. (2012), “A framework to assess national level vulnerability from the perspective of food security: the case of coral reef fisheries”, Environmental Science and Policy, Vol. 23, pp. 95-108.

Ijatuyi, E.J., Omotayo, A.O. and Mabe, L.K., 2017. Effect of extension service(s) and socio-economic characteristics on the livelihood of Nguni Cattle development project beneficiaries in North West Province: a TOBIT-OLS Regression Approach. South African Journal of Agricultural Extension, 45(1): 64-77. DOI: http://dx.doi.org/10.17159/2413-3221/2017/v45n1a427 (Copyright).

Intergovernmental Panel on Climate Change (IPCC), 2007. Impacts, adaptations and vulnerability. Fourth Assessment Report. Cambridge University Press, Cambridge, UK.

IPCC 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (eds.)], IPCC, Geneva, p. 104.

IPCC 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York.

IPCC., 2001. Climate change: Synthesis report. Contribution of working groups I, II and III to the third assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press.

Jones L. and Boyd E., 2011. Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Kala, N., Kurukulasuriya, P., and Mendelsohn, R., 2012. The impact of climate change on agro-ecological zones: Evidence from Africa. Environment and Development Economics, 17(6), 663-687. Retrieved from http://www.jstor.org/stable/26265545

Kotir, J., 2011. "Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security," Environment, Development, and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 13(3), pages 587- 605, June.

Leedy P.D. and Ormrod J.E., 2010. Practical Research, Planning and Design, 9th Ed. Pearson Merrill Prentice Hall, New Jersey, USA.

Leonard, S., Parsons, M., Olawsky, K. and Kofod, F. (2013), "The role of culture and traditional knowledge in climate change adaptation: insights from East Kimberley, Australia", Global Environmental Change, Vol. 23 No. 3, pp. 623-632.

Lincoln, Y.S. and Guba, E.G., 1985. Naturalistic Inquiry, Beverly Hills, CA: Sage Publications

Lindoso, D.P. et al., 2011. Smallholder farming and climate change: Assessing the vulnerability to drought in the semiarid region of the northeast regions of Brazil.

Liverman, D.M. 1990. Vulnerability to global environmental change", in Kasperson, R.E., Dow, K., Golding, D. and Kasperson, J.X. (Eds), Understanding Global Environmental Change: The Contributions of Risk Analysis and Management, Clark University, Worcester.

Luers, A.L., Lovell, D.B., Sklar, L.S., Addams, C.L., Matson, P.A., 2005. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change 13, 255–267.

Maliva R.G, Missimer T.M., 2012. Arid lands water evaluation and management. Environ Sci Eng 3(1948):806.

Maru, Y.T., Smith, M.S., Sparrow, A., Pinho, P.F. and Dube, O.P. 2014. A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities", Global Environmental Change, Vol. 28, pp. 337-350.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, K.S. (Eds.), 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge.

Moral F.J, Rebollo F.J, Paniagua L.L, García-Martín A, Honorio F., 2015. Spatial distribution and comparison of aridity indices in Extremadura, southwestern Spain. Theor Appl Climatol. https :// doi.org/10.1007/s0070 4-015-1615-7

Morton, J.F., 2007. The impacts of climate change on smallholder and subsistence agriculture. Proc. Natl Acad. Sci. USA 104, 19680: 19 685.

Mouton, J., 1996. Understanding Social Research. Van Schaik Publishers, Hatfield, Pretoria.

Mouton, J., 2001. How to succeed in your Master's and Doctoral Studies. A South African Guide and Resource Book. Van Schaik Publishers, Hatfield, Pretoria.

Mpandeli, S., Nhamo, L., Moeletsi, M., Masupha, T., Magidi, J., Tshikolomo, K., Liphadzi, S., Naidoo, D., and Mabhaudhi, T., 2019. Assessing climate change and adaptive capacity at local scale using observed and remotely sensed data. Weather and Climate Extremes, 26(2019): 1-13. http://www.elsevier.com/locate/wace

Mulinya, C., 2017. Factors Affecting Small Scale Farmers Coping Strategies To Climate Change In Kakamega County In Kenya. Journal of Humanities and Social Science, 22 (2), 100-109

Ncube, M., Madubula, N., Ngwenya, H., Zinyengere, N., Zhou, L., Francis, J., Mthunzi, T., Olivier, C. and Madzivhandila T., 2016. 'Climate change, household vulnerability and smart agriculture: The case of two South African provinces', Jàmbá: Journal of Disaster Risk Studies 8(2), Art. #182, 14 pages. http://dx.doi.org/10.4102/jamba.v8i2.182.

Nouman, M., Siddiqi, M.F., Asim, S.M. and Hussain, Z., 2013. Impact of socio-economic characteristics of farmers on access to agricultural credit. Sarhad Journal of Agriculture, 29(3): 469-476

O'Briena, K., Leichenkob, R., Kelkarc, U., Venemad, H., Aandahla, G., Tompkinsa, H., Javedc, A., Bhadwalc, S., Bargd,S., Nygaarda, L. and West, J., 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob. Environ. Change 14, 303:313. (doi:10.1016/j.gloenvcha.2004.01.001).

Omokanye, Akim and Yoder, Calvin and Sreekumar, Lekshmi and Vihvelin, Liisa and Benoit, Monika. 2018. On-farm Assessments of Pasture Rejuvenation Methods on Soil Quality Indicators in Northern Alberta (Canada). Sustainable Agriculture Research. 7. 74. 10.5539/sar.v7n2p74.

Scholze, M., Knorr, W., Arnell, N. W., & Prentice, I. C., 2006. A climate change risk analysis for world ecosystems. Proceedings of the National Academy of Sciences, 103(35), 13116e13120.

Schulze, R.E., 1995. Hydrology and Agrohydrology. A text to accompany the ACRU-3.00 Agrohydrological Modelling System. School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

SEI (Stockholm Environment Institute), 2004. Choosing methods in assessments of vulnerable food systems. Risk and Vulnerability Programme, SEI Briefing Note, Stockholm: SEI.

Smit B, Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob Environ Chang Hum Policy Dimens 16:282

Smith, J., and S. S. Lenhart. , 1996. Climate change adaptation policy options. Climate Research 6(2): 193–201.

Smith, J.K., 1983. Quantitative versus Qualitative Research. An attempt to clarify the issue. Educational Researcher, 12 pp 6-13.

Smithers J, Smit B., 1997. Human adaptation to climatic variability and change. Glob Environ Chang 7:129–146

Stephani, J., 2012. Power Outages, Flooding Persist as Sandy Tracks North. http://www.insurancenetworking.com/news/power-outages-flooding-persist-as-sandy-tracks-north-31277-1.html.

Tonmoy, F.N., El-Zein, A. and Hinkel, J. 2014. Assessment of vulnerability to climate change using indicators: a meta-analysis of the literature”, WIREs Climate Change, Vol. 5 No. 6, pp. 775-792.

Tshikolomo, K.A., Nesamvuni, A.E., Stroebel, A. and Walker, S., 2012. Water Supply and Requirements of Households in the Luvuvhu-Letaba Water Management Area of South Africa. International Journal of Business and Social Science, 3(3): 37-49.

Turner B, Kasperson R, Matson P et al., 2003. A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci U S A 100:8074–8079.

Uddin, M., Bokelmann, W., and Entsminger J., 2014. Factors affecting farmers’ adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. Climate Retrieved from http://www.mdpi.com/2225-1154/2/4/223/htm.

Vyas, S., and L. Kumaranayake. 2006. Constructing socio-economic status indices: How to use principal component analysis. Health Policy and Planning 21(6): 459–468.

Welman, C., Kruger, F. and Mitchell, B., 2005. Research Methodology, 3rd Edition. Oxford, Cape Town, South Africa.

Yin, R.K., 1989. Case Study research, Design and Methods, Newbury Park, CA: Sage Publications.

Yohe, G., Tol, R.S.J., 2002. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global Environmental Change 12, 25–40.

CHAPTER 10: AGRO-ECOLOGICAL CHARACTERISATION OF LIVESTOCK FARMING SYSTEMS AT NATIONAL LEVEL PROJECTED FROM PROVINCIAL LEVEL

Abstract

A study to characterise the agro-ecological attributes of livestock farming areas of South Africa was carried out based on geophysical mapping. For purposes of projecting the impacts of climate change (heat stress) on beef cattle and dairy; climate projections (scenarios) were used. The General Circulation Models (GCMS) (ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2) at the A2 emissions scenario, documented in the Intergovernmental Panel on Climate Change 4th Assessment Report of 2007, were employed. The downscaled temperature values derived from the GCMs were extracted at station level. The extracted climate projections were for the following periods: Present [1971 - 1990], Intermediate Future [2046 - 2065] and more Distant Future [2081 - 2100]. The land capability, aridity, crops and grazing capacity models were also used to depict the national picture as proposed.

Geophysical results showed spatial variability in the precipitation that was experienced throughout the country. The driest part occurs in the western part of the North-West, Free State, Eastern Cape and most parts of the Western Cape. This area experiences about 200 millimetres per annum (mmpa). The low rainfall deprives the development of the surface water resources; from this point of view, the livestock production system is highly exposed to the impacts of climate change. Climate modelling results showed the Eastern part of the country being more suitable for both Dairy and Beef Cattle based on projected impacts of temperature and humidity on feedlot cattle in South Africa using the temperature humidity index as an indicator of heat stress.

The results indicated that there are no soils in South Africa that are not subject to limitations in terms of capability. It was determined that nowhere in South Africa do good soils and a good climate coincide. Limpopo in the North of the country, together with the western side of the North-West, Northern Cape and the west of the Free State and Eastern Cape, the north eastern side of the Western Cape is more arid. The actual veld condition and biomass production that determine grazing capacity vary from season to season and are influenced by factors such as rainfall, temperature, bush encroachment, fire and the type of management system practised by the landowner. It is therefore the responsibility of the land owner to manage his animal numbers in such a way that there will be no degradation of natural resources, such as overgrazing of veld and erosion of soil. Lucerne, Rye and Sorghum should be promoted to close the gap in the quest to mitigate against the lack of fodder and grazing in the country.

10.1 INTRODUCTION

This chapter was initiated to project the national picture on the vulnerability of livestock farming systems. Central to the topic was to cover the existing and the potential level of vulnerability of the system looking at Land Capability, Fodder Production potential, and Grazing Capacity. It was necessary to then define and explain this aspect for purposes of the said projected national scenario. Land capability is the ability of land to support a given land use without causing damage. Assessment of land capability considers the specific requirements of the land use (e.g. rooting depth or soil water availability) and the risks of degradation associated with the land use (e.g. phosphorus export hazard or wind erosion). Land capability assessments are a first step in assessing land suitability for a given use. 'Suitability' considers other factors such as economics, infrastructure requirements, labour access, water and energy access, conflicting and complementary land uses, and the policy framework. We use the land capability assessment method to assess land suitability for existing and potential agricultural and non-agricultural uses.

For purposes of this study the Livestock Production System at national level depend on the availability of Fodder Crops that must be produced in strategic geographical areas based on land capability and production suitability. Crop models have developed over the years. Crop suitability model defines the congruence between the crop requirements and the Geo-environmental conditions necessary for such crops (FAO 1976). This phenomenon qualitatively outlines the land performance of the agricultural commodity of interest (He et al., 2011). According to Pan and Pan (2012), the principal purpose of conducting a suitability assessment on agricultural land is to predict the potential and limitation of land for crop production. Moreover, the conduction of a comprehensive suitability assessment incorporates inform strategic planning, in-depth spatial planning and optimal allocation of agricultural crops.

Agricultural crop production that is not preceded by commodity suitability, results in the critical destruction of the environment than the yielded resources (FAO, 1976). Ranya et al (2013), proposes for proper evaluation based on agriculture land use planning to eradicate this challenge. Though this is true, the scope of crop suitability analysis surpasses the environmental benefits, it enlightens the socioeconomic and agricultural benefits and investment returns prior to production. This study looked into fodder crops as a basis of looking into the potential for vulnerability for the total livestock production systems in the country.

10.2 METHODOLOGY

This section has been written to be a stand-alone part of each chapter with the aim to create independent papers addressing specific areas of the project and objectives. Each research method section will only vary depending on the approach used in data collection and analysis.

10.2.1 Study area

The study was conducted nationally with projected results focused on both Limpopo and Mpumalanga provinces, respectively. In each of the two provinces Vhembe and Gert Sibanda District Municipalities were chosen on the basis of proximity and convenience of having smallholder livestock farmers that are organised and within reach of the investigators. A map of South Africa with two provinces is attached as Figure 10.1.

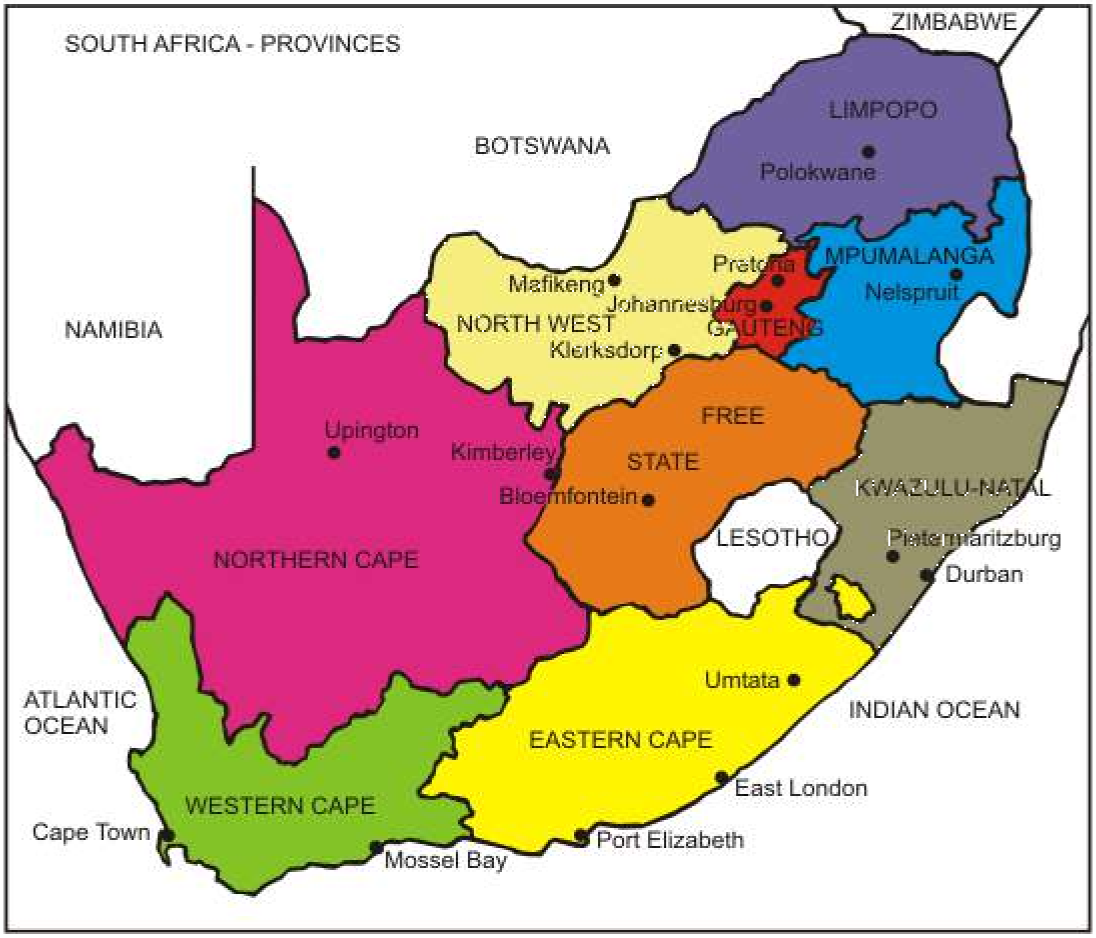


Figure 10.1. A Political map of South Africa with provinces

10.2.2 Data collection

Rainfall and temperature

The rainfall data was downloaded from the South African Weather Service and ISCW weather stations from 1920 – 1999 with a recording period of 10 years and more. The average rainfall and temperature maps were then developed to guide the different agro-ecological zones.

Climate modelling

The climate projections (scenarios) used in this study were the ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 General Circulation Models (GCMS) at the A2 emissions scenario, documented in the Intergovernmental Panel on Climate Change 4th Assessment Report of 2007. The downscaled temperature values derived from the GCMs were extracted at station level. The extracted climate projections were for the following periods: Present [1971 - 1990], Intermediate Future [2046 - 2065] and more Distant Future [2081 - 2100].

Thermal heat stress model for livestock

In this study, heat stress on dairy cattle (*Bos taurus*) was assessed using a Thermal Heat Index (Temperature-Humidity Index) equation (Yousef. 1985):

THI = T_{db} +036Tdp + 41.2

where, THI = Temperature-Humidity Index

T_{db} = Dry Bulb Temperature (^{o}C)

T_{dp} = Dew point Temperature (^{o}C)

Dew point temperature (T_{dp}) was computed. Daily temperature output generated from the ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCMs were used to project Temperature-Humidity Index(THI) values at present (1971–1990), intermediate future (2046–2065) and distant future (2081–2100) climate conditions 21st century for South Africa.

The heat stress index classification, adopted from a study by Mader *et al.* (2006),used in this study to indicate likely feedlot cattle stress are:

< 74 THI – Normal

74 to 78 THI – Alert

78 to 84 THI – Danger

> 98 THI – Emergency

c) Spatial Representation

Climate station locations, indicated in Figure 10.2, were used to extract the climate projections from the above mentioned GCMs. The station locations were selected to represent the climate over South Africa. These were computed at each station location derived climate projections and spatially interpolated over the country using Inverse Distance Weighting techniques in ArcView 9.3.1.

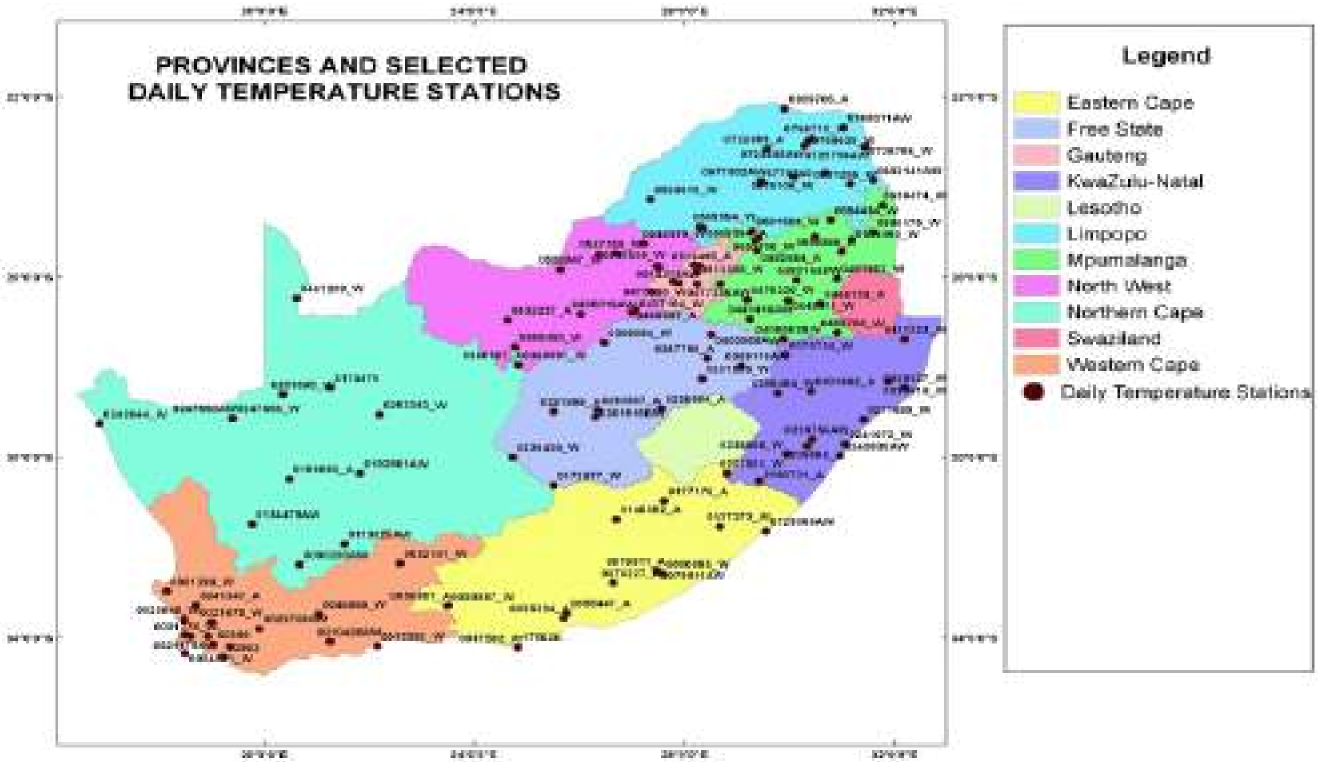


Figure 10.2. Study area's provinces and climate stations

Land capability 2016

This methodology was based on a spatial evaluation and modelling approach wherein the key modelling issues include the delineation of geographic units, the specification of both dependent and explanatory variables, the formulation of the model, the testing of the statistical significance of the model and the interpretation of the results. The end result is an agricultural-driven land capability evaluation model based on a spatial evaluation, modelling approach and a raster spatial data layer comprising of 15 land capability evaluation values, usable on a scale of 1:50 000 – 1: 100 000. The main contributing factors towards land capability were the soil, climate and terrain capabilities with a weighted reference of: Soil capability = 30%; Climate capability = (40%) and Terrain capability = (30%). The main contributing factors to the Soil capability consist of: (a) Plan available water (80%), (b) Soil sensitivity (17%) and (c) Soil fertility (3%). In terms of Climate capability, the main contributing factors were: (a) Moisture supply capacity (50%), (b) Physiological capacity (20%) and (c) Climatic constraints (rainfall & temperature (30%). For the Terrain capability consisted of: (a) Moisture accumulation (20%), (b) Photosynthesis (15%), and (c) Sensitivity (65%).

As the development of the newly refined land capability data layer was based on a spatial modelling exercise, all input data layers used in the modelling process were converted to raster data. The input data layers were transformed into a value range of 1 – 9. The calculated (developed/derived) data layers therefore resulted in a value range of 1 – 9. It should be noted that the mentioned approach/model components were based/determined on mathematical as well as published scientific principles, research, interpretation and analysis of the issues at hand. The lowest possible value assigned / obtained, and where applicable, was a value of 1, whilst the highest possible value was a 9. Due to the mathematical calculations of the relevant issues, the calculated values resulted in a floating point value (decimal values e.g. 4.1234). In certain instances, depending on the use of the data within the model, these values were adapted (rounded off) to integer values (e.g. a value of 4.123 becomes a 4 whilst a value of 4.67 becomes a 5). It is possible that certain values will not be applicable for a specific province due to the variance in the capability of the resources.

Aridity

The methods used to determine aridity was based on both the supply and availability of moisture for crop growth (rain-fed). The following steps were followed:

1) Moisture Supply Capacity as a function of the following variables (closest to your definition of aridity):

- Three-month growth season balances;
- The number of three-month growth season periods;
- Annual balances for the three-month growth season periods, calculated from the monthly calculations and also
- All three as a function of balances using supply (rainfall) and loss (evapotranspiration).

2) We then also consider:

- Soil Moisture Supply Capacity as a function of the following variables: Dominant- and sub-dominant forms and series fields included as part of the land-type database:
    - dominant soil form percentage of the land type / landform zone;
    - topsoil clay;
    - topsoil depth;
    - subsoil clay; and
    - sub-soil depth.

The following variables are calculated:

- permanent wilting point;
- drained upper limit;
- vertical clay distribution model value.

And from a topographical perspective:

- Moisture Accumulation as a function of the following variables: Topographical moisture flow and accumulation was modelled using flow accumulation, slope gradient and curvature variables.

Grazing capacity

GIS software and statistical analysis programmes were used to develop the new grazing capacity map. The median and majority (modal) statistics were generated from zonal statistical analysis using Vegmap as zones and the 1993 grazing capacity map as a reference dataset. The developed data set was then put through various provincial workshops where pasture scientists, agricultural extension services and natural resource specialists of each province made valuable inputs to ensure a realistic presentation of the long-term grazing capacity of each province, respectively.

Some provinces incorporate other sources into the product as well. These products were developed, verified and used by the provinces over an extended period of time. This explains the fact that the polygons from one province will differ in size and structure, compared to another province. For example, polygons of the Northern Cape will follow farm or district boundaries and cover larger areas than Eastern Cape boundaries, which follow natural vegetation boundaries and usually cover smaller areas.

Crop suitability methodology

The EnviroGIS methodology and approach to agricultural Crop Suitability Modelling was used, which has been built on the following six pillars:

- Literature Reviews;
- Expert Knowledge;
- Crop-Geographical Profiling – Climate and Soils;
- Multi-Criteria Evaluation within a Geographic Information System (GIS) Environment;
- Multi-Variable Suitability;
- Integrated GIS Database Model.

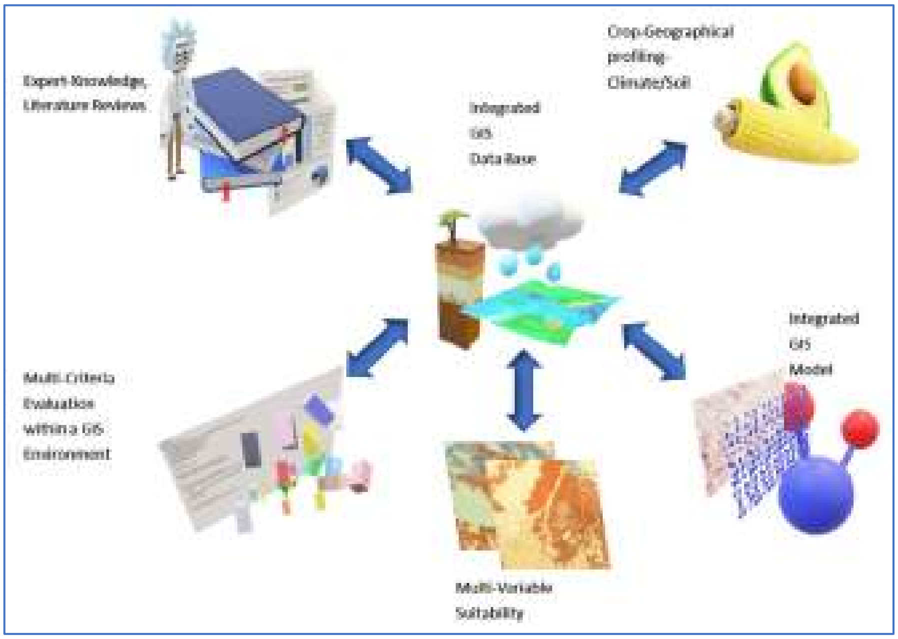


Figure 10.3. Integrated GIS Database and Spatial Model.

An integrated crop suitability database and spatial model are created and populated based on input from the following entities:

- Literature Reviews: Environmental (climate, soils and topographic) requirements were firstly sourced from local research reports and publications and secondly from international publications. Empirical data values were extracted and captured in an electronic database.
- Expert Knowledge: Interviews are conducted with experienced agronomists regarding the crop for which the model is developed. Results from the literature reviews are verified and adjusted if necessary.
- Geographic Profiling: An environmental profile was extracted from the EnviroGIS agro-climate, -soil and topographical database, based on the Geo-location of the actual crop-plantings. The GIS database of climate-, soil and topographical value ranges are adjusted and finalised.
- Multi-Criteria Evaluation: Crop suitability coefficients were created as part of the Spatial Model to create a Crop Model Base. The coefficients were shared between crop models. The crop suitability evaluation was applied to various timelines to fit in with the crops phenological growth stages.
- Multiple-Variable Suitability: For each crop, suitability data were created for multiple variables: climate (temperature, rainfall, etc.), soils (depth, texture, etc.) and topography (slope gradient, aspect, etc.).
- Integrated GIS Model: All data, empirical-, model-, and suitability- are stored in an integrated spatial database. The results are made available through an online spatial platform.
- Testing of the Results: The model results were continually tested and updated based on input from the agricultural industry: The Department of Agriculture, Forestry and Fisheries and the Agricultural Business Chamber.

10.3 RESULTS AND DISCUSSIONS

10.3.1 Rainfall patterns within Agro-ecological zones

According to Kotir (2011), precipitation is one of the key determent 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 experiences dictates the natures of the agro-ecological setting that shall prevail. If an area obtains a high amount of the rainfall (in excess of 2 500 mmpa) a rainforest is probably going to occur (Butler, 2005). On the other hand, if an area receives little rainfall that barely exceeds 400 mmpa, the area will be dry (Butler, 2005). Furthermore, rainfall serves as an instrument for decision-making as to which livestock to pursue. It also translates to the water availability and the nature of pastures and its respective recovery during the wet season (Kotchoni, 2019). In South Africa, pastures are hardly irrigated; this implies that they rely on rain-fed irrigation (Kotir, 2011). Figure 10.4 shows a map of the mean annual precipitation in South Africa. The map shows that there is spatial variability in the precipitation that is experienced throughout the country. The driest part, marked in brown, occurs in the western parts of North-West, Free State, Eastern Cape and most part of the Western Cape. This areas experiences about 200 millimetre per annum (mmpa). The low rainfall deprives the development of the surface water resources, from this point of view, the livestock production system is highly exposed to the impacts of climate change. Climate modelling results showed the Eastern part of the country being more suitable for both dairy and beefcattle based on projected impacts of temperature and humidity on feedlot cattle in South Africa using temperature humidity index as an indicator of heat stress.

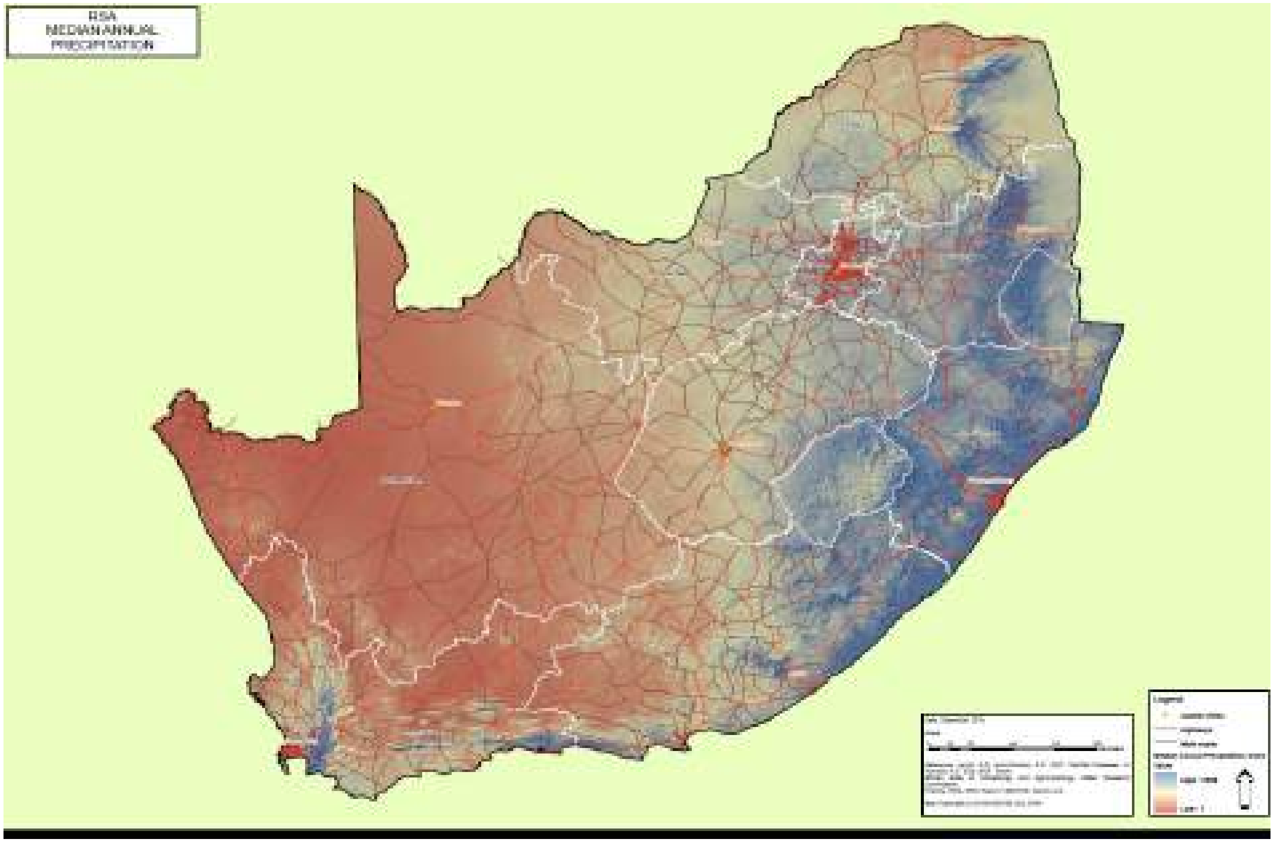


Figure 10.4. The mean annual rainfall of South Africa

10.3.2 Temperature variability within agro-ecological zones

There is general agreement that climate change is causing an increase in temperatures and in the frequency of extreme weather events (Easterling *et al*., 2000; Seneviratne *et al*., 2012). Climate change will have far-reaching consequences for dairy, meat and wool production mainly via impacts on grass and range productivity. Heat distress in animals will reduce the rate of animal feed intake and causes poor performance growth (Rowlinson, 2008). According to Alkire (2009), livestock (cattle) relishes the temperatures between 10 and 26 °C.

Figure 10.5 depicts the spatial distribution of the mean annual temperature for the country. There are spatial conformities between the precipitation and the mean annual temperatures. Generally, the annual temperature is higher in Limpopo, Mpumalanga, North-West and Northern Cape. The overall average temperatures in these regions are around the margin of 24°C. This implies that a diverse array of livestock can be farmed without subjecting the livestock to heat stress. Considering the potential Maximum Temperatures that occurs in these provinces to be as high as 38 – 42 °C these provinces may experience huge losses in livestock death due to drought and lack of feeds.

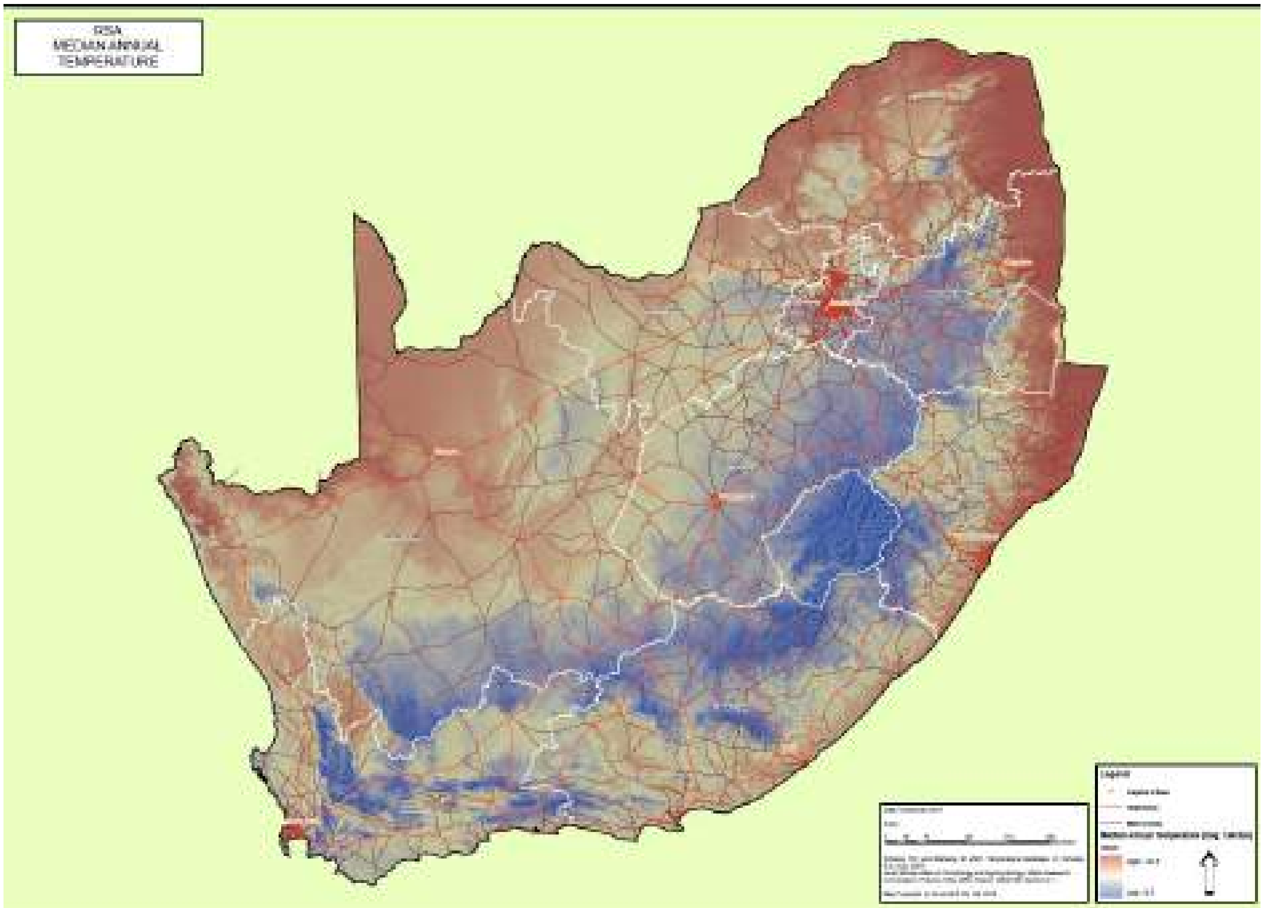
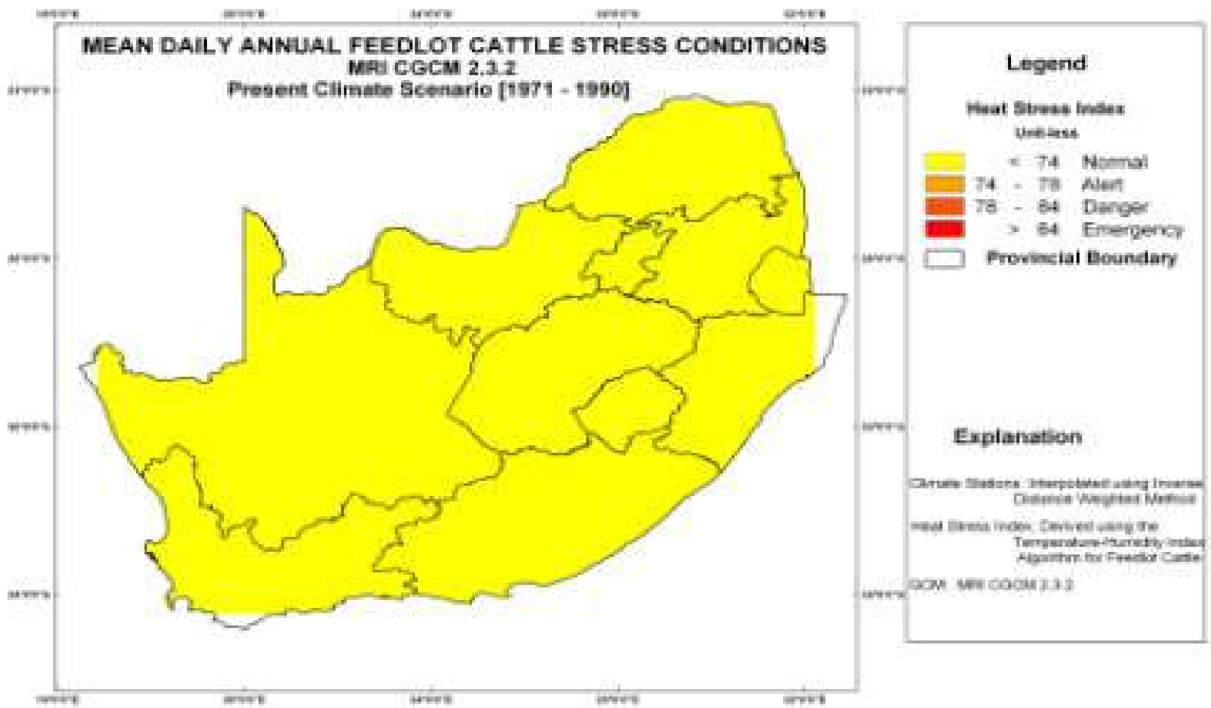


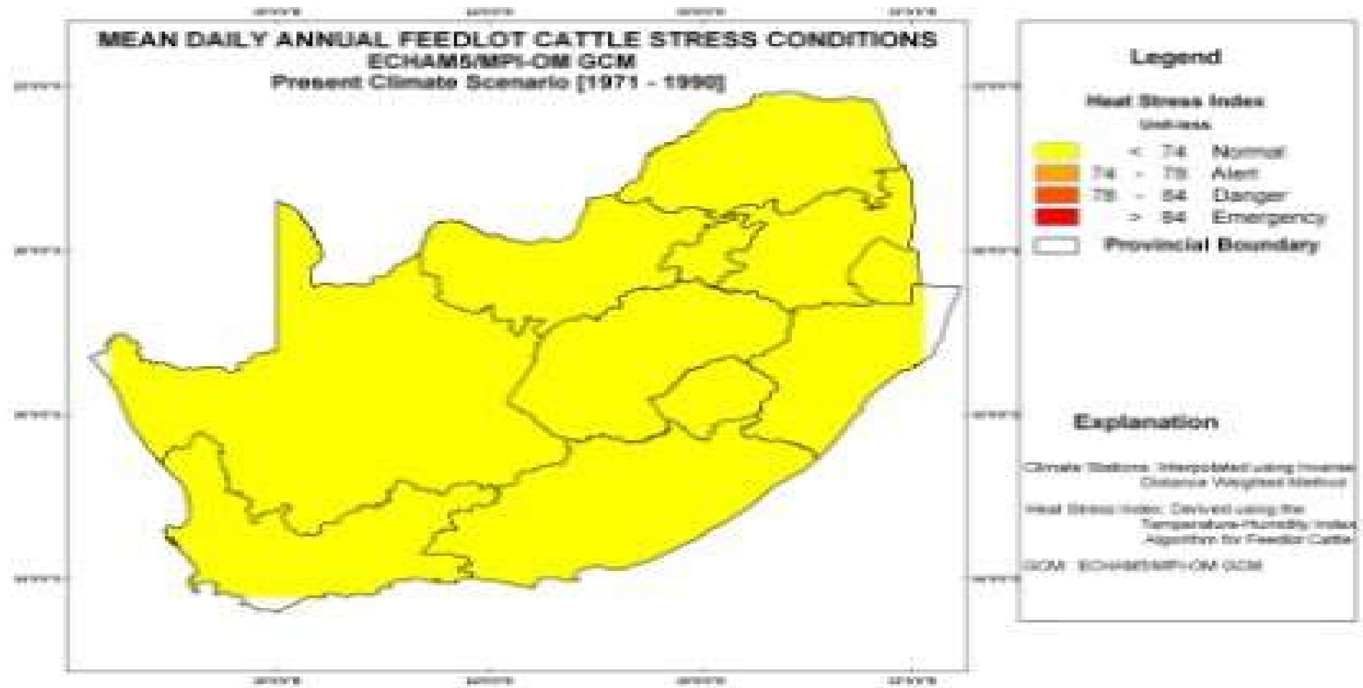
Figure 10.5. The spatial distribution of the mean annual temperature for South Africa

10.3.4 Projected impacts of temperature and humidity on feedlot cattle in South Africa

This section of the report was developed to give an indication of the projected impacts of temperature on feedlot cattle in South Africa. Though smallholder farmers in the main do not feedlot at the level of commercial farmers these results do give a projected picture of the future scenario of the proposed approach for small feedlots and livestock value chains in rural areas. Animal production in South Africa contributes a significant amount of income into the economy compared to other agricultural activities, such as grain crops and horticulture. Feedlot industry accounts for about 75% of beef production, with approximately 80% of cattle farmed for beef and the remaining 20% for dairy production of the total number of cattle in South Africa (DoA, 2008). DoA (2008) documented the greatest number of cattle per province to be in Eastern Cape followed by KwaZulu-Natal and then North West in 2003 and 2007. The one breed-type that is mostly suitable for feedlot and owned by smallholder farmers is the Nguni breed and its crosses. Mmbengwa et.al. (2016) wrote about the progress made by the South African livestock industry through the South African Marketing Council on the development of new value chains for small-scale and emerging cattle farmers in South Africa. Part of the value chain was a serious consideration for smallholder farmers to supply their livestock resources through feedlot system.

Therefore, information on heat stress in feedlot cattle is of importance to the management of livestock welfare and performance inclusive of Nguni-type cattle. Figure 10.6 shows mean annual THI derived from ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 (GCMs over South Africa. The present climate map of THI under mean climate conditions indicate normal conditions, hence suggest no stress is likely to be experienced by Feedlot cattle over all the country. In the intermediate future climate THI above normal (alert) conditions, however, are projected across all GCMs to be in patches along the northern border of the country. The alert stress condition areas are projected in the distant future climate to further increase spatially along the northern border.




MEAN DAILY ANNUAL FEEDLOT CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 74 Normal
74 - 78 Alert
78 - 84 Danger
> 84 Emergency
Provincial Boundary
Explanation
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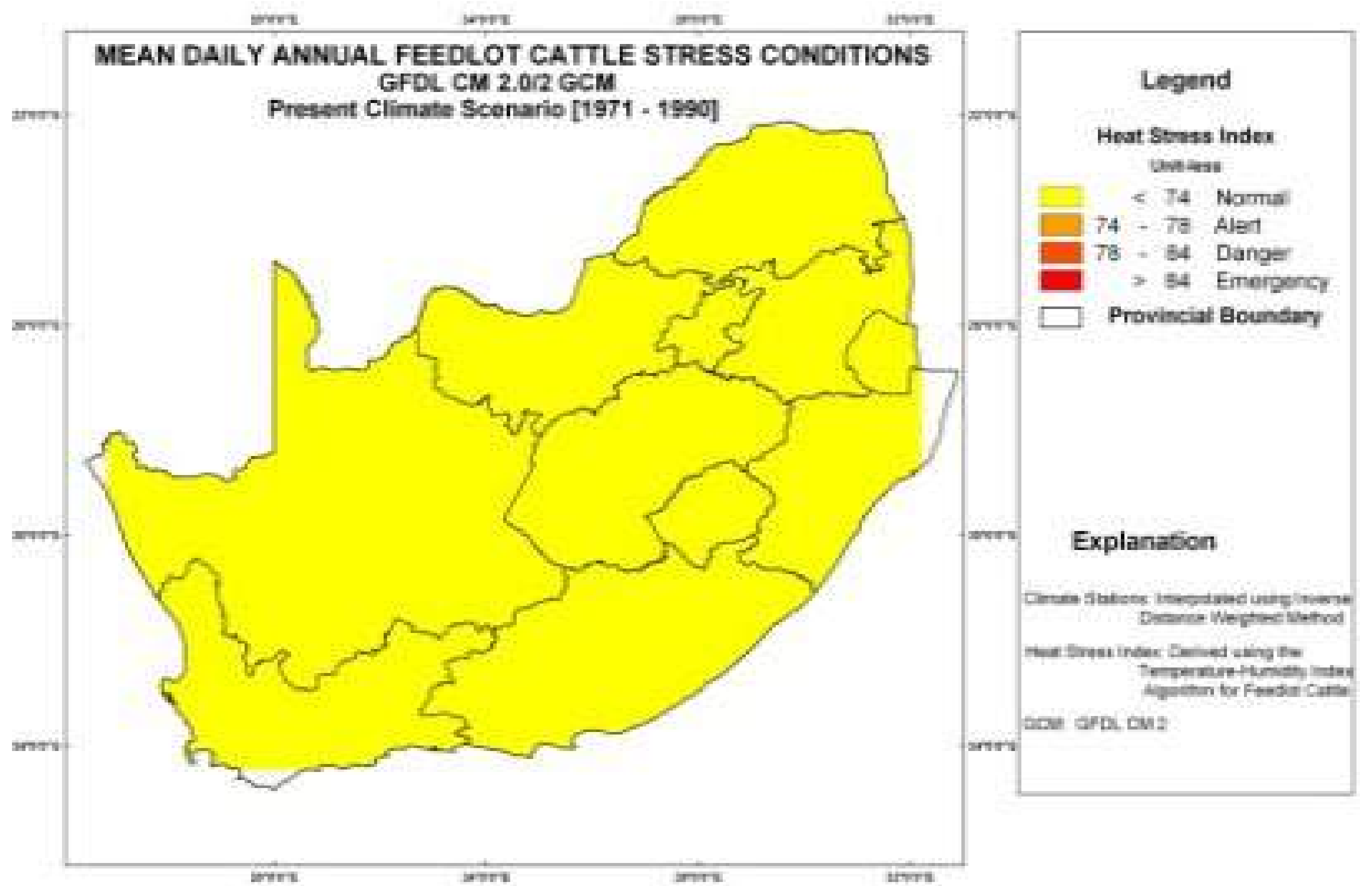
GCM: ECHAM5/MPI-OM GCM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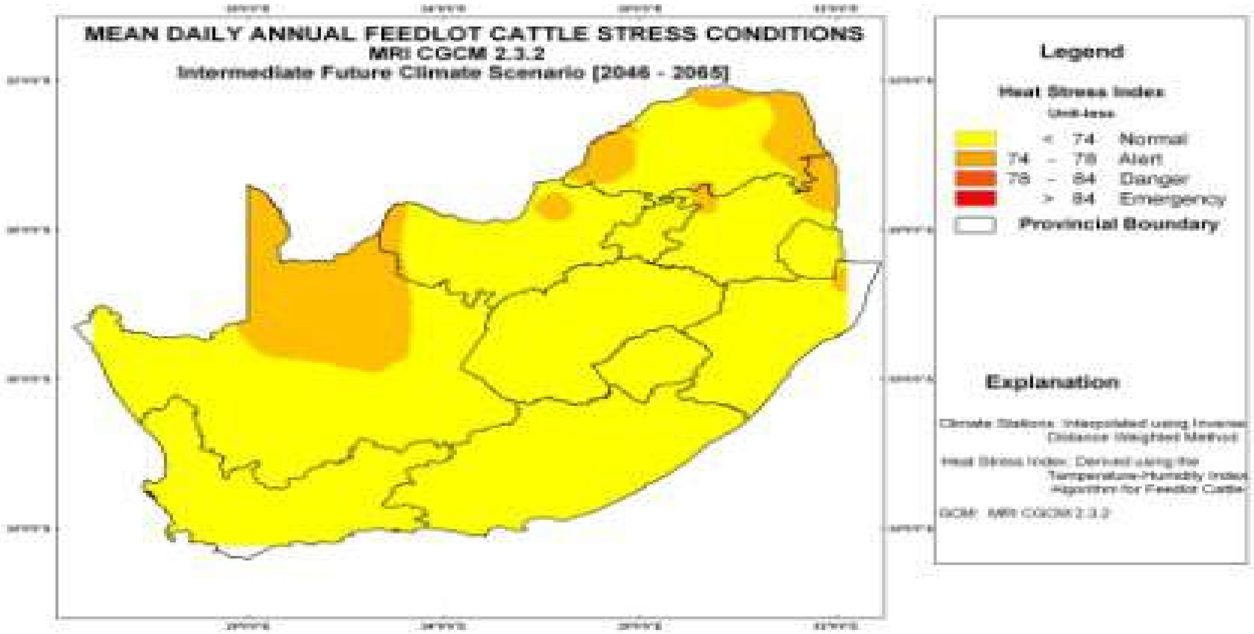
GCM: GFDL CM 2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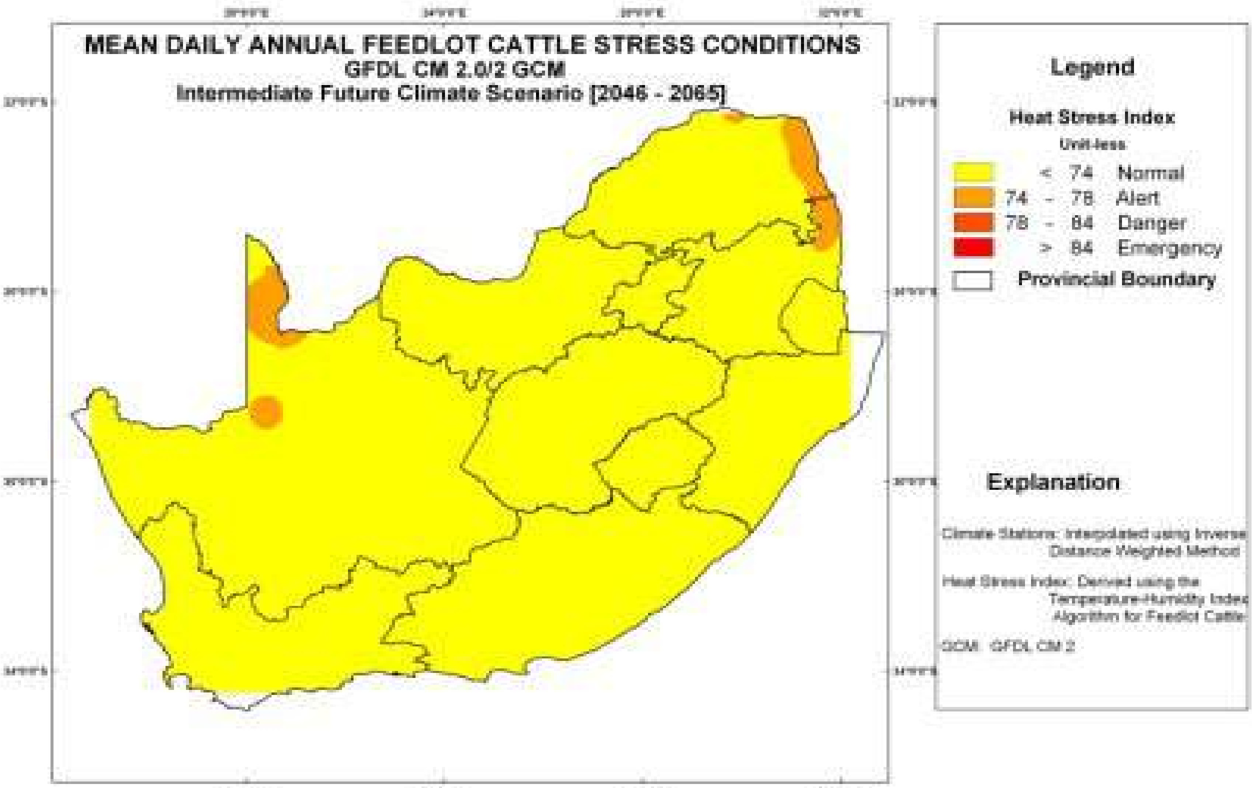
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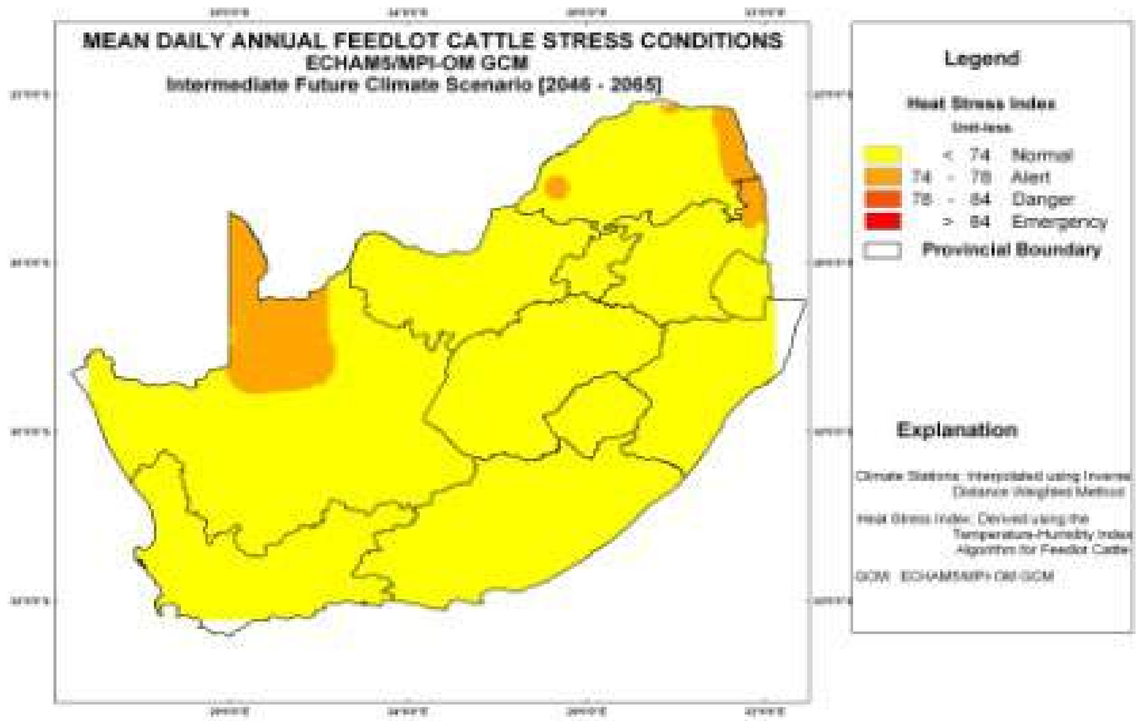
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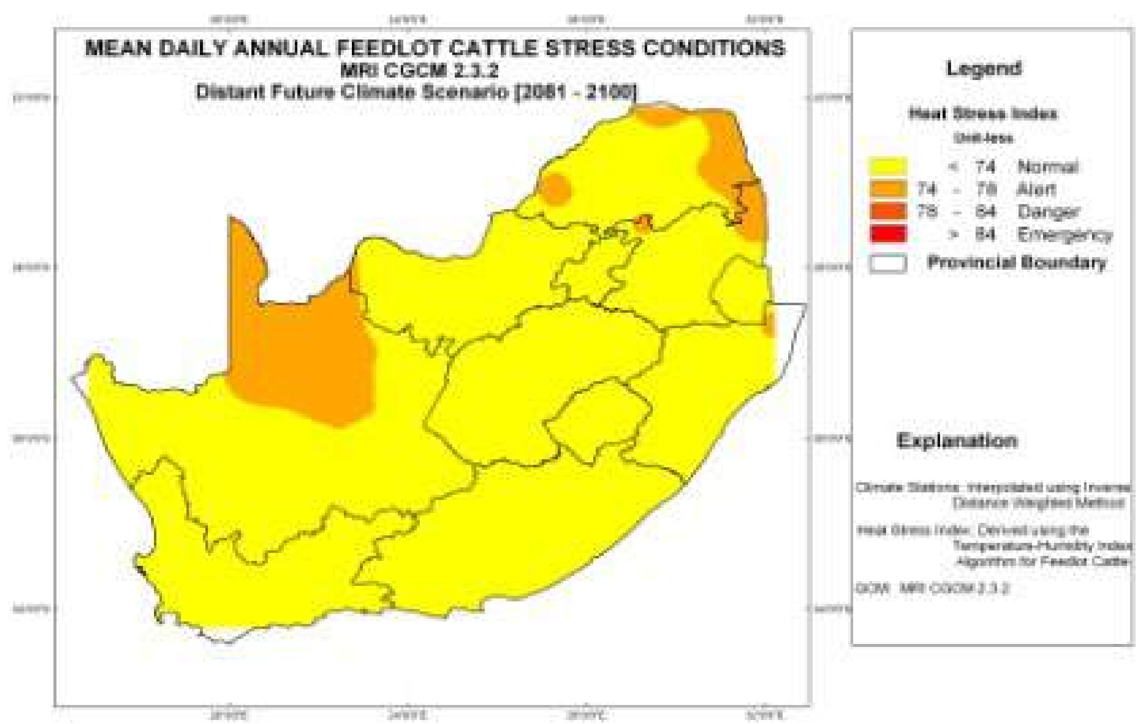
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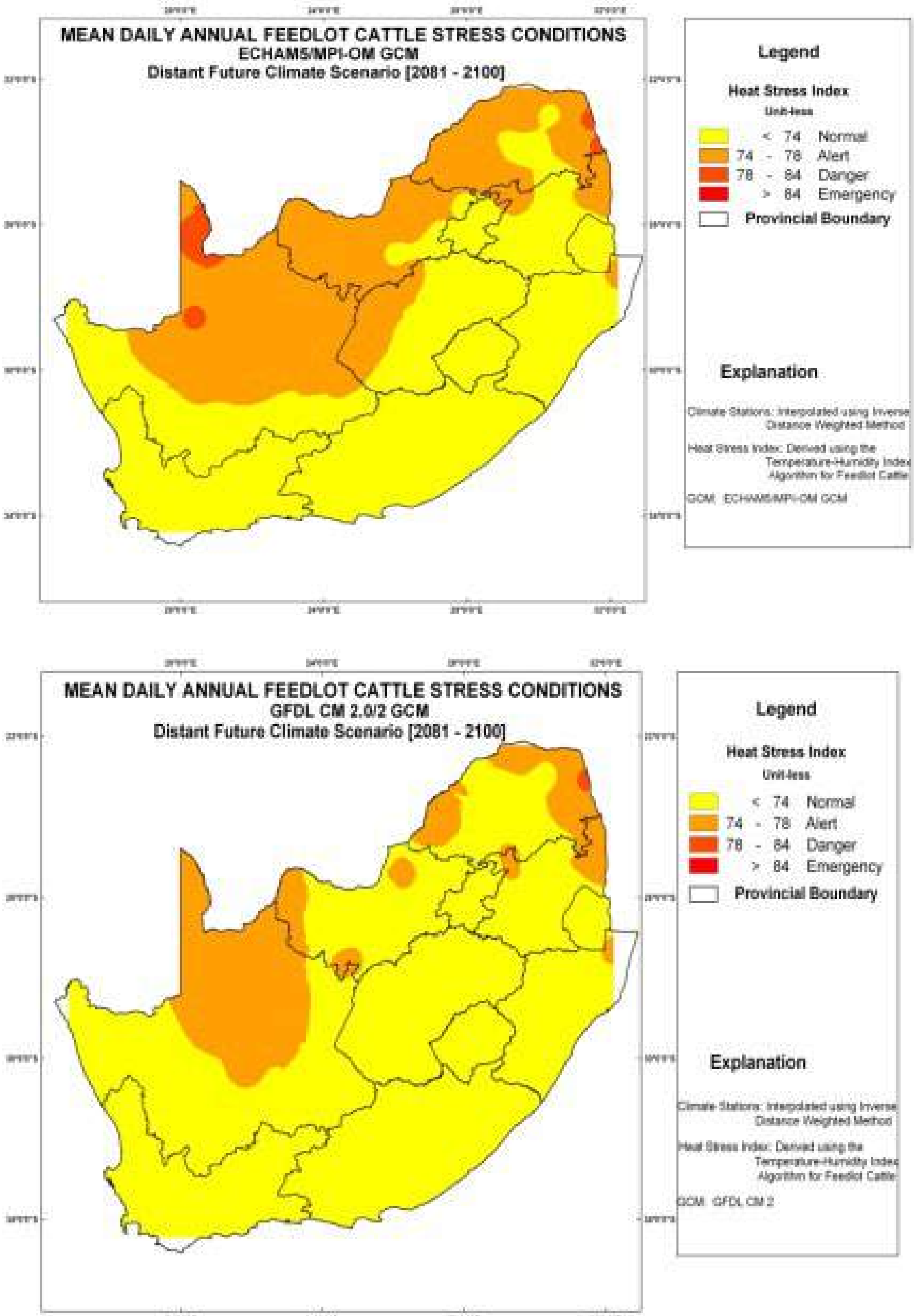
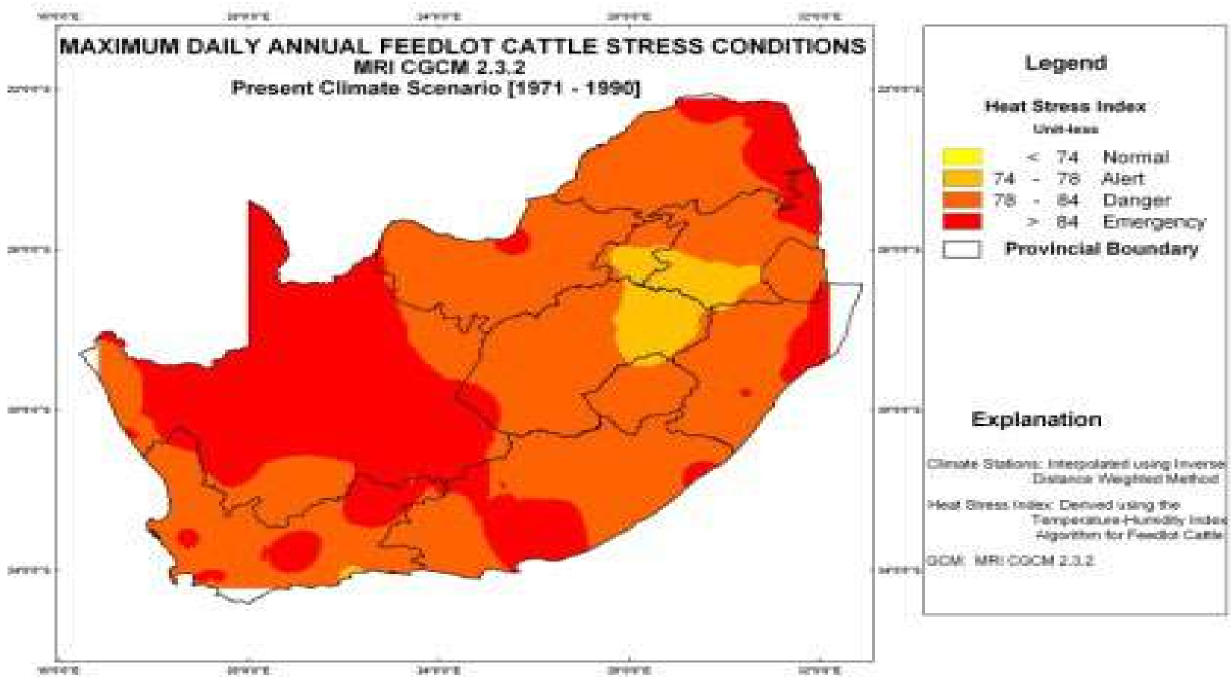
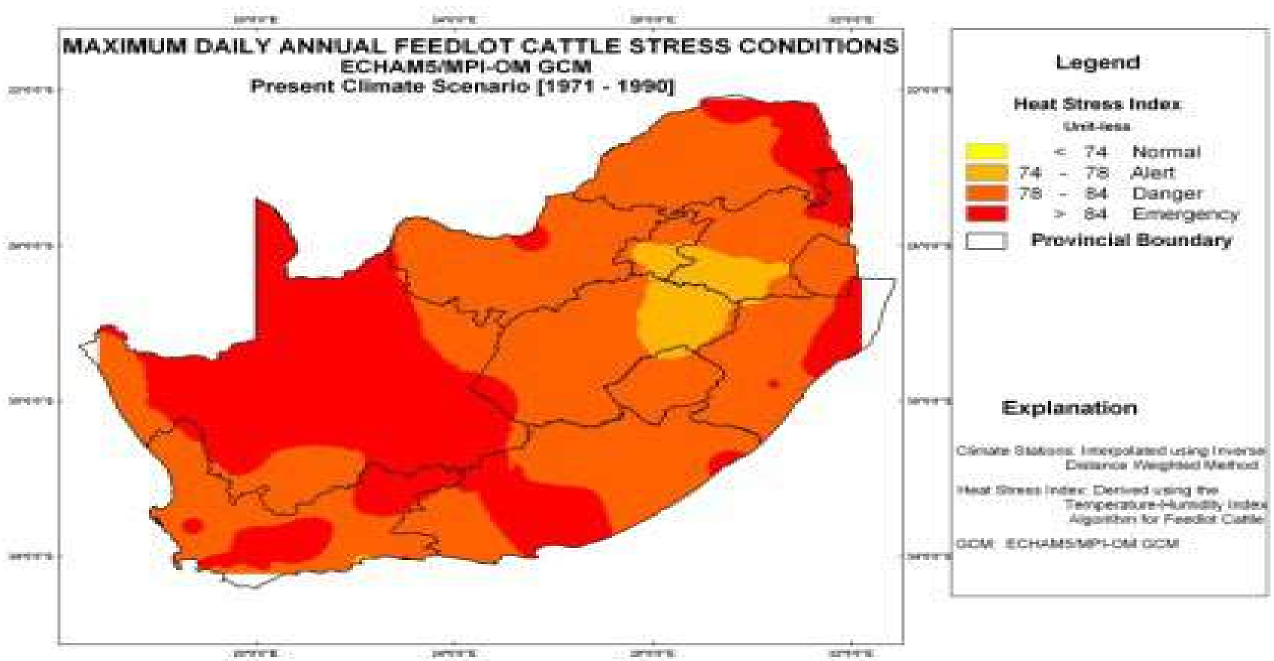
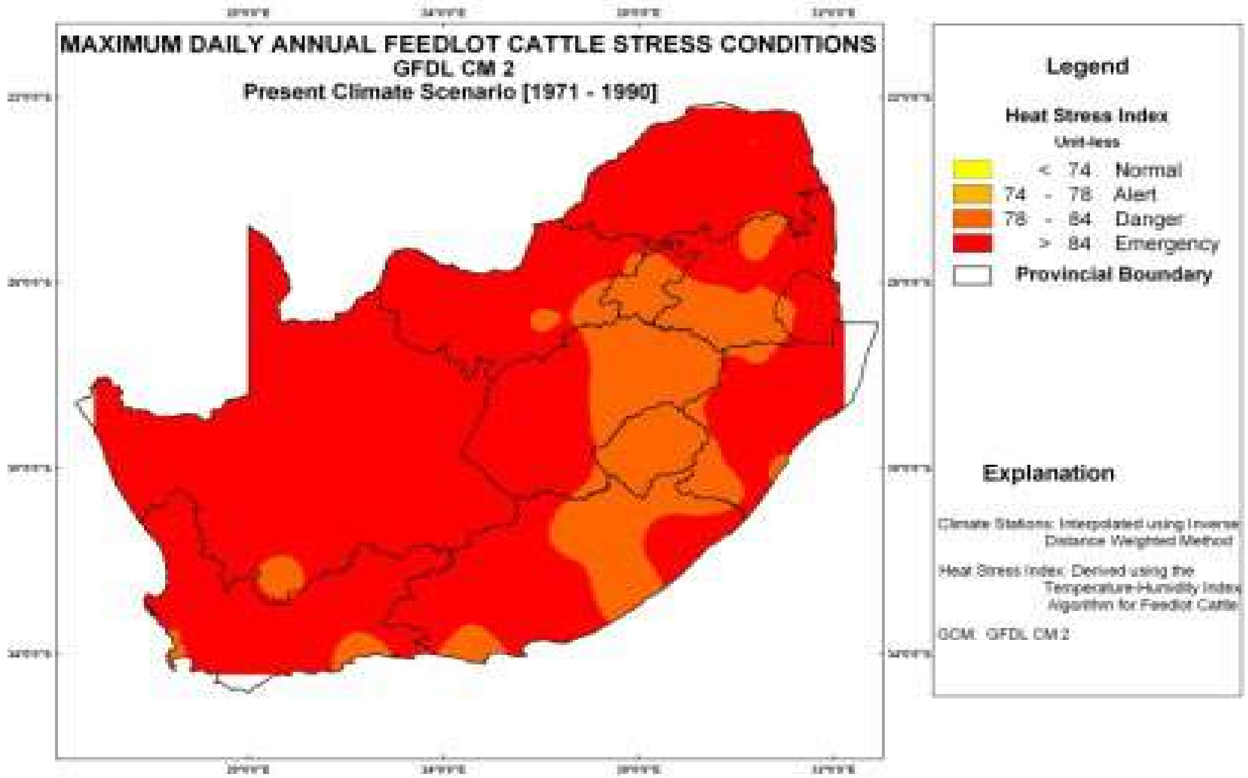


Figure 10.6 Mean annual thermal heat stress for feedlot cattle for present climate conditions derived from MRI-CGCM2.3.2 (top 3), ECHAM5/MPI-OM (middle 3) and GFDL-CM2.0/2 (bottom 3)

Figure 10.7 indicates maps of maximum annual THI for the ECHAM5/MPI-OM and MRI-CGCM2.3.2 projections for overall climate conditions, show similar over all distribution in the THI of alert heat stress index in eastern interior of the country and emergency conditions in parts west and east border. The emergency conditions are projected to further expand towards the central interior of the country in the intermediate to distant future climate conditions. Hence, the projections suggest that production in Eastern Cape, KwaZulu-Natal and North West provinces with the highest number of cattle compared with other provinces is likely to be affect by emergency heat stress index in future climate conditions.



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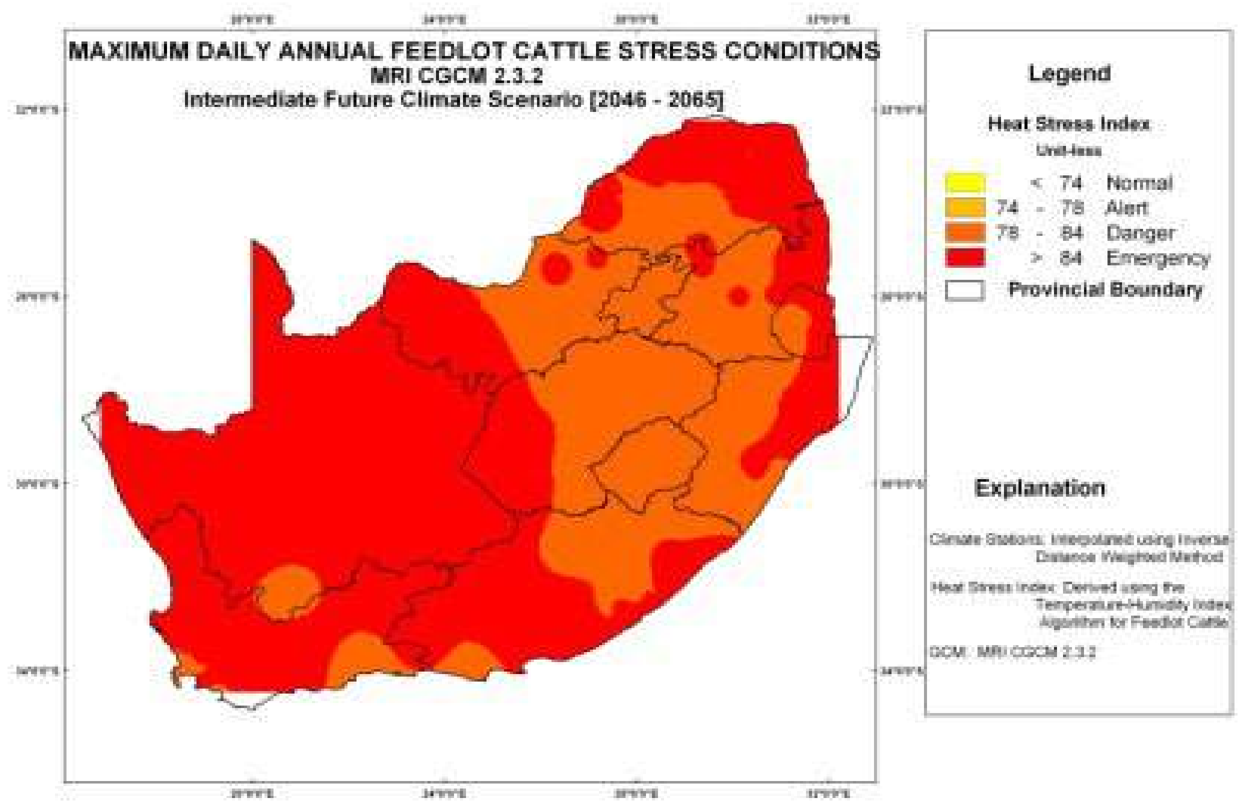
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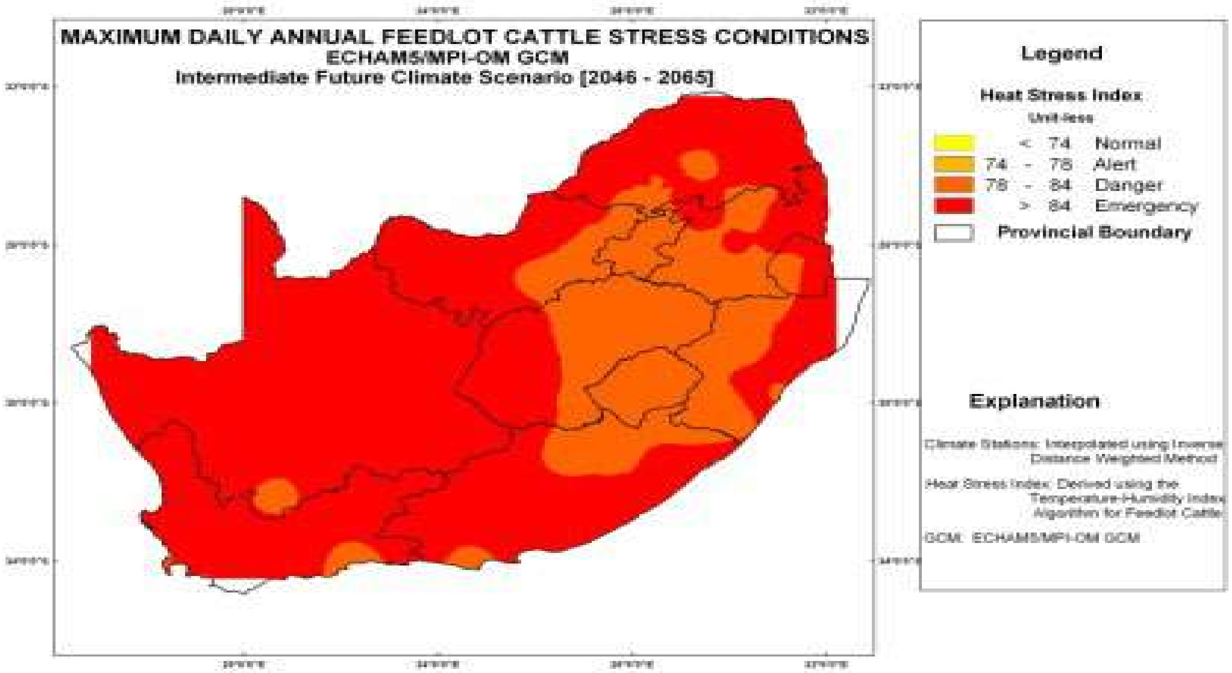
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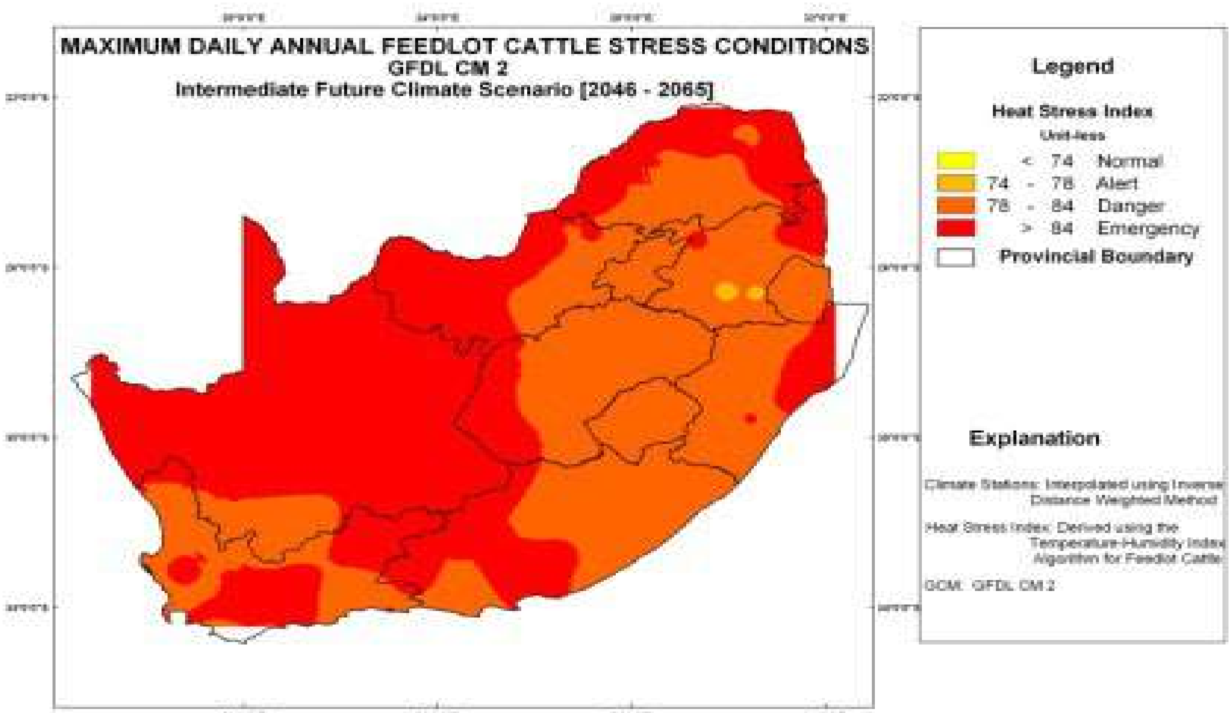
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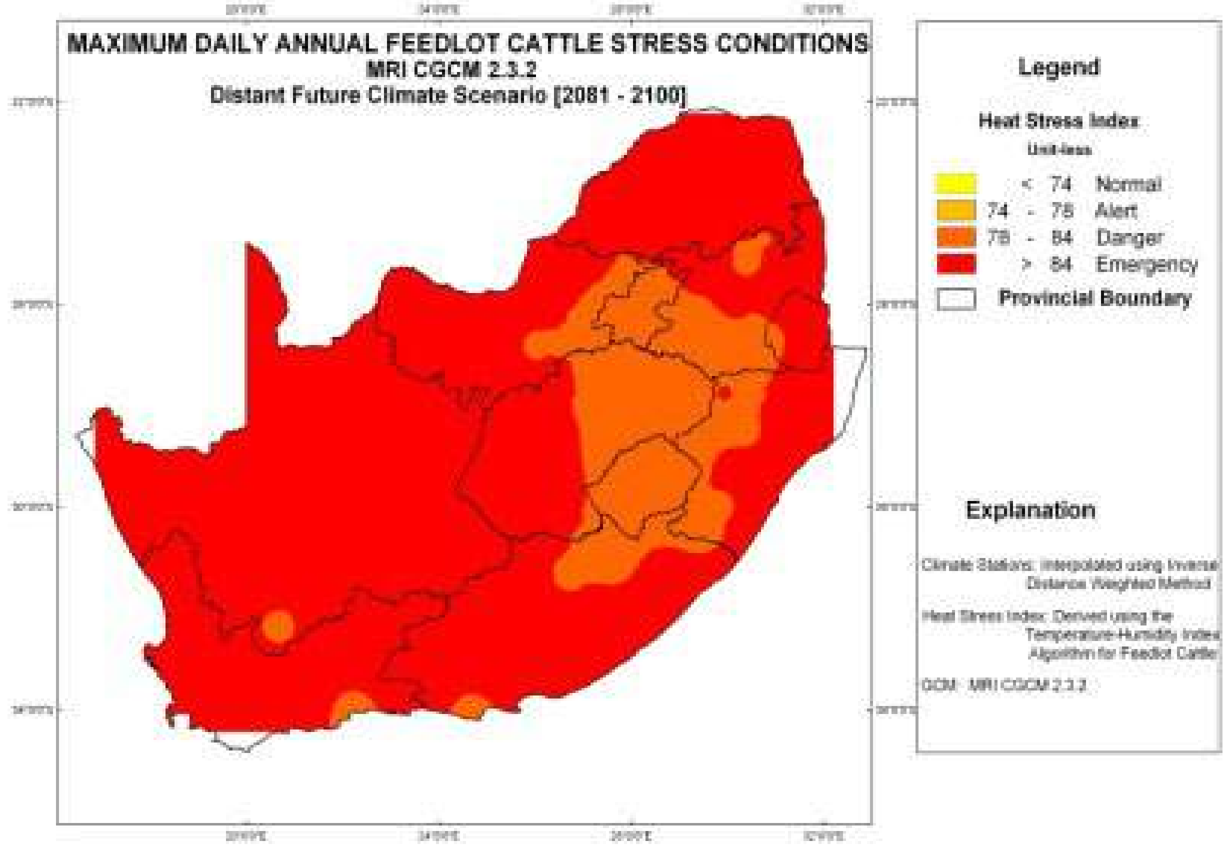
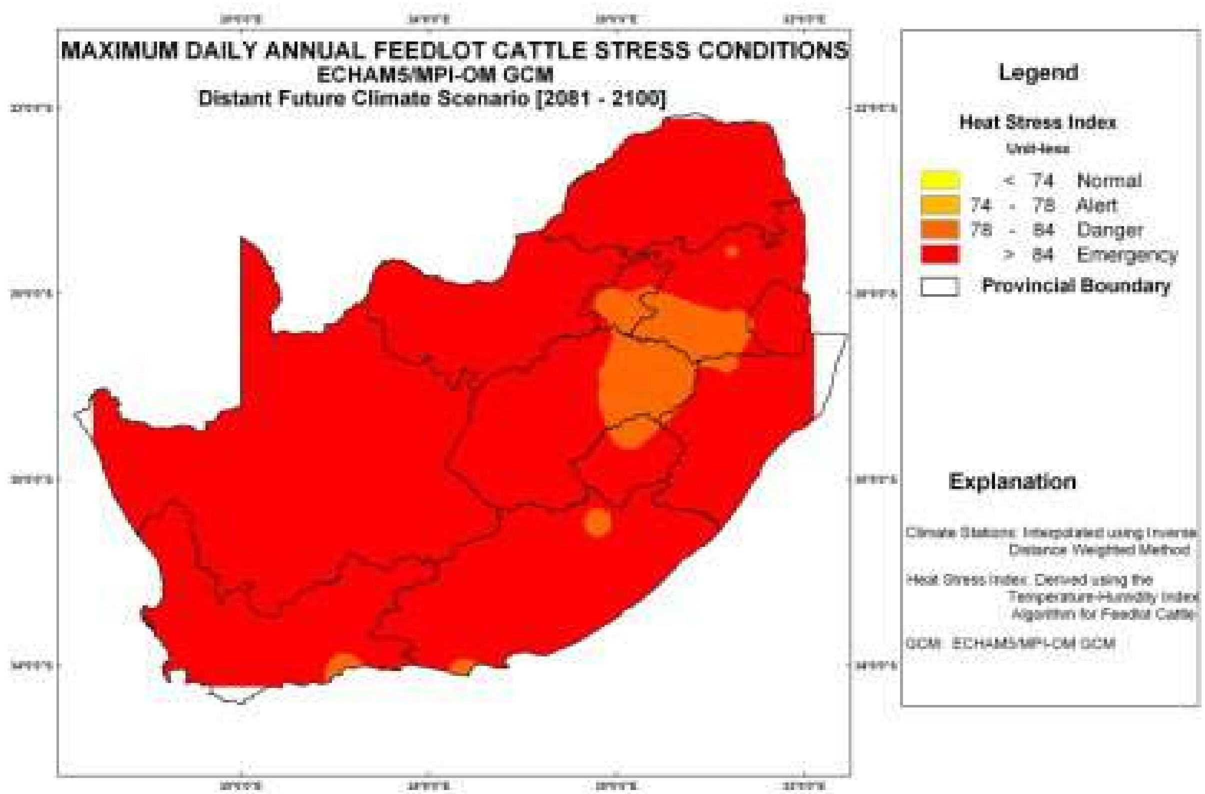

MAXIMUM DAILY ANNUAL FEEDLOT CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
< 74 Normal
74 - 78 Alert
78 - 84 Danger
> 84 Emergency
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Feedlot Cattle
GCM: MRI CGCM 2.3.2


MAXIMUM DAILY ANNUAL FEEDLOT CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
< 74 Normal
74 - 78 Alert
78 - 84 Danger
> 84 Emergency
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Feedlot Cattle
GCM: ECHAM5/MPI-OM GCM

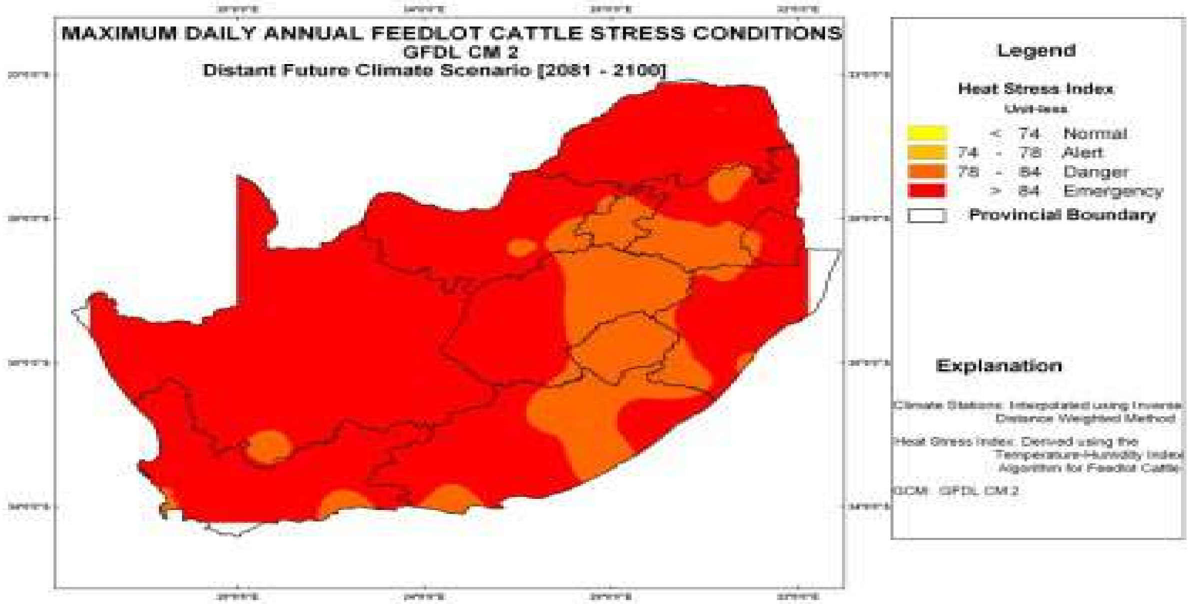


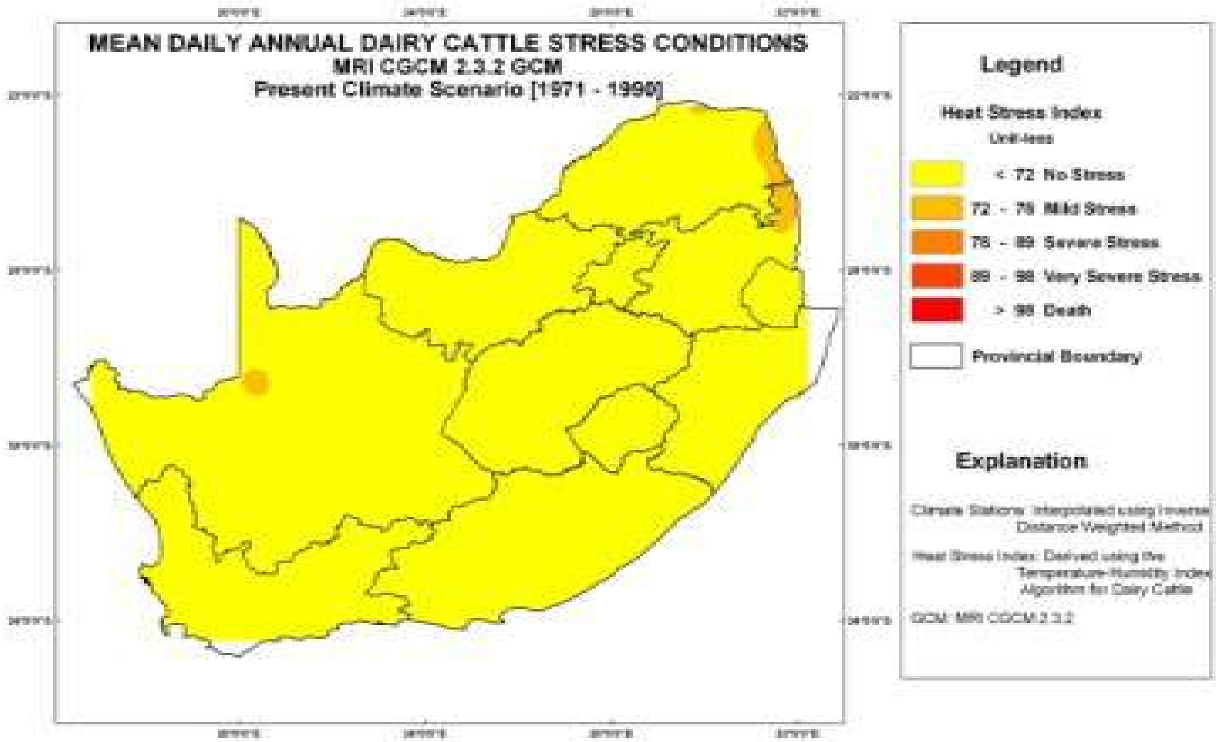
Figure 10.7. Maximum annual thermal heat stress for feedlot cattle for present climate conditions derived from MRI-CGCM2.3.2 (top 3), ECHAM5/MPI-OM (middle 3) and GFDL-CM2.0/2 (bottom3)

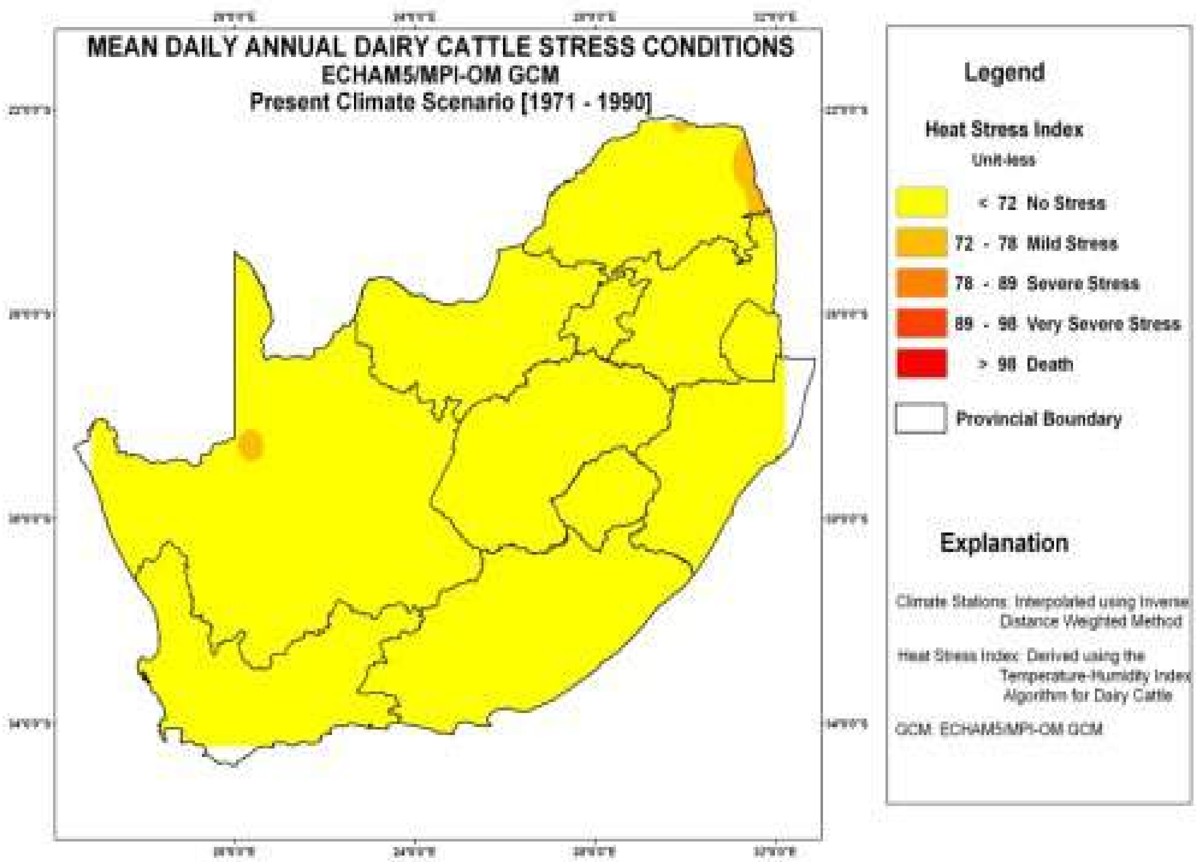
Mean annual THI indicates normal conditions mainly along the southern part of the country and alert conditions along the northern parts in projected future climate. For maximum daily annual THI emergency conditions are projected to spread from the western and eastern parts of the country towards the central interior in a future climate.

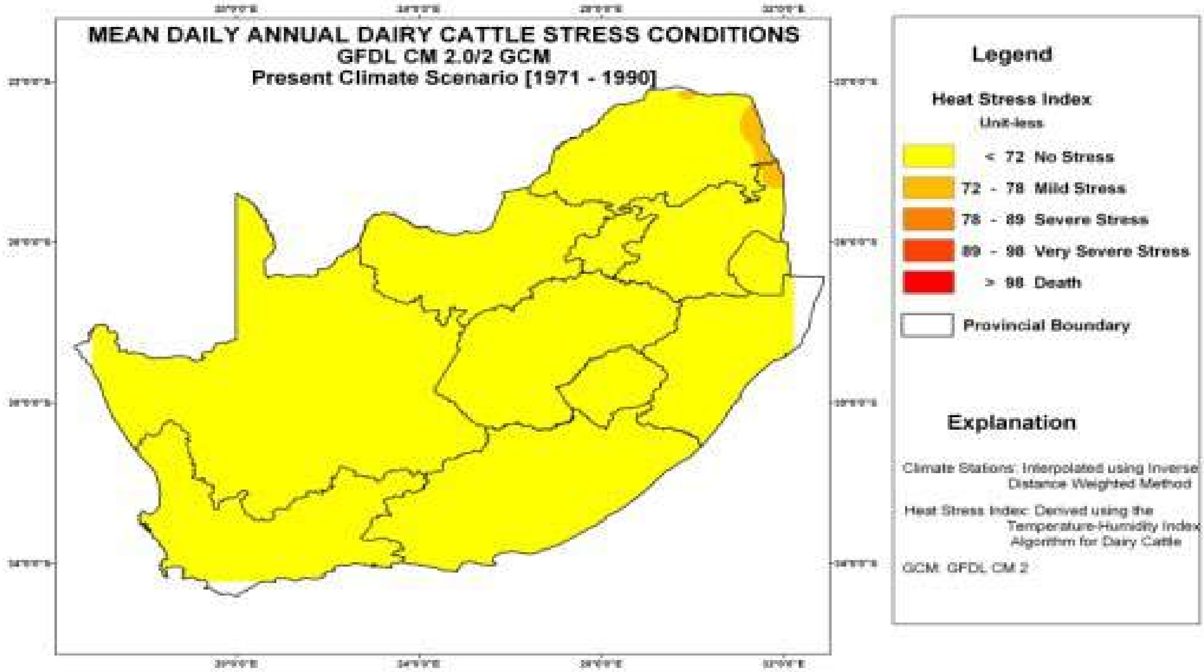
10.3.5 Projected impacts of temperature and humidity on dairy cattle in South Africa

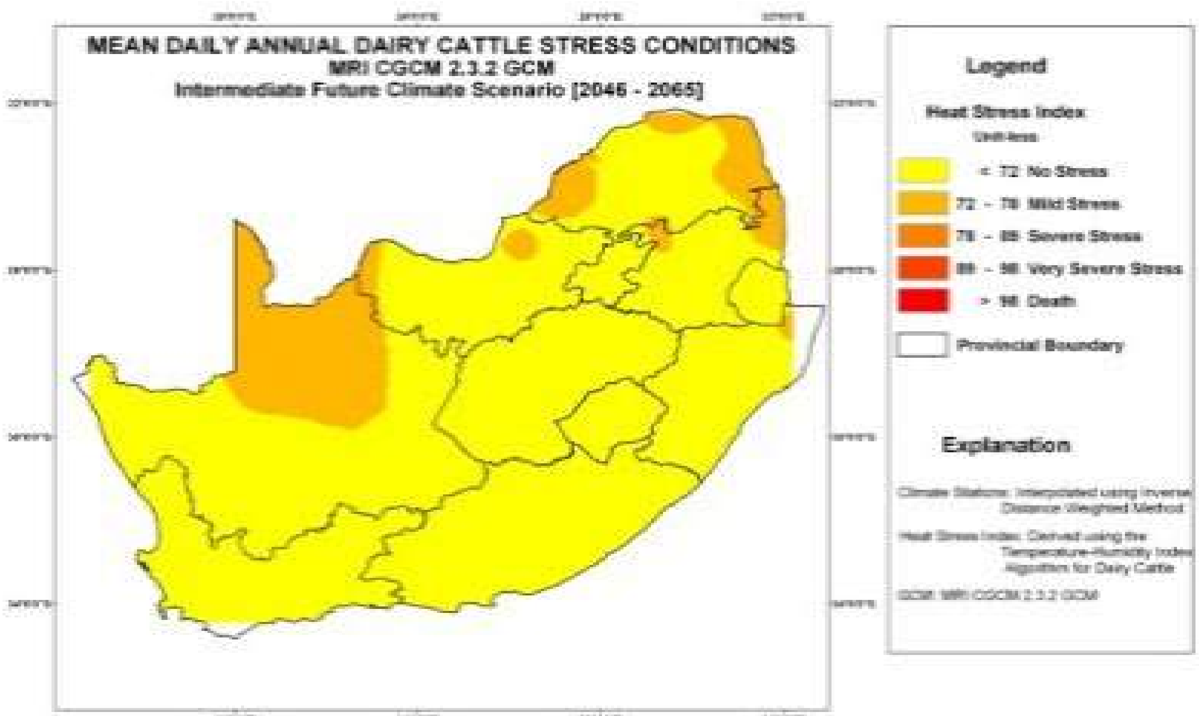
A similar approach is undertaken here as indicated in section 10.3.3., but for dairy. This section of the report was developed to give an indication of the projected impacts of temperature on dairy cattle in South Africa. Though smallholder farmers in the main do not farm with dairy cattle, they cross their Nguni-type breeds to improve the milk yield in circumstances where fodder is available. These results do give a projected picture of the future scenario in circumstances where the herds are crossed with any dairy breeds in rural areas. Dairy cattle production in South Africa accounts for about 20% of the total number of cattle in South Africa (DoA, 2008). Dairy bull calves are sporadically sold to smallholder farmers for fattening, but mostly used as crosses in a communal breeding system. Crossing with dairy bulls may have a potential for increased milk production, but may also compromise the adaptive capacity of the total herd.

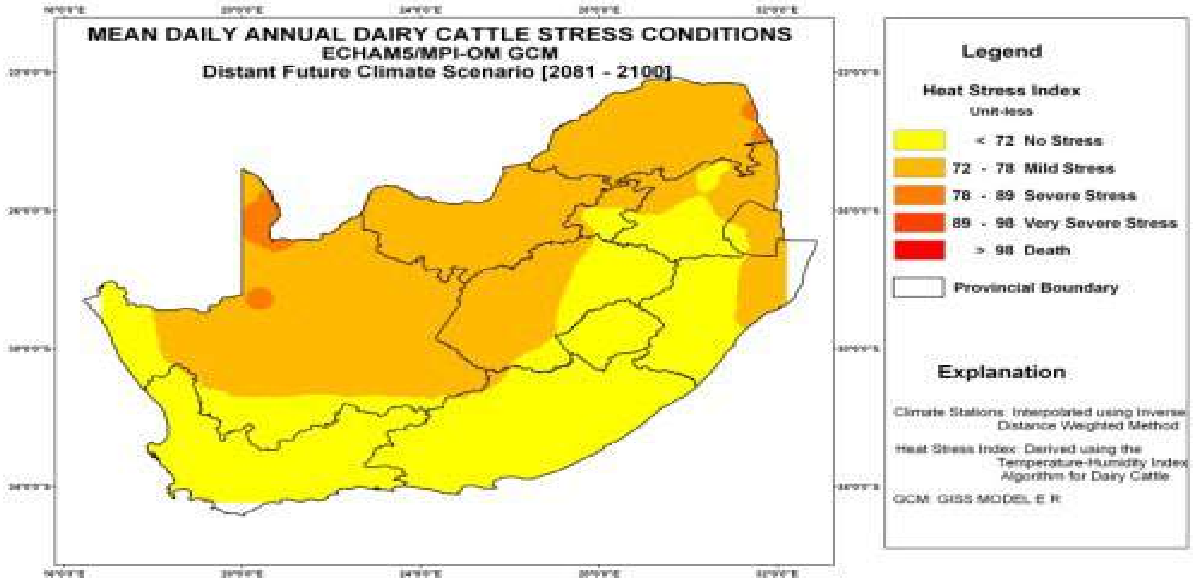
The projected impact of heat stress on dairy cattle is shown in Figure 10.7 and Figure 10.9. Figure 10.8. ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCM projections of heat stress in dairy cattle for mean daily climate under present climate conditions generally indicate no stress over the study area. In the intermediate future climate all GCMs indicate a similar signal of mild stress likely to be experienced in cows along the north borders of South Africa, which extents further inland in the distant future climate conditions.

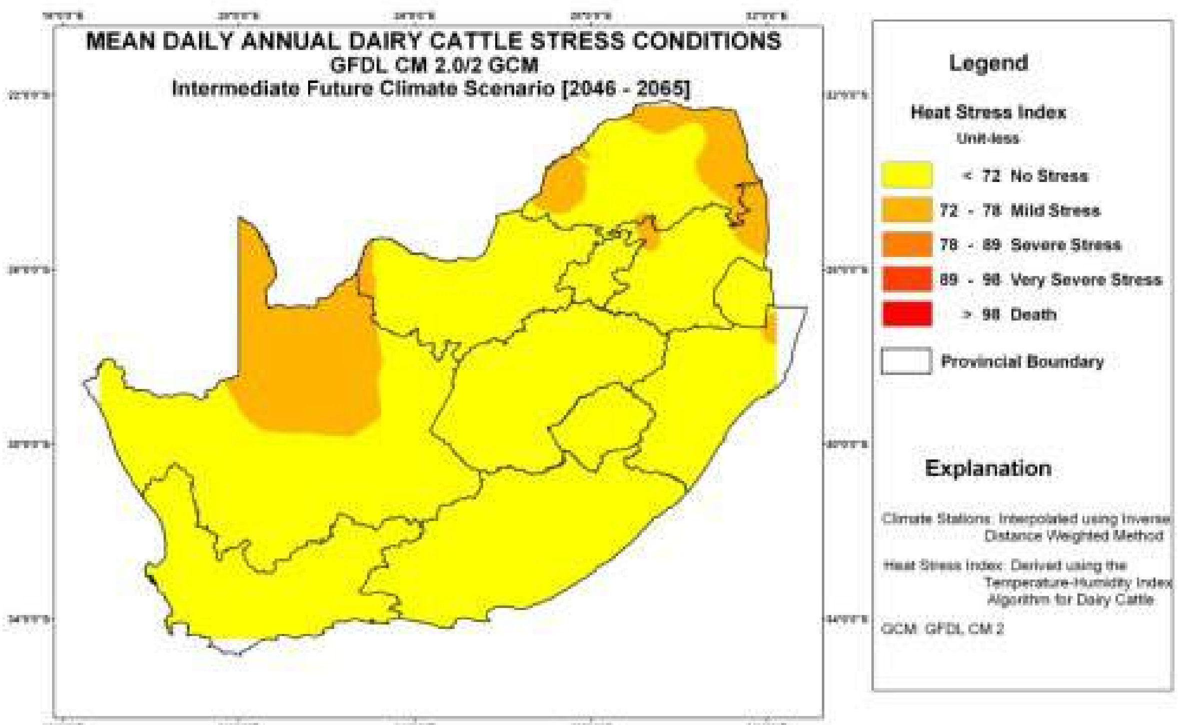

MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2 GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: MRI CGCM 2.3.2

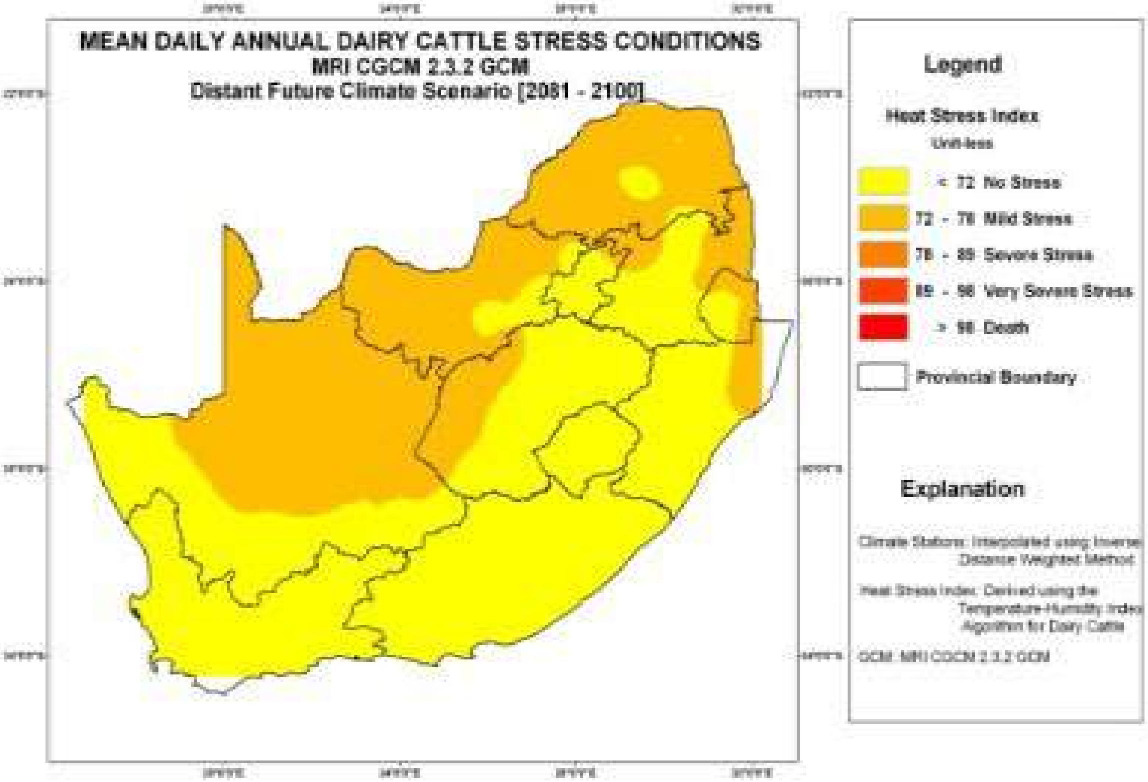

MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: ECHAM5/MPI-OM GCM


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
GFDL CM 2.0/2 GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: GFDL CM 2


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2 GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: GISS MODEL E R


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
GFDL CM 2.0/2 GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: GFDL CM 2


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2 GCM
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
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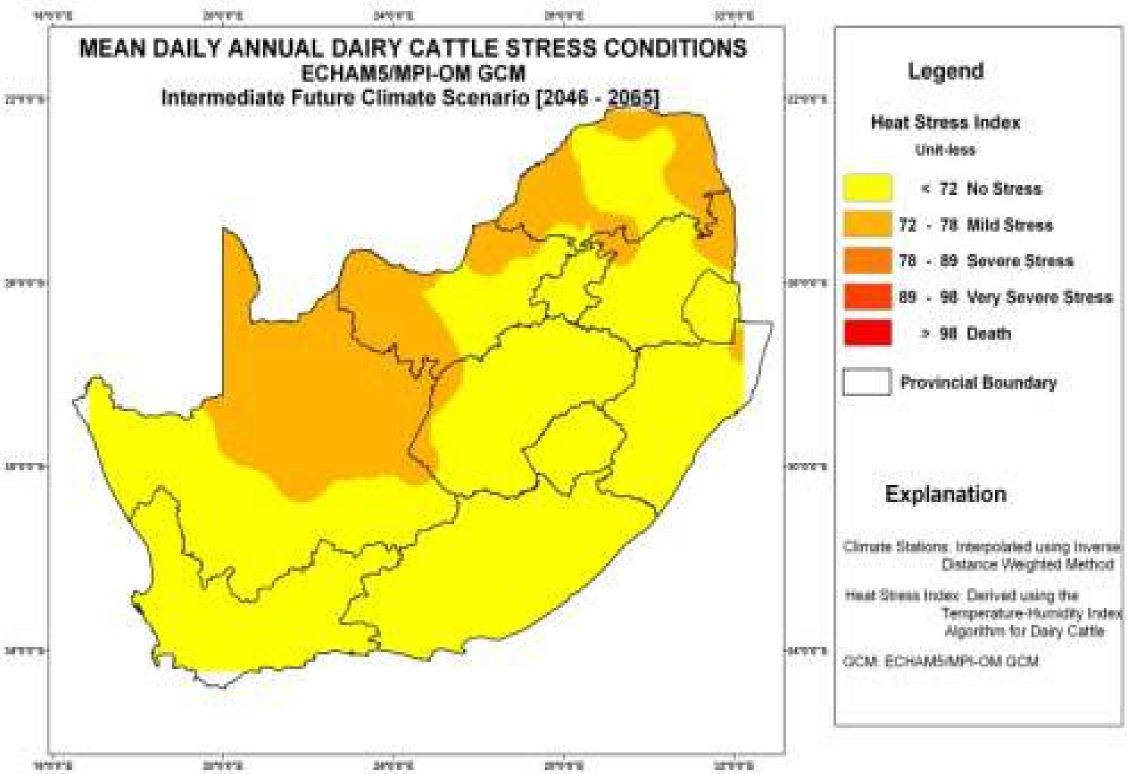
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: MRI CGCM 2.3.2 GCM


MEAN DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
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> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: ECHAM5/MPI-OM GCM

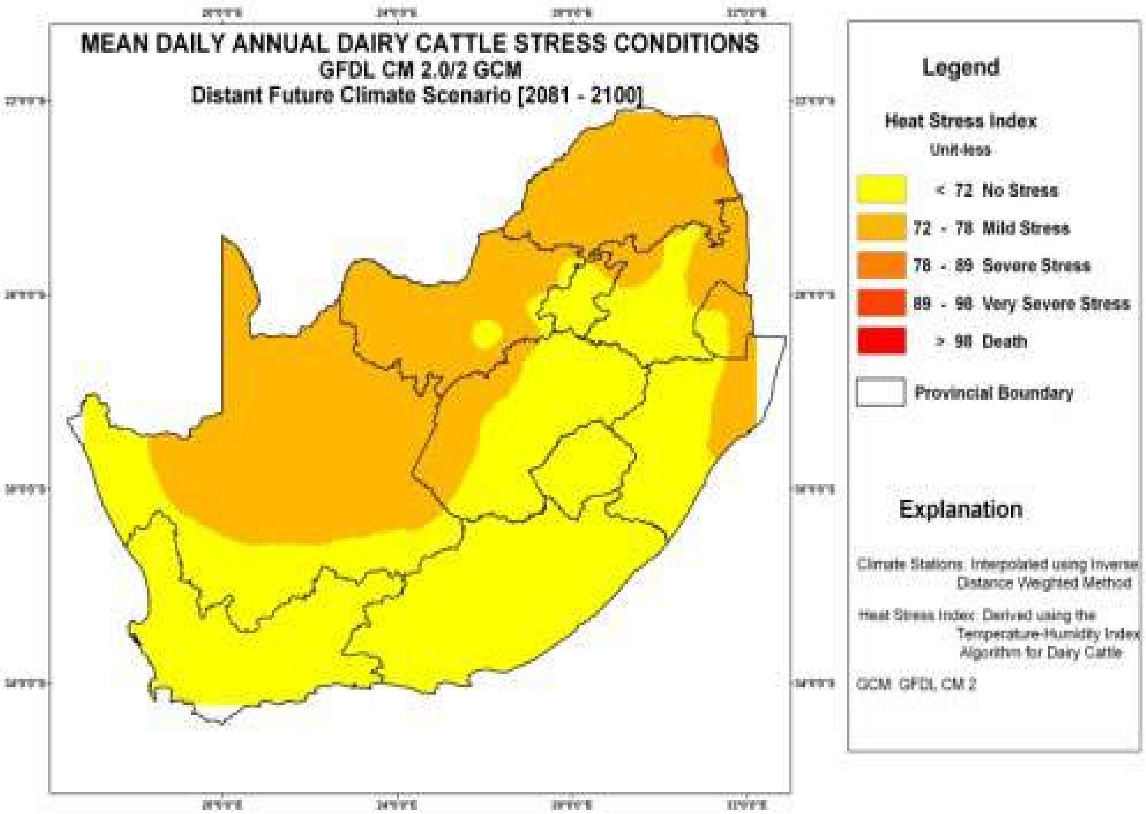
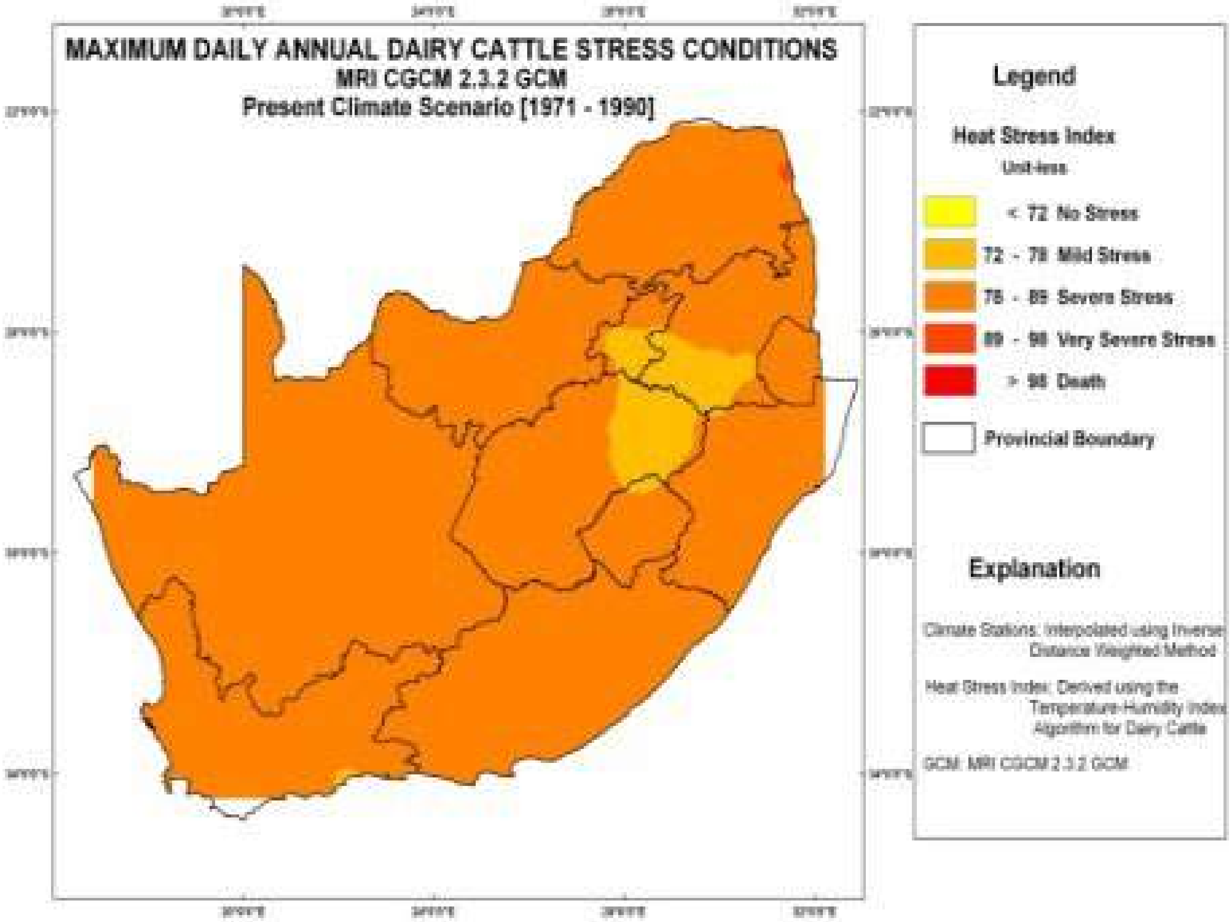


Figure 10.8. Mean annual thermal heat stress for dairy cattle for present, intermediate and distant climate conditions derived from MRI-CGCM2.3.2, ECHAM5/MPI-OM and GFDL-CM2.0/2

For maximum daily climate conditions heat stress, indicated in Figure 10.9, across all projections under present climate conditions indicates that severe stress is likely to be experienced over most of the study area, with mild stress in the eastern interior. In the intermediate future climate severe stress in is likely to be over the whole country. While in the distant future climate conditions, very severe stress is projected for parts of the northern to eastern borders and other parts of the study area.


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2 GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
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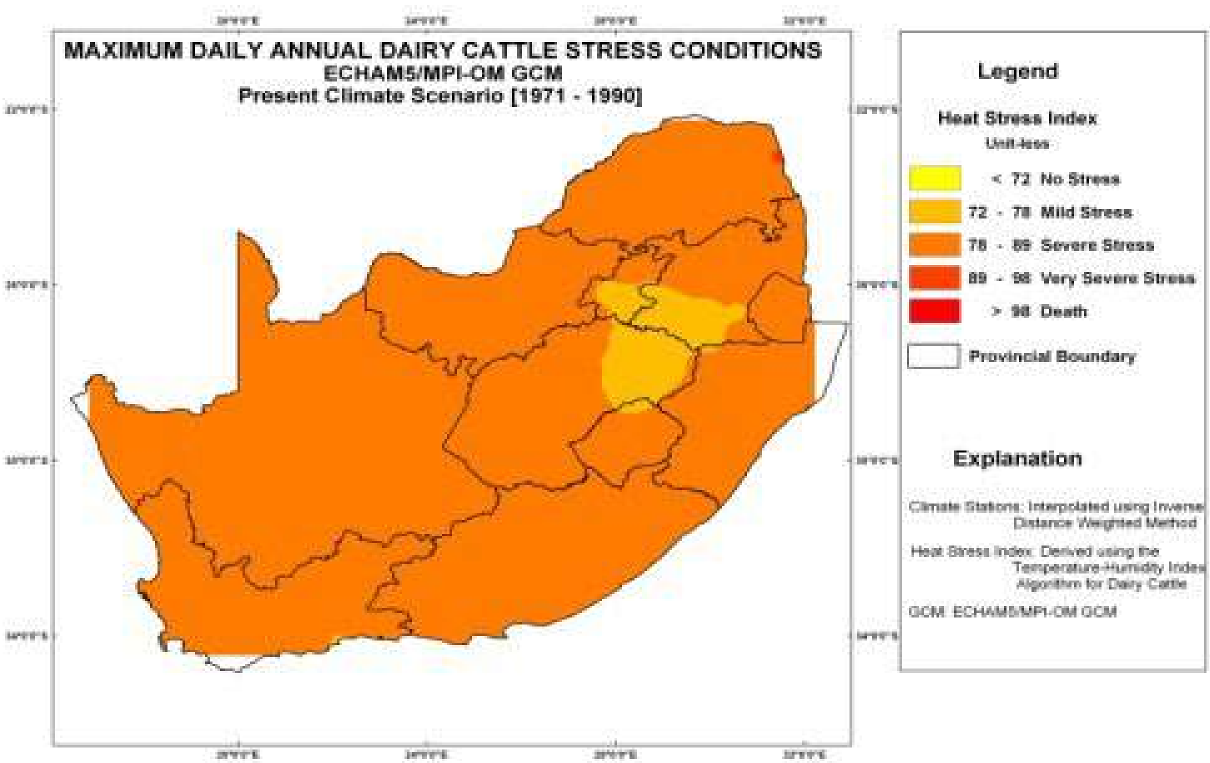
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: MRI CGCM 2.3.2 GCM


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
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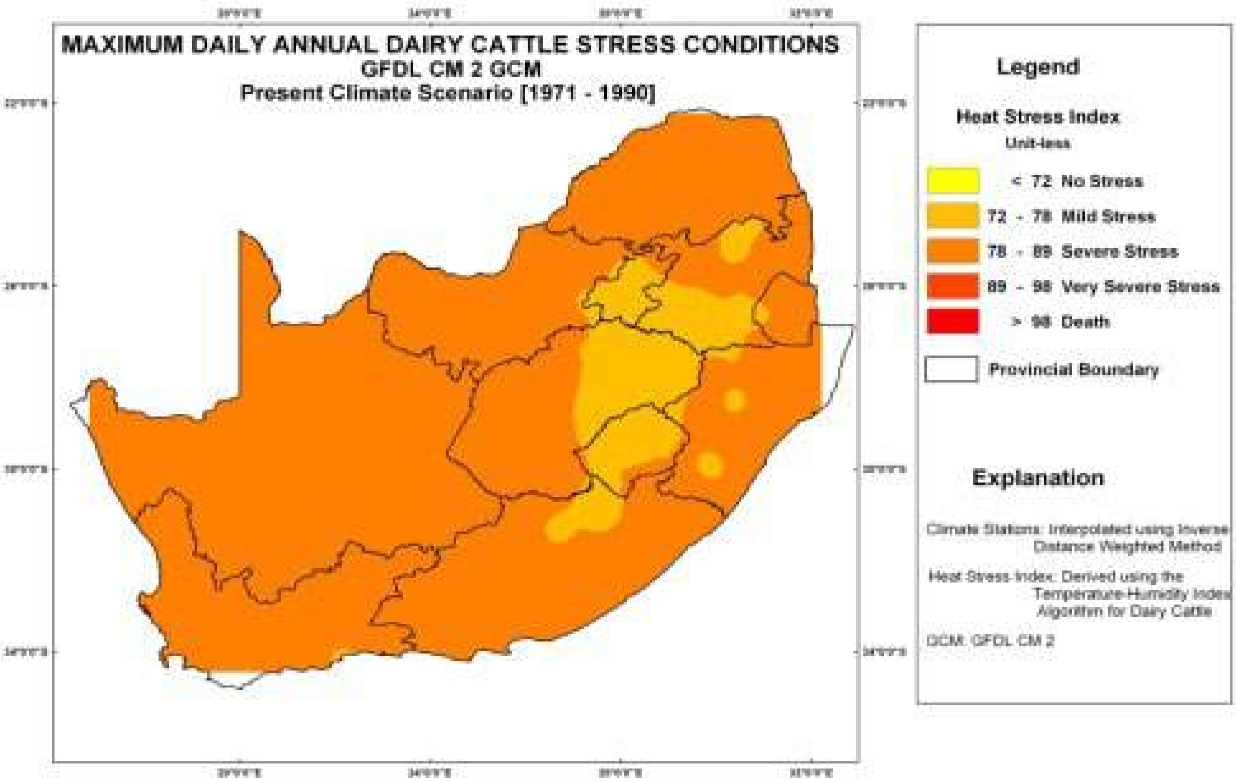
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: ECHAM5/MPI-OM GCM


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
GFDL CM 2 GCM
Present Climate Scenario [1971 - 1990]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
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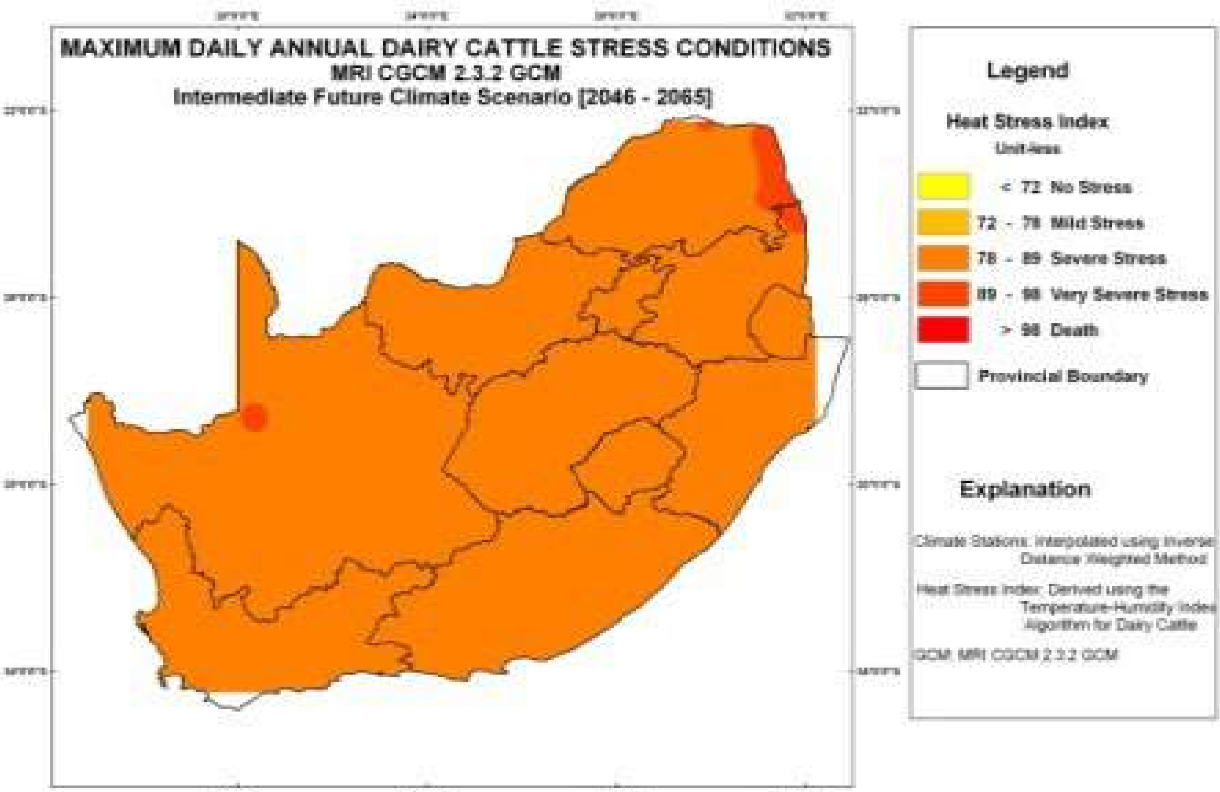
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: GFDL CM 2


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2 GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
Unit-less
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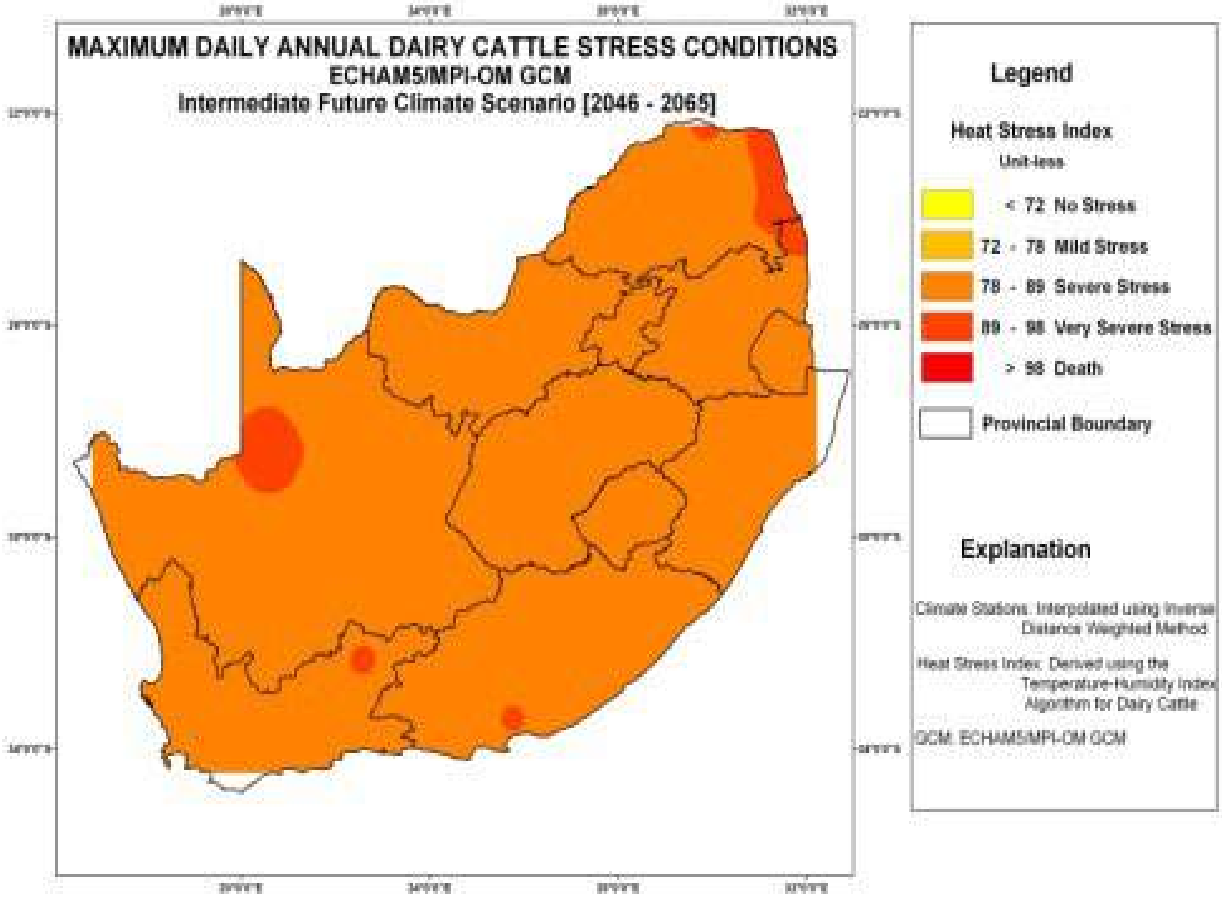
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: MRI CGCM 2.3.2 GCM



MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
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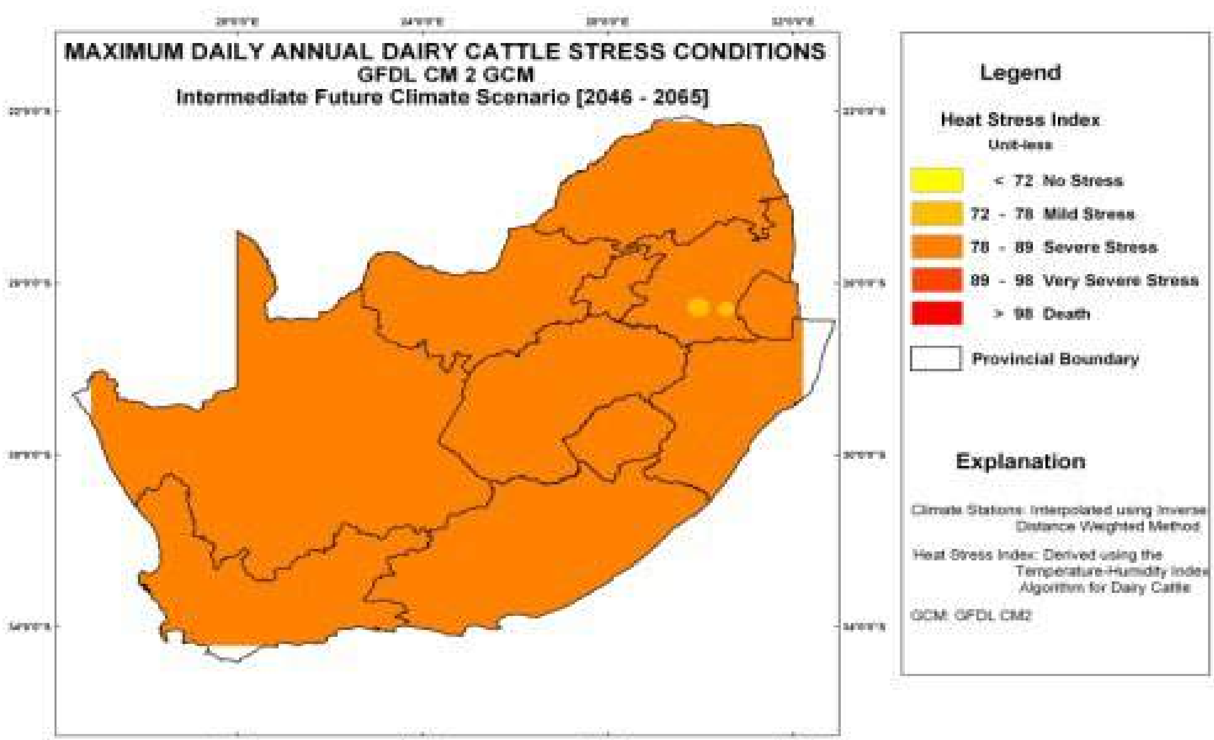
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: ECHAM5/MPI-OM GCM



MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
GFDL CM 2 GCM
Intermediate Future Climate Scenario [2046 - 2065]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
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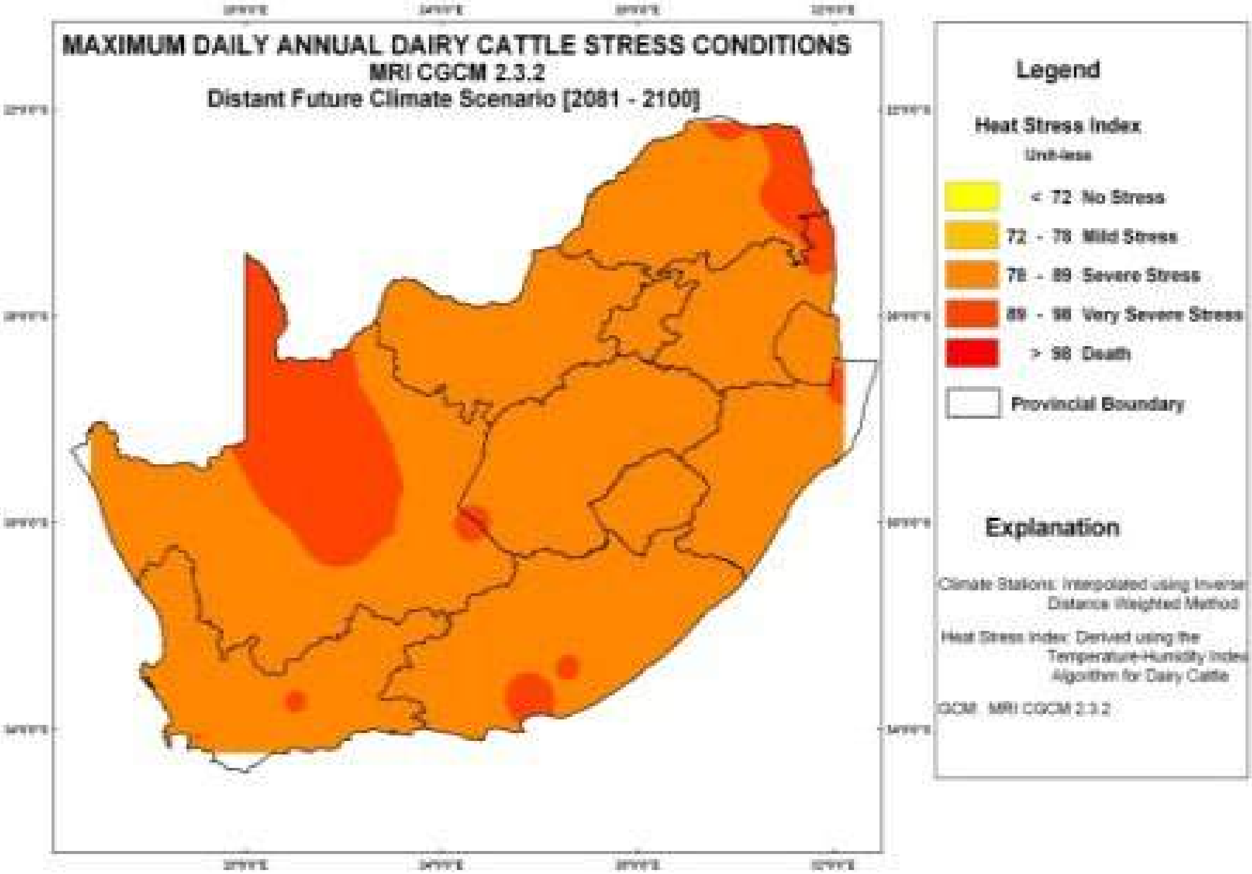
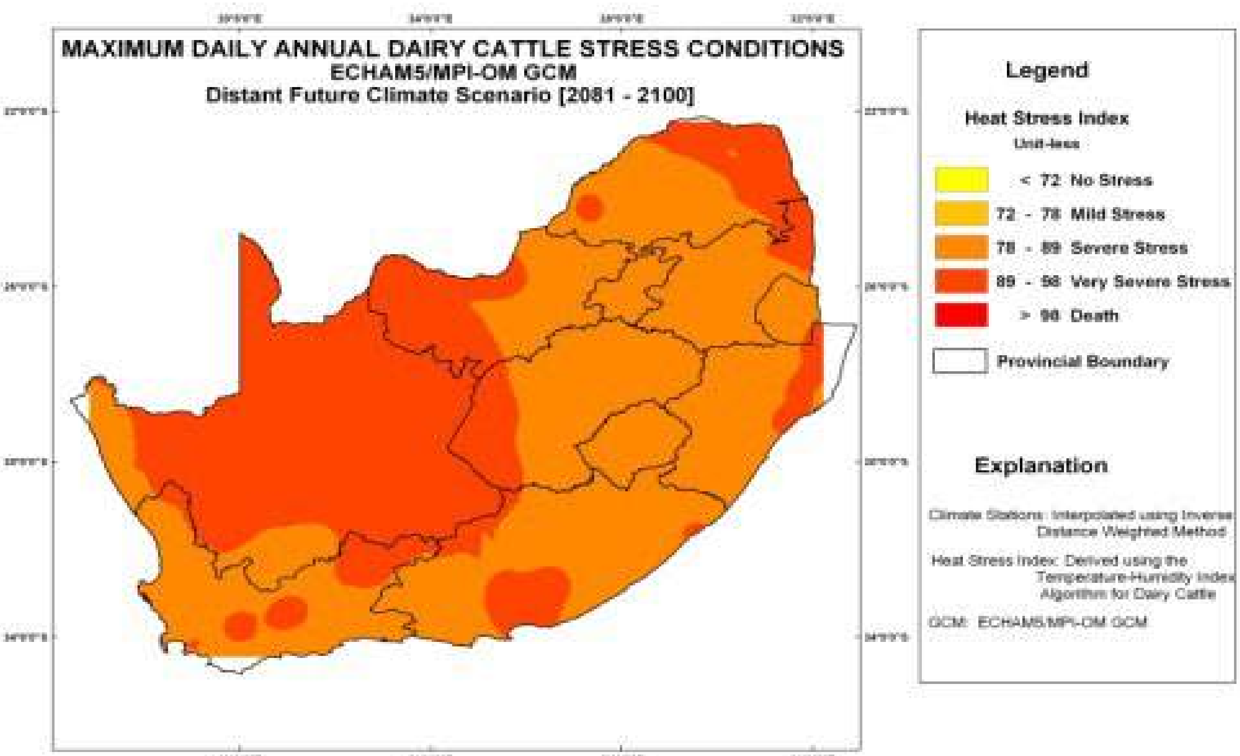
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: GFDL CM2


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
MRI CGCM 2.3.2
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
< 72 No Stress
72 - 78 Mild Stress
78 - 89 Severe Stress
89 - 98 Very Severe Stress
> 98 Death
Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: MRI CGCM 2.3.2


MAXIMUM DAILY ANNUAL DAIRY CATTLE STRESS CONDITIONS
ECHAM5/MPI-OM GCM
Distant Future Climate Scenario [2081 - 2100]
Legend
Heat Stress Index
Unit-less
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Provincial Boundary
Explanation
Climate Stations: Interpolated using Inverse Distance Weighted Method
Heat Stress Index: Derived using the Temperature-Humidity Index Algorithm for Dairy Cattle
GCM: ECHAM5/MPI-OM GCM

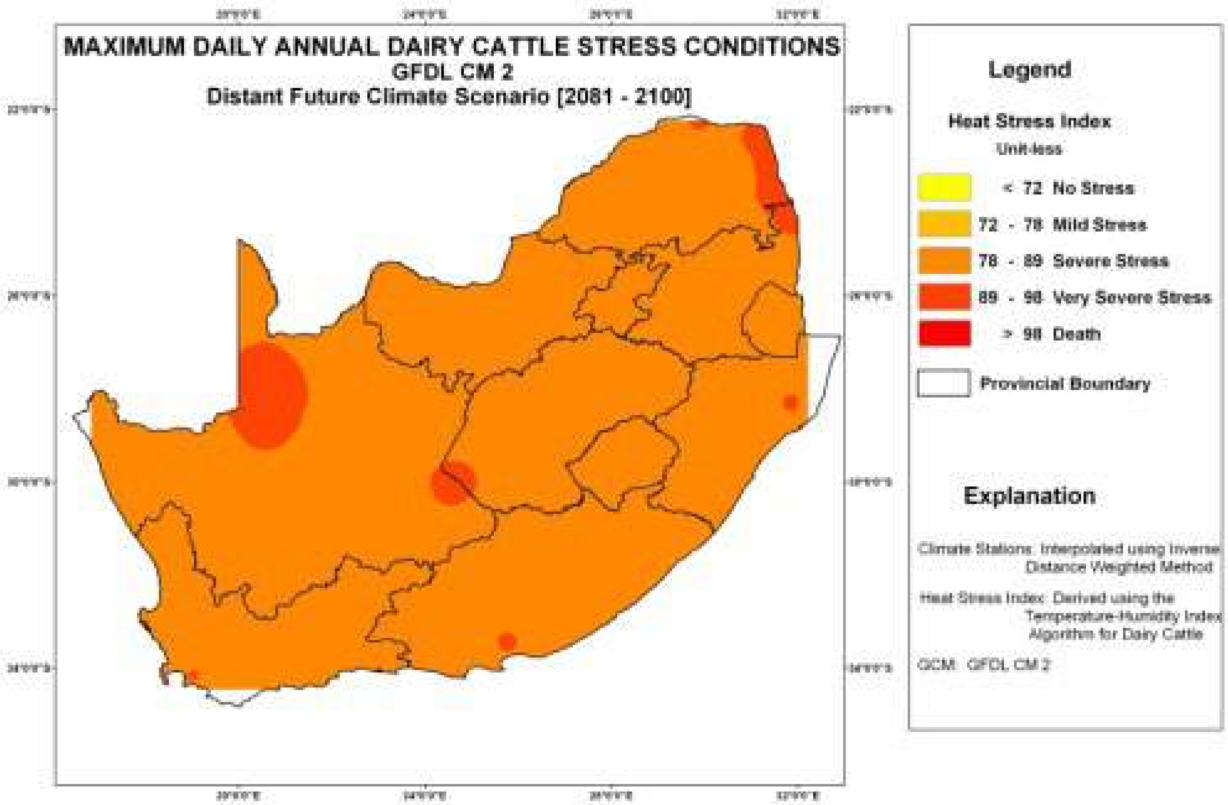

Figure 10.9 Maximum annual thermal heat stress for dairy cattle for present (Top 3), intermediate (Mddle 3) and distant climate (Bottom 3) conditions derived from MRI-CGCM2.3.2, ECHAM5/MPI-OM and GFDL-CM2.0/2

The ECHAM5/MPI-OM, MRI-CGCM2.3.2 and GFDL-CM2.0/2 GCM projections of heat stress indicates likely mild stress along the northern periphery and no stress over the rest of South Africa for mean conditions. Mild stress in dairy cattle will cause increased respiration rates and dilation of blood vessels, and minimal effects on milk production. For maximum daily conditions heat stress projections indicate that over most of the country severe stress will be experienced by dairy cattle, with patches of very severe stress along the northern periphery. Dairy cattle under severe stress will experience a reduction in milk productivity of about 10 to 25% and also a decline in their reproductive performance. The decline in milk production and reproduction responses to effects of projected heat stress will increase markedly under very severe stress. The projections of future climate on heat stress on dairy cattle suggest that climate change will have a direct impact on the dairy industry by affecting the intensity and frequency of cattle heat stress, hence can affect the milk production and reproduction. The management implications of livestock under heat stress might involve adoption of measures to minimize the effects on production. These measures range from low, moderate to high cost adaptation measures. For example, low cost measure might be reducing overcrowding and maximizing shade, moderate cost includes use of sprinklers for cooling and improving ventilation and higher cost measures include construction of new building design and installation of thermos-controlled air-conditioning (Wolfe *et al.*, 2008).

10.3.6 Land capability

In 2002, the Directorate: Land Use and Soil Management (DLUSM) within the Department of Agriculture, Forestry and Fisheries (DAFF) through the Agricultural Research Councils' (ARC) Institute of Soil, Climate and Water (ISCW) developed a national spatial land capability data set to depict the spatial delineation of the then defined eight land capability classes. The approach followed was based on the approach of Klingebiel and Montgomery (1961) but adapted for South Africa by the Multilateral Technical Committee for Agriculture and Environmental Affairs' Task team, to develop a system for soil and land capability classification but it further aimed to incorporate the parameters within a Geographic Information System (GIS). The resulted spatial data set was derived at a scale of 1:250 000 with the land type data set being the main input data set for the derived land capability classes together with climatic and terrain parameters.

Results indicated that there are little or no soils in South Africa that are not subjected to limitations. Areas with a very good climate, such as KwaZulu Natal and the former Transkei had to be down-graded due to high slopes and limited soil depth. It was determined that nowhere in South Africa do good soils and good climate coincide (Schoeman *et al*. 2002:35).

Table 10.1. Percentage distribution of land capability classes per province, 2002 (Source Schoeman *et al* 2002).

Province	Percentage of province occupied by various classes								
	I	II	III	IV	TOTAL I - IV	V	VI	VII	VIII
Eastern Cape	0.1	0.9	6.7	9.9	17.6	10.4	25.3	27.7	19.1
Free State	0.0	0.3	17.3	28.7	46.2	25.3	15.7	4.9	7.8
Gauteng	0.0	20.4	35.3	5.6	61.3	3.4	21.9	1.6	11.8
KwaZulu-Natal	0.1	5.7	24.9	11.1	41.8	3.0	29.5	16.2	9.5
Limpopo	0.0	0.7	16.8	20.2	37.8	25.7	17.5	6.9	12.2
Mpumalanga	0.0	12.1	26.9	12.2	51.3	5.1	26.2	5.0	12.5
Northwest	0.0	0.2	14.0	21.7	35.8	19.8	16.8	19.7	7.9
Northern Cape	0.0	0.0	0.0	0.0	0.0	2.7	4.0	78.6	14.7
Western Cape	0.0	0.2	6.9	6.8	13.9	4.7	14.6	39.7	27.1
RSA	0.2	1.8	10.6	11.0	23.4	10.5	15.5	36.1	14.4

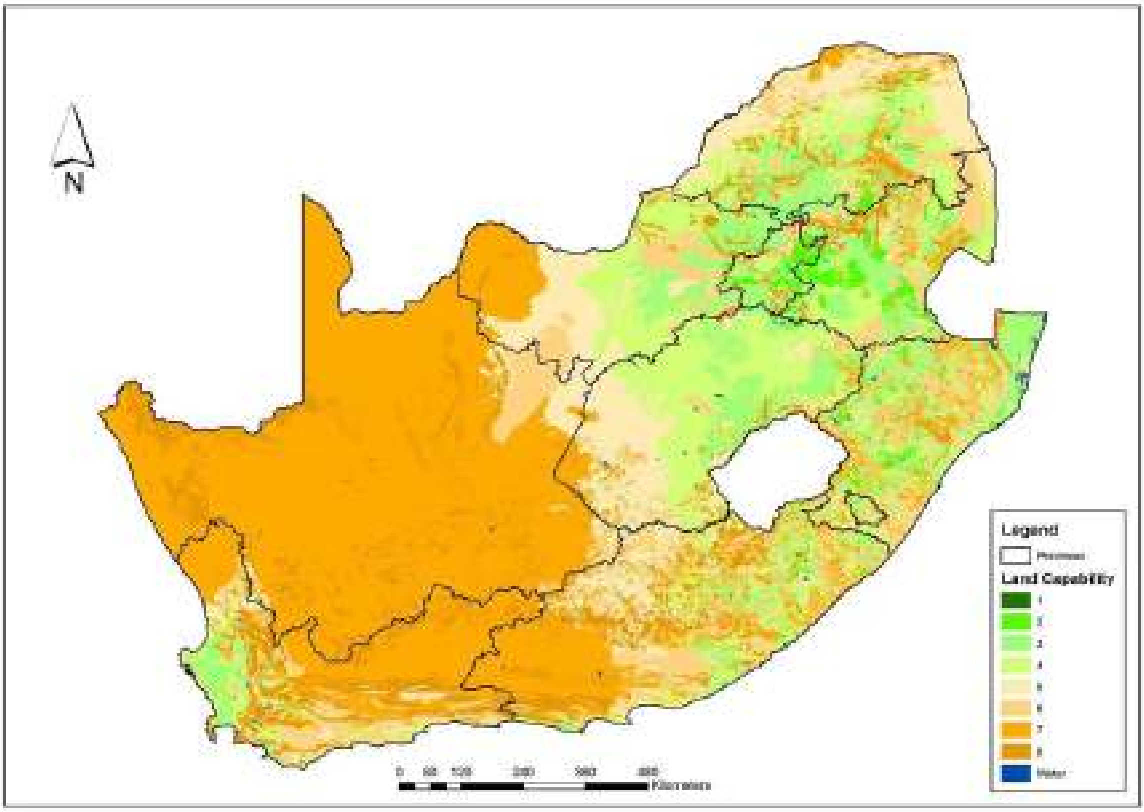

Figure 10.10. Spatial representation of the land capability classification classes in South Africa, 2002.

Land capability classes I – IV was generally regarded as arable land, whilst classes V – VII was regarded as more suited for grazing purposes and Class VIII is to be used for conservation purposes. It should, however, be taken into consideration that in many parts of the country cultivation is taking place on land capability classes V – VIII, due to a number of reasons. The 2002 spatially derived land capability data set did not take into consideration the current land use(s) occurring on any of the land capability classes nor did it include crop suitability or unique agricultural land.

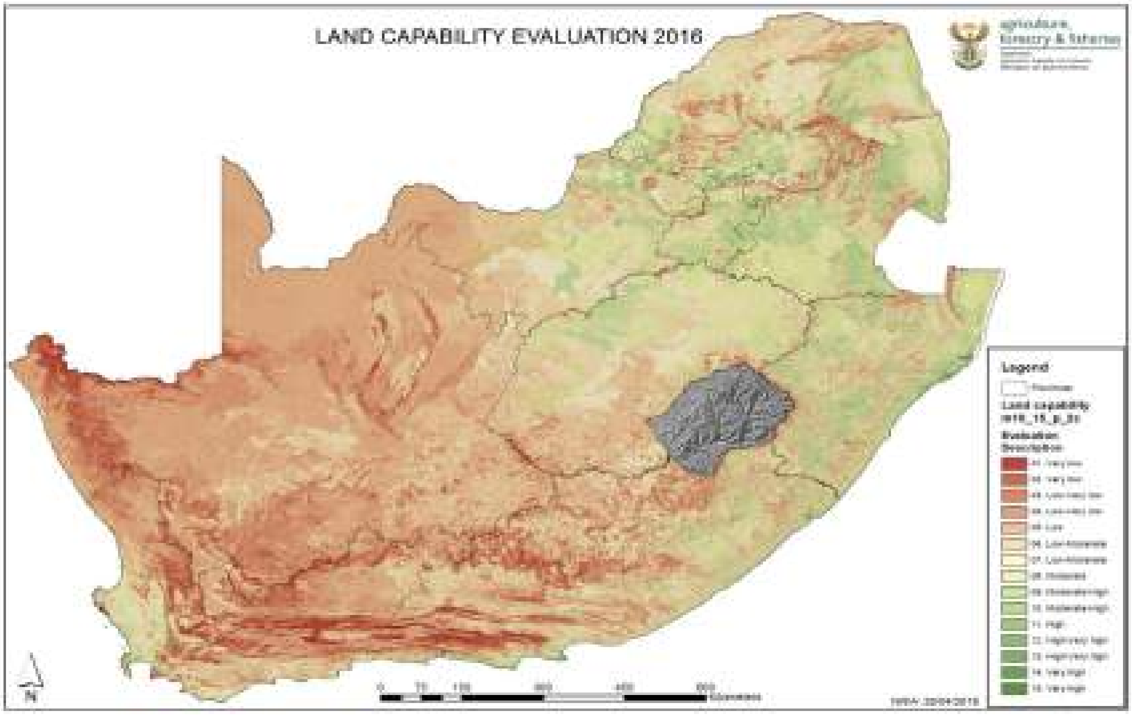

Figure 10.11. Spatial representation of the land capability classification classes in South Africa, 2002

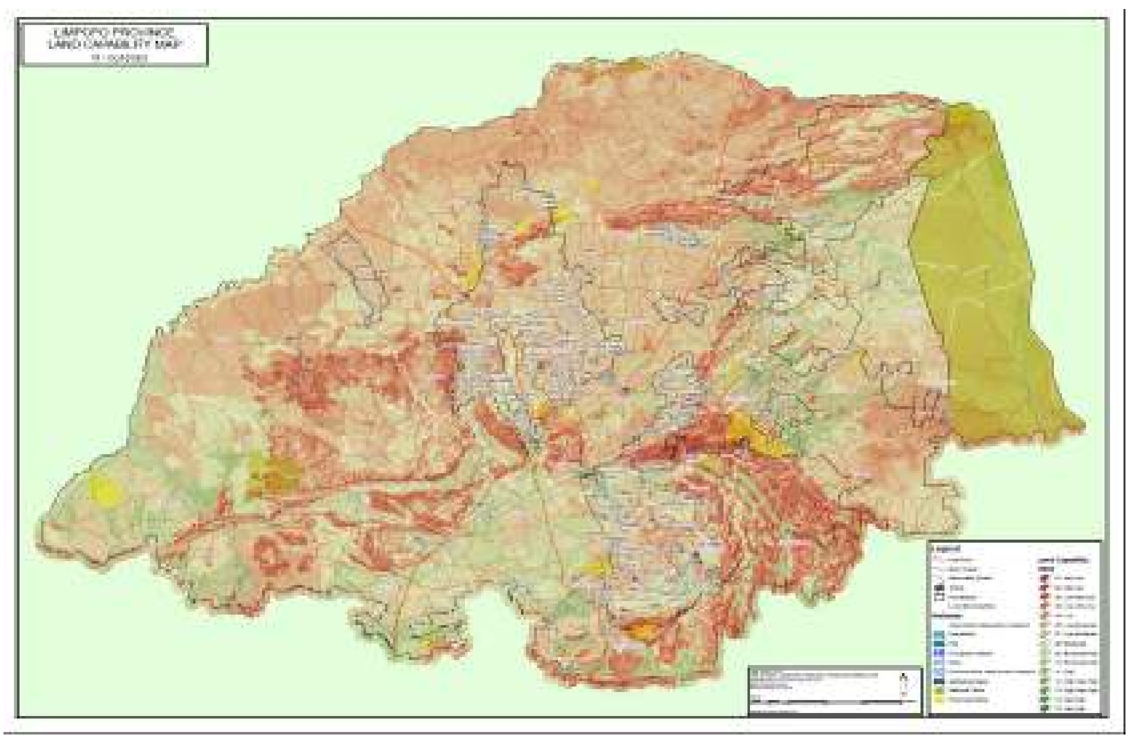

Figure 10.12. Spatial representation of the land capability classification classes in Limpopo, 2002

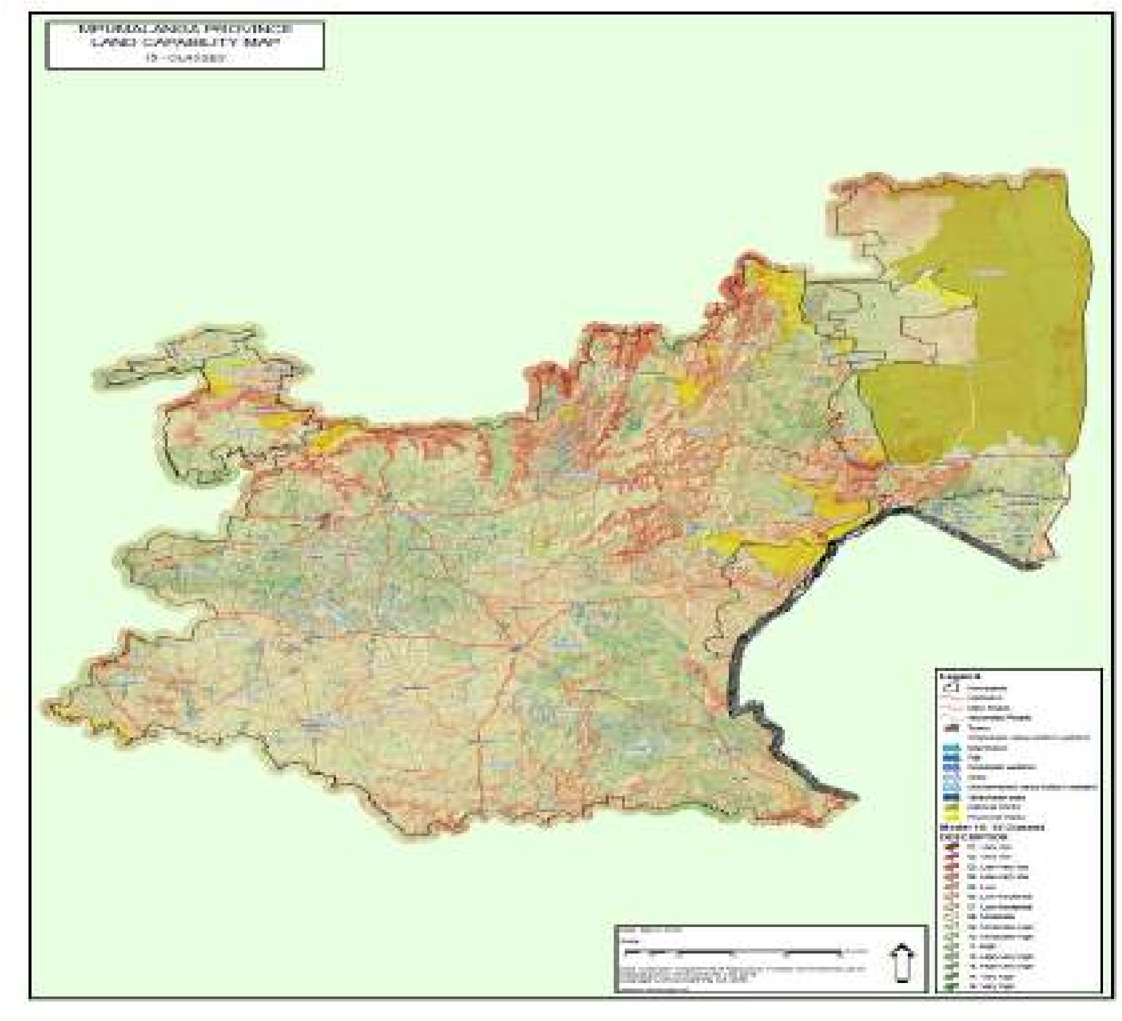

Figure 10.13. Spatial representation of the land capability classification classes in Mpumalanga, 2002

10.3.7 Aridity

Aridity index is a numerical indicator that denotes the degree of dryness at a particular location based on the ratio of the evapotranspiration to the precipitation (Derya, *et al*., 2009). Maliva and Missimer (2012) define 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. 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).

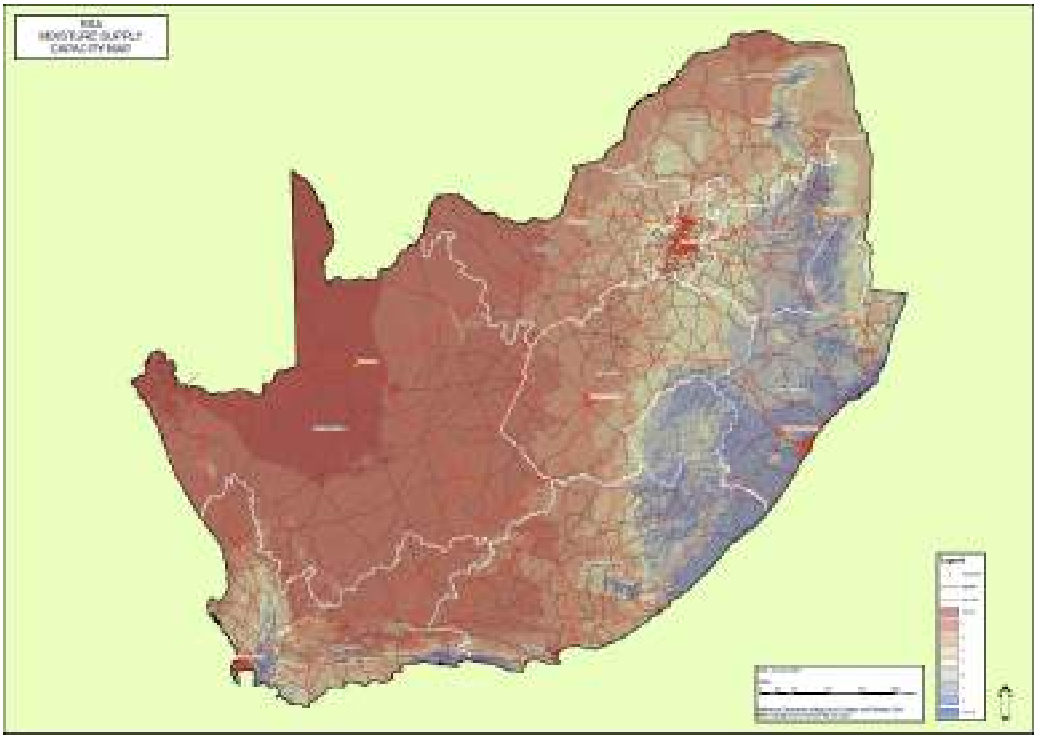

Figure 10.14. Map on the Level of Aridity – Measured as Moisture Supply Capacity.

The Limpopo in the North of the country together with the western side of the North-West, Northern Cape and the west of the Free State and Eastern Cape, north eastern side of the Western Cape are more arid.

10.3.8 Grazing capacity

The Grazing capacity layer is a wall-to-wall polygon layer that indicates the grazing capacity for a specific polygon in ha/LSU. This value indicates the amount of hectares required to sustain the production of a Large Stock Unit, defined as an animal with a mass of 450 kg and which gains 0.5 kg per day on forage with a digestible energy of 55%. The map was developed as part of the requirements of Act 43 of 1983, Regulation 10 (Conservation of Agricultural Resources Act). The purpose of these maps is to provide a guideline for landowners on how many grazing animals may be kept in a relatively homogenous area of natural veld without degrading the natural resources, taking into account that the value was calculated for veld in a good condition. For the objective of this project these give a picture for all the provinces as it is reflected for Limpopo and Mpumalanga.

The actual veld condition and biomass production that determine grazing capacity will vary from season to season and is influenced by factors such as rainfall, temperature, bush encroachment, fire and the type of management system practiced by the land owner. It is therefore the responsibility of the land owner to manage his animal numbers in such a way that there will be no degradation of natural resources such as overgrazing of veld and erosion of soil.

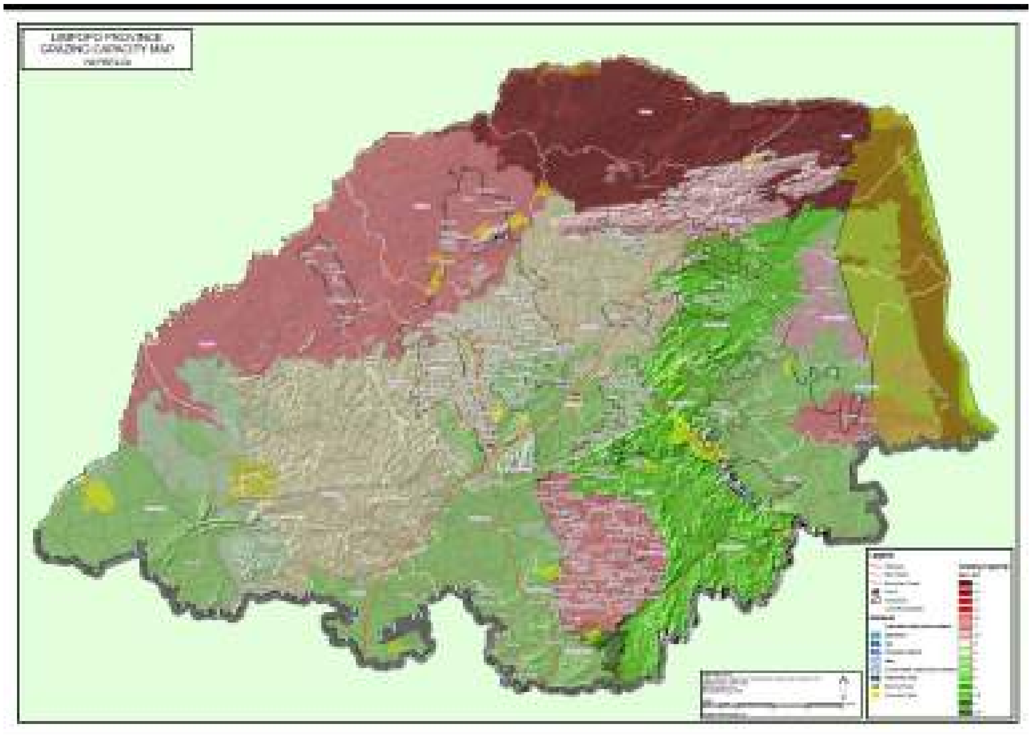

Figure 10.15. The grazing capacity map of Limpopo.

10.3.9 Selected fodder crops

Perceptions of the impact of climate change on livestock production were based on observation of less grass in pastures, drying streams, outbreak of diseases, death of livestock due to excessive heat or cold, shortage of feeds, drinking water and unknown disease and floods. Notenbaert *et al*. (2010) observed climatic trends that included reduced productivity of animal feed, higher disease prevalence, and reduced fresh water availability. This was due to the negative effects of lower rainfall and more droughts on crops and on pasture growth, and to the direct effects of high temperature and solar radiation on animals.

Forage quantity and quality are affected by a combination of increases in temperature, CO_2 and precipitation variation. What follows from section the subsequent sections are major fodder crops and grass species in terms of suitability of production in South Africa.

Eragrostis curvula

This is a tufted perennial with narrow leaves with in-rolled margins, originating in eastern Africa. It is the most important hay grass in South Africa, and is grown in the USA and used for winter pasture in Florida. Palatability varies between cultivars, but it is generally well accepted when young. It is a warm-season plant which withstands high temperatures and tolerates light frost. It can be grown with rainfalls from as low as 500 mm/yr up to 1 000 mm/yr and is drought tolerant. It prefers light soils, but will thrive on most, if well-drained. It is very tolerant of salinity and grows on soils of pH up to 8.5. It survives on poor soils, but for high production it requires fertilizer and extra nitrogen.

A firm, well worked seedbed is desirable. Seed should not be covered by more than 0.5 - 1 cm. *E. Curvula* is easy to establish. Seeding rates of the crop and nurse crop vary according to rainfall and sowing method. South African recommendations are: for areas with 650 mm/yr rainfall, 2 to 4 kg/ha *E. curvula* + 5 kg/ha teff; for 900 mm rainfall, 5 kg/ha *E. curvula* + 8 to 10 kg/ha teff; for low rainfall, broadcast, 2 to 4 kg/ha *E. curvula* + 4 to 6 kg/ha teff; for low rainfall, row planted, 2 kg/ha *E. curvula* + 5 kg/ha teff; for high rainfall, broadcast, 6 to 8 kg/ha *E. curvula* + 8 to 10 kg/ha teff; and for high rainfall, row planted, 3 kg/ha *E. curvula* + 6 kg/ha teff. It is sometimes grown in mixture with Lucerne. *E. curvula* seeds heavily and may be harvested with a header when a third of the seeds have turned brown. The threshed product is caryopses, not florets. High seed yields are obtained from row-planted crops. It is an obligate apomict. It is easy to dry, with its fine leaves, and makes good hay if cut before it becomes too coarse. In South Africa, most soils in Limpopo, North-west, Northern Cape, Kwazulu-Natal and most of the Eastern Cape will be classified as marginal unsuitable with pockets that can produce it as fodder under irrigation (Figure 10.16).

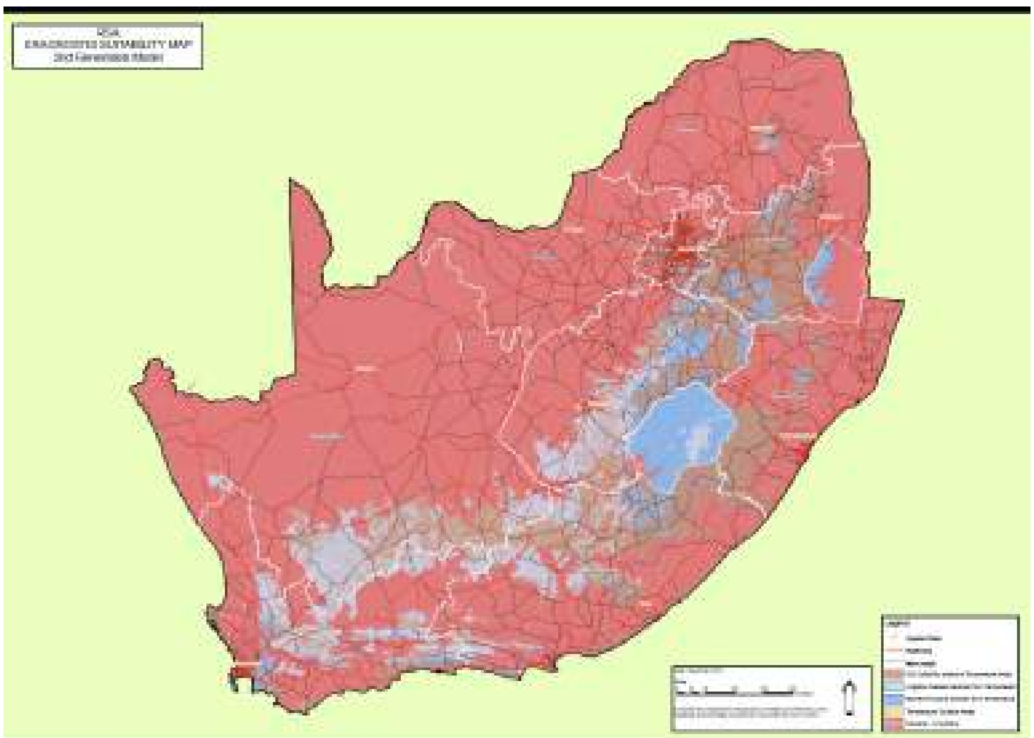

Figure 10.16. The Eragrostis Suitability Map of South Africa – 2nd Generation Model

***Kikuyu* (Pennisetum clandestinum)**

Kikuyu is a robust, vigorous creeping perennial that possesses strongly noded stolons (above ground) and rhizomes (below ground). Kikuyu regularly propagates vegetative from these vigorously spreading stolons that can form secondary stolons. The profusely branched stolons and rhizomes possess the ability to form roots at the nodes. Short leafy branches are formed from stolons, with leaf blades strongly folded into a bud when young, later expanding to 45-115mm long and 6mm wide, tapering to sub-obtuse tips. The sward tends to grow vertically to a maximum height of approximately 45 cm before lodging. The leaf surface of kikuyu is sparsely and softly hairy, the ligule characterised by a ring of hairs and the collar a prominent pale yellow colour. Under favourable moisture and soil conditions the persistent sod of kikuyu can be highly productive, but a thick, stemmy mat can form under less favourable conditions. South Africann kikuyu does not appear to flower under pasture conditions, but the cultivar Whittet does flower regularly. The seeds are dark brown in colour, flat and ovoid and 1.5 mm by 2.5 mm in size. The seed is formed almost at ground level and can only be seen by pulling away the sheathing leaves and the remaining flowers. The natural distribution of kikuyu is limited to the upland areas of east central Africa, at altitudes of between 2000 and 3050 m above sea level where the annual rainfall is approximately 1000 to 1 600 mm. Kikuyu is an aggressive coloniser and under different circumstances it can be viewed as a weed, soil cover or pasture grass. The growth pattern of kikuyu is greatly influenced and dictated by temperature. Kikuyu is a subtropical grass for which optimum growth occurs between 6-21ºC.

Growth of kikuyu reaches maximum levels at mean atmospheric temperatures of 25°C and ceases when mean atmospheric temperatures fall below 10ºC. Kikuyu is Kikuyu is more sensitive in terms of plant growth to high temperatures than many other tropical species, with growth often restricted when temperatures exceed 40°C. The soils suitable with rainfall are in western Kwazulu-Natal, west of Mpumalanga and Northern Free State (Figure 10.17).

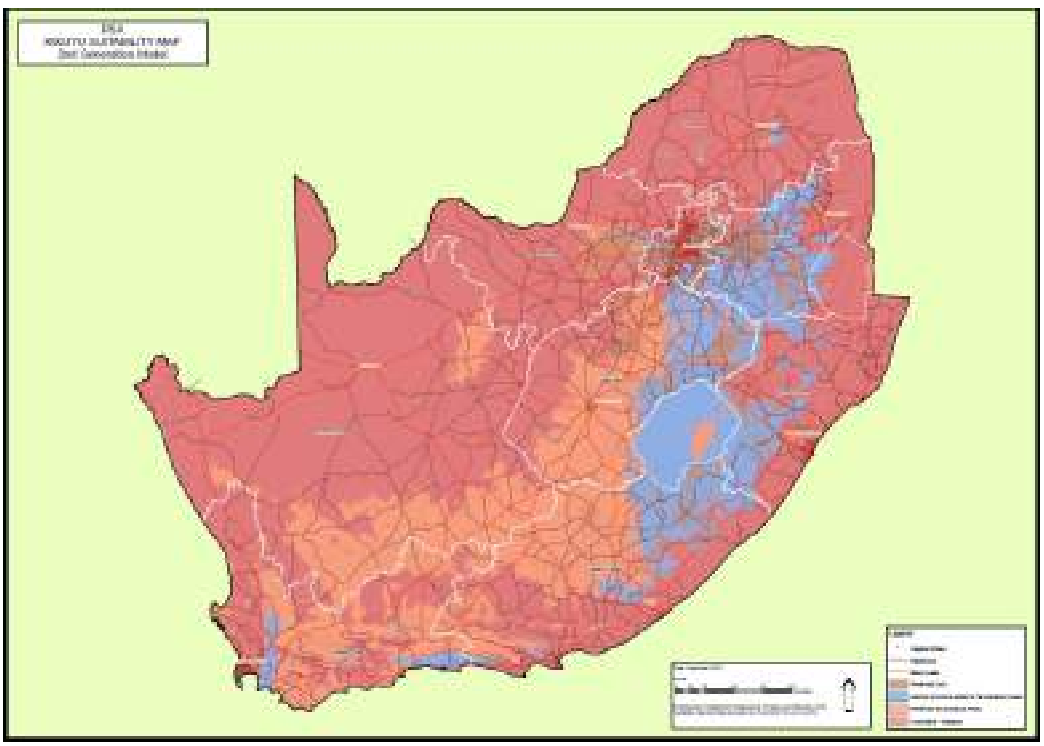

Figure 10.17. The Kikuyu Suitability Map of South Africa – 2nd Generation Model

***Lucerne or alfalfa* (Medicago sativa)**

Lucerne or alfalfa (*Medicago sativa*) is a deep-rooted, temperate, perennial pasture legume. An established Lucerne pasture provides an alternative source of forage for animal production, especially outside the growing season of annual crops and pastures. The deep roots of Lucerne can dry the soil and thereby increase the capacity of soil to store water in times of excess, which reduces groundwater recharge. Optimising plant densities at establishment is critical to ensure high production over the life of the stand. Due to its high water use and deep roots (>two metres on suitable soils) it is able to address rising water tables and associated salinity. Lucerne will provide additional green feed at the start and at the end of the normal winter growing season with peak production in spring and early summer.

It has the ability to respond quickly to significant summer rainfall (>10 millimetres) but requires 20-25 millimetres (mm) to produce substantial growth. A rain-fed Lucerne pasture produces between 4-8 tonnes (t) of dry matter per hectare per year (DM/ha/yr) which is similar to annual pasture, but production is spread more evenly over the year. Once established, Lucerne has good drought tolerance and is well suited to irregular rainfall patterns, but it will appear to go dormant during extended dry periods.

It grows in areas receiving as little as 325 mm annual rainfall but also provides good summer production in areas up to 700 mm rainfall. Out-of-season production can be used to reduce supplementary feeding requirements. Lucerne produces high quality green feed. It has high energy – digestibility of 65-72% with a metabolisable energy of 8-11 mega-joules per kilogram (MJ/kg) DM – and high protein (12-24%). The quality of feed remains relatively constant throughout the year while it is active. Lucerne is also a source of calcium, magnesium, phosphorus and vitamins A and D. In terms of its coverage (Figure 10.18) it is the only crop that covers most provinces except the Northern Cape. This is the recommended crop for promotion to deal with fodder for livestock across the country. Its combination with Rye grass makes it even more attractive.

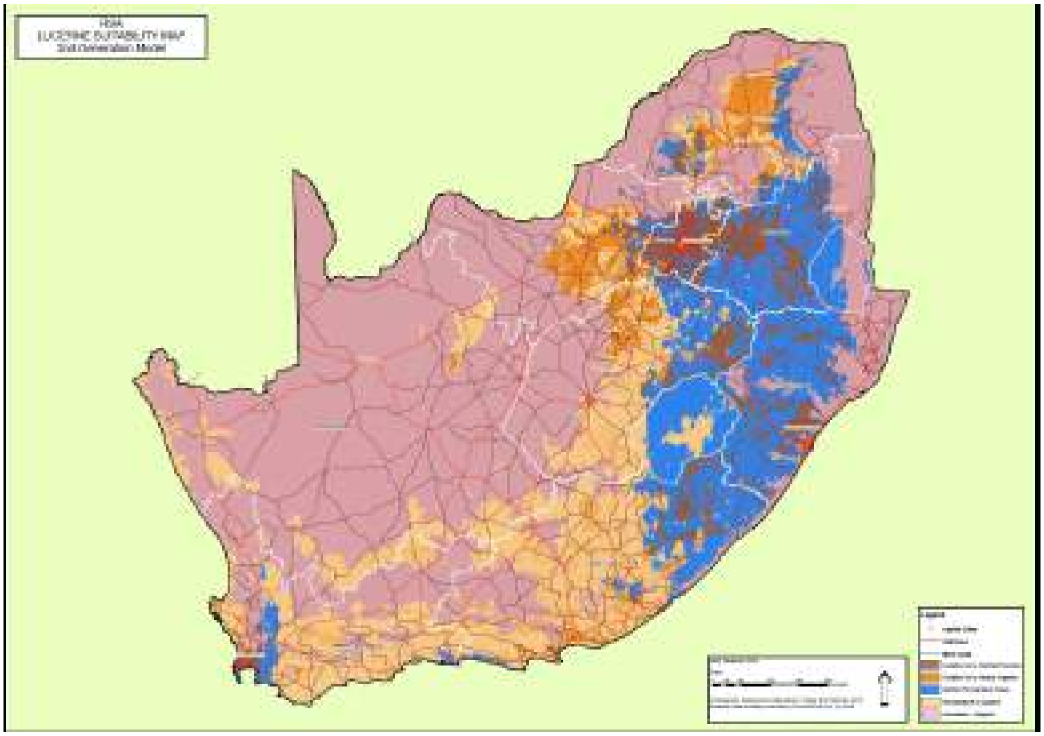

Figure 10.18. The Lucerne Suitability Map of South Africa – 2nd Generation Model

Maize **(Zea mays)**

It is important as fodder, the grain is widely used in livestock feed, the stover is fed to livestock, especially in the developing world, and the crop is grown specifically as fodder on a large scale. Tropical maize may reach four metres in height; those in temperate and subtropical areas are mostly under two metres. It is the supreme silage crop, but is sometimes dried as "hay." Maize for fodder is harvested at a slightly less mature growth stage than for grain (about two weeks pre-maturity, but with the grains fully formed but not quite hard; the greater part of the digestible energy is in the cobs and grain) and is now often grown for silage in areas where a seed crop would be risky. Maize is widely used as a fodder catch-crop in subtropical irrigated areas; it is broadcast thickly and the cultivar is of little importance.

Maize has a very large number of cultivars and hybrids with different maturity periods, and it will grow under a wide range of agro-ecological conditions, but requires high temperatures for good growth. Locally-adapted hybrids, where available, are far higher yielding than open-pollinated selections. It is mainly grown in the warm temperate and humid subtropical zones. In the tropics, it can be grown up to about 3 000 m elevation, but is better below 2 400 m. Maize does not tolerate waterlogging and requires high fertility, but within these very wide limits it can be grown in most fertile soils. Cultivars to fit a wide range of rainfall patterns are available. Maize is not drought resistant (although it can stand some drought when young), and drought-escaping short-duration types have been developed for areas with short rainy seasons.

Maize should be sown in lines into a well-prepared seed-bed. Row and plant spacings depend on cultivar and fertility level. It is often hill-sown, either with a precision seeder or by hand, and 80 – 120 cm is the main row-width range, but may be closer under irrigation with small cultivars. Plant populations are between 25 000 and 75 000 plants per hectare. It is very important to obtain a full and even stand, and therefore the seed should not be broadcast. Sowing with a wheat drill often leads to uneven stands, so a specialised drill, or hand sowing, is to be preferred. Since spacings are wide, maize is easy to sow by hand where the areas involved are not too large; various simple funnel-and-tube arrangements on traditional animal-drawn ploughs are used with success by experienced farmers.

The only risk for maize being produced as fodder is that it is staple in South Africa. It can only be fed efficiently as waste form the farms.

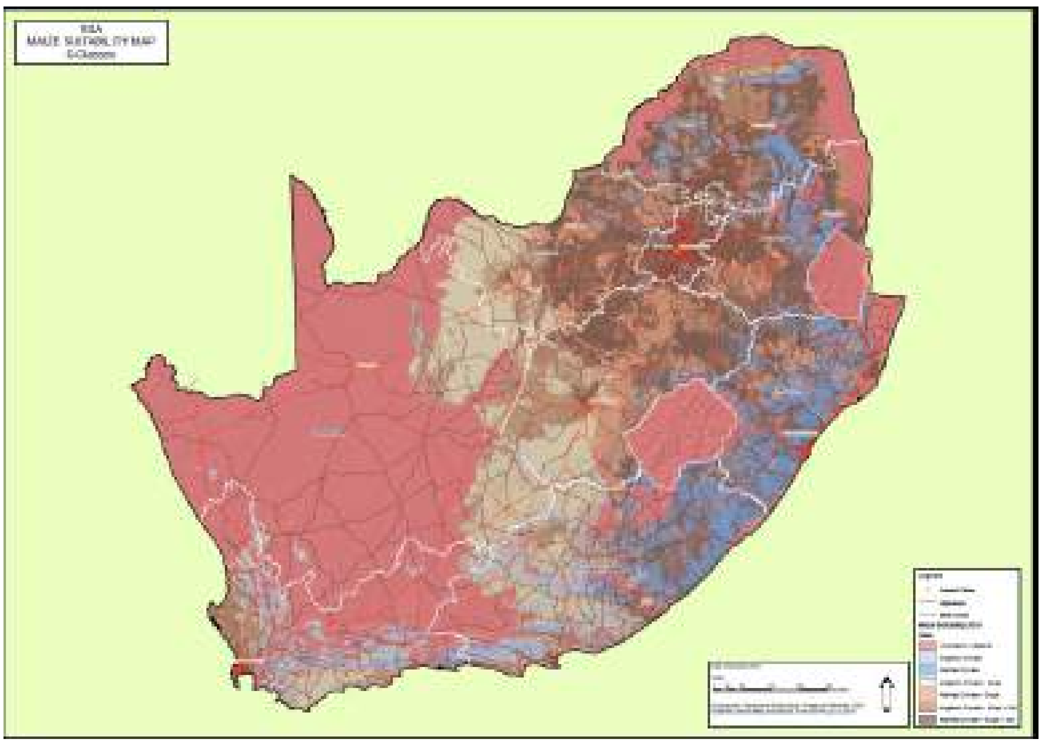

Figure 10.19. The Maize Suitability Map of South Africa

***Rye* (Secale cereale L.)**

Rye (*Secale cereale L.*) is a tufted annual or biennial grass reaching up to 150 cm high. Rye has an extensive, fibrous root system that may go as deep as 1.5 m. Rye culms are slender, erect, and mostly glabrous (except near the spike). The leaves are smooth, bluish flat blades, 14 mm broad, shorter than the culms. Rye leaves are smaller than wheat leaves. The inflorescence is a curved, much awned, 7-15 cm long spike that bears sessile spikelets at each node. The seeds are oblong, light brown, 0.8 cm long. Rye is mainly used for its grain but it is also a valuable fodder (for pasture, hay or silage) and cover crop during winter. When it is used as cover crop in double cropping systems (a warm season crop followed by rye as late fall crop), harvesting rye forage during spring provides supplementary income to farmers who usually grow maize grain and vegetables. Rye is the tallest and the hardiest annual cereal crop. There are many cultivars of Secale cereale. Diploid cultivars are more drought-hardy than tetraploids. In Africa, the related species Secale africanum (wild rye) is a palatable pasture species. Rye grows best at temperatures ranging from 15°C to 20°C but can tolerate a wider temperature range (3°C to 31°C). Once well-established it can withstand very cold conditions (down to -35°C). Its winter-hardiness is partly due to the structure of the plant, which enables it to capture and hold a protective snow cover.

Rye grows well under 600 to 1000 mm annual rainfall and is relatively drought-resistant: it can tolerate dry conditions with annual rainfall as low as 400 mm. Rye prefers well-prepared, fertile, well-drained sandy or loamy soils, with a soil pH ranging from 5.6 to 6.5. Because it is tolerant of low temperatures, of droughty conditions and of acid soils, rye may be cultivated in places where wheat cannot grow. The crop has the same coverage as Lucerne, with just the Northern Cape as a province that may not have suitable soils and climate for its good production (Figure 10.20).

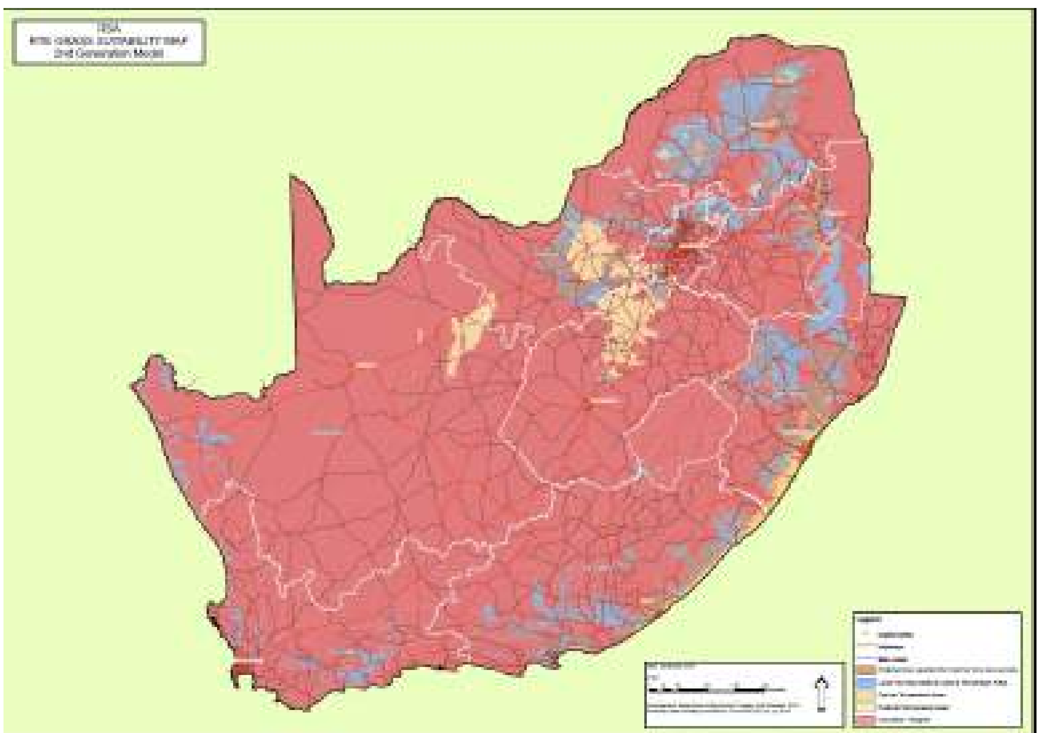

Figure 10.20. The Rye Suitability Map of South Africa – 2nd Generation Model

***Sorghum* (sorghum bicolour)**

Sorghum – a tall, clump-forming, tillering annual or short-term, ratooning perennial with culms up to at least 4 m high – is fourth in importance among the world's cereals, and is also an important fodder. It is widely grown in the drier parts of Africa and Asia for human consumption; it provides good malt and is important in brewing in parts of Africa and, notably, China. Its stover is a valuable feed, fuel and building material. In dry, hot areas of developed countries, it is grown for stock-feed. It is, however, susceptible to bird damage and has a big bird-scaring labour requirement under savannah conditions: maize is often preferred, in Africa, by small-scale farmers, despite the risk of crop loss in a drought year.

Sorghum has a very wide range of adaptation and can produce a grain crop under conditions which are un-favourable for maize and most other cereals. It can be grown on poorer soils and in drier climates than maize It thrives on heavy soils, including cracking clays, even with temporary waterlogging. Even in the seedling stage, sorghum is drought-hardy and suited to areas of unreliable rainfall. Seedling can survive wilting for at least two weeks and then recommence growth. The rainfall range is 400 - 755 mm. It is a crop for hot to warm conditions, and is killed by frost. Under equatorial conditions, it can grow up to about 2 200 m above sea level, although most is grown below 1 000 m, but traditional, cold-tolerant types are used at much higher elevations in Ethiopia. Its latitudinal range is 40° on either side of the Equator. Its range of pH adaptation (5.0 - 8.5) is wide; it withstands salinity better than maize. Sorghum is a short-day plant with marked response to photoperiod, so cultivars must be chosen accordingly; sorghums which grow tall as a summer crop may flower as dwarfs if grown in the shorter days. In South Africa as per the crop suitability Map Figure 10.21 the crop is the most adaptable that can be grown in most parts of the country.

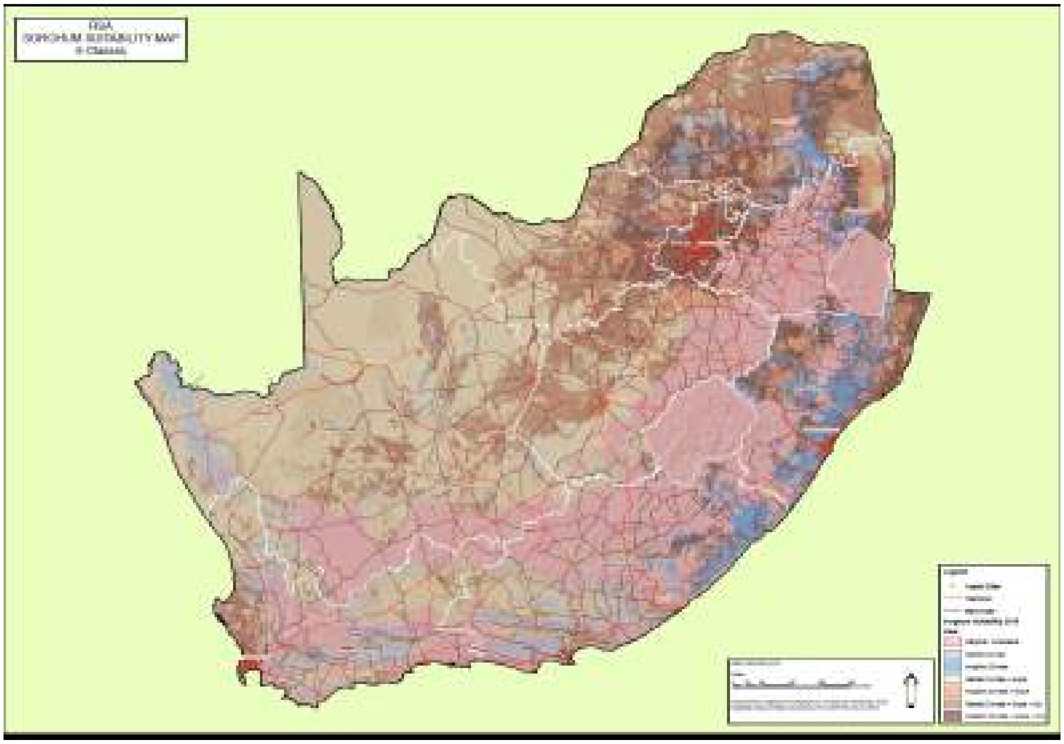

Figure 10.21. The Sorghum Suitability Map of South Africa

10.4 CONCLUSIONS

The agro-ecological attributes of livestock farming areas of South Africa can be classified as an 85% semi-arid region. The area experiences extended spells of the dry season and shorter wet periods. The arid area is characterised by a severe lack of water resources to the extent of hindering the growth of plants and vegetation. Based on the geo-physical and climatic attributes the country's land capability is such that there is nowhere in South Africa where good soils and good climate coincide. Livestock that graze are likely to suffer the negative impacts of climate change while those that browse are likely to survive. It is highly recommended that small stock (goats) be the preferred farming animal as they are drought-tolerant, while farmers that are practicing cattle farming will be more likely exposed to the impacts of climate change. The actual veld condition and biomass production that determine grazing capacity vary from season to season and is influenced by factors such as rainfall, temperature, bush encroachment, fire and the type of management system practiced by the land owner. It is therefore the responsibility of the land owner to manage his animal numbers in such a way that there will be no degradation of natural resources such as overgrazing of veld and erosion of soil.

10.5 REFERENCES

Abdul-Razak, M. and Kruse, S (2017). The adaptive capacity of smallholder farmers to climate change in the Northern Region of Ghana. Climate Risk Management, 17:104-122.

Adams, S. (2013). WRC – leading the charge on groundwater research. Water Wheel. Groundwater Special Edition. 2013.

Alkire, D. (2009). Protecting against summer temperatures. Retrieved from Farm Progress: https://www.farmprogress.com/livestock/protecting-cattle-against-summer-temperatures

Aydın, M. (1995). Water: Key ingredient in Turkish farming. Forum for applied research and public policy. A Quarterly Journal of the University of Tennessee. 10: 68-70.

Baltas, E.,(2007) Spatial distribution of climatic indices in northern Greece. Meteorol Appl 14:69–78.

Brown-Brandl T M; Eigenberg R A; Hahn G L; Nienaber J A. (2001). Correlations of respiration rate, core body tempera-tures and temperatures for shaded and non-shaded cattle.Proceedings, Sixth International Livestock. EnvironmentSymposium, pp 448–454. American Society AgriculturalEngineers, Louisville, Kentucky

Butler, R. A. (2005) A Place Out of Time: Tropical Rainforests and the Perils They Face. Published online: Rainforests.mongabay.com

Collin, A., van Milgen, J., Dubois, S. and Noblet, J. (2001). Effect of high temperature on feeding behaviour and heat production in group-housed young pigs. British Journal of Nutrition, Vol.86, pp. 63-70. ISSN: 0007-1145

Croitoru, A.E, Piticar. A., Imbroane AM., Burada, D, C., (2013) Spatio-temporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania. Theor Appl Climatol 112:597–607

Deniz A, Toros H, Incecik S (2011). Spatial variations of climate indices in Turkey. Int. J. Climatology 31(3):394–403

Derya, Ö., Mehmet, A., Süha, B., Sermet, Ö., and Tomohisa, Y. (2009). The use of aridity index to assess implications of climatic change for land cover in Turkey. Turk J Agric For(33), 305-314. doi:doi:10.3906/tar-0810-21

Easterling, D. R., Meehl, G.A., Parmesan, C., Changnon, S.A., Thomas R.K. and Mearns, L.O. 2000. Climate Extremes: Observations, Modeling, and Impacts, Science. VOL 289 SCIENCE www.sciencemag.org.

FAO, (1976). A framework for land evaluation. Food and Agriculture Organization of the United Nations, Soils Bulletin 32. FAO, Rome.

FAO. 1978. Report on Agro-Ecological Zones Project. Vol 1. Methodology and Results for Africa. World Soil Resources Report #48. FAO: Rome.

Griffins, J. (1985). Handbook of applied Metereology. (D. D. Houghton, and J. W. Sons, Eds.)

He, Y., Yao, Y., Chen, Y., Ongaro, L., (2011). Regional Land Suitability Assessment for Tree Crops Using Remote Sensing and GIS. Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM) IEEE, Changsha, pp. 354–363.

Hrnjak I, Lukić T, Gavrilov MB, Marković SB, Unkašević M, Tošić I (2013) Aridity in Vojvodina, Serbia. Theor Appl Climatol 115(1–2):323–332

Ingrin. D., and Rainier., D (2012). Climate change vulnerability index for South African aquifers. http://www.scielo.org.za/pdf/wsa/v38n3/08.pdf

Intergovernmental Panel on Climate Change (IPCC) (2007). Impacts, adaptations and vulnerability. Fourth Assessment Report. Cambridge University Press, Cambridge, UK.

Jones L. & Boyd E (2011) Exploring social barriers to adaptation: insights from Western Nepal. Glob Environ Chang 21:1262–1274

Kala, N., Kurukulasuriya, P., and Mendelsohn, R. (2012). The impact of climate change on agro-ecological zones: Evidence from Africa. Environment and Development Economics, 17(6), 663-687. Retrieved from http://www.jstor.org/stable/26265545

Kotchoni, D.O.V., Vouillamoz, JM., Lawson, F.M.A. et al. Hydrogeol J (2019) 27: 447. https://doi.org/10.1007/s10040-018-1806-2

Kotir, J. (2011) "Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security," Environment, Development, and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, vol. 13(3), pages 587- 605, June.

Lazaro R, Rodrigo FS, Gutierrez l, Domingo F and Puigdefafregas J. (2001). Analysis of a 30-year rainfall record (1967-1997) in semi-arid SE Spain for implications on vegetation. J. Arid Environ. 48 373-395.

Lekalakala., (2017). Options for Managing Climate Risk and Climate Change Adaptation in Smallholder Farming Systems of the Limpopo Province, South Africa. Doctoral Thesis. Goettingen (IPAG), Faculty of Agricultural Sciences, Georg-August-University Goettingen, Germany

Li x-y, Shi, P-J, Sun Y-l, Tang J and Yang Z-P (2006). Influence of various in-situ rainwater harvesting methods on soil moisture and growth of Tamarix Ramosissima in the semiarid loess region of China. For. Ecol. Manage. 23 (1) 143-148.

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2012) Indicators for Assessing the Vulnerability of Smallholder Farming to Climate Change: the Case of Brazil's Semi-Arid Northeastern Region. Poverty Practice, Bureau for Development Policy, UNDP Esplanada dos Ministérios, Bloco O, 7º andar, 70052-900 Brasilia, DF - Brazil

Lindoso, D.P., & Rocha, J.D., Debortoli N., Parente I.I., Eiró, F., Bursztyn, M. & Rodrigues-Filho, S. (2014). Integrated assessment of smallholder farmings vulnerability to drought in the Brazilian Semiarid: a case study in Ceará. Climatic Change, https://www.researchgate.net/publication/262485038. DOI 10.1007/s10584-014-1116-1

Mader TL (2003) Environmental stress in confined beef cattle. Journal of Animal Science 81, 110–119.

Maliva RG, Missimer TM (2012). Arid lands water evaluation and management. Environ Sci Eng 3(1948):806.

McDowell, J. Z., Hess J. J. (2012): Accessing Adaptation: Multiple Stressors on Livelihoods in the Bolivian Highlands under a Changing Climate. – Global Environmental Change 22: 342-352.

Mmbengwa, V., Nengovhela, N.B., Ngqangwenia, S., Spies, D., Baker, D.S., Burrow, H., and Griffith, G. 2016. Developing New Value Chains for Small-Scale and Emerging Cattle Farmers in South Africa. Proceedings in System Dynamics and Innovation in Food Networks. www.centmapress.org.

Moral FJ, Rebollo FJ, Paniagua LL, García-Martín A, Honorio F (2015) Spatial distribution and comparison of aridity indices in Extremadura, southwestern Spain. Theor Appl Climatol. https :// doi.org/10.1007/s0070 4-015-1615-7

Mpandeli, S. and Maponya, P. (2014). Constraints and Challenges Facing the Small Scale Farmers in Limpopo Province, South Africa. Journal of Agricultural Science; Vol. 6, No. 4

Mzezewa, J., Misi, T., and and van Rensburg, L. D. (2010, January). Characterisation of rainfall at a semi-arid ecotope in the Limpopo Province (South Africa) and its implications for sustainable crop production. Water SA, Vol. 36 (No. 1). doi:ISSN 0378-4738

Nesamvuni E, Lekalakala R, Norris D and Ngambi J.W., 2012. Projected impacts of temperature and humidity on feedlot cattle in South Africa using temperature humidity index as an indicator of heat stress. Journal of Animal & Plant Sciences 14 (2) 1931-1938.

O'Brien,K., Leichenkob, R., Kelkarc, U., Venemad, H., Aandahla, G., Tompkinsa, H., Javedc,A., Bhadwalc, S., Bargd, S., Nygaarda, L., and Westa, J. (2004a). Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change 14 (2004) 303–313

Omokanye, Akim and Yoder, Calvin and Sreekumar, Lekshmi and Vihvelin, Liisa and Benoit, Monika. (2018). On-farm Assessments of Pasture Rejuvenation Methods on Soil Quality Indicators in Northern Alberta (Canada). Sustainable Agriculture Research. 7. 74. 10.5539/sar.v7n2p74.

Ormsby, T.; Napoleon, E.; Burke, R.; Groessl, C.; Feaster, L. 2001. Getting to know ArcGIS desktop. Basics of ArcView, ArcEditor and ArcInfo. Redlands, Ca. ESRI Press.

Pan, G., and Pan, J., (2012). Research in cropland suitability analysis based on GIS. Computer and Computing Technologies in Agriculture 365, 314–325.

Quiniou, N., Dubois, S. and Noblet, J. (2000.) Voluntary feed intake and feeding behaviour of group-housed growing pigs are affected by ambient temperature and body weight. Livestock Production Science, Vol. 63, No. 3 (May 2000) pp. 245–253. ISSN: 0301-6226

Ranya Elsheikh, Abdul Rashid B. Mohamed Shariff, Fazel Amiri, Noordin B. Ahmad, Siva Kumar Balasundram, Mohd Amin Mohd Soom (2013). Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops, Computers and Electronics in Agriculture 93, pp 98–110.

Rowlinson, P., 2008. Adapting Livestock Production Systems to Climate Change – Temperate Zones. Livestock and Global Change conference proceeding. May 2008, Tunisia.

Seneviratne, S., Nichols, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., Reichstein, M., Sorteberg, A., Vera, C., and Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment, chapter 3 in IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation Cambridge University Press, Cambridge, UK, New York, NY, USA (2012)

Smit B. and Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Chang Hum Policy Dimens 16:282

Sonwa, D.J., Somorin, O.A., Jum, C., Bele, M.Y. and Nkem, J. (2012), "Vulnerability, forest-related sectors and climate change adaptation: the case of Cameroon", Forest Policy and Economics, Vol. 23, pp. 1-9.

South Africa (Republic) 2018. Long-term grazing capacity for South Africa: Data layer. Government Gazette Vol.638, No.41870. 31 August 2018. Regulation 10 of the Conservation of Agricultural Resources Act (CARA): Act 43 of 1983. Pretoria. Government Printing Works

Turpie, J. and Visser, M. (2013), "The impact of climate change on South Africa's Rural areas", Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.

DoA. 2008. Department of Agriculture. Trends in the Agricultural Sector 2007. National Department of Agriculture, Pretoria, RSA.

St. Pierre NR, Cobanov B, Schnitkey G (2003) Economic losses from heat stress by U.S. livestock industries.Journal of Dairy Science 86(E Suppl):E52–E77

Yousef, M. K. 1985. Stress Physiology in Livestock. CRC Press, Boca.

Mader, T. L., Davis, M. S. and Brown-Brandl, T.2006. Environmental factors influencing heat stress in feedlot cattle. Journal Animal Science, 84:712-719.

Wolfe, D.W., Ziska, L., Petzoldt, C., Seaman, A., Chase, L and Hayhoe, K. 2008. Projected change in climate thresholds in the Northeastern U.S.: implications for crops, pests, livestock, and farmers. Mitig Adapt Strat Glob Change, 13:555–575.

IPCC (Intergovermental Panel on Climate Change). 2007. Technical Paper on Climate Change and Water. Working Group II. Cambridge University Press, Cambridge, UK. [Internet]. Available from: http:// www.ipcc.ch/meetings/session21. [Accessed on: 22 August 2008].

CHAPTER 11: PUBLICATIONS REPORT

11.1 INTRODUCTION

This section of the report focuses on the publications and dissemination of the study. Focus is placed on presentations, congress abstracts and papers and as well as publications in peer reviewed journals, which were authored by post-graduate students and research team members.

11.2 PRESENTATIONS

The study resulted in several presentations, which was done by the project leader and the post-graduate students:

- Nesamvuni, A.E. 2018. Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate. Inaugural Meeting of the Joint Teams KIS and Vhembe District Executive of Limpopo Department of Agriculture. 7th June 2018 Nwanedi Centre, Musina Local Municipality, Vhembe District, Limpopo.
- Nesamvuni, A.E. 2019. Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate. Progress Report Meeting of the Joint Teams KIS, Vhembe District Executive and Extension Officers Limpopo Department of Agriculture. 3rd September 2019 Nwanedi Centre, Musina Local Municipality, Vhembe District, Limpopo.
- Nesamvuni, A.E. 2019. Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate. Limpopo Research Forum – A Forum of Government Departments and all HE and Government Owned Institutions. 16th October 2019 Tzaneen Local Municipal Chambers, Mopani District Limpopo.
- Ndwambi K. 2019. Climate Change Talk. Tshilamba Circuit Careers Guidance. Tshilamba, Thulamela, Municipality, Vhembe District, Limpopo.
- Mahopo, T.C. 2019. Student Assistant on the project Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate. 4th WRC Biennial Symposium. 11-13TH September 2019. Sandton, Johannesburg.
- Nesamvuni, A.E. 2019. Vulnerability Assessment and Adaptive Response for Smallholder/Small Scale Livestock Sector to the Changing Climate – Keynote Speaker. 35th Annual Conference South African Society for Atmospheric Sciences, 8-9 October 2019 at Riverside Sun Hotel, Vanderbijlpark, Gauteng.

11.3 CONGRESS ABSTRACTS

- Nesamvuni, A.E., Tshikolomo, K.A, Lekalakala, G.R., Raphulu, T., Petja, M.B., Van Niekerk, J., and Mpandeli, N.S., 2020. Agro-Ecological Characterisation of Smallholder Livestock Farming System in Limpopo – Mpumalanga Provinces. Southern African Society of Grassland Sciences Virtual Congress 2020

  Nesamvuni, A.E., Tshikolomo, K.A, Lekalakala, G.R., Raphulu, T., Petja, M.B., Van Niekerk, J., and Mpandeli, N.S., 2020. Vulnerability Assessment for Smallholder Livestock farmer to the Changing Climate. Southern African Society of Grassland Sciences Virtual Congress 2020
- Raphulu, T., A.E. Nesamvuni, K.A. Tshikolomo, G.R. Lekalakala, B.M. Petla, J. Van Niekerk & P.J. Sebei. 2020. Adaptive capacity of smallholder livestock farmers to the impacts of climate change. South African Society of Animal Sciences Congress 2020/2021
- Nesamvuni, K.A. Tshikolomo, G. R. Lekalakala, T. Raphulu, B.M. Petla & J. Van Niekerk. 2020. A Framework to Monitor and Evaluate Vulnerability of smallholder livestock farmer: A case study of Limpopo & Mpumalanga. South African Society of Animal Sciences Congress 2020/2021

11.4 SHORT PAPERS

- Nesamvuni, A.E., Ndwambi, K., Tshikolomo, K.A., Van Niekerk, J., Raphulu, T., Lekalakala, G.R., Petja, M.B. 2020. Small-Holder Farmers Perceptions on the Impact Of Climate Variability & Extremes On Livestock Production In Limpopo & Mpumalanga Provinces. South African Society of Agricultural Extension Congress 2020
- Nesamvuni, A.E., Ndwambi, K., Tshikolomo, K.A., Van Niekerk, J., Lekalakala, G.R., Petja, M.B. 2020. Climate Vulnerability and Small-Holder Livestock Water and Fodder Use Analyses. South African Society of Agricultural Extension Congress 2020
- Sikhipha, N.M., Tshikolomo, K.A., Nesamvuni, A.E., Van Niekerk, J., Mpandeli, N.S. 2020. Analysis of Multiple Stakeholders Influencing Smallholder Producers of Subtropical Fruits in The Limpopo Province Of South Africa. South African Society of Agricultural Extension Congress 2020
- Tshikolomo, K.A., Nesamvuni, A.E., Van Niekerk, J., Raphulu, T., Petja, M.B. 2020. Livestock Farmer Demography and Adaptive Capacity to Climate Change and Variability: A Case of Limpopo and Mpumalanga Province of South Africa. South African Society of Agricultural Extension Congress 2020
- Syed Md. T. M., Van Loon, A., Artur, L., Bharucha, Z., Chinyama, A., Chirindja, F., Day, R., Franchi, F., Geris, J., Hussey, S., Nesamvuni, A.E., Nhacume, A., Petros, A, Roden, A., Rohse, M., Tirivarombo, S. and J.C. Comte. 2020. Multisector collaborative groundwater-surface water modelling approach to improve resilience to hydrological extremes in the Limpopo River Basin. Geo-Ethics and Groundwater Management Congress, Porto, Portugal 2020

11.5 PUBLICATIONS

- Ndwambi, K., Nesamvuni, A.E., Mpandeli, N.S., Tshikolomo, K.A., and Van Niekerk, J. 2020. The Geo-Environmental Suitability Modelling Survey of the Selected Subtropical Fruit, a Case of Limpopo Province. *Journal of Human Ecology*, accepted for publication
- Van Koppen, B., Hofstetter, M., Nesamvuni, A.E. and Chiluwe, Q,.2020. Integrated management of multiple water sources for multiple uses: rural communities in Limpopo Province, South Africa. *Water SA* 46(1) 1–11

11.6 CONCLUSIONS

The investment done through the Water Research Commission has yielded major returns in terms of publications and how the research has been disseminated to date. Leverage has also been made to expose students and the team to international teams through collaborations. In this regard the team managed to collaborate with the International Water Management Institute towards a publication as indicated in 10.5.2. The team also collaborated with CONNECT4 project which is led from Aberdeen University, this led towards the congress paper indicated in 10.4.5.

CHAPTER 12: CAPACITY BUILDING OF STUDENTS, FARMERS AND EXTENSION OFFICERS

12.1 EXECUTIVE SUMMARY

Capacity building is central to the success of this project and its legacy. Key to the process of empowerment and capacity building will be the value proposition of the project, mainly transformation and redress, human capital, community empowerment, and informing policy and decision making. For this report the capacity building hinges on student development – human capital development, smallholder livestock farmers and households empowerment together with Extension Officers. Human capital is a construct that embeds Intellectual Capital (the people), Structural Capital (infrastructure & systems) and Relational Capital (collaborations).

Intellectual Capital: The project had in the main One Doctoral Student (Mr Ndwambi Khuthadzo) and Two Masters' Students (Ms Ndivhuwo Makhalimela & Livhuwani Khobo). Mr Khobo could not register for 2019 due to an employment opportunity. Mr Ndwambi won the WRC Scholarship and had one paper accepted for publication. He made another submission of a conference paper to the South African Society of Agricultural Extension. For its real impact the project extended its reach to extra four Doctoral Students – Messrs Jutas Mavhungu & Clopus Mahopo together with Ms Namadzavho Sikhipha and Bernadette Brown-Webb – who benefited from climate change and vulnerability approaches of the projects in the construction of their doctoral thesis.

Structural Capital: The project coordinated the training of students under the project leader through various institutions such as universities – University of Free State, University of Venda; Government Institutions – Limpopo Department of Agriculture (Madzivhandila Agricultural College, Toowoomba, Mara Research Station) and Farmer Organisations (National Emerging Red Meat Organisation, African Farmers Association of South Africa). The students also benefited from QUANTEMNA a private SMME that trained them in data analysis and RAMIES another SMME that facilitated data collection and logistics.

Relational Capital: The project in its impacts leveraged on other international initiatives, namely Creative Drought Pilot that was running at Folovhodwe. The students, farmers and community in general were trained in Climate Extremes and its impacts to Livestock, Crop and Subtropical small holder farmers. The project collaborated with Birmingham University in the UK and National University of Science & Technology in Bulawayo, Zimbabwe under the project leader Dr Anne van Loon.

The workshops done are well narrated in this report with demonstrable sessions they facilitated. The other international Project that the project leveraged on has just been inaugurated in February 2019. The one Doctoral student Khuthadzo Ndwambi attended the inaugural planning session in Maputo, Mozambique, funded by the University of the Free State.

Community Empowerment: Smallholder farmers participated in all the facilitated workshops led through the Joint Team of the Project Leader Prof AE Nesamvuni and the Birmingham Project Leader Dr Anne Van Loon. All the students were research assistance and played a role in facilitating groups of smallholder farmers with the advantages of translating the vernacular language – VENDA to ENGLISH and vice versa. The same workshops were ran for Tshipise, Mukovhawabale and Gumbu villages facilitating to elicit their experiences to deal with climates extremes.

Informing Policy and Decision Making: Central to the legacy of this project and its national and international collaboration will be to inform policy and help in decision-making at the village, local municipality, district, province and indeed national level. The experimental workshops that the students attended and facilitated led to some suggestions by the farmers on what needs to be done to deal with drought, floods and other extremes, such as storms and heat waves. Agricultural Extension Officers will also be empowered by the development of The Extension Manual.

12.2 STUDENT PROGRESS AND FUNDING

Three students were part of the project (Table 12.1) – one Doctoral Student, Mr Khuthadzo Ndwambi, is registered with Free State University for his Doctoral Degree. He won their part funding through tuition and also won the WRC scholarship. He made significant progress with his research, having satisfied all the requirements for proposals, data collection and analysis. He wrote one paper as part of his thesis, which got accepted by the *Journal of Human Ecology* (The Geo-Environmental Suitability Modeling Survey of the Selected Subtropical Fruit, a Case of Limpopo Province: K. Ndwambi, A. E. Nesamvuni, S. N. Mpandeli, K. A. Tshikolomo, and J. Van Niekerk). He is currently working on his second paper and making good progress to be part of the main project through participation in writing chapter papers. His other contribution has been the submission of a conference paper:
Small Holder Farmers Perceptions on the Impact of Climate Variability & Extremes on Livestock Production in Limpopo & Mpumalanga Provinces: K. Ndwambi, A. E. Nesamvuni, K. A. Tshikolomo, and J. Van Niekerk.

Ms Ndivhuwo Makhalimela is a Masters' student at TUT who also made progress currently doing data collection after the mandatory compliance with proposal writing, and literature review. The project supported her in capacity building and partly funded by TUT for her tuition. She has support of the broader project for her data collection. She is currently at data collection stage – she was trained on the project as facilitator of groups, recording of proceedings and also to transcribe interviews to text.

Mr Livhuwani Khobo got a job with Minerals and Energy and could not continue with his studies for 2019. But he has been part of the project for two years had his project approved and draft literature review.

Table 12.1. Student Profiles that were part of the project

STUDENT NAME	UNIVERSITY TUITION	WRC SCHOLARSHIP	DEGREE
Ndwambi Khuthadzo	UFS	YES	PhD Sustainable Agriculture
Makhalimela Ndivhuwo	TUT	NO	M.Sc. Agric
Khobo Livhuwani***	UNIVEN	NO	M. Env, Mining Geology

12.3 INTERNATIONAL COLLABRATIONS LEVERAGED FROM THE WRC PROJECT

12.3.1 Connect4 Water Resilience

The project Leader – Prof AE Nesamvuni together with the WRC funded Doctoral Student, Mr Khuthadzo Ndwambi – attended the inauguration of the New Project CONNECT4 WATER RESILIENCE in Eduardo Mondlana University in Mozambique. Mr Ndwambi was also sponsored by his university of the Free State for his accommodation for the week of the inauguration workshop. The student was capacitated through the events of the workshop to plan projects and how to engage with major stakeholders for project sustainability.

12.3.2 Specific research objectives of the project

The specific research objectives of the project were:

(a) To assess the spatiotemporal physical availability and connectivity of groundwater and surface water resources across the Limpopo river basins and the long-term hydro-meteorological and geographical control on drought-flood responses;

(b) To assess connectivity between different social groups and governance levels at and across different scales with respect to drought-flood related knowledge and practices;

(c) To improve the connectivity between physical and social understanding to strengthen resilience at community, regional and basin scales through implementation drought-flood-drought policies based on both physical and social requirements and possibilities.

The research anticipated uutputs were:

(a) A hydrological model of the Limpopo river basin and multiscale map of physical connectivity.

(b) A map of practices and channels of communication in water management including multiscale social connectivity.

(c) Identified effective actions for building resilience to drought-flood-drought cycles on the appropriate scales accounting for both physical and societal knowledge(s) and structure(s).

12.3.3 Post-graduate student training on farmer group facilitations

As part of objective (b) which is "To assess connectivity between different social groups and governance levels at and across different scales with respect to drought-flood related knowledge and practices"; the following students and extension officers contributed to the field work and facilitation done with Farmers at Ha-Gumbu, Mukovhawabale and Tshipise villages. Table 12.2 shows the profile of the total number of student that were trained and carried out the methodology of facilitation, story- telling, recording the stories and transcribing into useful text scientifically.

Table 12.2. Student Profile Trained in Facilitation

Name	Degree	Villages	Type of Farmers Facilitated
Mandoma T (Female)	M. Env, Mining Geology	Tshipise	Arable – Rain-fed Agriculture, Livestock
		Folovhodwe	Young Farmers; Orchards Farmers
Makhalimela N (Female)	M.Sc. Agriculture	Tshipise	Domestic water users.
		Folovhodwe	Livestock Farmers; Elderly Women Group of the Village
Khobo L (Male)	M. Env, Mining Geology	Mukovhawabale	Arable – Rain-fed Agriculture, Livestock, Landcare and Domestic Water Users
		Ha-Gumbu	Arable – Rain-fed Agriculture, Livestock, and Domestic Water Users
		Folovhodwe	Orchards Farmers, Old Generation Men of the Village
Ndwambi K (Male)	Ph.D Sustainable Agriculture	Folovhodwe	Livestock Farmers; Older Generation Irrigation Scheme Farmers

The facilitation done together with extension officers, students and farmers assisted to achieve objective (b) of the projects which was to elicit local knowledge of historical droughts and floods for validation of work being done on hydrological models. The facilitation covered (a) water management practices; (b) responses to droughts and floods as experienced; (c) sources, availability and uptake of knowledge information regarding forecasting and management; (d) communication with formal institutions and agencies; (e) awareness and perceptions upstream and downstream and downstream communities.

The project had an impact to the way extension officers conduct their businesses and how they interact with the farmers. Gaps were identified on which government extension services may need to intervene in terms on transfer of information, infrastructural development and general farmer support areas.
Table 12.3 shows the profile of extension officers that were trained and participated in the facilitation processes.

Table 12.3. Extension Officers Profile Trained in Facilitation

Name	Position	Village	Type of Farmers Facilitated
Mudzielwana Matodzi (Male)	Agricultural Advisor	Folovhodwe	Irrigation Scheme, Livestock and household water use
Mutswari M Alson (Male)	Agricultural Advisor	Tshipise	Arable – Rain-fed Agriculture, Livestock, Domestic Water Users & Youth Farmers
Nengovhela A Daniel (Male)	Agricultural Advisor	Ha-Gumbu	Arable – Rain-fed Agriculture, Livestock, and Domestic Water Users
Netshiungani M Milton (Male)	Agricultural Advisor	Mukovhawabale	Arable – Rain-fed Agriculture, Livestock, Land-care and Domestic Water Users

12.4 INTRODUCTION TO THE PILOT PROJECT – CREATIVE DROUGHT THAT TRAINED POST-GRADUATE STUDENTS IN CLIMATE EXTREMES

The project Leader – Prof AE Nesamvuni together with the WRC funded Doctoral Students Messrs Khuthadzo Ndwambi, Livhuwani Khobo, and Ms Tshimangadzo Mandoma, Ndivhuwo Makhalimela – were part of the pilot project Creative Drought that was conducted at Folovhodwe to capacitate Students, Farmers, Extension Officers and the Community. The local Extension Officer Messrs Mudzielwana and Jutas Mavhungu were central to facilitate the meetings and the workshops. What follows will be the broad narrative of the pilot project indicating the areas and skills where the students participated.

Drought events cause severe water and food insecurities in many developing countries. In many of these countries resilience to drought is low for a myriad of reasons, including poverty, unequal political and social structures, limited access to information, and problems adapting traditional knowledge to changing situations. The project Creative Drought was used to empower students, farmers, extension officers and community. The aim of the project was to increase drought resilience by combining local indigenous knowledge with scientific methods. With a multi-disciplinary research team, they developed an interdisciplinary approach that:

- collects existing drought narratives (i.e. stories about past drought events) and other useful local knowledge,
- organises creative workshops in which communities build future drought narratives based on the narratives and model scenarios, and
- embeds the outcomes of these workshops in local water management.

The pilot study area was selected in the Limpopo Basin in South Africa, a rural area, with a dry and irregular climate, traditional dryland farming systems, and limited effective water management. The area was a typical rural village which resembled the broader Limpopo and Mpumalanga provinces where the VULNERABILITY was to be done. The region was experiencing a severe drought, related to normal rainfall in two consecutive rainy seasons, and leading to major impacts on local communities in terms of food and water. The students were trained to conduct interviews and group sessions, based around narrative elicitation, with various groups within a local community in the Limpopo Province. In this way the students, farmers and extension officers learned about the experience, perspective and cultural significance of drought events. Using hypothetical future scenarios with support of hydrological model the communities were empowered to use their own experience and the scenarios to experiment with stories about possible future drought events and possible effective ways of responding to them. The idea was try and increasing resilience to drought with support of scientific methods, with culturally embedded and bottom-up approach. Old members of the community, youth, and women together with both crops and Livestock farmers were engaged separately and also combined with commodities. This approach ensures that the perspectives of different members of the community were heard and incorporated. The students were also exposed to meetings with local authorities to make sure the future drought narratives that the communities have developed will feed into official decision-making processes.

12.4.1 The Pilot Village – Folovhodwe

Folovhodwe, is a rural village between Tshipise and Musina not far from the Zimbabwe border. The landscape was dry and red with scattered trees with green reddened leaves during the period of the pilot. In scanning the scene, the coned but rivulet slag heap from the magnesite mine (a former supplier of employment but no longer working) sat near the village of scattered houses.

There was a stark contrast between irrigated and unirrigated parts of village in terms of green-ness. Current reservoir levels were posted on a chalk board outside the neighbouring nature reserve (see picture below).

There was a borehole and the water storage tank higher up a slope. The water pump was not working so villagers were loading several donkey carts (four beasts aligned) with large containers to take water back to houses in the village.

Daily occurrence in Folovhodwe, shows groups of women washing brightly coloured clothes in river and irrigation channels and laying them out to dry on fences. Some villagers were selling large bags of oranges, massive avocados and tomatoes along the dirt road back to the main tarmacked road. There was a pre-workshop visit, in which the team spoke to two community elders under huge baobab trees in the Chief's garden, and then oriented around the village including seeing the apparently new community hall in the centre of the Folovhodwe – the venue which was used for workshops (see picture below).

The workshops used a methodology that worked to bring together science and narrative in future 'scenarios' – focusing on 'Challenges', 'Exchanges' and 'Solutions'. The workshops in were run with 'invited' members of different 'community' groups – orchard farmers, livestock farmers (day 1); older and younger women with children (day 2). The workshops ran for 2-3 hours with a break for refreshments and fruit.

The community were getting their water from different sources: drinking water from a groundwater well, irrigation water from a reservoir that releases water into the river, and water for bathing, washing, brick making, and cleaning cars from the river. By showing how a drought would affect each of these water supplies and discussing amongst groups that would be affected differently by a drought, they learned about the connection between the water bodies and how abstraction in one would affect the other.

12.4.2 Some lessons on the interviews

The pilot focused on drought but when the team asked the community to tell them about droughts they had experienced in the past, many also told us about flood events. For the community both are water-related extreme events that often even impact them similarly, with crop loss, drinking water problems, diseases, etc. Even though floods and droughts are governed by different processes (floods by fast, mostly near-surface pathways and droughts by slower, sub-surface storage related pathways) and different tools and indices were used to characterise both extremes, people at local scale have to deal with both floods and droughts when the hydrological system goes from one into the other or when both occur simultaneously in different parts of the hydrological system. We realised that our academic world is so fragmented that we often forget about connecting floods and droughts in our scientific work. Furthermore, we forget that we may affect one hydrological extreme when trying to manage our resources for the opposite hydrological extreme.

The most important, but unintended connections we discovered, however, were the connections between people. The project also helped the community rediscover some connections between generations (young mothers and elderly ladies) and between different sectors (livestock farmers and irrigation farmers). And finally, the scientific team connected with the community. As a token for our newly established connection, the children's dance group performed traditional dances during our final visit with the chief and the village leaders (see below), only bestowed on very special guests. That is the best confirmation we could get that personal connections are important and that our water management and our science depend on them!

12.4.3 Lessons for the students on the methodology

This situation was perhaps unavoidable given people were aware of the impacts of lesser droughts from their recent drought history in 2015/16 when the livestock farmers lost cattle. Linked to this was the challenge to our ability to communicate the concept of a scenario as 'one possible future' in a clear way that was not lost in translation. Some villagers understood the "scenario" as an actual prediction – a situation that appeared exacerbated when only one scenario was presented. There were also difficulties in presenting the more nuanced situation of different variables changing alongside climate, and climate change of 3ºC being only one possible future – most extreme scenario – over the given timespan to 2050.

Additionally, there were language issues in the conversion of the narrative of the scenario into Venda, the local language of the villagers. This was limited by the initial but developing expertise in storying science and the understanding of the four STUDENTS who were the research assistants, and then compounded by issues about how to convert the "scenario" into something accessible to the villagers given the availability of words and meanings within Venda language. It was also useful to reflect on approaches to scenario-ing the science. The question was could the scenario be more storied in cultural communication in Venda? One issue was how to communicate in the local culture – in the oral tradition (with variable literacy) and without using visualisation which might be routinely used in Western settings of science communication

Local cultural memories of extreme drought among workshop participants were more limited than expected. Recent drought memory (2015/2016) was mainly about livestock loss and government help. Some people either possibly chose to forget or did not to remember previous more severe droughts and their impacts (e.g. in 1983 – most extreme drought in the last 40 years). The methodology also facilitated very different types of knowledge exchange and brokering that took place face-to-face in the mix of the workshop processes. These knowledge exchanges included those between villagers (within and between selected livelihoods and socio-economic situations); from villager to researcher via intern; from scientist to villager via intern; from villager to intern.

12.4.4 Thinking about the nature of the stories

Stories varied from more dominant or most obvious narratives of impacts (disease and mortality featured highly; emotional impacts, impacts on the family unit) to more in depth exploration of less dominant or counter narratives that were shared with outsiders – around adaptation. The analysis of the connections within a network of more systemic impacts: on parents' ability to pay for the costs of school if livelihoods were suffering; on children's ability to work and progress at school if they had insufficient food leading to longer term impacts on local capital; on increased crime rates with people stealing water and food in desperate times; of shocks to the food chain with implications for livelihoods – of hungry baboons taking down weakened livestock.

Some adaptations and 'ways to get prepared' suggested by villagers were borne of old practices – digging down the river bed to access further water reserves when the river was dry; growing and storing maize; drying fruit, vegetables and meat in times of relative excess. Other stories focused on health and wellbeing – use of bleach to kill germs in water; of hungry children fainting in school. Some stories shared the ramifications of excess heat as well as lack of water – inability to gain shade from trees; the need to bath in ditch water that might be contaminated; the necessity to sleep outdoors with the risks of disease. Some stories were of piecemeal small adaptations; the possibility of accessing more local grazing land with reduction in the size of the neighbouring Nature Reserve – impounded in the 1930s – was muted by some livestock farmers but, of course, is out of their control.

12.4.5 Community feedback

The team jointly had a session to feedback the workshop narratives with the community. Sharing of the story archive with the village and with government officials seemed particularly important in this setting.

CHAPTER 13: CONCLUSIONS AND RECOMMENDATIONS

This chapter covers conclusions and the recommendations from the study. The chapter provides a summary of findings from all major aspects of the study, mainly demographic and agro-ecological characterisation, and management of risks in extreme climatic conditions, impacts of climate extremes on livestock, water use efficiency and impacts of climate extremes on livestock production.

13.1 CONCLUSIONS

13.1.1 Livestock farmer demography and adaptive capacity to climate change and variability in Limpopo and Mpumalanga provinces of South Africa

The findings of the study revealed that 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. This was true for all the three types of demographic factors studied, namely personal characteristics, economic status, and aspects of livestock farming.

Personal characteristics

The position of respondents in households comprised 58.7% heads and 25.7% parents to heads all of whom probably provided accurate information on household decisions. The respondents were mostly male (63.4%) with good health (97.8%) associated with high adaptive capacity to climate change and variability. Assessment of the educational status revealed that four in five (81.5%) of the livestock farmers had only secondary education at most, probably associated with low capacity to adapt to climate change and variability.

Economic status

While no definite conclusions could be drawn based on employment status, household incomes seemed low and could be associated with low capacity to adapt to the negative effects of climate change and variability. To the contrary, the quality of housing for the livestock farmers was described as either top (48.5% of farmers) or medium (47.4%) associated with high adaptive capacity to climate change and variability. Similar conclusions could be drawn to the size of housing with 45.9% owning 4 to 5 rooms and 44.5% owning six or more rooms, especially considering the fact that 88.5% of the respondents financed their houses. The probability of high adaptive capacity was perhaps affirmed by that almost all the respondents (97.3%) had access to electricity.

Aspects of livestock farming

The fact that the majority of households had members who were fit to work in farming (one male and female member for 40.1% and 39.3% of the families respectively; 19.9% of two members for each gender category) suggested high capacity to adapt to climate change and variability. Livestock was owned by heads in 52.9% of the households and by children to heads in 29.0% (sons in 21.1% and daughters in 7.9%) of the households, affirming the high capacity to adapt to climate change and variability. To the contrary, almost all respondents (99.2%) used communal land, had fewer livestock owned (for various types), suggesting low capacity to adapt to climate change and variability. The dearth of adaptive capacity was perhaps exacerbated by lack of exposure to capacity building as the respondents had no training (99.5%), never belonged to a farmers' union (99.7%) or a producer organization (100.0%), and had no access to financial support from government (99.2%). Full time farming by majority (86.7%) of farmers and the fact that fewer of their dependents (22.1% male and 15.7% female) stayed off-farm could be positive or negative for adaptive capacity development.

13.1.2 Agro-ecological characterisation of smallholder livestock farming systems in Limpopo And Mpumalanga provinces

The Agro-ecological attributes of smallholder livestock farming areas of Limpopo and Mpumalanga Provinces are classified as 85% semi-arid region. The area experiences extended spells of the dry season and shorter wet periods. The arid area is characterised by a severe lack of water resources to the extent of hindering of plants and vegetation. There are localised microclimate zones that are arranged in a north-south direction that experience in excess of 1 000 mmpa in the five percent sub-humid component of the study areas. Based on the geo-physical and climatic attributes animals that graze are likely to suffer the negative impacts of climate change while those that browse are likely to survive.

13.1.3 Smallholder farmers' perceptions on the impact of climate variability and extremes on livestock production in Limpopo and Mpumalanga provinces

The study on the perception of smallholder farmers on the impact of climate change has shown the level of exposure that affects their daily choices for their livelihood. Their awareness and knowledge on climate change underlay an imperative prerequisite in their exposure to the impacts of climate change. Though multiple stakeholders capacitated farmers with climate change information their level of education impedes their understanding of this phenomenon to their livestock business ventures. Unexpectedly, almost all livestock farmers (98.58%) have not heard about climate change from the government. On the other end of the spectrum, radio was the most imperative medium for the conveyance of the climate change information. Almost all farmers (94.32%) receive climate change-related information through the radio. It may also be a consequence of the language being used by the radio which is mostly their indigenous languages. The intervention that could empower the farmers will be regular workshops within commodity groups on climate change. Unfortunately, 95.89 % of the farmers have not attended a workshop on climate change.

The manifestation of climate change to smallholder farmers is identified through drought. The majority of the farmers (77.87%) identified a dip in rainfall quantity and frequency as the major visual evidence to the down of climate change. The other evidence is the loss of natural grazing, almost all farmers (90%) confirmed that there is a change in grass availability. With the consideration that the majority of the livestock farmers participate in cattle farming, this is a critical impact as animals rely on grazing. The majority of the respondents (70.22%) also outlined that the shrubs dominate the pasture which is symptomatic to over-grazing. Consequently, over half of the farmers (55.19%) asserted that the main contributing factor to the livestock fatality is the lack of pastures. When smallholder farmers were exposed to extreme weather they were not comprehending the events as part of the climate change phenomenon. The following percentile of the farmers indicated that each of these factors does not conform to the climate change; tropical cyclones 95.63%, land erosion/degradation 93.17%, destruction of buildings 98.91 and Unpredictable seasons (short or long rainy season) 96.17%.

It can be concluded from the study that the Early Warning system of government is operational and effective at the level of less than %. The main challenge is the capacity of government at 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 Forecasts 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' perception suggests a need for strategic shifts from natural pastures to small scale feedlots. The shift should be coupled with the need to establish dedicated fodder bank as a specialized business. Also the need for a shift into small stock farming based on agro-ecological analysis. For the farmers to cope and adapt to climate change there is a great need for an early warning system. Government should intervene by providing facilitated water and small-scale feedlots infrastructure for small holder farmer.

13.1.4 Managing climate risks using seasonal climate forecast information in Vhembe District In Limpopo Province, South Africa

Farmers have used a variety of information sources to help themselves to manage climate risk. Some elite farmers have been exposed to scientific climate forecasting with some starting to use the information as a guide during the decision-making process. The rainfall distribution patterns in the Vhembe district various from area to area and small –scale farmers are using various coping and climate change adaptation strategies including: (a) Crop diversification, (b) Early planting strategies, (c) Plant crops that require less water, (d) Some farmers use local climate indicators, for example cloud formation as part of the decision making tool, (e) Changing farming practices. If small – scale farmers in the Vhembe district are planning to obtain higher yields they should use several climate change adaptation strategies in order to have good agricultural production and be able to sustain their livelihoods. The fact that these small – scale farmers are situated in a semi –arid area with high climatic variability and poor rainfall distribution makes farming very difficult to manage.

13.1.5 Climate vulnerability and smallholder livestock water and fodder use analyses

Smallholder farmers are located in areas that conforms to the microclimatic regions that experience high rainfall. Purposefully for their locations the main source of water is the river system. The municipal/piped water together with boreholes were found to be the second and third level stream for farmers to access water. Municipal piped water to farmers' households were critical to supply small-stock, chickens and pigs within homesteads. Cattle seemed to get water within 1 -10 km mainly to the river sources which are within the recommend 30 km distance for livestock to avoid stress levels. The majority of smallholder livestock farmers accessed fodder from communal grazing. It follows logically that the exposure to climate change led them to have bought in feeds when the grazing becomes scars. Even with the use of crop residues and own crop harvest grazing was found to be the biggest challenge for large stock (cattle) and small stock (sheep). The greatest challenge for poultry farmers were increasing in temperatures, whereas for pigs were pest and diseases. For sustainable socio-economic well-being of smallholder farmers and to adapt to changes in geo-climatic conditions intensive production systems are proposed. In order to cope with climatic variability and extremes small feedlot facilities are proposed to avoid long distance to access water and grazing by livestock. Heat and drought tolerant breed's needs to be promoted, especially in areas that have high aridity indexes.

13.1.6 Adaptive capacity of smallholder livestock farmers to the impacts of climate change

Smallholder farmers have the potential to create thriving enterprises with rural communities. An average smallholder farmer has on average 16 years of farming experience and have enough knowledge and skills to deal with climate change and variability. The main objective of keeping livestock are for meat production, cultural ceremonies, cash and manures. Men are generally responsible for all animal activities like purchasing, selling and breeding. There were no changes observed in the average total number of cattle between recent years and 10-20 years ago. Currently, livestock farmers have slightly more sheep, goats, fowls and pigs than 10-20 years ago. Natural increase (calving, lambing, or farrowing) is the main reason for the increase in the recent 2 and last 10-20 years and selling or slaughtering was the main reason for the decrease in livestock for the last 10-20 years. The main environmental challenges affecting livestock are drought, lack of grazing, heat stress, pest, diseases, and lack of water. Smallholder farmers reported taking different types of adaptation measures to deal with climate change like provision of water, allowing livestock to graze near the river, water storage, and provision of feed supplements and selling of livestock to buy feeds.

Empowerment programmes for smallholder farmers should be directed towards activities and projects that are self-sustaining with support for local governance structures to initiate and lead a process on service delivery within the prescripts policy and law (Disaster Management Act 2002).

13.1.7 A localised framework to monitor and evaluate vulnerability of smallholder livestock farmers In Limpopo and Mpumalanga

- 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 reviewed of the indicators under each of the attributes. The indicators omitted in the original framework were reflected under each attribute as follows:

- Exposure – Drought; floods; Mean Annual Temperature (MAT); Thermal Heat Index (THI); wind occurrence; and Normalized Difference Vegetative Index (NDVI)
- Sensitivity – Distance covered by smallholder farmer to furthest water source (km); Distance covered by animals to 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 (m^3/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 (%);
- 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 a different employment status (%); Establishments in which producers received financial support (%); and Establishments in which producers received material infrastructure support (%)
- Although that could not be critical, the introduction of thematic areas in this study allowed for categorization of related indicators under each of the three attributes of the Lindoso (2011) Framework (exposure, sensitivity, and adaptive capacity).

13.1.8 Agro-ecological characterisation of livestock farming systems at national level projected from provincial level

The Agro-ecological attributes of livestock farming areas of South Africa can be classified as 85% semi-arid region. The area experiences extended spells of the dry season and shorter wet periods. The arid area is characterised by a severe lack of water resources to the extent of hindering of plants and vegetation. Based on the geo-physical and climatic attributes the country's land capability is such that there is nowhere in South Africa do good soils and good climate coincide. Livestock that graze are likely to suffer the negative impacts of climate change while those that browse are likely to survive. It is highly recommended that small stock (goats) be the preferred farming, animal as they are drought-tolerant, while farmers that are practicing cattle farming will be more likely exposed to the impacts of climate change. The actual veld condition and biomass production that determine grazing capacity vary from season to season and is influenced by factors such as rainfall, temperature, bush encroachment, fire and the type of management system practiced by the land owner. It is therefore the responsibility of the land owner to manage his animal numbers in such a way that there will be no degradation of natural resources such as overgrazing of veld and erosion of soil.

13.2 RECOMMENDATIONS

Following the research on all aspects of the topic that influence the capacity of smallholder livestock farmers to adapt to adverse effects of climate change and variability, it is recommended that:

13.2.1 Disaster management

A review be conducted to seriously build human capacity and the intellectual capital appropriate to drive the functions of Disaster Management in the country. Organigrams of the Department of Agriculture, Land Reform & Rural Development be reviewed with the purpose building appropriate positions at Provincial, District and Local Municipalities. Functions of Early Warning, Risk Assessment and Disaster Recovery be evaluated for an effective and efficient system to improve livelihood of the farmers. These functions demand that they be led by well qualified Disaster Management Officials at Director Level at province for purposes of responsibility of budget and to manage the policy instruments foundations to the Disaster Management Act of 2002. Agricultural Advisory Officials to be appointed at levels appropriate to Provincial Positions dedicated to dealing with Early Warning, Risk Management and Disaster recovery. Same to be true for District Officials at appropriate positions and dedicated to manage disaster functions with the support of officials at Local Municipalities and Service Centres.

13.2.2 Agricultural advisory and extension services should consider the following:

a) Governance at village level: Extension Officers are encouraged to facilitate the formation of intra-village committees – each village should have an umbrella committee, which acts like an executive committee of about eight people - The Civic Committee. The subcommittee should also be formed that deals with Livestock, Rain-fed crops, Irrigation Schemes, Water, and in certain areas Land Care and Seed Multiplication. In the formation of these committees there should be great consciousness to include women and youth, though some villages may have specific Women and Youth committees. The sub-committees manage and collaborate between villages all the natural resources such as natural grazing, source of water and theft. Two members of the sub-committees are nominated to represent a village in the inter-village committees on say Livestock, Rain-fed crops, Irrigation Schemes, Water and Theft.

b) ***Drought coping strategies***: Extension Officers are encouraged to facilitate that smallholder farmers lead to initiate and adopt different types of adaptation measures to deal with climate change. During drought livestock farmers should be encouraged to work with stakeholders in an innovative way to provide water for their livestock, some of the strategies found in some villages include selling livestock to buy fodder and feeds supplement, allowing livestock to graze near the river, water stored in containers, use of self-initiated borehole, and cooperatively buying fodder.

c) ***Flood/heavy rains strategies***: Extension Officers are encouraged to facilitate that smallholder farmers cooperatively procure medication, dip, shelter, water containers. To work within the local and district municipalities for bulk water supply, building of earth and concrete dams.

d*) Long-term strategies*: The local governance committees at village level should develop long term plans to deal with climate extremes. (a) Despite the gross lack knowledge, awareness, sources of funding, land and markets there is a growing realisation by smallholder farmers that they should spare part of their rain-fed land and irrigation schemes to grow their own fodder, fodder crops should be part of the menu of commodities for production; (b) Central to these strategies is also disjointed access to weather-related information (Early Warning

System) and cooperation between farmer groups and or committees with agricultural extension services; (c) The power of many that comes with the formation of committees helps smallholder farmers to mobilise support from Traditional Leaders, Municipal Councillors and Municipal Officials on Local Economic Development projects such as roads, dams, boreholes, and other community needs related to service delivery.

13.2.3 Follow-up studies

Research should be conducted as a follow-up using the principles derived from the sustainable livelihoods approach (SLA) to investigate how that may have some influence on the smallholder farmer capacity to adapt to climate change and variability, be it livestock or crop farmers. The idea being that is it one of a number of conceptual approaches that take an asset/vulnerability approach to analyse the vulnerability of the poor. This way of approach recognises that livelihoods are multi-sectorial, that all aspects of people's lives will impact on the livelihood choices that they make and that livelihoods are embedded within institutional context.

Research should be conducted as a follow-up study to investigate the impact of climate on change in Land Use across from Agriculture to Environmental Conservation of Biodiversity (natural vegetation to game). The current debate on game farming and the shift from beef cattle ranching can create a profitable continuum for the country.

The results of the study have shown agro-ecological differences and way of adaptation by smallholder farmers that necessitate follow-up studies beyond Limpopo & Mpumalanga. The impact of extreme climate in most provinces may necessitate new Extension approaches to farming e.g. Livestock and Game, Production of Fodder Trees intercropped with Fodder crops, and the Production of Fertilizer Trees.

It is highly recommended that indigenous breeds be promoted in arid zones of the provinces with strong diversification and mix in promote indigenous small stock (goats & sheep) as they are drought-tolerant. A strong recommendation to create demand and market for indigenous goat and lamb market.

The study, based on smallholder farmers' perceptions, suggests a need for strategic shifts from natural pastures to small scale feed-lots. The shift should be coupled with the need to establish dedicated fodder banks as a specialized business. A Follow-up study on land available and suitable for fodder production per province and in each Municipality should be done.

Crop models, especially for crops that also play a role in Livestock Fodder, may need to be reviewed with special consideration to ground water as a source in the context of some areas where ground water is the only source of irrigation water. Special emphasis should also be placed on legumes and fodder trees on and above the cultivated pastures reported.

13.3 CONCLUSION

The project leveraged the investment made by the WRC for the benefit of students, smallholder farmers and communities in which the project were operating. The geographic coverage of the project was in the main Vhembe District in Limpopo Province and Bushbuckridge in the Mpumalanga Province. The coverage was on rural marginalised smallholder farmers to foster redress and transformation to these communities. Capacity was also build to students and farmers through data collection, transcription and analysis. The students and farmers also benefitted by learning international standards on report writing from international collaboration which were linked to the WRC funded project. The returns on the value of the WRC funding were higher than expected for a project which was only running for just over a year and half effectively.