VULNERABILITY MAPPING

Improvement of early warning system to reduce impacts of climate change and capacity building to integrate climate change into development plans

Linakeng Community Council

Institute of Natural Resources

Institute of Natural Resources NPC

Sian Oosthuizen, Kabir Peerbhay, Leo Quayle, Fonda Lewis, Thabo Nobala and Bonang Mosiuoa

INR Report No:

498/14

VULNERABILITY MAPPING

Linakeng Community Council

Improvement of early warning system to reduce impacts of climate change and capacity building to integrate climate change into development plans

August 2014

Report prepared for:

Ministry of Energy, Meteorology and Water Affairs

Report prepared by:

Institute of Natural Resources NPC
Contact: Mrs Sian Oosthuizen
Institute of Natural Resources NPC
67 St Patricks Road, Scottsville, Pietermaritzburg
South Africa
Tel: (0027) 33 346 0796
Fax: (0027) 33 346 0895
Email: soosthuizen@inr.org.za

Serumula Development Association
Contact: Ms Bonang Mosiuoa
Serumula Development Association
No. 88 Qoqolosing Road, Maseru West
Lesotho
Tel: (00266) 2231 7875
Fax: (00266) 2231 0635
Email: bonang@serumula.org.ls

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

CA	Conservation Agriculture
CC	Community Council
CIP	Climate Information Platform
CSAG	Climate System Analysis Group
CSO	Civil Society Organisations
DA	District Administrator
DCS	District Council Secretary
DDCCs	District Development Coordinating Committees
DPUs	District Planning Units
DSSAT	Decision Support System for Agrotechnology Transfer
EIF	Enhanced Integrated Framework
GCM	Global Circulation Model
GDP	Gross Domestic Product
GHG	Green House Gases
GIS	Geographic Information System
HoD	Head of Department
HU	Heat Units
IKS	Indigenous Knowledge Systems
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LDCs	Least Developed Countries
LHWP	Lesotho Highlands Water Project
LMS	Lesotho Metrological Services
MAFS	Ministry of Agriculture and Food Security
MEMWA	Ministry of Energy, Meteorology and Water Affairs
MFLR	Ministry of Forestry and Land Reclamation
MSAL	Meters Above Sea Level
MTICM	Ministry of Trade and Industry, Cooperatives and Marketing
NAPA	National Adaptation Programme of Action
NCCST	National Climate Change Study Team
NGO	Non-Governmental Organisation
NSDP	National Strategic Development Plan
RCP	Representative Concentration Pathways
SWOT	Strengths, Weakness, Opportunities and Threats
TFCAs	Transfrontier Conservation Areas
UCT	University of Cape Town
UN	United Nations

1. Introduction

The vulnerability assessment undertaken to inform the First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change (Ministry of Natural Resources, 2000) revealed that the impacts of climate change are already evident in Lesotho by the increasing frequency of natural disasters, devastating droughts and emerging signs of progressive desertification. The fragile soil/terrain characteristics, erratic climatological conditions, difficulties of realising the full potential of agro-ecological conditions, the growing level of poverty which is currently estimated at more than 50% of the households, and the relative deprivation of the inaccessible mountain region which makes up more than 60% of the country, ranks Lesotho as one of the most highly vulnerable developing countries.

The Intergovernmental Panel on Climate Change (IPCC) indicated that the majority of the world is likely to be impacted by projected implications of climate change. Such implications range from impacts on food security (reduction of agricultural yields as a result of changing conditions), health (increase in tropical diseases), water shortages and physical infrastructure destruction, to name a few. Lesotho is no exception and, being a poorer country whose population is primarily reliant on natural resources for survival, is more vulnerable to the negative implications of climate change (LMS, 2001).

According to the Lesotho Metrological Services (LMS, 2007), the country is described as "small and landlocked, is liable to drought and desertification, has a fragile mountainous ecosystem, is prone to natural disasters, is situated in the sub-tropics and has a semi-arid climate". Lesotho is classified as an underdeveloped country with high poverty levels, with communities in the Senqu River valley living under high chronic poverty conditions, depending on survivalist livelihoods (LMS, 2007). As a result, it is particularly prone to the numerous environmental stresses, namely; drought, soil erosion and land degradation, desertification, deforestation, rangeland degradation, loss of biodiversity, degradation and drying up of the wetlands and mountain sponges. These environmental stresses will be exacerbated under climate change conditions (Mhlanga, 2004; Mwagi, n.d.). In addition, the majority of communities are particularly vulnerable to the projected climate change implications due to their insufficient capabilities of surviving the consequences of change and variability (LMS, 2007).

As a means of preparing regions for such projected implications, a vulnerability mapping exercise is conducted to understand the consequences and likely results of the onset of climate change. The project strives to achieve the following:

- **Aim**: Consultancy for the improvement of early warning systems to reduce impacts and capacity building to integrate climate change into development plans is the key aim of this project.
- **Objectives**:
    - Produce GIS-based hazard maps that focus on the project zones

- Develop sectoral risk and vulnerability maps focused on key productive sectors such as agriculture, water, livestock and forests, and that include relevant socio-economic data
- Support evidence based decision-making capacity at national level. The analysis will therefore include consideration of potential for maladaptation in order to support the integration of climate change into sectoral frameworks.

1.1. Project Sites

The study sites selected for this project are the Linakeng, Tosing and Qibing Community Councils, which are located in the Thaba-Tseka, Quthing and Mafeteng districts respectively (Figure 1). Each community council has two pilot villages, namely Tokho and Maputsoe (Linakeng), Ha Rakhomo and Ha Tamanyane (Tosing), and Litšoeneng and Lekhari (Qibing). The three community councils differ in characterises (climate, topography, resources, etc.), displaying varying situations within Lesotho. To unpack the vulnerability and projected climate change that each community council is likely to experience, an in-depth review of the characteristics of each site is conducted. This report displays the findings for the Linakeng Community Council.

Figure 1: Location of three Community Council project sites (Linakeng, Tosing and Qibing)

1.2. Overview

The report is structured according to the overarching phases (steps) of the project, which are demonstrated in the schematic below (Figure 2).

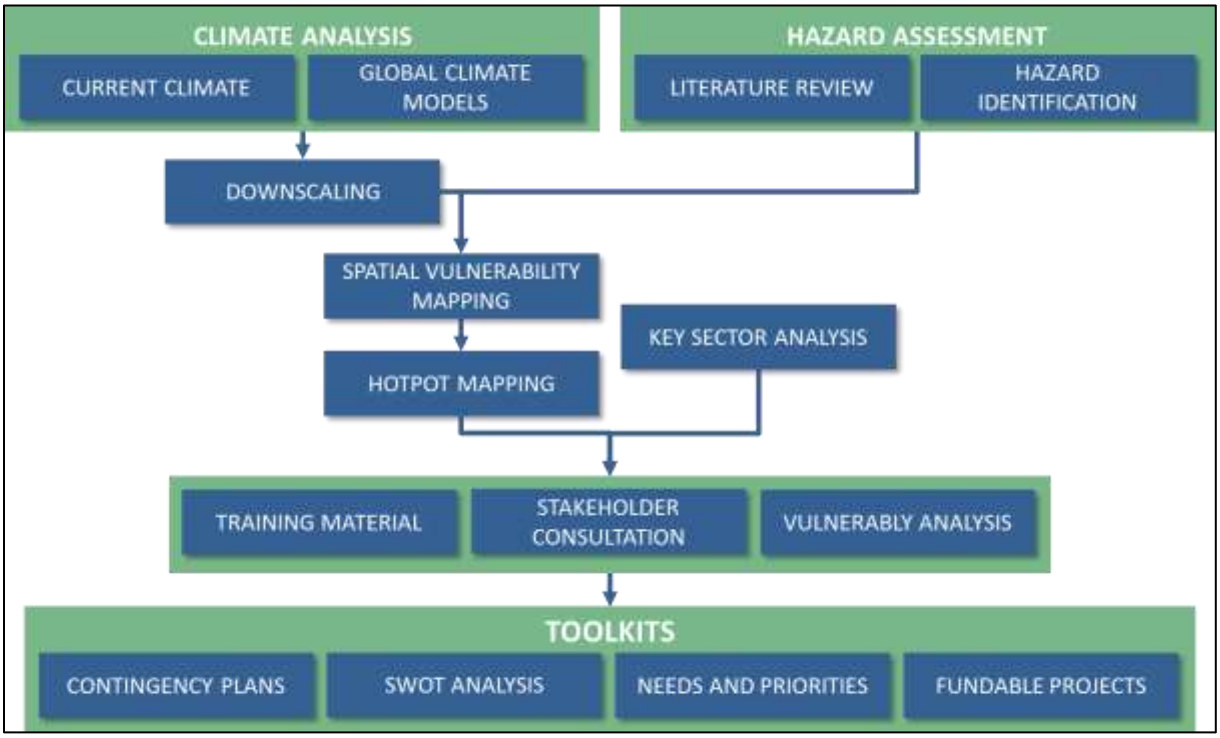


Figure 2: Schematic demonstrating the main phases and methodology of the project

It is important to note that all climate change projections displayed in this project are based on a worst case scenario for the 2020-2040 time period. This timescale was selected due to its applicability with planning and management frameworks. Additionally, it must be highlighted that projecting climatic changes and its spatial mapping is not an exact truth, but rather based on several modelling processes and methodologies that vary in outcomes. As a result, projections and consequential analysis is founded on common outcomes and projections. Lastly, the outcomes produced are based on the availability of data and, where inaccuracies or unavailability are evident, it has been noted.

2. Current Climate

In order to understand the implications that projected climate change hazards will have on the three country councils, the current climatological conditions of the country are defined. This assessment is based on existing climate data which has been gathered from a variety of channels. This has included rainfall and temperature data from a number of meteorological stations across Lesotho. In addition, in order to gain a broad insight into the climatic conditions of Lesotho and to be able to illustrate the data in the form of a map, modelled climatic data at a national scale has been sourced from the Southern African Atlas of Agrohydrology and Climatology produced by Schulze et al (2008). An overview of the countries rainfall and temperature will be given, followed by site specific climatic condition.

2.1. Overview

Lesotho is described as “small and landlocked, is liable to drought and desertification, has a fragile mountainous ecosystem, is prone to natural disasters, is situated in the sub-tropics and has a semi-arid climate” (LMS, 2007). The country is classified as an underdeveloped country with high poverty levels, with communities in the Senqu River valley living under high chronic poverty conditions, depending on survivalist livelihoods (LMS, 2007).

The climate of Lesotho is classified as temperate continental and has four distinct seasons of summer, autumn, winter and spring (Water Commission Report, 2007; Lesotho Meteorological Services, 2001). The temperate climate varies throughout the four seasons (Ministry of Forestry and Land Reclamation, 2011) and the prevailing weather patterns form as a result of Lesotho’s location between the Indian and Atlantic Oceans. These combine to result in a wide variability between rainfall and temperatures (Water Commission Report, 2007). The diversity of annual temperatures in Lesotho is very large, ranging from -20°C to 28°C between winter and summer respectively, with the mean temperatures varying from 15°C in winter to 25°C in summer (Ministry of Forestry and Land Reclamation, 2011).

The latitudinal position of Lesotho, within the subtropics zone, primarily determines the countries climate. Winters (May to July) are typically characterised low weather activities as a result of the strengthened high pressure system, displaying warm daytime and low night-time temperatures, dry air and minimal precipitation, and clear skies. However, the intrusion of extra tropical systems due to the weakening of the system results in snowfall and strong westerly winds. Low pressure systems dominate over southern Africa in summer (November to January), bringing rain and tropical air masses across Lesotho. Spring (August to October) and autumn (February to April) are transitional seasons and display either winter or summer characteristics (LMS, 2007). The length of the summer growing season is determined by heavy frost which is frequently experienced, particularly in the mountainous regions.

Precipitation levels vary across the country, with the lowest levels (from 450mm per annum) being experiences in the Senqu River Valley regions and extending to the highest levels (upwards of 13000mm per annum) in the Drakensberg Mountain region (LMS, 2007). Annual mean precipitation is approximately 700-800mm of which 85% occurs between October and April (Water Commission Report, 2007; Ministry of Forestry and Land Reclamation, 2011). Precipitation levels vary in time and space resulting in common drought and flood events. High intensity rainfall events commonly result in flash floods, accelerating soil erosion and consequential siltation of water systems. Snowfall occurs irregularly in the lowland regions (every 3 years) but annual in the mountainous regions. Heavy snowfall events are known to result in isolation and loss of access for communities as well as extreme cold spells.

2.2. Lesotho's Current Climate

2.2.1. Rainfall

Figure 3 below demonstrates average distribution of annual rainfall across Lesotho. This is illustrated using measured data from Lesotho Meteorological Services' (LMS) rainfall records (point features) and the modelled rainfall distribution from Schulze *et al*. (2008). The measured data correlates strongly with the modelled data, and generates confidence in the accuracy of the modelled data.

This illustrates the strong rain shadow effect generated by the Maluti Mountains and the Drakensberg escarpment, with the upper and middle Senqu Valley experiencing comparatively low rainfall (<600mm/yr in some areas) in contrast to the highest lying areas. The image also illustrates the comparative dryness of the lowland areas in the south west of Lesotho.

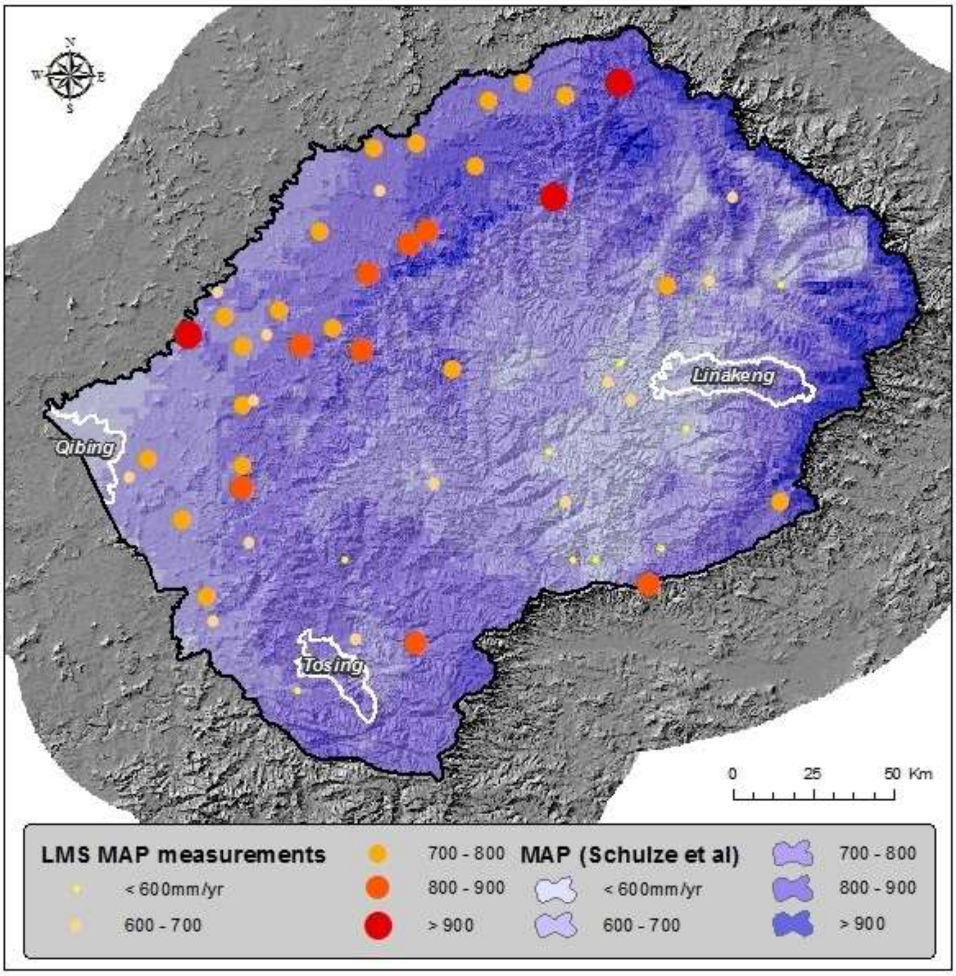


Figure 3: Annual rainfall distribution in Lesotho

2.2.2. Temperature

Temperature distribution (Figure 5) in Lesotho correlates strongly with altitude (Figure 4), with the warmest areas occurring in the lowlands of the south west, and the coolest areas in the highlands of the north east.

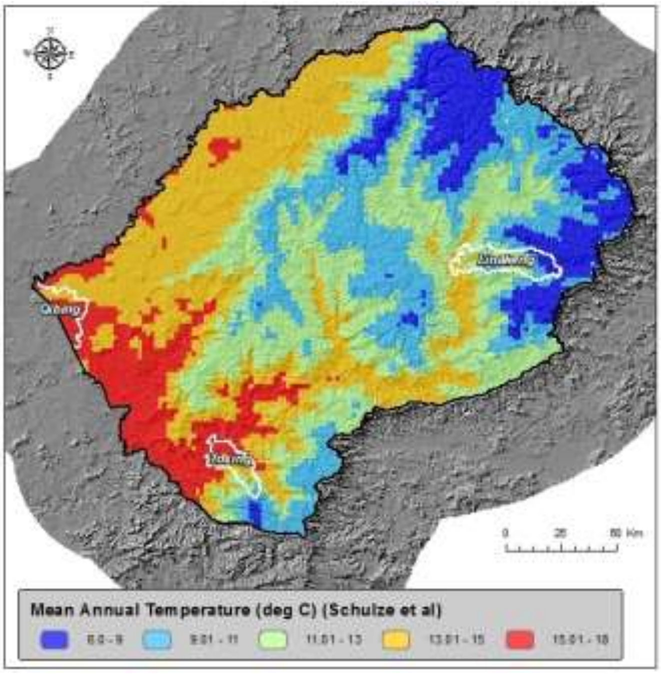


Figure 5: Mean annual temperature map for Lesotho

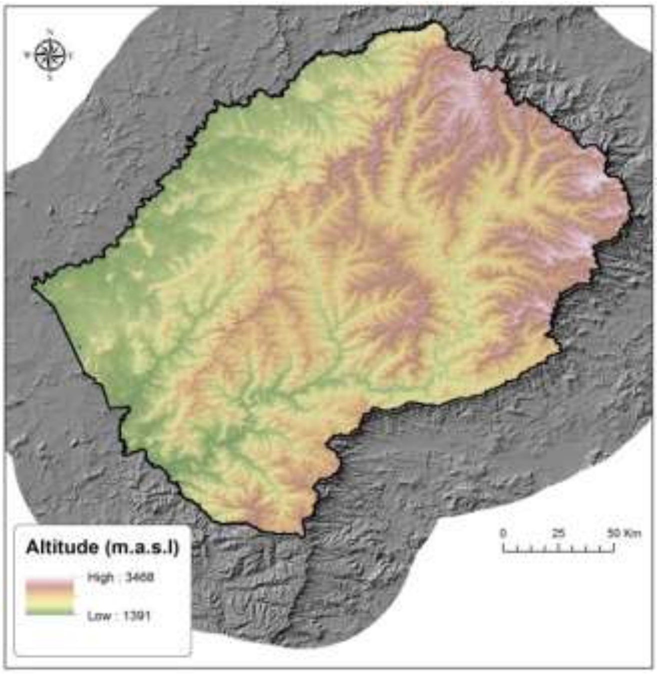


Figure 4: Altitudinal map of Lesotho

2.3. Linakeng's Current Climate

To depict the current climatic conditions of each community council, temperature, rainfall and seasonal graphs are displayed. These graphs have been taken form the CSAG (2014) website, whose data was sourced from the Lesotho Meteorological Services (LMS) as part of this project. Several gaps in data are evident; however climate trends can still be identified to understand the current conditions of each community council.

Data for the Linakeng Community Council (CC) is represented by data from the Thaba-Tseka meteorological station, a single measuring point located at 2160 meters above sea level (masl). The Thaba-Tseka station provides a good representation of climatic conditions in the lower Linakeng CC region; however the higher lying areas in the CC are likely to vary from this. The Figures below (Figure 6, Figure 7 and Figure 8) demonstrate the weather conditions as displayed by the meteorological station.

2.3.1. Rainfall

Monthly rainfall data for the Thaba-Tseka station is relatively continuous, with only a few data poor periods occurring between 1976 and 2000, with the most obvious being in 1989 (see Figure 6 below). This record provides a good indication of rainfall distribution and intensity under historical and current climatic conditions.

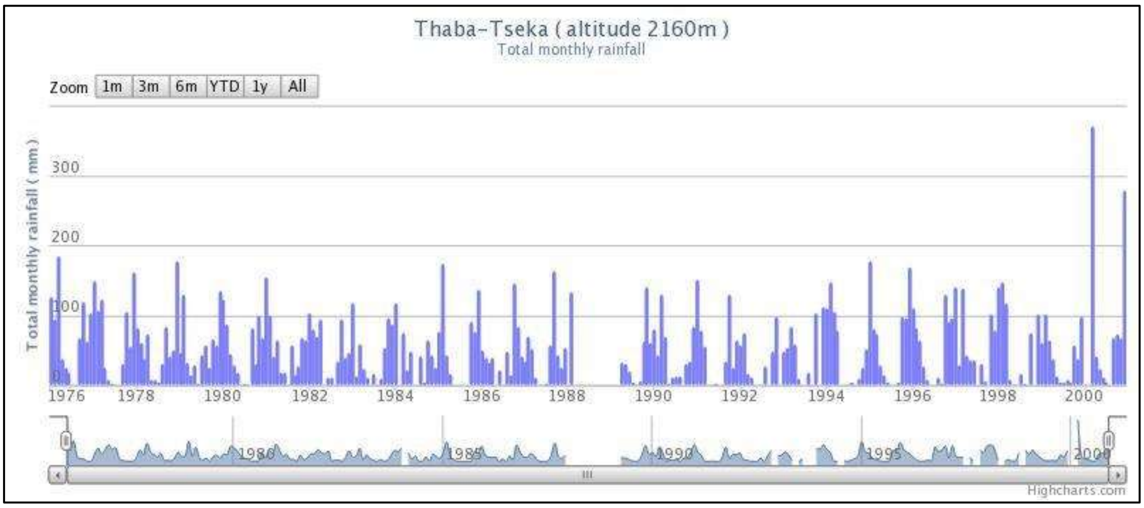


Figure 6: Total monthly rainfall for Thaba-Tseka between 1976 and 2001 (Source: CSAG, 2014)

2.3.2. Temperature

As with the rainfall data the temperature records show a relatively continuous data set from 1976 to 2000. Although the number of data gaps is greater than that of the rainfall data, the record still provides a good indication of historical climatic conditions in Thaba-Tseka.

This data indicates a seasonal fluctuation in maximum and minimum average temperatures ranging between 8^{o}C and 27^{o}C (max – see Figure 7) and 13^{o}C and -6^{o}C (min – see Figure 8).

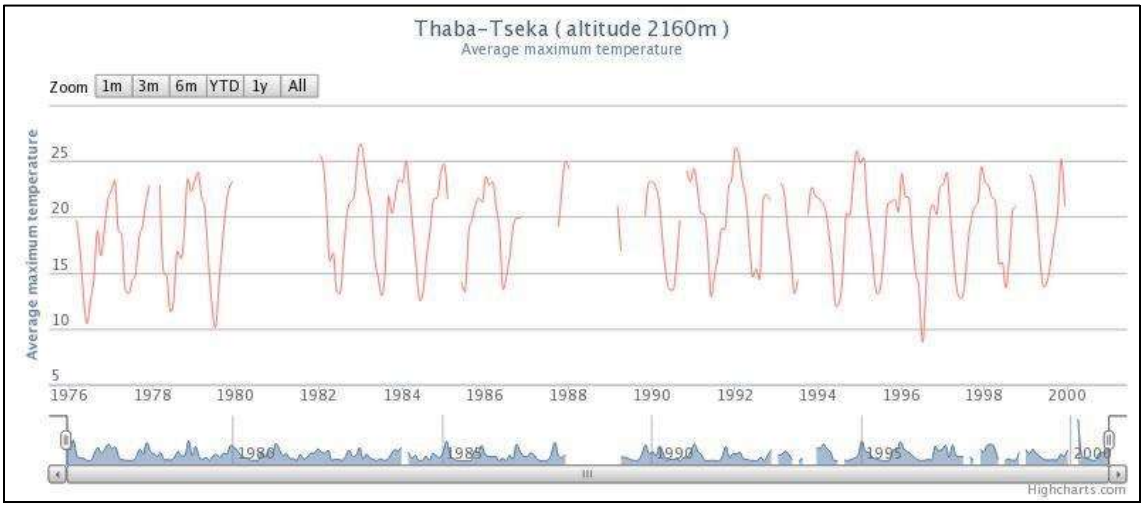


Figure 7: Average maximum temperature for Thaba-Tseka between 1976 and 2000 (Source: CSAG, 2014)

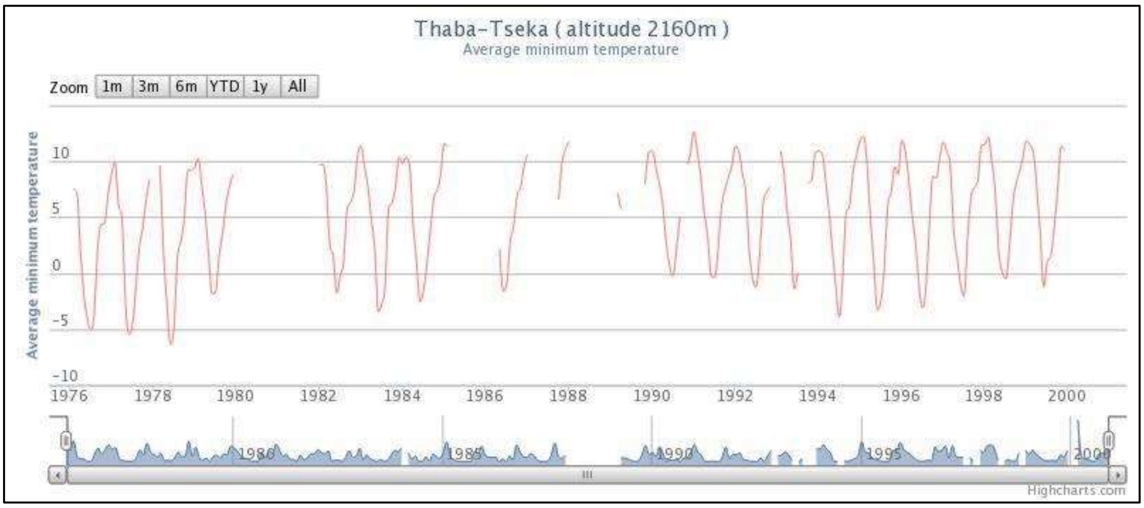


Figure 8: Average minimum temperature for Thaba-Tseka between 1976 and 2000 (Source: CSAG, 2014)

2.3.3. Average Seasonality

Using the data available, an average seasonality picture can be generated for the Thaba-Tseka region by averaging out all historical records to provide one record for each month of the year. This is useful as it provides a basis against which to define the current and historical climate of this region and a baseline against which climatic change can be assessed.

This is illustrated using temperature and rainfall in Figure 9 below. It is evident that temperatures in this region range from 13°C to 24°C (maximum) and -2°C to 11°C (minimum), while rainfall varies between 6mm to 100mm per month.

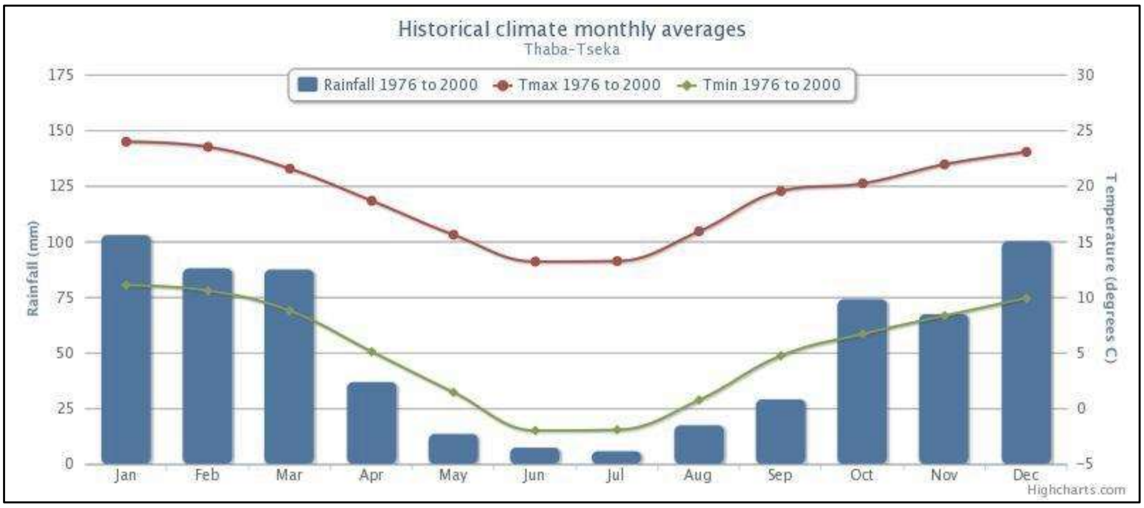


Figure 9: Average seasonality of rainfall and temperature for the Thaba-Tseka region (Source: CSAG, 2014)

2.3.4. Summary

The following table (Table 1) provides an overview of the current climate variables for the Linakeng project site.

Table 1: Summary of Current Climate Conditions in the Linakeng Community Council

COMMUNITY COUNCIL	Average Rainfall (mm)	Average Max Temp (°C)	Average Min Temp (°C)
Linakeng	6 – 103	13 – 24	-2 – 11

From the above table, it is evident that Linakeng Community Council experiences large rainfall variation between the dry and wet seasons. The region has a relatively cool climate, likely due to its location in the highlands region.

3. Climate Change Projections

The Intergovernmental Panel on Climate Change (IPCC) indicated that the majority of the world is likely to be impacted by projected implications of climate change. Such implications range from impacts on food security (reduction of agricultural yields as a result of changing conditions), health (increase in tropical diseases), water shortages and physical infrastructure destruction, to name a few. Lesotho is no exception and, being a poorer country whose population is primarily reliant on natural resources for survival, is more vulnerable to the negative implications of climate change (LMS, 2001).

Lesotho is particularly prone to the numerous environmental stresses, namely; drought, soil erosion and land degradation, desertification, deforestation, rangeland degradation, loss of biodiversity, degradation and drying up of the wetlands and mountain sponges. These environmental stresses will be exacerbated under climate change conditions (Mhlanga, 2004; Mwagi, n.d.). In addition, the majority of communities are particularly vulnerable to the projected climate change implications due to their insufficient capabilities of surviving the consequences of change and variability (LMS, 2007).

The country is delineated into three climate change vulnerability zones (Figure 10) as specified in the National Adaptation Programme of Action (NAPA) report (Gwimbie et al, 2011).

- Zone 1: The Southern Lowlands and Senqu River Valley – inhibited by small scale livestock and subsistence farmers, most vulnerable
- Zone 2: The Mountains – mountainous with minimal cultivation land, second most vulnerable
- Zone 3: The (Western) Lowlands and Foothills – combination of urban and farming areas, prone to drought, least vulnerable

Figure 10 below demonstrates the location of each site in relation to the climate change vulnerability zones.

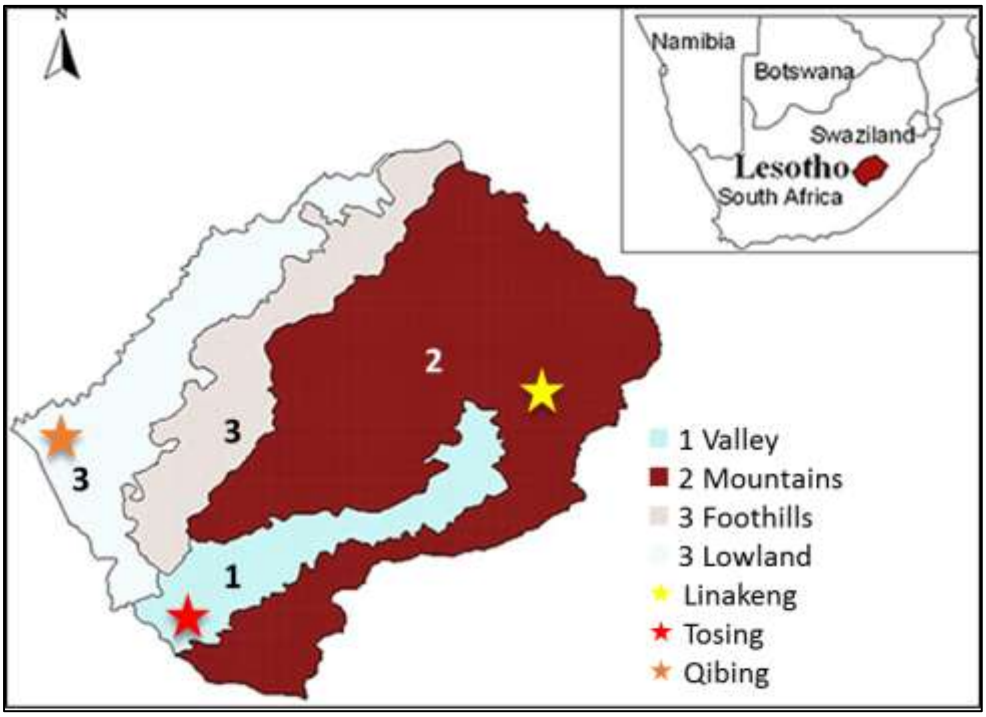


Figure 10: Climate Change Vulnerability Zones in Lesotho (Source: Matarira et al, 2013)

In the late 1970s and early 1980s, Lesotho began introducing and implementing policies, that although were not particularly related to climate change projections and planning, resembled adaptation strategies for dealing with such implications. Actions included the launch of biogas projects, the promotion of renewable energies, an afforestation programme, water development, new agricultural policies, sanitation enhancements and environmental regulation, to name a few. Such movements not only displayed adaptations strategies, but mitigation actions against the projected climate change projections. In 1997/8, Lesotho set up a National Climate Change Study Team (NCCST) that conducted a Green House Gases (GHG) emissions assessment using various models and methodologies (LMS, 2001).

Since then, the government of Lesotho has undertaken tasks to generate climate change projections through the use of historical data (1961-1992) (Mwagi, n.d.; LMS, 2007). In addition, Global Circulation Models (GCMs) have been used to project future conditions (Mhlanga, 2004). Generally, it is projected that Lesotho is likely to be warmer with less precipitation, particularly in the summer and spring months. This will result in lower surface and ground water yields, which, in the absence of adaptation strategies, will lead to water scarcity in the country. Some have projected that warming temperatures may benefit agricultural yields, however such changes to agro-ecological conditions are likely to have serious impacts on various economic sectors such as health, land-use change, water and forestry amoung others. On the other hand higher levels of perception are expected in winter, showing a shift in precipitation patterns. This shift is likely to result in the early onset of frost and summer rains to only occur in early autumn, shortening and pushing forward the growing season, resulting in serious agro-ecological implications (LMS, 2007). The projected increase of precipitation in winter will also negatively affect the country as the occurrence of heavier snowfall events and strong, devastating winds are likely to have devastating consequences. Therefore, it is vital for the country to investigate the implications of climate change and plan accordingly (Mhlanga, 2004).

3.1. Downscaling of Climate Change Projections

The projection of the change in climate with the increase in carbon dioxide levels in the atmosphere can be carried out through computerised modelling of the many factors which influence climate. This modelling process is by no means an exact science and a number of different models exist which do not always concur on the likely future climatic conditions. Projections regarding future climatic conditions are thus presented as a range of projections with decision makers able to assess for themselves the level of risk they are willing to accept.

A downscaling of these models has been conducted for a number of sites in Lesotho, which were conducted by the University of Cape Town's (UCT) Climate System Analysis Group (CSAG) and is available on their Climate Information Platform (CIP)[1]. This web interface integrates two information sources (CSAG, 2014):

[1] http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged-cmip5/

1. A climate database that houses and manages observational climate data and future projections
2. An vast collection of documents that guide the best use of above data, its interpretation and the subsequent actions

The need for this integration is based on the idea that data cannot simply be used in its raw form, but rather requires interpretation to provide meaningful outcomes and projections. Thus, CIP used the relevant data for the 3 project sites and was interpreted to provide meaningful climate change projections. The climate change projections generated are the outcomes of numerous models which, despite their use of the same input data and emission scenarios, display different outcomes due to the parameters of each model (CSAG, 2014[1]). In spite of such differences, general climate change projection trends and patterns are evident as results display similar likelihoods.

The IPCC defines four different emission scenarios known as Representative Concentration Pathways (RCPs). They range from a 'low scenario' of RCP 2.6, to the intermediate RCP 4.5 and 6, to the highest RCP 8.5, which is used to display the worst case scenario demonstrated in this project. The CIP website only displays the projections for RCP 4.5 and 8.5

This CIP allows the user to interrogate a range of different climate variables based on choices regarding the future period to be assessed and the carbon emission scenario to be assumed. Historical climate and seasonal, as well as climate change projection graphs are available on the CIP, which the user can view and export as desired. The figures included in this report are largely generated in this fashion.

3.2. Climate Change Projections for the Linakeng Community Council

As a means of demonstrating the projected climate change projections for the Linakeng Community Council, several graphs were extracted from the downscaling process (CSAG). An overview of the projections is given below (Table 2), however, for the sake of brevity, all the graphs used to formulate the projections can be found in Annex 1. These graphs demonstrate the current climate of the regions as well as the general climate change projections (which vary based on the models used to generate projection). It is important to remember the models used to demonstrate projected changes vary in their process, and provide varying and even conflicting results. The importance is to identify dominant and reoccurring trends and patterns based on the findings of all the models used in the downscaling process. The models demonstrate a worst case projection for the 2020-2040 time period. The outcomes of these projections will later be used to assess the likelihood of identified hazards occurring in each community council (Section 6.3: Hazard Identification).

Table 2: Summary of Climate Change Projections for the project site for the 2020-2040 period (Source: Annex 1; CSAG, 2014)

	LINAKENG COMMUNITY COUNCIL
Total Monthly Rainfall	Large variation, projections could range from a decrease of 11mm to an increase of 19mm of rain per month, throughout the year. Generally, there is a projected increase in the wet season (spring and summer months), and a predominant decrease in the dry, winter periods (particularly in June).
Max. Daily Rainfall	Mostly notably is the decrease in May and June, of up to 4mm, and the large increase in January and October of up to 7mm. The rest of the year shows a large variability in the model projection and is thus difficult to identify any trends or likelihoods.
Count of Wet Days (95th percentile)	Small reduction of wet days in May and June, however there are currently so few wet days during this period so the change is not significant. There is a projected increase by up to 0.35 days in January, followed by a 0.3 increase in August.
Avg. Max Temp.	All year round increase expected, between 0.5°C and 2.4°C. Greatest increase expected in September, demonstrating an early onset of spring conditions. Summer months that already have relatively high temperatures are expected to increase more than winter temperatures.
Avg. Min. Temp.	All year round increase expected, between 0.3°C and 2.4°C. Greatest increase expected in September, followed by October (start of the growing season). This replicates the average maximum temperature trends.
Count of Hot Days (>32°C)	Range from an increase in hot days in the summer and spring months (particularly in January and October) by almost half a day. Winter does not show any change (temperature not likely to currently exceed 32°C in winter). Possible decease at the start of spring and end of summer.
Mean Dry Spell Duration	Increase in the duration of dry spells in the predominantly dry, winter months (May-August), of up to 7 days. Duration projected to decrease in wet season, but not by a significant amount.
Count of Frost Days (<0°C)	All year round decrease of frost days, by up to 4 days in winter (July). This followed by the other winter months were a decrease of 2.8 and 3 days is expected. This is most likely due to the general increase of average temperatures.

4. Historical Records of Changing Patterns

A general, national level analysis of changing climatic patterns and trends is conducted using rainfall and temperature historical data. Figure 11 demonstrates average monthly climate variations between 1960-1990 and 1990-2009 for Lesotho. This gives a clear outline of the variation of rainfall and temperatures between seasons as well as over a historical time scale.

From the two graphs, it is evident that there has been a general increase in winter temperatures (June and July) in the most recent time period in comparison to the 1960-1990 records. However, the summer (November – February) temperatures have remained relatively constant, with only a slight increase in the February average temperatures in more recent years. Rainfall averages show a significant increase particularly in the wet, summer months (December and January), however a decrease in the late summer and early autumn months (February to April). This shows evidence of the early onset of winter conditions as well as a polarisation of rainfall patterns.

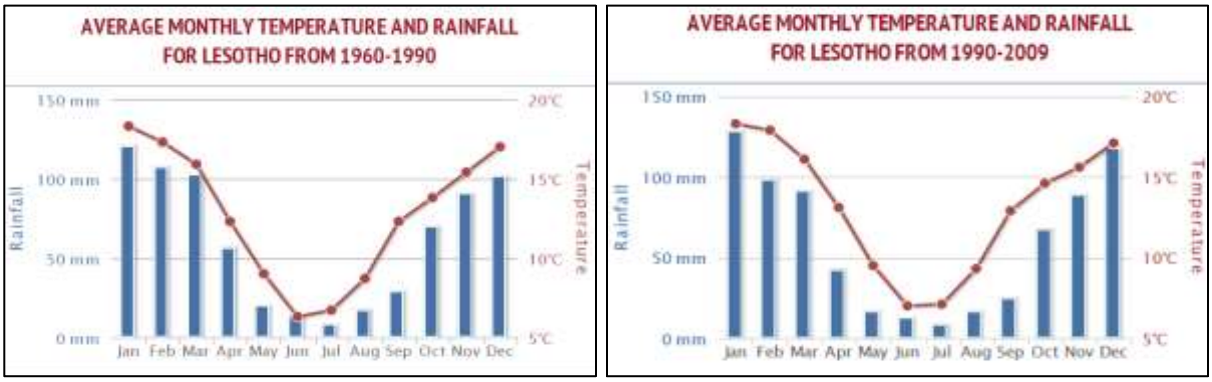


Figure 11: Average monthly temperature and rainfall for Lesotho between 1960 and 2009 (Source: World Bank, 2014)

In a similar notion to the national graph above, the historical seasonality of the project site can be used a basis for the identification of climate change trends and patterns (those shown in 2.3 - Linakeng's Current Climate). Some of the historical records demonstrating changing patterns in the project site is shown in the graphs below.

As indicated in the "defining Lesotho's current climate" section, the outcomes are used to highlighted trends of hazards experienced in Lesotho in the past 30 Years. To determine these trends, historical mean monthly rainfall and temperature graphs have been used to assess these changes[2]. The Thaba-Tseka station has been used as a representative for the Linakeng Community Council.

4.1. Rainfall

To identify trends and patterns of the changing rainfall of the last several decades, graphs demonstrating the total monthly heavy rain days (>95th percentile of observed wet days) have been

[2] Graphs taken from CSAG downscaling (http://cip.csag.uct.ac.za/webclient2/datasets/africa-merged-cmip5/) conducted in Task 7

used. Despite the data gaps evident, particularly in the late 1980s, it is clear when high rainfall conditions were prominent.

Figure 12 demonstrates heavy monthly rainfall days for the Linakeng CC. Annual trends are evident throughout the historical records, demonstrating rainfall peaks at the start and end of each year. A gradual annual increase and decrease in heavy rain fall days is evident in the 1970s and 1980s, however the pattern changes to a more polarised trend in more recent years. In the latter half of the 1990s, there is evidence of several very high rainfall days in some months, and then little to none in others. This demonstrates a shift in the frequency and intensity of rainfall patterns. Most evident is the dramatic spike in 2000 (almost 25 high rainfall days recorded), showing the likelihood of flood conditions. This is contrasted to the very low records in the remaining parts of the year, mirroring an intensification of rainfall frequency and prolonged heavy rainfall.

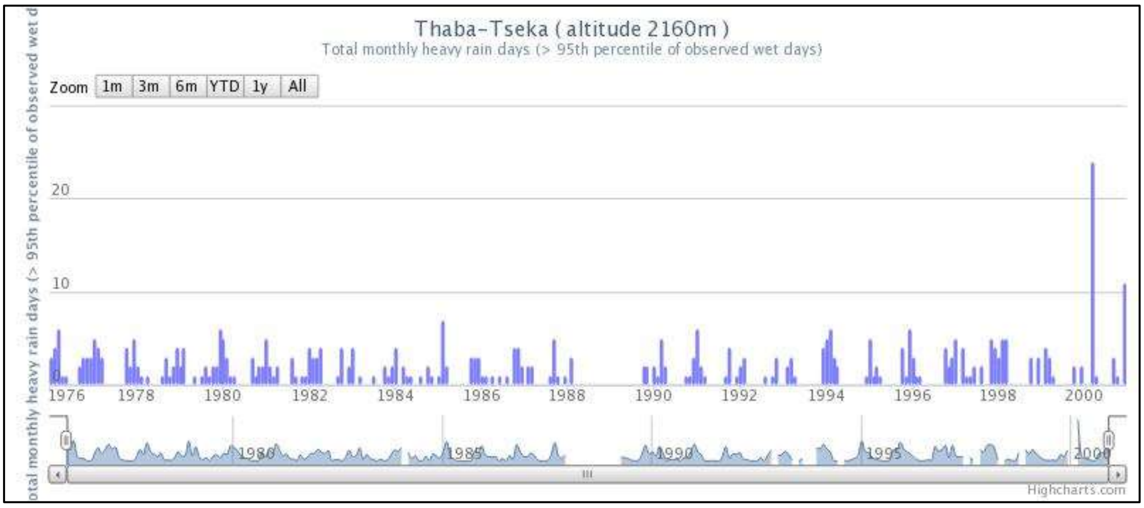


Figure 12: Historical total monthly heavy rain days (>95th percentile of observed wet days) at Thaba-Tseka between 1975 and 2002 (Source: CSAG, 2014)

In conclusion, it is evident from the Linakeng graph that rainfall patterns have seen a shift in more recent years, demonstrating a polarisation and intensification of rainfall events. In addition, possible flooding activity is likely to have been evident, which was probably coupled with drought events where little to no high rainfall days have been recorded. More recent spikes and lows of heavy rainfall days suggest a highlighted variation, possible as a result of the onset of climate change.

4.2. Temperature

In addition to rainfall patterns, temperature variation can be used to unpack to occurrence of climate change trends in the project site. The average maximum and minimum temperature graphs were previously displayed (in Section 2.3: Linakeng's Current Climate), however the average maximum temperature graph is duplicated here for the purposes of identifying historical evidence of climate change trends and patterns.

Figure 13 below displays the historical record of the average maximum temperatures experienced in the Linakeng CC. Mirroring the rainfall patterns, the highest temperatures are experienced in the summer months, at the close and start of each year. Peaks in average maximum temperatures over the time scale are evident in the 1982/1983, 1991/1992 and 1995/1996 summer seasons. It is also important to note the temperature dips that have been experience, particularly in 1997, displaying evidence of uncommonly low winter temperatures. Due to the several data gaps, it is difficult to make assumptions of the overall trends of average maximum temperature. However, the most intense peaks and dips in average maximum temperatures have been experienced in more recent times, suggesting the onset of climate change conditions.

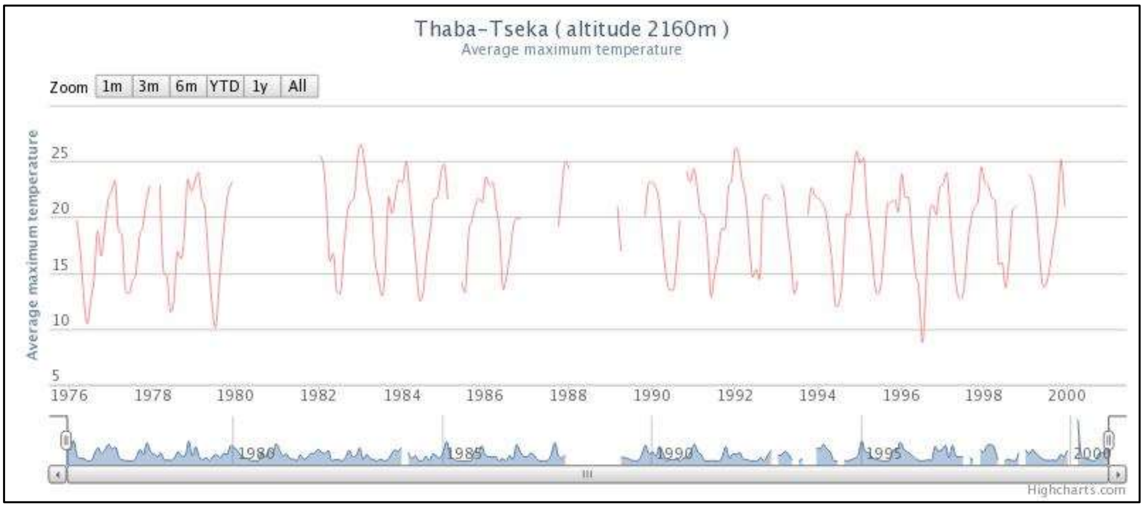


Figure 13: Average maximum temperature for Linakeng between 1976 and 2000 (Source: CSAG, 2014)

The evidence of high average maximum temperatures could display the onset of climatic changes such as heat waves, droughts and general temperature extremes. In conjunction, the temperature dips suggest cold periods that have a range of consequences. As previously indicated, temperature trends seem to run in 10 year cycles, peaking and dipping (polarisation of temperature ranges) in the middle of each decade. Overall, it is evident that slight temperature increases have been experienced in the more recent records, therefore displaying the likely onset of climate change conditions.

The outcomes of the above trends and patterns analysis will the used to justify the likely occurrence of climate change hazards in for the community council.

5. Vulnerability of Key Sectors

A vulnerability assessment is conducted in this study as a means of understand the sensitively of specific sectors to climatic changes. Vulnerability is defined by the United Nations International Strategy for Disaster Reduction (UNISDR,2009) as:

> *"The characteristics and circumstances of a community, system or asset is what make it susceptible to the damaging effects of a hazard. "*

The source of such vulnerability can vary, possibly arising from physical, economic, environmental and social factors (UNISDR, 2009).

In order to unpack and project the implications that climate change is likely have in Lesotho, a state and vulnerability assessment of the five key sectors is conducted. These sectors are:

1. Agriculture (crops and livestock)
2. Water Supply (water and hydropolitics)
3. Natural Resources (soil, biodiversity and vegetation)
4. Forestry
5. Socio-Economics (health and Basotho culture)

It is important to note that overlap between the sectors is evident and thus climate change implications that are likely to be experienced in one sector may also occur or influence another. For example, implications of the water sector will affect the other sectors as this is a resource that they are all reliant on and thus vulnerable to its changes. To avoid repetition, such overlaps have not been explicitly indicated, however such ripple effects will be addressed at a later stage. It is also important to note that the vulnerabilities of the first 4 sectors (agriculture, water supply, natural resources and forestry) all impact and effect the socio-economic sector as people and the economics of the country are directly reliant of the first 4 sectors.

The initial assessment of these sectors (this section) was conducted through an extensive literature review based on a broad, national scale overview. This analysis is narrowed down to the community council scale in Section 7, where the produced vulnerability maps are used to expand on and discuss this review.

5.1. Agriculture

5.1.1. Overview of Agriculture (Crops and Livestock)

It is evident that climate change implications are already negatively impacting food security across southern Africa, and more intensely in the Least Developed Countries (LDCs), such as Lesotho, which is predominantly rural and relies on subsistence, rainfed agriculture (Dejene *et al,* 2011). In Lesotho, agriculture accounts for 10% of the country's Gross Domestic Product (GDP) and the majority of livelihood earnings (LMS, 2007). Lesotho is considered as a resource poor country, with the agriculture sector historically being a major employer. Rural communities (estimate as 85% of the population) rely on agriculture to generate income and meet their daily food demands (LMS, 2007).

However, the sector is susceptible to shocks and stresses which increase the vulnerability of livelihoods (Gwimbie *et al*, 2013). Such shocks and stresses are being exacerbated by climate change, which, coupled with decreasing employment opportunities and rising food prices, negatively affects the resilience of households. Such conditions are made worse by the heightened competition for arable land as a result of population growth, deteriorating soil and water resources, migration to the lowlands, deepening poverty, loss of vegetation cover and limited external income opportunities (Dejene *et al*, 2011). The impact of climate change on the agricultural sector in Lesotho will be quite significant and worsen the already severe food insecurity and failing livelihoods (LMS, 2007).

Climate related stresses are not a new phenomenon in Lesotho as such implications, the most predominant being droughts, have resulted in the development of a range of coping mechanisms in response to change (LMS, 2007). However, recent climatic changes are not only increasing in time, but in frequency and magnitude, resulting in the inability of evolving agricultural practices to keep up (Dejene *et al*, 2011). Some have argued that, due to Lesotho's relatively cool climate, the projected warming could have positive implications on the agricultural sector. It is projected that cold stresses will be reduced and winter growing seasons may be extended, particularly in the mountainous regions. However, summer crops (such as maize) are likely to be negatively impacted, particularly in the foothills and lowlands, due to the predominance of droughts (Dejene *et al*, 2011). In conjunction with this, warmer temperatures, coupled with droughts or flooding, are likely to bring with them unfamiliar pests and diseases that Lesotho has not formally experienced (Dejene *et al,* 2011). Land degradation is already severely decreasing the productivity of both croplands and rangelands, which is projected to escalate in the face of climate change (GEF, 2009)

5.1.2. Vulnerability of Agriculture

Livestock and arable (crop) agricultural has been highlighted as priority within Lesotho not only because of their importance as economic activities but because of their vulnerability to climate change. Such consequences are projected to be as a result of drought and extreme weather events (LMS, 2007). Agriculture is perceived to be particularly susceptible to climate change because of the rapid increase of soil erosion, resulting from of intense storm activity, higher temperatures, droughts, strong winds and heavy snowfall. Such factors will not only accelerate the rate of erosion but also its extent, consequently destroying existing and potential agricultural land. It is projected that the availability of arable agricultural land (currently at 9%) could shrink to 3% as a result of expected climate change implications (LMS, 2007).

Thererfore, drought, snow, hail and frost already pose as significant threats for the agricultural sector, which are expected to worsen in terms of frequency and intensity as a result of climate change. Of those, intermittent rainfall and chronic droughts are expected to have the most severe impact of the agricultural sector (LMS, 2007). The country is already renowned for thin, highly erodible soils with varying fertility which makes the region more susceptible to the implications of climate change. As a result, the quality and condition of soil will decrease further, adding a greater impact on the agricultural sector due to the decreased amount of arable land (Dejene *et al*, 2011).

a) Crops

Crop production is one of the most important elements of farming systems that support livelihoods in Lesotho, accounting for approximately 9-12% of the total land use in the country (LMS, 2007). The agricultural sector supports the highest portion of people than any other sector in the country and contributes to 19% of the country's GDP (Chakela, 1997). The main crops produced in Lesotho are maize, sorghum and wheat which, between 2006 and 2008, accounted for 84.7% of the cultivated land in the country. Of that, maize is the most predominant, accounting for 61.7%, with sorghum and wheat occupying 13.6% and 9.4% respectively (Gwimbie *et al,* 2013). Other significant crops grown are Legumes, such as beans and peas, which are used as both cash crops and for subsistence, as well as potatoes and vegetables.

Crop production and conditions vary between the lowlands and the high mountainous and foothills regions[3]. The lowlands are significantly drier and as a result, are more prone to drought and crop failure. In the highland and foothill regions, rainfall is higher however the growing season is much shorter due to the early onset of frost and winter conditions (LMS, 2007). The impacts of climate change are already being felt in Lesotho. For example, maize yields have fallen from 1400kg/ha in the 1970s to 450-500kg/ha. This decrease, combined with the country already having to import 60% of their cereals, has resulted in the Government declaring a food shortage state of emergency and having to appeal to the international community for food aid on a regular basis (LMS, 2007).

Climate change is projected to bring with it extremes events and hazards such as hail, frost, strong winds, heavy rains and extreme temperature (LMS, 2007). Such events will damage crops, decreasing the harvest outputs as well as the condition of crops lands due to dust storms and soil erosion. In addition, temperatures are expected to increase and, although, as previously mentioned, some have argued that this may have positives spins off for Lesotho's agricultural sector, it is projected that the negative impacts will outweigh possible benefits. For example, higher midday temperatures will result in crop wilting while the increase of fungal disease will decrease outputs. Such implications will particularly influence vegetable producers and will have high economic implications. With higher temperatures come pests and disease, which under normal circumstances in Lesotho, would be eliminated with the cold winter temperatures. However, with the projected increase in temperatures, such pests and disease will be more prominent, which locals do not have the mechanisms or knowledge to eradicate (Dejene *et al*, 2011).

As a means of adapting to climatic changes, some practices are being shifted in accordance with the delayed rainy seasons (first rains occurring a month or two later than expected). Due to this delay, lands that are traditionally ploughed in the late winter or early spring period are now having to be reploughed when the rains arrive. This results in multiple tillage operations, which further decreases soil quality and increases the time and cost of crop production. In some cases, crops that are planted in the early spring (as traditionally done) have to be replanted, further exacerbating the negative implications. As a result, crops may not have enough time to reach maturity before they are destroyed by early frost incidences, particularly in the mountainous regions where the growing season is much shorter than that of the lowlands. To make matters worse, the early summer rains

[3] The lowlands (Tosing and Qibing Community Councils) and the high mountainous and foothills regions (Linakeng Community Council).

are projected to increase in amount and intensity, resulting in flooding. With such rainstorms come strong winds which result in increased erosion, particular of susceptible areas and where vegetation cover has not had time to re-establish after the winter (Dejene *et al*, 2011).

Various climate and crop models have been used to project the implications of climate change in Lesotho. Gwimbie et al (2013) indicated that the Decision Support System for Agrotechnology Transfer (DSSAT) was run as a means of assessing the yield changes of the three main crops produced (maize, wheat and sorghum). Maize yields showed a disease due to the decline in rainfall and increase in temperatures. However, due to its high drought tolerance, sorghum yields painted a different picture as significant yield gains in some zones were projected. In general, the climate and crop model projections demonstrated that the country would experience potential food deficits as a result of decreased rainfall and increase temperature. If effective adaption does not occur, it is likely that current crop land will become fallow, further decreasing crop yields. However, this can be counter argued in that the changing climate will enable former non-arable land to be cultivated as increasing temperatures will allow areas that were previously too cold, to be used for crop production (Gwimbie *et al*, 2013).

b) Livestock

The livestock sector in Lesotho consists of sheep, goats, cattle, donkeys, pigs and poultry, which have both economic and social (cultural) value. Cattle are one of the most dominant livestock and are mainly raised for subsistence purposes to produce milk, fuel (dung), power (for ploughing) and meat (Gwimbie *et al*, 2013). Livestock also acts as an important source of cash to produced food in times of poor crop production or wage decreases. Therefore, not only are livestock important in sustaining livelihoods, but act as a safety net against shocks and stresses. From a socio-cultural perspective, cattle not only have cultural value but are used in many traditional events such as burials, feasts, celebrations, sacrifices, offerings and as bride wealth (Gwimbie *et al*, 2013).

Rangelands account for approximately 70% (approximately 1 981 896 hectares) of the total land in Lesotho, making it the largest land use type in the country. Such areas are used for grazing livestock as rearing in rural areas in completely dependent on open land grazing as commercial fodder production is limited. Lesotho's rangelands are generally in poor conditions and are decreasing in quality and quantity (Gwimbie *et al*, 2013). Livestock grazing is the main contributor to the countries annual soil loss, with an estimated 23.4 million tonnes being lost per annum (LMS, 2007). This rate is expected to worsen with the onset of climate change due to major destruction and suffering projected for rangelands.

Degraded rangelands are particularly vulnerable to chronic drought, which impends the recovery of vegetation, resulting in bare land that is more susceptible to the erosion implications of intense storms which bring with them heavy rainfall and strong winds (Gwimbie *et al*, 2013). The initial cause of degradation is due to the combination of constant grazing and trampling, particularly in cases of overstocking. This is supported by Dejene *et al* (2011) who indicates that degraded areas are much more sensitive to climate change hazards than those that have good vegetation cover and soil water infiltration capabilities. The influence of climate change in degraded rangelands is projected to not only increase soil loss rates, but decreases their carrying capacity, resulting in a significant deterioration of the quantity and quality of livestock (LMS, 2007). This deterioration will have dire knock-on effects to the nation's economy as the production of meat, milk, wool and mohair are major contributors to the country's GDP.

As previously indicated, an increase in temperature and shifting of rainfall patterns are projected climate changes that Lesotho is likely to face, which will negatively impact the carrying capacity of rangelands and the sustainability of the ecosystem (Gwimbie *et al*, 2013). Such impacts include a reduction in the availability and widespread shortages of water, livestock diseases and changes in the productivity of rainfed forage. The First National Report on Climate Change (2000) supported this by indicating that change in precipitation patterns would result in the loss of nutritious climax grass species, which would be replace by hardy, nutrient poor species. The occurrence of such undesirable species will have negative implications on livestock production. However, as with the vulnerability of crops discussed above, some have argued that the increase in temperatures may benefit rangeland grasses (Gwimbie *et al*, 2013).

As with crop production, livestock pests and diseases are also likely to become more apparent with the increasing temperatures as winters will no longer be able to inhibit such pests and diseases (LMS, 2007). Cattle are prone to tick borne diseases and anthrax while sheep are more likely to get scab, a parasite disease. The majority of farmers do not have access to adequate to pest and disease control or veterinary services, resulting in severe implications on livestock agriculture. Climatic changes will also influence livestock in terms of the impacts of unseasonal cold snaps. For example, cold snaps have been recorded in early summer just after shearing season, killing small stock (Dejene *et al*, 2011).

In conclusion, it is projected that significant precipitation and temperatures changes could have sever livelihood implications, particularly on agriculture. Such impacts will affect the most densely populated and crop-growing areas in the country, particularly in the lowlands, foothills and Senqu Valley (Gwimbie *et al*, 2011)

5.2. Water Supply

5.2.1. Overview of Water Supply

a) Water

Lesotho's major natural resource is water, which is often referred to as 'white gold' by the Basotho people (Ministry of Natural Resources, 2010). Water resources in Lesotho are abundant in relation to demand (Ministry of Natural Resources, 2010), although their availability is highly variable across the country, with the south-eastern lowlands having run-off of less than 50mm per annum whereas the northern highlands experience over 300mm per annum (SADAC, 2013; Ministry of Natural Resources, 2010). Despite the country having an abundance of water, there are severe water shortages in the Lowlands, which is home to two-thirds of the population. This is due to the physical division between the abundance of clean water available in the valleys of the Highlands which is separated from the Lowlands where the main population resides (SADAC, 2013). This requires careful planning and managing at a policy level.

Throughout Southern Africa, water resources and access to water are impacted by climate change (Dejene *et al,* 2011). Lesotho is one of the richest water resource countries in Southern African adding considerable value its economic development through water exports to South Africa, its neighbouring country, by means of the Lesotho Highlands Water Project (LHWP) (Gwimbie *et al*, 2013). The LHWP is one of the largest water transfer scheme in the world and acts as a means of harnessing water resources for the benefit of both countries. The scheme transfers more than 2billion m^3 of water per year, generating a substantial income for Lesotho. For example, between 1996 and 2004, Lesotho earned US$225 million from the transfer of water (Gwimbie *et al*, 2013). Lesotho is not currently in a state of water deficit or scarcity, as a result, the country does not have a copying strategy for managing and planning for such a situation (Mwagi, n.d.).

The average overall water output for Lesotho has been calculated as 159.53m^3/sec, as calculated by TAMS in 1996 (Ministry of Natural Resources, 2010). Higher flows of water are generally observed during the rainy season (spring and summer) and the low flow rates during the dry season (autumn and winter) (SADAC, 2013; Ministry of Natural Resources, 2010). The country has three major river systems namely: The Senqu River that drains 24,485km^2, equating to two thirds of Lesotho; the Mohokare River that borders on South Africa and has a total catchment area of 6,890km^2; and the Makhaleng River, with a catchment area of 2,911km^2 (SADAC, 2013). The mean annual run-off of these three catchments has been quantified to be approximately 160m^3/s with the total groundwater flow calculated as approximately 10m^3/s (Water Commission Report, 2007).

b) Hydro-politics

In most circumstances, water resources are no isolated to a single country but rather the demand of several countries who rely on the resource. In Lesotho’s case, this is evident in that the Senqu River is the source of the Orange River, which feeds the majority of southern African countries. As a result, water supply is not an internal resource, but rather one that is governed by the politics and demands of several states (Mwagi, nd.). However, this is not the only means which complicates water supply and demand in Lesotho. Due to the country abundant water supply, it neighbour, South Africa, has an agreement with Lesotho to transfer water to meet its own demands.

As indicated, the LHWP, signed on 24 October 1986, defines this bi-national agreement which harness water resources to benefit both countries (Mgwadi, nd.). South Africa is able to meet its water demand requirements while Lesotho benefits through the generation of a stable income. An excess of 2million m^3 of water is transferred per annum, while Lesotho already having generated a substantial income (for example, US$225 million between 1996 and 2004) (Mgwadi, nd.).

5.2.2. Vulnerability of Water Supply

a) Water

Despite the stable income generated from the water transfer scheme, such benefits may be crippled by the water stress and scarcity threat that the future poses. Projected unseasonal flows act as a serious risk to water supplies, both internally and for international export (Gwimbie *et al*, 2013). The implications of climate change are already being felt in Lesotho as once perennial springs running dry; large, robust rivers being reducing to small trickle; and dams lying dry for large parts of the year (LMS, 2007). In response, the management and preservation of water resources has formed a critical element of development challenges facing the nation.

The potential implications of climate change on water resources within Lesotho are expected to stem from the projected lower level of precipitation and result in a reduction of fresh water availability (Mwagi, 2007). This would result in a water stress situation where it has been projected that the current water available per capita could drop by approximately 60% (Gwimbie *et al*, 2013; LMS, 2007). In addition, it is projected that the warming associated with climate change will result in an increase of intensities of rainfall meaning that low intensity rainfall events that allow sufficient time for infiltration, will decrease. This will further add to extended time periods between rainfall events, resulting in longer dry spells and consequential drought and flooding (Dejene *et* al, 2011). It has been projected that Lesotho is likely to enter a water stress period by 2019, where less than 1700m^3 of water will be available per capita per year. This is projected to decrease to 1000m^3 by 2062, demonstrating the severe implications that climate change may have (LMS, 2007). This, combined with population pressures are projected to result in further pressure on the already strained service provision requirements (Mwago, 2007). Some have even indicated that such implications may occur sooner as climate change exacerbates the situation, affecting not only humans, but animals and ecological systems (LMS, 2007).

The *National Report on Climate Change* demonstrates the projected impacts of climate change on the country's water resources (Gwimbie *et al,* 2013; LMS, 2007):

- Demise of water based social and economic activities due to a decrease in runoff and the shrinkage of surface and ground water resources (due to diminishing rainfall), which will also negatively affect ecologically systems.
- Decrease in sub-surface flows as a result of more prominent dry conditions annually causing drying of wells and springs, lowering of water tables and increased boreholes costs, reduction in water source yields and severe water stresses. Such implications will affect rural populations the most as they are heavily dependent on ground water and natural sources of water.

One of the key challenges facing Lesotho in terms of climate change implications on water resources, is the vulnerability of communities who are highly dependent on the resources to sustain their livelihoods. Rural communities access water from natural outputs such as springs, wetlands, sponges and rivers making them more susceptible to the drying out of such sources (Mwagi, nd.). Access to water is critical in sustaining livelihoods through domestic use, hydropower generation, livestock rearing, crop irrigation, performing rituals and small-scale industry (LMS, 2007).

a) Hydro-politics

In addition to the internal water supply issues that are likely to occur in the face of climate change, international agreements and reliance will also be heavily affected. Water scarcity will result in Lesotho being unable to meet the agreed water transfer requirements, drastically effecting the demands of South Africa. If Lesotho is unable to meet the external transfer demands, not only will the bi-national agreement be lost, but the income generated from the project will diminish. Thus, the substantial stable, non-tax income that Lesotho have become dependent on will no longer be generated, negatively effecting the country's economic and development profile. The reduction of this revenue will result in lower social expenditures, causing an increase in poverty and human suffering in the country (Mwagi, nd.).

With the rise of unprecedented dry spells, the storage of water in the LHWP dams is likely to be lower, reducing royalties that are gained from exports. In additional to the loss of income generation, the breaking of the treaty with a neighbour that they are so heavily involved in, will have negative ripple effects to other relationships and agreements that the two have. This is likely to spark conflict between the two countries and threaten international security (Mwagi, nd.). With the face of climate change, South Africa is also likely to experience their own water shortages, further increasing their reliance on the transfer scheme and thus on Lesotho's resources. This strain will increase tension as the projected implications of climate change become more apparent.

In additional to international hydropolitics, it is important to note that internal tensions are also likely to rise as water resources are depleted. In many countries, access to water is already managed with allocations given to relevant users. However, due to Lesotho's current abundance of water, such management plans are not evident. This lack of allocation is likely to result in internal conflict as water scarcity becomes an issue. It is evident that within Lesotho, tension over limited resources such as rangelands and arable farming lands is a sensitive issue and as a result, management plans have been developed to mitigate such tensions. Therefore, even though water scarcity is not currently an issue, it is important that the resources be managed and allocated as rapid climate change implications are likely to spark conflict and tension related to the critical resource.

5.3. Natural Resources

5.3.1. Overview of Natural Resources

a) Soil

Soil is a vital resource in Lesotho, with the majority of the population basing their livelihoods (or part of their livelihoods) on the resource by means of agricultural activities. The suitably of soil is highly variable, being influenced by topography and rainfall (including sever flood and drought events) in conjunction with human induced pressures such as cultivation, grazing and generally poor management practices (LMS, 2000). Not only is soil limited by its quantity and quality in Lesotho, but it is a shrinking non-renewable resource that the country is highly dependent on. Currently, just under 40 000 000 tonnes of soil is lost per year by means of gully, sheet and rill erosion, accounting for more than 2% of the topsoil being lost per year (LMS, 2007; GEF, 2013). The susceptibility of the soil eco-system is due to the fragile mountainous terrain in Lesotho.

b) Biodiversity

Biodiversity is an important resource in Lesotho due to its tourism value, medicinal and cultural use, and income generation. The variable soil, topographic and climatic conditions that Lesotho experiences has led to a wide range of biodiversity and resultant high endemism, especially in remote, mountainous regions (LMS, 2000). As a result, the country has particular biodiversity wealth due to the high number of animal and plants species, 1388 and 3094 species respectively. The mountainous regions are known to be particularly rich in biodiversity with very high levels of endemism (LMS, 2001).

c) Vegetation

In general, Lesotho is characterised as a mountainous country, with the majority of vegetation cover classified as Grassland. However, the country is rich and diverse in flora, as demonstrated in the biodiversity section. There are approximately 300 species of grasslands in the country, making them the biggest plant family in Lesotho. Such vegetation is able to be well maintained and remain dominant due to frequent fire and frost occurrence. Thickets and scrublands are present in the river valleys and foothill regions, which are known to encroach in grasslands in the face of grazing pressure and lack of intense fires. It is currently estimated that 12% of grasslands (rangelands) have been invaded by such shrubs (mainly Chrysocoma tenuifolia) (Kirkman and Lewis, 2013).

Grasslands are classified into three types in Lesotho, namely Highveld, Afromontane and Afroalpine Grasslands. As previously indicated, these areas dominate the Lesotho Landscape, with 70% of the country's land being used as rangelands (livestock grazing). The remaining areas classified as: 10% being arable (crop production); and 20% being unusable (inaccessible or subject to severe land degradation). Very small portions of the country are under protection or conversation, or classified as forestry (both planted and natural woody vegetation) (First Country Report to the COP, n.d,).

5.3.2. Vulnerability of Natural Resources

a) Soil

Climate change implications on soil resources are expected to increase soil loss by means of erosion, as well as soil fertility. Erosion will be exacerbated by (LMS, 2007):

- Increased temperatures which results in the aridification of soil
- Scarce vegetation cover causing bare soil that is easily eroded
- Frequent drought which dries out soil and increases run off as rainwater is unable to infiltrate
- Rainstorms which increase runoff
- Strong winds causing wind erosion
- Heavy snowfall resulting in a loss of vegetation cover

This will further increase the already diminishing non-renewable resource in terms of its quality and quality (LMS, 2007). This is supported by the projections of the GCM scenarios which indicate that climate change conditions are likely to increase the rate and magnitude of soil erosion in Lesotho (LMS, 2000).

b) Biodiversity

Some projections indicate that Lesotho's is likely to display warmer conditions which will positively affect biodiversity through improved species diversity (either through migrations or improved adaptation of exotic species). However, the occurrence of drought, flooding and severe winter conditions will have negative implications (LMS, 2000).

The destruction of the natural environment as a result of projected climate change implications will have severe implications on biodiversity resources. Such implications will stem from the destruction of natural habitats such as the drying up of rivers, wetlands, mountain sponges and springs. Increased aridity coupled with soil erosion and land degradation will further destroy natural systems and vegetation cover, and consequently the country's biodiversity. Such implications will not only negatively affect indigenous species, but exotic plant and animal species as well (LMS, 2007; LMS, 2001). The change in the natural environment is projected to happen at such a rate that species may not be able to adapt to. Therefore, specific conservations mechanisms need to be put in place to preserve such species that are likely to disappear with the onset of climate change.

In addition, the rapid spread of alien invasive species is contributing to biodiversity loss. Typically, alien invasive species are more resilient to change, resulting in them adapting faster than indigenous species, consequently negativity impact the countries biodiversity (LMS, 2001). As with crop yields, it can be argued that the increased temperatures will allow for the diversification of biodiversity through natural migrations or improved adaptation of imported species. However, with the projected accelerated rate of change associated with climate change, it is unlikely that species will have adequate time to adapt and thrive, resulting in their probable extinction (LMS, 2001).

c) Vegetation

The vulnerability of vegetation is likely to follow a similar trend to that of agriculture, particularly for the livestock sector that is primary reliant on grasslands. To avoid repetition, the vulnerabilities demonstrated in the agriculture (livestock) section will not be indicated. However, there are additional implications that grasslands are likely to incur in the face of climate change projections. As indicated above, grasslands are reliant on certain conditions to remain the dominant vegetation type in Lesotho. For example, grasslands remain dominant in winter by being highly susceptible to frost and cold conditions. With projected temperature increases during these periods, such frost events and low temperatures may diminish, creating climatic conditions that other vegetation types can thrive in. This is particularly a problem for alien invasive species, which are unable to withstand current winter conditions. However, in the face of climate change and consequential increases, they will be able to survive the winter months and take over vital, natural grasslands. A similar trend is evident in shrubby vegetation, which currently dies back in winter months. However, climate change conditions will enable such species to thrive, further contribute to the likely loss of important grasslands.

In addition, these important grasslands are reliant on winter snowfall to return vital nutrients into the soil. With the projected increases or shift in temperature and infrequent snowfall events, this nutrient cycle would be lost, dramatically affecting grasslands.

5.4. Forestry

5.4.1. Overview of Forestry

Lesotho is one of the least forested countries is Africa, with a mere 1% of the total land being forest or woodland. Natural forests, better described as 'woody vegetation', make up the most of forestry in the country, coving approximately 42 000ha (FAO, 2010). Only 874ha is planted forestry, which makes up 0.2% of the country's forestry sector. These planted areas consist mainly of eucalyptus and pine trees. However, forestry acts an important source of fuel wood, building material, forage, shelter, income generation and tourist attraction as well as a mechanism for the prevention of soil erosion (LMS, 2007). Currently, approximately 40% of households are struggling to meet their household firewood demands. In response, both communal and private sectors have made attempts to afforest areas as a means of mitigating the loss of the diminishing resource. Forestry does not contribute to the national economy in a significant way and the trade of the resource is so small that it does not feature in Trade Statistics (FAO, 2010).

It is indicated that wood is the third most important natural resource in the country, with almost all households dependent on it for heating and / or cooking. This dependency is greatest in the mountainous regions where access to alternative forms of energy such as gas, paraffin or cow dung, are limited. In mountainous areas, the lack of natural forests results in people walking hours in search of woody shrubs as a source of energy, whereas in lowland regions, despite the lack of mature government woodlots, natural forests are more prominent (LMS, 2007). Therefore, those living in mountainous regions are more susceptible to the loss of woody vegetation and those in the lowland areas.

The small areas of tree plantations comprise of exotic species and are categorised into two types (FAO, 2010). The first being Government owned woodlots, developed primarily for wood production. The second being Government planted trees, for erosion stabilisation purposes, which are now regulatory harvested by locals for firewood and building material.

Forested land in Lesotho is characterised onto 3 types, based on the altitude in which they are located and the species that occur or are planted in each. These types are indicated below, demonstrating the altitude and area in which they occur (MFLR, 2014).

1. Escarpment and Riparian level (1300 – 1800m)
2. Escarpment Grasslands and Scrubs Woodland (1800 – 3000m)
3. Alpine/Sub-Alpine Grassland and Heartland (3000m)

Tree seedlings are distributed proportionally in the above agro-ecological zones as a means of afforesting areas.

5.4.2. Vulnerability of Forestry

It is predict that the implications of climate change will lead the destruction of natural vegetation, which includes trees. Currently, there is a net depletion of forests as a result of drought events with limit the ability of trees to bounce back. This exhaustion of forests is projected to continue as impacts of climate change become more prominent and more especially as the frequency and intensity of drought increases (LMS, 2007).

As previously indicated, efforts have been made to afforest areas to secure wood resources. However, the survival of trees in the face of climate change implications such as warming temperatures, changing perception patterns, fire incidences, presence of pests and disease as well as land degradation (Dejene *et al*, 2011). According to the Ministry of Forestry and Land Reclamation, implications of climate change on the sectors are mainly due to (personal communication with Ministry, 2014):

- Change is seed physiology and repercussions observed on bees
- Seed production pattern change (early late or nothing)
- Change in rainfall patterns – excess rain results in flooding which causes erosion and siltation, for example.

Dejene *et al* (2011) further indicates that fast growing trees and shrub species currently cannot tolerate the cold winter conditions, which limits the woodlot potential of many areas. As harsher weather conditions as result of climate change become evident, this lack of tolerance by these species will be exacerbated. However, results generated by the Holdridge Life Zone Classicisation predict positive impacts for afforestation programmes as the warmer temperatures may benefits the growth of both exotic and indigenous species (LMS, 2000).

A deduction can be made that the forestry sector will be vulnerable to the projected conditions of climate change in a similar manor to that of crops. As with crops, wood species are more vulnerable in their initial growth phases and hardier as they mature and become more resistant to change. Through this deduction, it can be projected that, forestry in the lowlands regionsmay decline in the face of climate change as a result of more frequent and intense dough conditions. Not only will this hinder the initial growth wood species, but also the survival of species over several years of their life span. In the highland and foothill regions,, rainfall is higher and thus eliminates problems associated with drought, however the early onset of winter conditions (snow and frost) will hinder the growth of woody species (LMS, 2007). It is important to note that this is simply an assumption based on the deduction that the projected effects of climate change conditions on crops will be similarly reflected in the forestry sector.

5.5. Socio-Economics

5.5.1. Overview of Socio-Economics

Lesotho has a population of 1.8 million with an estimated growth rate of 1% annually. The population has seen a decline from the first decade of the 21st century which was approximately 2.4 million, which has resulted in a lower population density of 59 people/km^2 (Mokorosi and Matete, 2009). In addition, there has been a decline in fertility rates for over a decade, possibly explaining the decrease in population. The decline in fertility rates has been attributed to contraceptive prevalence, increased access to education and often improved economic status (Hall and Jennings, 2007). HIV/AIDS has severely impacted Lesotho, further impact the population decline.

Lesotho is characterised as a ‘least developed country’ according to the UNDP Human Development Report of 2005 which ranks the country at 149 out of 177 member countries based on the Human Development Index (Water Commission Report, 2007). The population structure also indicates that Lesotho is a developing country. 6% of the population is 65 years and older, 58% is aged 15-64, and 36% of the population is less than 15 years old (Mokorosi and Matete, 2009). The ratio of males to females is normal with the population consisting of 51% of females and 49% males (Mokorosi and Matete, 2009).

The country’s gross domestic product (GDP) as increased at an average of 3.4% over the last decade (as recorded by the Lesotho Bureau of Statistics in 2006) and generally continues to increase (Gwimbie et al, 2011). Most of Lesotho’s GDP is drawn from agriculture, which contributes 17% to the total GDP, with the rest made up by construction (14%), manufacturing (16%) and various services (40%) (Mokorosi and Matete, 2009). Agriculture has been showing a remarkable decline since 2001 whereas manufacturing and services have shown positive growth (Mokorosi and Matete, 2009).

Despite this growth, the poverty level in Lesotho remains high, with 62% of the population living on less than US$2 per day. The country is classified as economically resource poor that is prone to economic crashes resulting in continually high unemployment (estimated at 42%) and poverty rates (LMS, 2007). Lesotho’s NAPA report demonstrated that the majority of the country’s population (more than 85%) are subject to climate change risks and made more vulnerable due to their severe poverty situation. It is evident that poverty is worse in rural areas where livelihoods are based on farming which is dependent on rainfall (Gwimbie *et al*, 2011).

Most of the country’s population reside in the less mountainous regions of the country situated in the western part of the country and covering approximately a third of its surface area (First Country Report to the COP, n.d.). Approximately 85% of Lesotho’s population live in rural areas (Bisaro, 2007; Water Commission Report, 2007; Lesotho Meteorological Services, 2001). Over 70% of those living in the rural areas derive a large portion, or most, of their livelihood from agriculture (Lesotho Meteorological Services, 2001) with a large portion of this being subsistence, as well as livestock farming (Bisaro, 2007). This sector is of critical importance for determining the socio-economic conditions of the country (Lesotho Meteorological Services, 2010). The other main livelihood source in the highlands is in the form of wages from migrants who have worked in the mining industry in South Africa (Bisaro, 2007). This has, however, decreased over the two decades as new employment laws came to the fore in South Africa (Bisaro, 2007).

Urban areas have shown a steady increase of the last 5 decades, growing from a mere 3.4% in 1960 to over 25% in 2008 (Gwimbie *et al*, 2011). This increase is mainly as a result of urban migration from rural areas which lack opportunities in comparison to the perceived economic benefits in urban areas. This migration is also due to declining agricultural potential in rural areas as a result of poor soil conditions, changing climatic conditions and poor farming techniques.

a) Health

In terms of health, Lesotho has the third highest global HIV/AIDS infection rate with an estimate one in three adults suffering from the disease. This high prevalence further undermines already weakened livelihoods and exacerbates the existing poverty situation (LMS, 2007). Due to the country's high altitude and severe winter conditions, Lesotho is free from climate related diseases that are often experience in tropical regions (LMS, 2000). However, prolonged exposure to winter conditions (such as snowfall) are known to result in climate related fatalities. Additional health problems stem from poor water quality as well as poor water and sanitation facilities and practices (LMS, 2000).

b) Basotho Culture

The culture and livelihoods of the Basotho people is based on the unique conditions of Lesotho. The Basotho culture is directly reliant on rich biodiversity of the country due to their use of certain plants for traditional medicine, for example. Indirectly, natural resources also play a role in the culture through the provision of grazing lands to support cattle (cultural wealth), for example. The regions in which people live is also a large cultural contributor and thus the landscape, topography and general 'sense of place' is an important element of the Basotho culture (LMS, 2000).

5.5.2. Vulnerability of Socio-Economics

The Lesotho NAPA report (LMS, 2007) clearly demonstrates that specific socio-economic sectors are particularly vulnerable to climate change implications and, as a result, require "immediate and urgent" intervention programmes. These are the water, agricultural, forestry, rangelands, soils and desertification, biodiversity, health and the Basotho culture sectors. The majority of these sectors have already been explored, however the health and Basotho Culture sectors are unpacked below.

Due to Lesotho's high reliance on natural resources (including agricultural land, biodiversity and water supply), the socio-economic profile is highly vulnerable to the susceptibility of the other key sectors. Changes to agricultural outputs will not only effect social wellbeing in the form of a threat to subsistence lifestyles, but also economically due to market and trade implications. In the same way, water supply vulnerability severely affects socio-economic stability, not only for the populations direct domestic and agricultural purposes, but also for international royalties and the economic reliance on this trade (as described in the 'hydropolitics' section). As previously indicted, the vulnerability of natural resources (soil, biodiversity and vegetation) have direct implications on the agricultural and water supply sector, and thus on the counties' socio-economic sector. Finally, the forestry sector also plays a role in social and economic resilience. This stems from the use of natural woody vegetation for domestic purposes as well as the use of planted woodlots for market and trade purposes. Therefore, although the socio-economic sector is within itself vulnerable to projected climate change implications, as highlighted below, it is also susceptible to the implications of the other key sectors.

a) Health

As previously indicated, the country's cold winters and high altitudes result in it generally being free of diseases which are commonly associated with tropical regions. However, climate change projections predict that the country will have a generally warmer climate which is likely to result in the occurrence of tropical disease that they are not equipped for (LMS, 2007). Cheke (2012) demonstrates that climate change studies on health have indicated that the prevalence of diseases will not be uniform across the country. It is evident that some districts will remain relatively dry and cold in the face of climate change. However, the majority of the country will be subject to temperature increases and changes in precipitation patterns, making them vulnerable to tropical diseases. Additionally, the projected sever and prolonged winter conditions are likely to exacerbate the occurrence of fatalities due to exposure to such harsh, lengthy conditions (LMS, 2000).

Projected climate change implications on human health are both direct and indirect. Changing weather patterns and frequent extreme events (sever snowfalls, droughts, flooding) directly affecting people, causing fatalities. Additionally, water-borne (such as typhoid) and vector-borne diseases as well as worsened child undernourishment also directly affect the health of the nation (LMS, 2007). Indirectly, the climate change impacts on the quality of water, food and air are altering important elements that people rely on such as agriculture, the economy, ecosystems, agriculture and human settlements (Gwimbie *et al*, 2011). Indirect impacts can also be experienced through a lack of access caused by damage to transport routes for example, which result in isolation of rural areas and increasing food prices. This reiterates the vulnerability of rural populations to the projected implications of climate change.

b) Culture

The demise of farming and the livelihoods in rural areas that are dependent on the sector result in the migration of the working population to urban areas in search of alternate income opportunities. This demographic shift has already resulted in numerous social issues and conflicts in both rural and urban areas. In addition, such changes impose the nation’s cultural heritage as people are forced into new ways of living. The natural heritage and Basotho culture is closley linked to the country’s natural environment, with their medicine, housing, clothing and other traditions all stemming from nature. It is evident that climate change is projected to impact the natural environment, consequently altering the heritage of the people (LMS, 2007).

6. Key Hazards of Relevance to Project Sites

6.1. Introduction

Hazards are defined by UNISDR (2009) as:

> "*A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.*"

Thus it is evident that the occurrence of a hazard is not the danger, but rather its impact on the people or ecosystem that it affects. This is reiterated by the supporting statement made by UNISDR (2009), which highlights that:

> *"Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis."*

6.2. Hazards Categories

Hazards are commonly categorised according to their cause or driver. For the purposes of this study, three categories have been used; namely Natural, Androgenic of Social cause, and Technological Hazards. These categories are defined as follows (UNISDR, 2009):

a) Natural Hazards:

> *"Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage."*

This term is used to describe the hazard as an event as well as the underlying conditions that may develop in the future as a result of the event. Such natural hazards are often categorised or characterised according the intensity, scale (area/impact), duration, onset, frequency or magnitude. This enables the extent of the natural hazard to be analysed. For example, a drought develops and slowly terminates, however its impacts tend to affect a large area. On the other hand, an earthquake has a rapid onset and but only effects a small area. Natural hazards can also be the cause or consequence of another, indicating that they may be coupled. For example, a drought may result in the drying of land which causes flooding as infiltration cannot occur. Another common example is an earthquake causing a tsunami. Therefore, the assessment of natural hazards not only varies in scale and scope, but also in their ability to cause additional events (USISDR, 2009).

b) Anthropogenic or Social Cause Hazards:

> *"The phenomenon of increased occurrence of certain geophysical and hydrometeorological hazard events, such as landslides, flooding, land subsidence and drought that arise from the*

interaction of natural hazards with overexploited or degraded land and environmental resources."

Anthropogenic or social cause hazards are thus an event that occurs as a result of human activities that outweigh the natural threshold. Such events can be reduced or avoided through proper management of natural resources (USISDR, 2009).

c) Technological Hazards:

"A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage."

Therefore, technological hazards are also related to human induced consequences which stem from activities or infrastructure that has been developed. Examples include dam failures, toxic wastes, chemical spills, transport accidents, nuclear radiation, fires and industrial pollution. Such events may also be triggered by natural hazard events, such as flooding resulting in the destruction of a dam wall (USISDR, 2009).

In conclusion, it is important to note that categorising hazards under a single umbrella can be a challenging task due to interrelated causes. The occurrence of a single hazard may trigger another, or even several other hazards thus causing a ripple or cumulative effect that is difficult to house. Such occurrence has already been highlighted in the 'Natural Hazards', where the example of drought resulting in flooding is used. Such ripple effects of hazards also cut across the types of hazards, such as an Anthropogenic Hazard result in the onset of a natural event. For example, grazing mismanagement (Anthropogenic Hazard) can cause slopes to become unstable and thus causing landslides (Natural Hazards). Another example is provided in the 'Technological Hazards" section, where they example of flooding (Natural Hazard) may cause a dam failure (Technological Hazard). Therefore, it is evident that there are often strong overlaps when attempting to classify hazards, making it a challenging task to unpack.

6.3. Hazard Identification

An extensive literature review was conducted to identify key hazards in Lesotho, including their drivers and implications. Once this list of hazards was finalised, the categorisation process was initiated. As previously indicated, this was a challenging process to conduct as overlaps between hazards are vast. However, focused was placed on the cause or driver of the hazard to complete the task. In some cases, a single hazard was placed in more than one category as the driver or cause of the event differ and therefore stemmed from various sources.

For the purposes of this categorisation, the term 'Climate Change' is used to categorise 'Natural Hazards'. This is due to the study's focus, indicating that the natural hazards focused on here are those that are induced by projected climatic changes.

Once the categorisation process was complete, a mindmap (shown in Annex 2) was developed to understand the links between the various hazards. This clearly demonstrates the complexity and integrated nature of hazards and how the onset of a single hazard can have ripple effects to others. Not only is this process conducted to understand and unpack the nature of the hazards, but also a means of understanding the source of such events. In many cases, it is a combination of activities or conditions that cause such hazards. The diagram therefore provides a good basis for understanding the integrated dynamics and is used at a later for developing strategies of climate change resilience.

Table 3 below summaries the key climate change (natural) hazards that have been identified as relevant for the three project types as well as their projected implications and triggers (of other climate change hazards). The mindmap (Annex 2) was conducted to simply trigger thoughts about such dynamics and interrelationships and therefore does not include all of the likely links.

Table 3: Key climate change hazards that are relevant to the project sites

HAZARD	DESCRIPTION	IMPLICATIONS	TRIGGER OTHER HAZARDS
Chronic Drought	Prolonged droughts are projected to occur in the face of climate change are rainfall activity becomes intermittent and an overall decrease is experienced. The projected mean temperature increase will contribute to the occurrence of chronic drought as this, combined with prolonged dry spells, will increase the severity of drought events.	• Negatively affect the production and condition of cultivated and grazing lands as well as the forestry sector. • Prolonged water shortages - famine • Decrease the functionality of wetlands and consequentially affect the ecosystem services they supply. • Effect the functionality of rivers and other water systems • Loss/ extinction of indigenous and medicinal plant species • Disease (heat stroke) and general discomfort • Increase incidences of alien species • Decrease soil fertility and moisture content • Poor water quality • Stagnant water may be source of water borne diseases (e.g. cholera)	• May result in **flooding** as water is unable to infiltrate after dry conditions • Dry lands are likely to contribute soil **erosion**
Acute Drought	Short term drought events are expected to increase with the increase of intermittent rainfall, combined with increased mean temperatures. Heat waves and high temperate form part of this hazard.	• Most likely to negatively affect cultivated lands. • Intermittent water shortages. • May negatively impact the functionality of wetlands and other water systems such a rivers • Soil moisture loss • Disease (heat stroke) and general discomfort • Increase incidences of alien species • Poor water quality • Stagnant water may be source of water borne diseases (e.g. cholera)	• May result in **flooding** as water is unable to infiltrate after dry conditions • Dry lands are likely to contribute soil **erosion**
Frost	Frost events are typically experience in winter months, however, with the projected shifts of season, early onset or extend occurrence of frost into the growing seasons is likely. Also projected that frost in winter may decrease which could have both positive and negative implications	• Negatively impact crop production and the quality of grazing lands due to the change of frost occurrence into growing season. • Wilting of crops and poor harvest • Decrease of frost event in winter periods enable the encroachment of shrub vegetation and alien species into key grassland biomes.	

HAZARD	DESCRIPTION	IMPLICATIONS	TRIGGER OTHER HAZARDS
Hail	The projected increase in intense storm activity is likely to result in frequent and heavy hail events. It is difficult to assess the occurrence of hail, but deductions from rainfall events and storm frequency can be made to predict such events	• Projected increase in occurrence and intensity will damage crops, decreasing production • Heavy hail storms can damage buildings (settlements) • May damaged woodlots that are in the early stages of growth	
Flood	The projected increase of flooding events is likely to stem from the combination of drought conditions and intermittent, yet intense rainfall activity.	• Prolong flooding or flash floods are likely to negatively affect buildings (settlements), infrastructure (roads, bridges) and cultivated lands • Grazing lands in flood prone areas are likely to be lost and non-usable during flooding events • Woodlots that are in the early stages of growth may be implicated • Increase of pests and water borne diseases (e.g. typhoid) • Poor water quality	• Flash floods are likely to accelerate soil **erosion**
Snow	Snowfall events are a delicate balance as they act as an important source was water and nutrient supply, however prolong and intense snowfall activity can be determinable. It is difficult to access the likelihood of snowfall activity; however deductions can be made from rainfall and temperature projections with the onset of climate change.	• Heavy or prolonged snowfall events are likely to damage buildings (settlements) • Snow destroys crops and prolonged events will prohibit production on cultivated lands • Prolonged snowfall will kill vegetation on grazing lands, thus making them unproductive • Heavy snowfall may destroy woodlots	• If snow event decrease, intensify or result **drought** conditions in dry, winter periods as snow is a vital source of water • Heavy snowfall and movement of heavy snow bodies may dislodge soil and accelerate **erosion**
Erosion	Erosion is brought on by the trigger of other hazards, such as flood/drought events, combined with anthropogenic causes (overgrazing for e.g.). Erosion is projected by combining the occurrence of such hazards with the soil types and slope to determine the level of land degradation that is likely to occur in the face of climate change.	• Erosion causes loss of arable cultivated, grazing and forestry land • In severe cases, erosion can destroy infrastructure and buildings (settlements) • Erosion is also likely to negatively affect wetlands through siltation	• Erosion will result in vegetation loss, reducing the infiltration ability of soil, increasing the risk of **flooding**

It is important to note that the hazards above (Table 3) are categorised as natural (in this case, climate change induced) hazards, which can be worsened or triggered by anthropogenic and technological hazards. Similarly, climate change hazards will have ripple effects to other types of hazards, demonstrating a complex web of causes and effects.

The diagram in Annex 2 demonstrates a simplistic version of the complex interrelationship between the three categories of hazards, to indicate how climate change hazards can be triggered by anthropogenic and technical factors. These types of relationships are fleshed out when the analysis of the vulnerability maps is conducted.

6.4. Summary

Conclusions about the likely occurrence of hazards in the project site are based on the following three analyses' conducted in this report:

1. Analysis of projected climate changes using the CSAG (2014) downscaling models (Table 2) conducted in section 3.2 (Climate Change Projections for the Linakeng Community Council)
2. The historical trend and pattern analysis conducted in section 4 (Historical Records of Changing Patterns)
3. The hazard summary table above (Table 3)

From this analysis, it is evident that all of the hazards identified are likely to be evident in the project site. Their occurrence, intensity and consequential implications are unknown. As a result, all of the key hazards identified will been mapped and analysed against the vulnerability of the key sectors.

7. Climate Change Projections

This section aims to reveal the projected climate change implications for the community council by producing vulnerability maps. These are produced to identify the general condition in the face of climate change as well as assess the vulnerability of the key sectors to projected climate change hazards and conditions.

It is important to note that the spatial vulnerability mapping and consequential analysis is based on the availability of data and, as previous indicated, demonstrates a worst case projection for the 2020-2040 projection period[4]. In cases where none/limited data was available, deductions have been made and narratives provided.

The vulnerability maps which demonstrate the vulnerability of a feature to the implications of climate change hazards, can be applied to the sector vulnerability review conducted (Section 5: Vulnerability of Key Sectors). This analysis is conducted in three phases:

1. Overview Climate Change Projection Maps
    - The projected shift in rainfall and temperature (heat) patterns are mapped to paint general picture of the projected climate likely to be experienced in each community council
    - There are compared against current distribution maps
    - An erosion vulnerability map is demonstrated as a contributing factor to climate change implications
    - From this, the changing trends are applied to the vulnerability of the key sectors to reveal possible implications
2. Vulnerability Feature Maps
    - The above climate change distribution maps are then overlaid with vulnerability features to assess the likely implications for the key sectors (agriculture, water supply, natural resources, forestry, socio-economic).
    - This analysis is structured according the key sectors and the maps generated will form part of the discussion to both the climate change projection and vulnerability feature maps.

What follows is a detailed projected worst case climate change sector vulnerability analysis for the Linakeng Community Council for the 2020-2040 time period.

7.1. Overview of Climate Change Projection

Before a key sector climate change vulnerability analysis of the Linakeng Community Council is conducted, an overview of the project site is provided. An overview of the projected climate conditions is then given by demonstrating the current rainfall and temperature (represented by heat units)

[4] The methods taken to develop the maps are demonstrated in Annex 3: Methods for Spatial Vulnerability Mapping

distributions in comparison to the projected climate change distributions. In addition, the erosion vulnerability of the community council is spatially represented to understand the contributing factors to likely consequences of climate change. Lastly, the hazards that can be mapped (for example flood and drought) are displayed for the community council to inform the sector vulnerability analysis.

Figure 14 below demonstrates the spatial distribution of land use types in the Linakeng Community Council. There is only one main road which runs across the western portion of the region as well as several bridges along this access route. The two pilot villages, Ha Tokho and Maputsoe, are located in the south eastern region of the community council. It is evident that the majority of the region is used grazing land (85.18%), however portions of this may be grasslands that are inaccessible for grazing. Settlements (1.44%) and cultivated crop lands (13.33%) are usually situated in close proximity, and are scattered throughout the community council. Settlement and cultivated lands are concentrated around the main road and pilot villages in the western portions and in the valley regions of the central and eastern portions. There is only a very small portion of forestry (0.05%) evident in the community council.

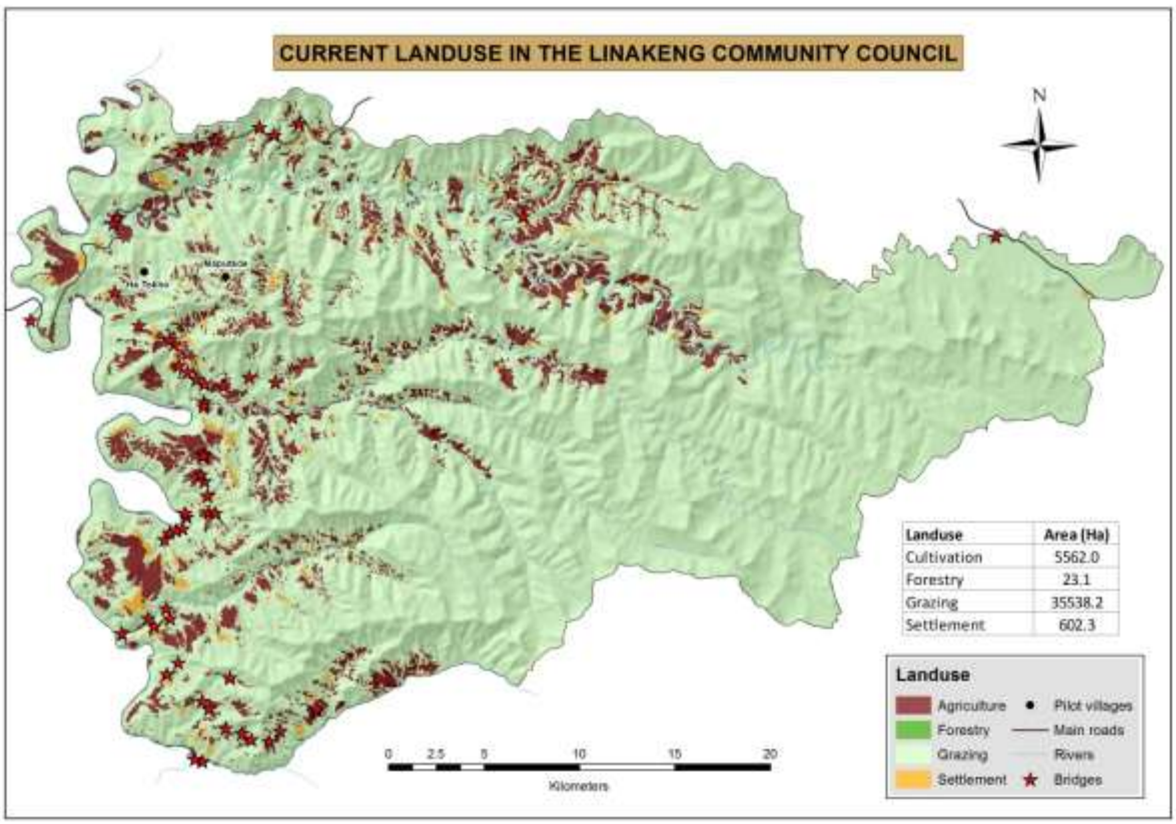


Figure 14: Current land use for the Linakeng Community Council

7.1.1. Rainfall

The maps below (Figure 15 and Figure 16) respectively demonstrate the current and projected rainfall distribution patterns during the growing season (November to February) for the Linakeng Community Council. The growing season was selected to be represented due the rainfall importance for agricultural, water supply (storage for dry months), forestry, natural resource and consequentially socio-economics.

From the current map, it is evident that the region receives 300-700mm of rain during the growing season, which is considered a high rainfall area in Lesotho. It is evident that the western portions of the CC receive the least rain (300-400mm per growing season), with the distribution increase towards the eastern highland regions. The majority of the population resides in the western and central portions or the region, where rainfall is low but accessible and usable land is dominant.

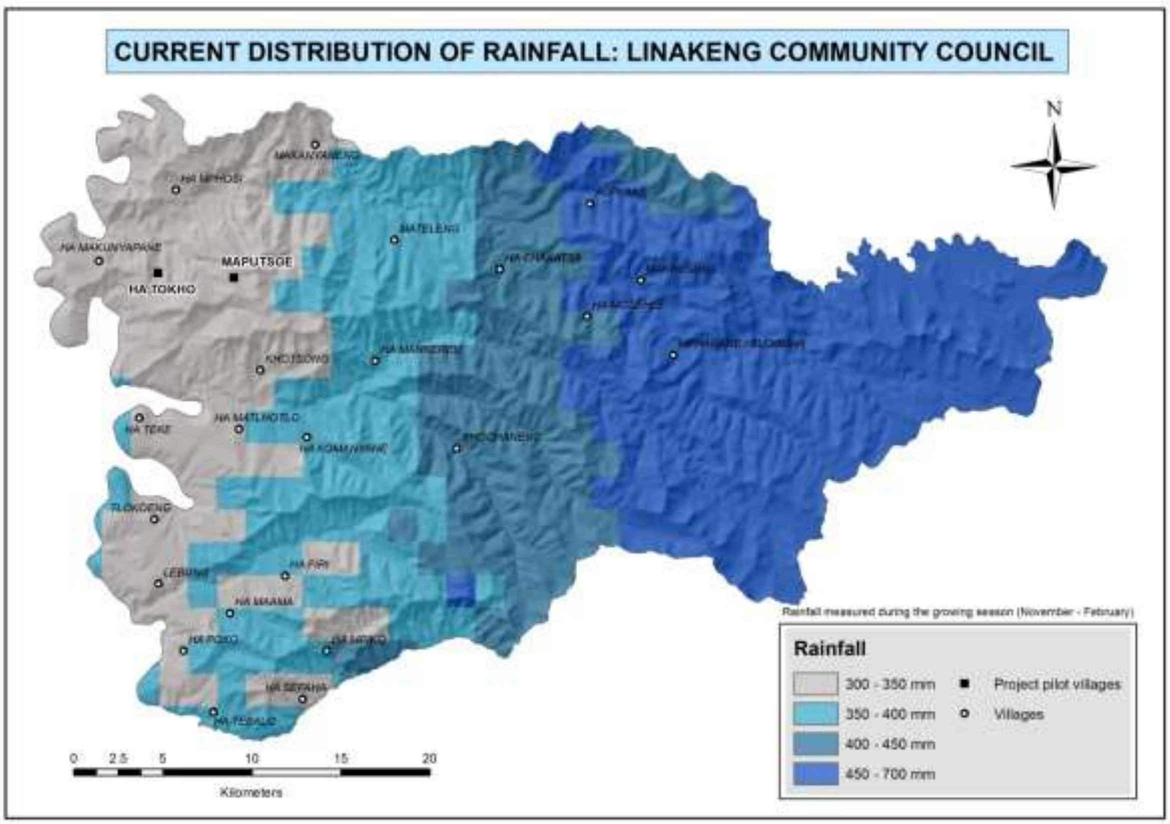


Figure 15: Current spatial rainfall distribution (during the growing season) for the Linakeng Community Council (Data source: CSAG, 2014 and Schulze et al, 2010)

The projected growing season rainfall distribution map (Figure 16) displays an eastwards shift in decrease distributions. The low, lying western regions are predict to receive 250-350mm of rain during the growing season, indicating a decrease by up to 50mm in the face of projected climate change conditions. It is unlikely the highland regions in the eastern portion will fell such changes as they will still receive a projected 450-700mm of rain during the season. This shift in rainfall distribution is likely to make the area more susceptible to climate change hazards, particularly to drought (and consequential flooding and erosion). It is also likely that such changes will affect the all of the key sectors. Such implications will be discussed in the sector vulnerability analysis to follow.

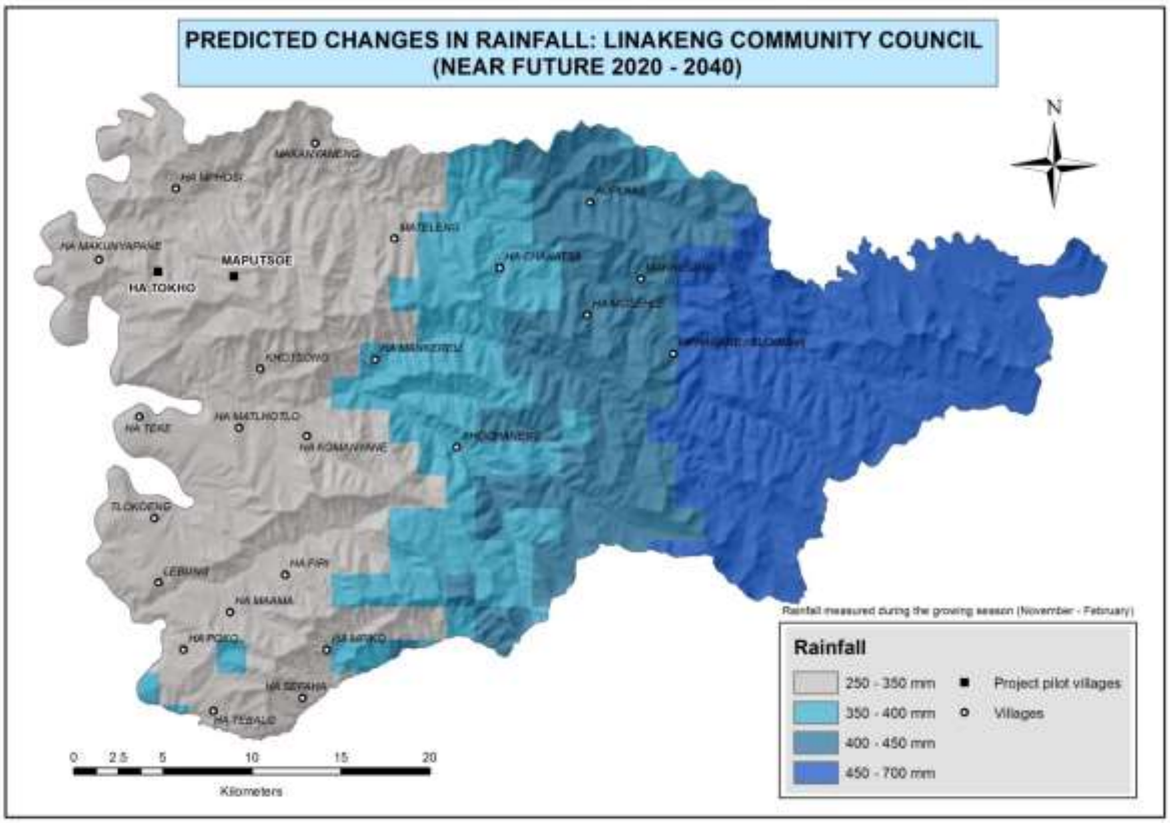


Figure 16: Projected spatial rainfall distribution (during the growing season) for the Linakeng Community Council for the 2020-2040 period (Data source: CSAG, 2014 and Schulze et al, 2010)

7.1.2. Temperature

The maps shown in Figure 15 and Figure 17 indicate the current and projected changes in temperature (using heat units) distribution (during the growing season) for the Linakeng Community Council. Heat units[5] are used instead of temperature as they display a more accurate measurement of actual heat on the ground, disregarding that which may sway a temperature reading. Smith (2006) indicates that the majority of crops required more than 750 heat units (HU) during their growing season. Therefore, any regions above 750HU are considered ideal during the growing season, while anything below makes those cultivated areas vulnerable.

From the current heat unit distribution, it is evident that a similar west to east pattern is evident as is for rainfall distribution. However, in this case, the low lying, western and central portion of the community

[5] Daily heat units: the difference between the daily average maximum and minimum temperatures, and a certain critical basal or developmental "threshold" temperature (http://www.hort.purdue.edu/rhodcv/hort410/csheatuj.htm)

council receive the highest values. As expected, temperatures (heat unit) decrease towards the eastern, highland regions. Heat units currently range from 600-1000HU in the west making conditions largely ideal for crop production. The central and eastern portions receive between 150-600HU per growing season and are therefore considered as marginal to unsuitable regions for crop production.

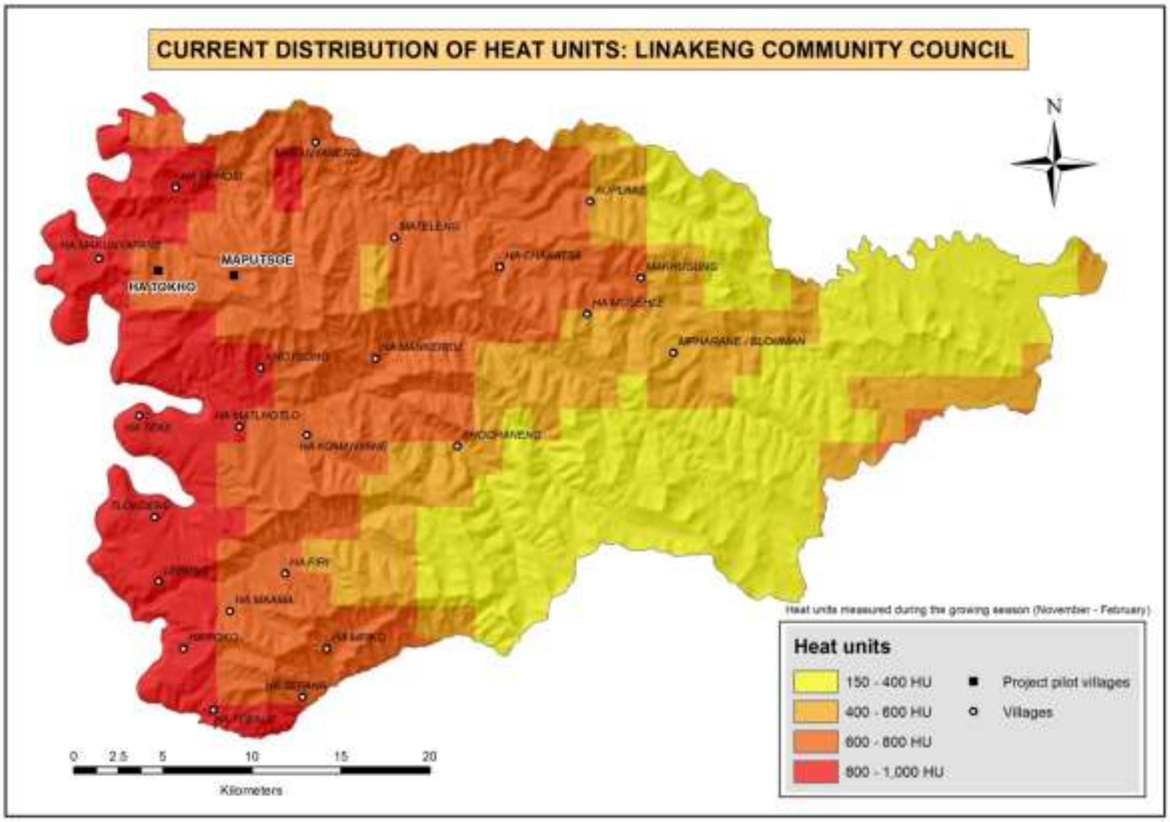


Figure 17: Current spatial heat unit distribution (during the growing season) for the Linakeng Community Council (Data source: CSAG, 2014 and Schulze et al, 2010)

The projected heat unit distribution (Figure 18) in the face of climate change paints a similar picture to that of rainfall distribution during the growing season. Regions in the far most western portions of the CC display an increase by up to 1000-1200HU, with parts of the central regions increasing to 600-1000HU. Such increase, combined with the above rainfall distribution shift, may result in the drying out of western portions, making them more susceptible to drought (and in turn flooding). The currently cooler portions of the region (in the eastern parts) are also likely to see increases. This, however, may be beneficial to such areas as the increase may result in more areas being suitable for agricultural purposes. Although, when combined with the findings of the projected rainfall distributions changes, this may not be the case. Such contrasting notions will be elaborated on per key vulnerability sector in the following section.

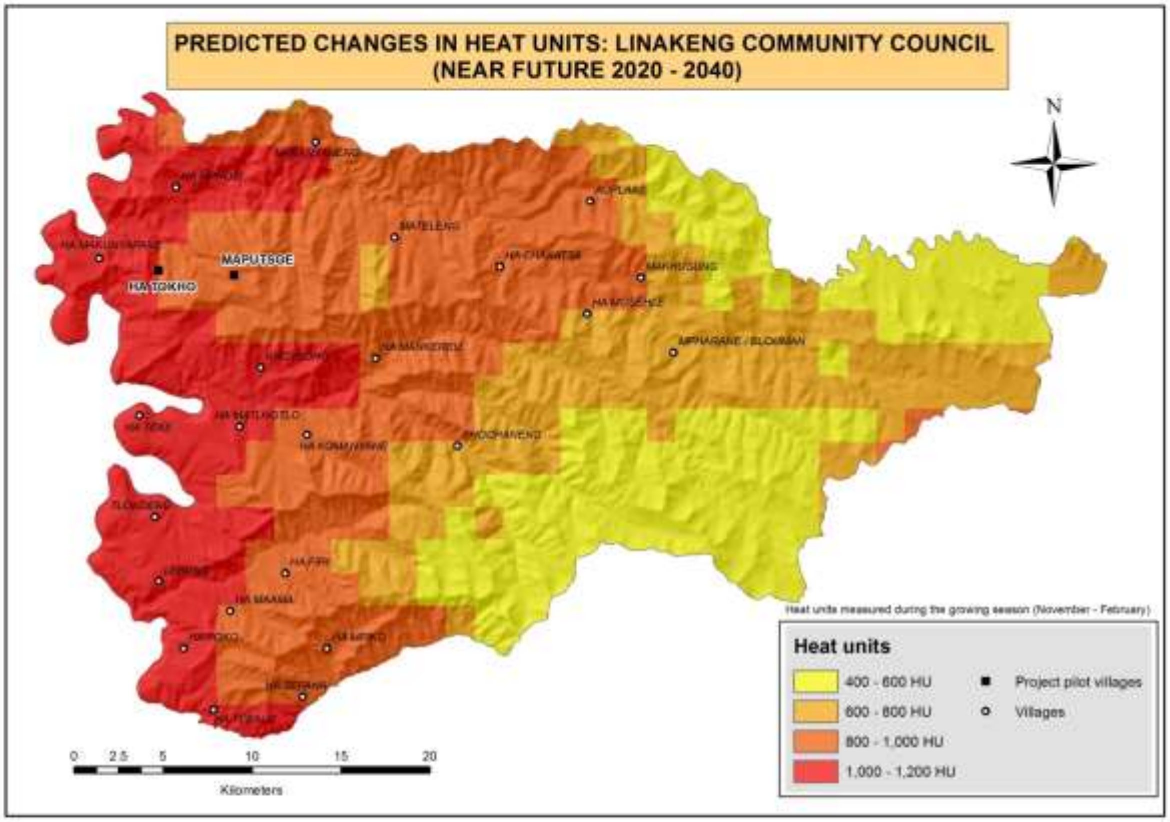


Figure 18: Projected spatial heat unit distribution (during the growing season) for the Linakeng Community Council for the 2020-2040 period (Data source: CSAG, 2014 and Schulze et al, 2010)

7.2. Vulnerability Mapping

In order to map the potential occurrence of hazards in the project site, a vulnerability analysis of key features was conducted. It is evident that the effects of a hazard event are determined by the occurrence of the event (drought, flood, hail, etc.) in relation to the elements on the ground that it is likely to impact (cultivated land, settlements, grazing lands, etc.). To spatially represent this vulnerability, the vulnerability level to various hazards had to be determined.

A matrix was developed (Figure 19), which illustrates the vulnerability level (on a scale of 0 to 3, with 0 being “no vulnerability” and 3 being “high vulnerability”) that the type of hazard is likely to have on a specific feature. The matrix was then used to apply a ‘level of vulnerability’ to spatial data to evaluate the implications that hazard events are likely to have. An example of this is that cultivated lands have a high vulnerability to floods, therefore given a ‘3’ score.

	HAZARDS	Erosion	Flood	Drought	Crop Productivity[6]
VULNERABLE FEATURES	Cultivated lands	3	3	3	3
	Grazing lands	3	0	3	0
	Forestry	2	1	2	0
	Infrastructure	2	3	0	0
	Settlements	1	3	0	0
	Socio-Economics	1	1	1	0

Figure 19: Matrix to assess the vulnerability levels (0- no vulnerability; 1- low vulnerability; 2- medium vulnerability; 3- high vulnerability)

By applying these vulnerability levels to the relevant spatial data, vulnerability maps to projected climate change hazards were generated[7].

7.2.1. Erosion

An erosion vulnerability map (Figure 20) was produced to demonstrate the overall susceptibility of the land, as a discussion basis for climate change hazard projections. This has been conducted to further assess the Linakeng Community Council area and assist in identifying areas that are particularly vulnerable. This map has been generated through the use of slope variations and soil types. It is evident that large portions of the westerns, central and even eastern parts of the CC are susceptibility to erosion, particularly in valley regions where slope instability plays a role. Moderate to high erosion vulnerable areas are also dominant, particularly in the low lying areas where the community relies most on adequate soil quality and quantity for agricultural purposes. The trends and patterns of this map will be used in the following sections to contribute to the sector vulnerability analysis.

[6] Reduction in productivity of cultivated crops as determined by HU and rainfall distributions

[7] The inability to map and predict certain hazards (such as snow and hail) combined with unavailable data makes this a challenging task. As a result, the maps generated are based the most accurate and available data. Therefore, it must be noted that gaps in data are evident and consequentially acknowledged.

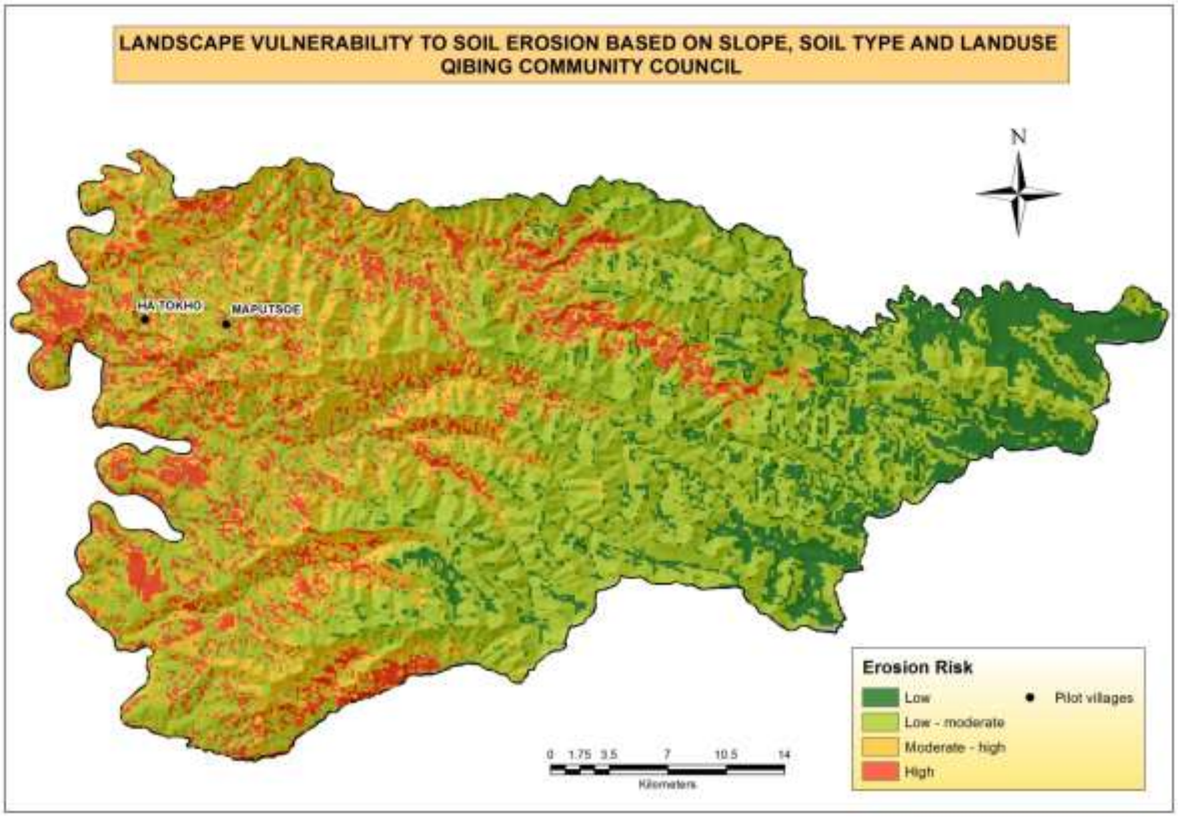


Figure 20: Current erosion vulnerability of cultivated land and settlement in the Linakeng Community Council (Data source: CSAG, 2014 and Schulze et al, 2010)

The above maps, in combination the hazard and vulnerability maps to follow will be combined to produce the final hotspot vulnerability map for the community council. What follows is an analysis of the key sectors (agriculture, water supply, natural resources, forestry and socio-economic) in the face of projected climate change conditions as demonstrated above. Where available the spatial data of the sector or its subcomponent will be overlaid with the specific projected climate conditions to indicated specific vulnerability to such changes.

7.2.2. Flood

Flooding has been projected for the community council based on the sectors that are vulnerable to the hazard (cultivated crop lands, grazing lands, settlements and infrastructure) in combination with flood prone areas (flood plains, low lying areas, etc.). The flood risk level is demonstrated in Figure 21 below, which indicates that the vast majority of the community council has a low flood risk level. This is likely due to the mountainous topography of the area, which results in flooding activity being isolated to deep valley regions. Those areas that demonstrate a high flood risk level are in such valley regions, thus making it an easy task to identify projected flooding zones in the face of climate change. From the land use map, it is evident that cultivated lands are predominantly found in the areas where there is a high flood risk. The location of these cultivate lands in the flood plain makes them more vulnerability and thus at risk.

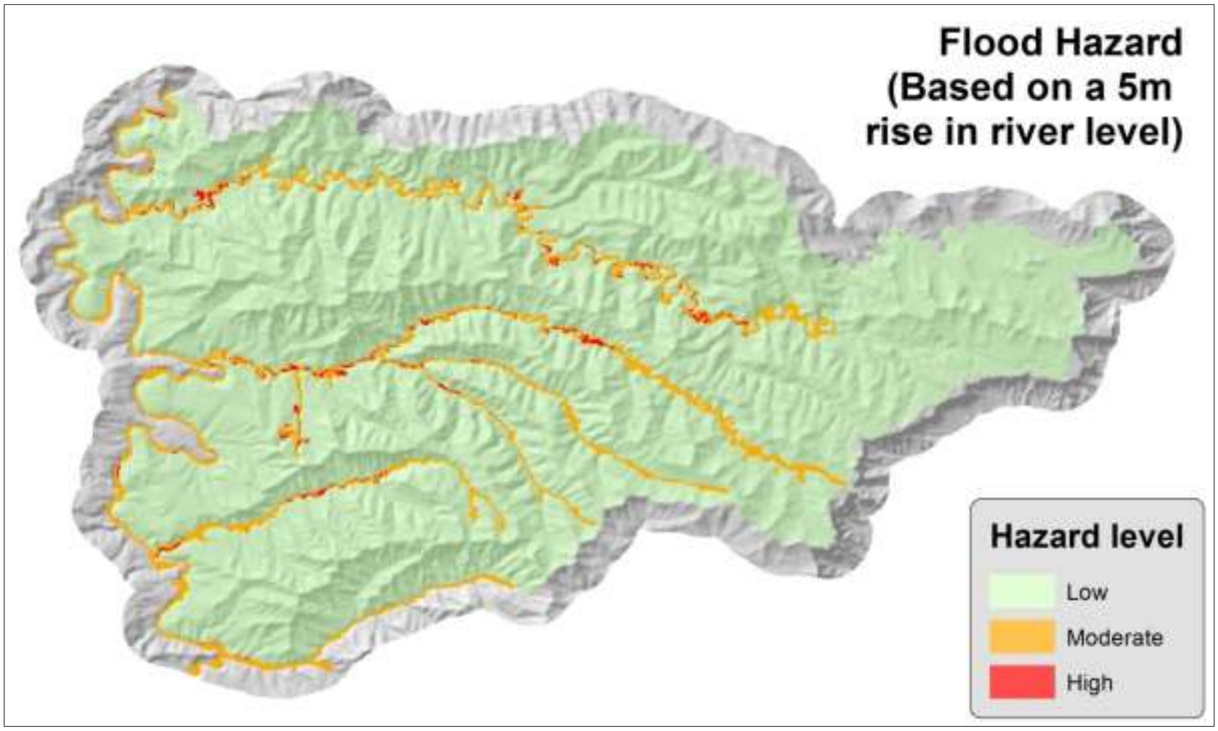


Figure 21: Projected flood risk for the Linakeng Community Council for the period 2020-2040 (Data source: CSAG, 2014 and Schulze et al, 2010)

7.2.3. Drought

Figure 22 below demonstrates the projected, drought risk for the Linakeng Community council, based on the vulnerability of grazing and cultivated crop lands during the growing season (November – February). It is important to note that the variation between chronic and acute drought is difficult to map and thus a general drought risk map was generated. It is evident that more than two-thirds of the community council is at high risk to drought, with the majority of the remaining portions having a moderate to high risk. These findings and projections will be used in the key sector vulnerability analysis at the end of this section.

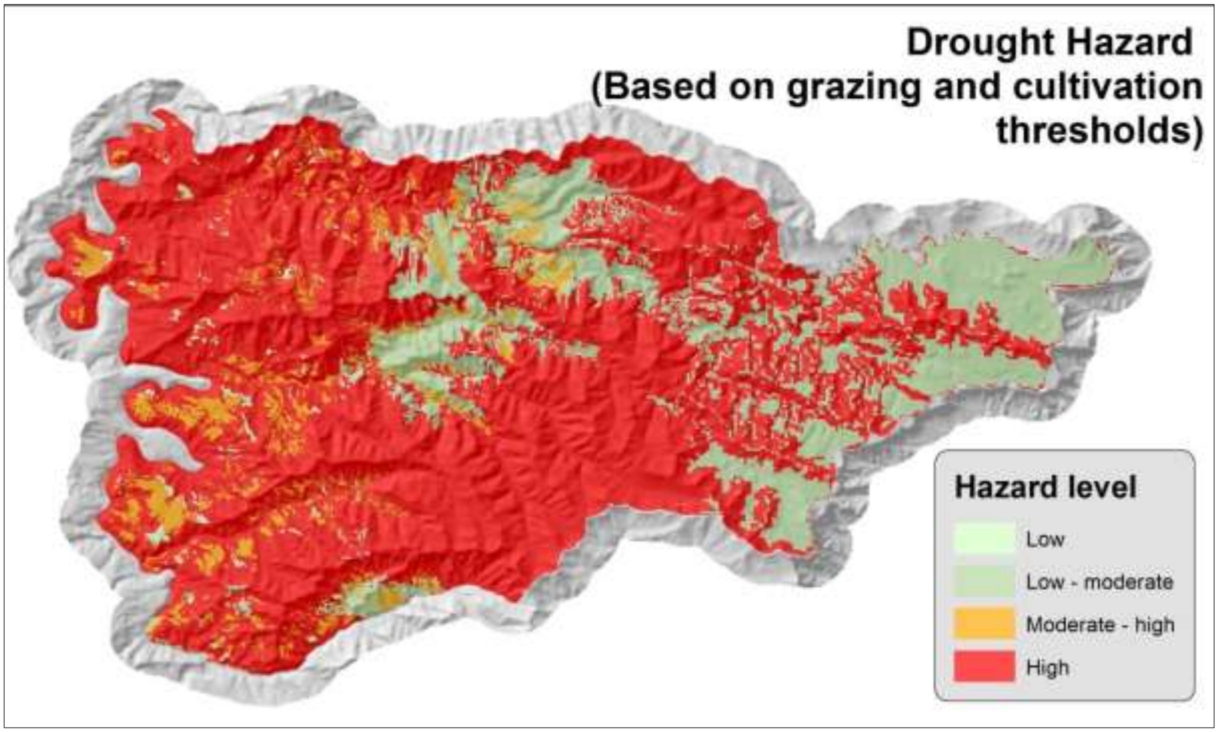


Figure 22: Projected drought risk for the Linakeng Community Council for the period 2020-2040 (Data source: CSAG, 2014 and Schulze et al, 2010)

7.2.4. Other Hazards

It is not possible to map the remaining hazards due to the inability to spatially predict their occurrence in the face of climate change. These include snow, hail and frost hazards. Deductions that have been made (Table 2) from the CSAG (2014) downscaling graphs are used to predict the trends of these hazards and the consequential implications of the key sectors.

7.3. Key Sector Climate Change Vulnerability Analysis: Linakeng

The following section demonstrates the vulnerability of the key sectors (agriculture, water supply, natural resources, forestry and socio-economics) to the climate change projections, based on the worst case projection for the 2020-2040 time period. Where possible, projections and the implications on the key sector have been spatial demonstrated to enhance the analysis of vulnerability across the span of the community council. A summary of the projected climate changes and the implications on the sector has been given at the end of each sector analysis.

7.3.1. Agriculture

a) Crops

The vulnerability of crops to climate change projections is based on the rainfall and heat unit patterns demonstrated in the maps above. The current rainfall and heat unit maps (Figure 15 and Figure 17) demonstrate the current crop production vulnerability for the crop growing season (November-February). This is based on the thresholds of du Plessis (2003) and Smith (2006) who respectively indicated that more than 450mm of rain and greater than 750HU per growing season is required to sustain crop production. To generate a discussion about the implications of projected future rainfall and heat unit variations, the projection distribution maps are analysed (Figure 16 and Figure 18).

In terms of current rainfall during the growing season (Figure 15), which ranges from 300mm in the west to 700mm in the west, the eastern portions are most ideal from crop production (450mm-700mm). Parts of the central region are considered as moderately appropriate as they receive between 400-450mm of rain. The projected changing in rainfall distribution (Figure 16) demonstrates an overall decrease in rainfall by up to 50mm, causing an eastwards shift of rainfall distribution. Therefore, the areas in the east that are currently not receiving sufficient rainfall are likely to receive even less in the face of climate change. This also results in less portions of the CC receiving ideal rainfall, demonstrating that central regions will not long be appropriate and only the far eastern areas, which are projected to receive 450-700mm, are ideal. However, the eastern parts are highland, mountainous areas and therefore the topography may not be ideal for cultivation to shift with the change in rainfall distribution.

The current heat unit distribution (Figure 17) ranges from 150HU to 1000HU, with the lowest levels in the east, increase westwards. As previously indicated, 750HU or more per growing season is required to sustain crop production. Therefore, the most western portions, which currently receive between 800-1000HU per growing season are the most ideal, with central regions receiving 600-800HU, and this moderately ideally for crop production. It is evident from the landuse map that cultivated croplands are currently located in these areas of the CC. The projected heat unit patterns shown increase from current levels, ranging from 400-1200HU, demonstrating is significant increase. This results in more portions of the CC (particularly in the central and even eastern parts) becoming ideal from crop production from a heat unit perspective. Therefore, the projected implications that climate change is likely to have of heat units received during the growing season is likely to benefit crop production and make more areas appropriate for cultivation.

However, it is important that rainfall and temperature are not assessed in isolation as their combined affects may not paint the perceptions evident above. Despite the projected heat unit increase for the CC, when coupled with the projected rainfall decrease, it is likely to cause unfavourable conditions such as drought, severally impacting the crop production. This is supported by the drought hazard map (Figure 22), where it is evident that the majority of the CC has a high drought hazard risk.

The outcomes of the above projected rainfall and heat unit distribution in relation to the thresholds were used to produce the overall crop productively risk map as demonstrated in Figure 23. This supports the above analysis as it demonstrates that the overall crop productivity risk is highest in the western portions of the CC, with central region having a moderate to high risk. The majority of the CC is projected to have a low crop production risk, however this is evident due to the large portion of grazing lands that are evident. From the landuse map (Figure 14) it is evident that cultivated crop lands are mainly in the western and central portions of the CC, thus indicating that they are at risk. Such high vulnerabilities will affect the yields produced per hectare, thus impacting the livelihoods and subsistence of those who are dependent on such yields.

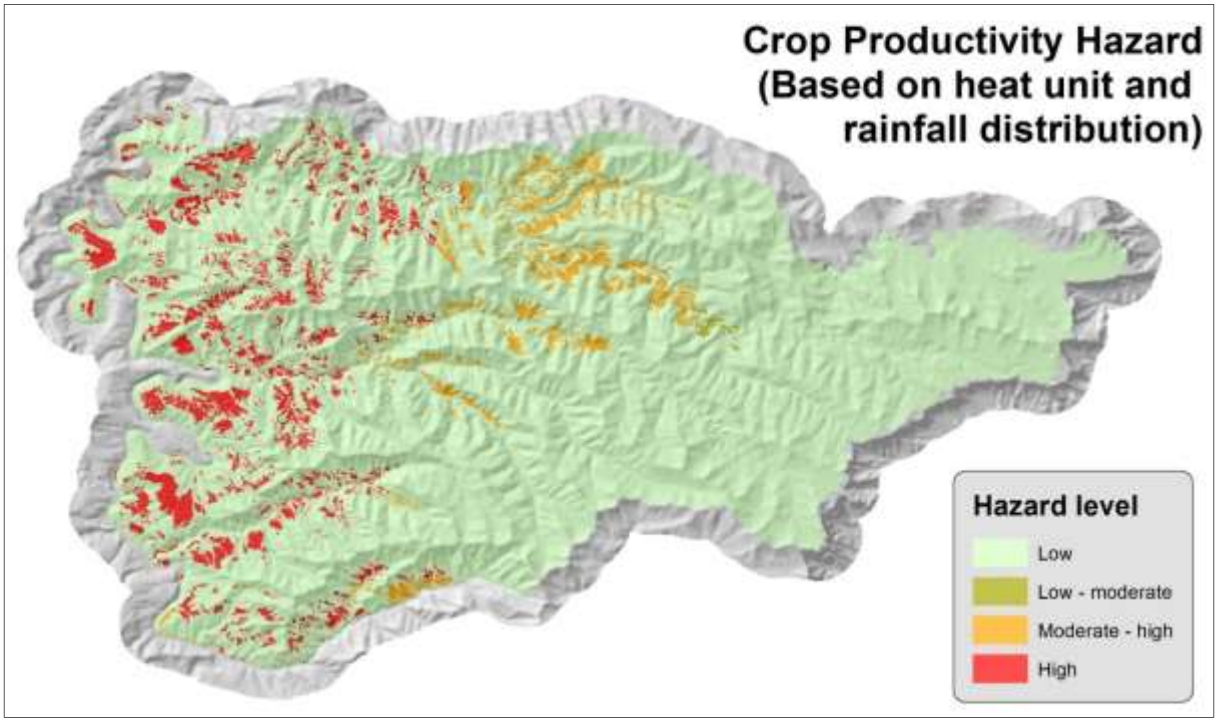


Figure 23: Projected crop production risk (during the growing season) for the Linakeng Community Council for the period 2020-2040 (Data source: CSAG, 2014 and Schulze et al, 2010)

In the face of the changes highlighted above and the associated risk level, the following conclusions are made about the crop production implications of the projected climatic changes and hazards (based on the worst case projection for the 2020-2040 period). These outcomes are deduced from the maps produced as well as the vulnerability review conducted in section 5, and assessed according to the projected climate change hazard.

Table 4: Crop vulnerability to projected climate change hazards in the Linakeng Community Council

HAZARD	RISK LEVEL AND PATTERNS	IMPLICATIONS ON AGRICULTURE (CROPS)
Drought	Wide range of risk level. Eastwards shift of rainfall distribution increase crop vulnerability in western and central portions.	• Rainfed crops unable to withstand dry conditions (no irrigation) • Decrease nutrient content of soil decrease crop yields • Intermittent rainfall patterns are too unstable to allow adequate crop production. • Coupled with flooding activity
Frost	*Unable to project spatially*. Predict decrease winter frost days	• Projected decrease of winter frost days likely to benefit crop yields • Possible early onset or prolonged occurrence of frost days will decrease crop yields, particularly if they extend to the growing season (November- February)
Hail	*Unable to project spatially.* Predict frequency and intensity of hail events	• Damage crops and thus yields • Community do not have the infrastructure or means of protecting crops from hail damage
Flood	Majority low risk, high risk evident in valley regions.	• Unlikely to have severe implications on crop yield. • Flash floods (coupled with drought conditions) are likely to negatively affect crop yields and accelerate erosion.
Snow	*Unable to project spatially.* Increase intensity of snowfall events, however overall decrease on winter snowfall is projected	• Projected prolonged and intense snowfall events will damage any winter crops. • Early onset or prolonged winter conditions are likely to shift snow conditions into the growing seasons and have drastic consequences crop yields
Erosion	Majority high or moderate to high risk. Eastern, central and steep, valley areas of western portions are most vulnerable to erosion.	• Likely loss of croplands due to erosion, combined with dry drought conditions and heavy rainfall events, erosion be spread up • Loss of nutrient rich top soil to erosion, no long good quality soil for cultivation

In addition, it is important to note that projected climate change condition, which are not hazard events, are also likely to impact crop vulnerability and consequential yields. Currently, crop production contributes to 19% of the country's GDP, which is likely to decrease with the onset of climate changes.

Although the increase in temperatures is likely to benefit crop yields, shifting rainfall patterns resulting in drought conditions and intermittent rainfall patterns are projected to negatively impact the sector and thus the overall crop output. Increasing temperatures are likely to bring with them uncommon disease and pests which the community doesn't not have the means to prevent or treat. In addition, the shortening of the growing period due to the likely early onset of prolonged winter conditions (particularly frost) is likely to have negative effects on crop yields. Lastly, damage to crops stemming for the increase of intense, infrequent storms bring heavy rain and hail will contribute to this overall reduction.

The key projected climate change hazards that are likely to have negative implications on the crop (agricultural) sector are **drought**, infrequent **rainfall** patterns, change in **frost** patterns, changing **snowfall** patterns and accelerated **erosion**.

b) Livestock

Livestock is an important component not only for subsistence purposes (milk production, fuel (dung), power (ploughing) and meat, but also for cultural purposes and as back up income generator in times of poor crop production or income decreases. As a result, the livestock sector is also vulnerable to the susceptibility of crop production as decreases of yields will result in the community being forced to consume or sell livestock to meet their basic needs.

Table 5: Livestock vulnerability to projected climate change hazards in the Linakeng Community Council

Hazard	Risk Level and Patterns	Implications on Agriculture (livestock)
Drought	Wide range of risk level. Eastwards shift of rainfall distribution increase crop vulnerability in western and central portions.	• Loss of grasslands due to drought conditions due to accelerated erosion • Water shortages associated with drought conditions – unable to sustain livestock • Force grazing to occur in wetlands and marginal areas, increase grazing pressure and causing soil erosion
Frost	*Unable to project spatially*. Predict decrease winter frost days	• Negatively affect grasslands as other vegetation (shrubs and aliens) are able to encroach – decrease winter grazing availability
Hail	*Unable to project spatially*. Predict frequency and intensity of hail events	• No implication on livestock
Flood	Majority low risk, high risk evident in valley regions.	• Unlikely to have severe implications on livestock • Grasslands may be lost through accelerated soil erosion
Snow	*Unable to project spatially*. Increase winter temperatures cause snowfall decline	• Grasslands dependent on snow for nutrients - decrease winter grazing quality • Snow acts as source of water for livestock in winter - decrease
Erosion	Majority high or moderate to high risk. Eastern, central and steep, valley areas of western portions are most vulnerable to erosion.	• Infrequent and intense rainfall activity combined with drought conditions and existing erosion vulnerability is likely to accelerate erosion, degrading vital grasslands for livestock production (decrease carrying capacity)

In additional, the likelihood of tropical conditions occurring due to projected increase temperature may spark disease and pests outbreaks among livestock. Local communities are not equipped to prevent or treat such diseases and thus pose a huge threat to the livestock agricultural sector.

The key projected climate change hazards that are likely to have negative implications on the livestock (agricultural) sector are **drought**, decreased winter **frost**, decrease **snow** activity and accelerated **erosion**.

7.3.2. Water Supply

Water supply ranges in its sources from rivers, dams, wetlands to springs. It is difficult to predict that change in water sources supply due to the lack of spatial data pertaining to such sources, particularly springs, which are one of the primary water source points for local communities. For these reasons, water supply has been deduced from the average annual rainfall projections depicted at the beginning of this section. Deductions can be made about the projected shift in rainfall patterns and the likely impacts that climate change hazards are projected to have on the overall water supply in the community council.

a) Water

The overall water shortages projected in the face of climate change not only affect the supply needs (quantity), but also the quality of water. Stagnant water in such periods are also likely to be the source of uncommon diseases that the region is not able to withstand. It is important to note that water supply is a key sector and the basis of all life, and thus impacts all of the other sectors.

Table 6: Water Supply vulnerability to projected climate change hazards in the Linakeng Community Council

Hazard	Risk Level and Patterns	Implications on Water Supply
Drought	Wide range of risk level. Eastwards shift of rainfall distribution increase vulnerability in western and central portions.	• Short and long term water shortages, particularly in winter months where rainfall in already low and snowfall is the main source of water • Intermittent rainfall activity thought to worse this issue
Frost	*Unable to project spatially*. Predict decrease winter frost days	• No implication
Hail	*Unable to project spatially.* Predict frequency and intensity of hail events	• No implication
Flood	Majority low risk, high risk evident in valley regions.	• Shift in rainfall patterns resulting in western portions receiving less rainfall, however not low enough to pose a significant implication
Snow	*Unable to project spatially*. Increase winter temperatures cause snowfall decline.	• Decline in water availability in winter months
Erosion	Majority high or moderate to high risk. Eastern, central and steep, valley areas of western portions are most vulnerable to erosion.	• Erosion causes siltation of water systems, decreasing the storage capacity thus affect quantity • Siltation negatively affects the quality of water

As water is a dynamic resource that is shared by a variety of users, it is evident that the implications on the resource in this area are likely to affect those downstream as well as the local community. Therefore, implications such as the siltation of water systems due to accelerated erosion will not only decrease the quality and quality of water for downstream users, but also the overall storage capacity of the greater water systems, resulting in cumulative implications.

The key projected climate change hazards that are likely to have negative implications on the water supply sector are **drought**, decrease **snow** activity and accelerated **erosion**.

b) Hydro-politics

Hydro-politics is directly impact by the water supply discussion above due the countries dependence on the transfer scheme as an income generator. Water shortages will not negatively impact that economic component, but the countries relationship with South Africa. Such negative implications will have ripple effects into other components such a government spending on communities such as Linakeng.

7.3.3. Natural Resources

The natural resources sector is broken down into three subcomponents, namely soil, biodiversity and vegetation (predominantly grasslands).

a) Soil

The implications on soil not only negatively affect the natural environmental, but the degradation of its quality and quantity will affect other key sectors that are reliant on the natural resource. The greatest implications will most likely be felt by the agriculture (both crops and livestock) sector.

Table 7: Soil vulnerability to projected climate change hazards in the Linakeng Community Council

Hazard	Risk Level and Patterns	Implications on Soil
Drought	Wide range of risk level. Eastwards shift of rainfall distribution increase vulnerability in western and central portions.	• Water decreases (particularly in western portions) will dry out soil, making it more susceptible to erosion • Combined with intense, infrequent rainfall events, this is likely to be accelerated resulting in the loss of nutrient rich topsoil
Frost	*Unable to project spatially*. Predict decrease winter frost days	• No implication
Hail	*Unable to project spatially. P*redict frequency and intensity of hail events	• Possible that heavy hail storms may accelerate soil erosion
Flood	Majority low risk, high risk evident in valley regions.	• Flooding may not have significant risk as majority of the area has a low vulnerability. However, intense and infrequent rainfall activity is likely to accelerate erosion
Snow	*Unable to project spatially*. Increase winter temperatures cause snowfall decline	• Projected heavy snowfall activity may accelerate erosion as large bodies of snow move and dislodge soil. • Rapid melting of snow due to increased winter temperatures may cause flood like activity, thus accelerating erosion
Erosion	Majority high or moderate to high risk. Eastern, central and steep, valley areas of western portions are most vulnerable to erosion.	• Erosion vulnerability likely to affect the quality and quality of soil as climate changes

The key projected climate change hazards that are likely to have negative implications on the soil subcomponent are **drought**, intense **hailstorms**, **flood** (particularly heavy rainfall activity), heavy **snow** activity and accelerated **erosion**.

b) Biodiversity

Biodiversity is a key component in terms of its use for medicinal and cultural purposes as well for the tourism industry. Such species are greatly affected by climate changes, particularly those who are unable to adapt, allowing easily adaptable alien species to encroach. Mountainous regions, such as the Linakeng community council, are particularly known for having high levels of endemism and are thus of high value and consequential vulnerability.

Changing in climate results in indigenous species not being able to adapt - alien invasive species likely to become dominant and encroach on important biodiversity.

Table 8: Biodiversity vulnerability to projected climate change hazards in the Linakeng Community Council

Hazard	Risk Level and Patterns	Implications on Biodiversity
Drought	Wide range of risk level. Eastwards shift of rainfall distribution increase vulnerability in western and central portions.	• Insufficient water supply will negatively affect indigenous species • Increased temperatures result in indigenous species unable to adapt, encroachment of alien species • May have positive implications as always for species diversity and migration into regions that are not currently suitable
Frost	*Unable to project spatially*. Predict decrease winter frost days	• Decrease in winter frost days may positively affect species diversity and migration as more regions become inhabitable. However, this may allow for alien to encroach and thus negatively implicate indigenous species.
Hail	*Unable to project spatially.* Predict frequency and intensity of hail events	• Heavy and increased hail storm activity likely to damage indigenous species
Flood	Majority low risk, high risk evident in valley regions.	• Severe flooding likely to negatively affect biodiversity, however the risk is low and thus no major flooding implication projected
Snow	*Unable to project spatially*. Increase winter temperatures cause snowfall decline	• Severe snow conditions likely to negatively impact species • Decrease winter snow may allow a diversity and migration of indigenous species – however, this may also allow aliens to encroach
Erosion	Majority high or moderate to high risk. Eastern, central and steep, valley areas of western portions are most vulnerable to erosion.	• Accelerated erosion causes loss of soil quality and quantity that indigenous species require to survive

The key projected climate change hazards that are likely to have negative implications on the biodiversity are **drought**, **hailstorms**, **flood**, sever **snow** activity and accelerated **erosion**. The increase in winter temperatures and consequential decrease of frost and snow activity may positively impact the sector through species migration and diversity, however this may also be negative due to the increased ability of alien species to encroach and take over.

c) Vegetation

As previously indicated, the most predominant vegetation type in Lesotho is grassland biomes, which is evident in the Linakeng Community Council. The majority of grasslands are used for grazing purposes, which makes their vulnerability similar to that of livestock, who are largely dependent on the resource for survival. For this reason, the vulnerability of grasslands will not be demonstrated as it this analysis had been covered in the livestock (agricultural) sector vulnerability.

7.3.4. Forestry

As seen in the land use map (Figure 14), there is little forestry, both planted woodlots and natural woody vegetation, evident in the Linakeng Community Council. For this reason, a vulnerability analysis of the sector is not conducted.

7.3.5. Socio-Economics (Health and Basotho culture)

As previously indicated, the socio-economic sector is directly affected by the vulnerability of the other four key sectors. Therefore, the agriculture (crop and livestock) sector vulnerability will not only affect the local community in terms of yields outputs for subsistence purposes, but also impact economic incomes generated from local markets. Natural resource vulnerability affects the community directly in terms of their use of grasslands for livestock productions as well as the extraction of indigenous plants species for various purposes. However, indirect implications are also evident as natural resources sustain other sectors, particularly agriculture, which the community is almost entirely dependent on. The water supply sector is vital to not only directly support the socio-economic sector, but also sustains all the other key sectors, and thus the vulnerability of the two sectors are intertwined. As previously indicated, there is minimal forestry evident in the community council and its vulnerability cannot be determined. Although it is likely that the community does rely on this sector of domestic purposes, its coverage is very small.

In addition the above implications of the other sectors, the socio-economics are also vulnerable to the following subcomponents.

a) Health

With projected temperature increases expected for the community council, the climate is likely to shift to tropical conditions, making way for uncommon diseases that the population is not immune to or have the means to treat such threats. This is likely to negatively affect the health of the community with negative spinoffs into other sectors such as agriculture, where an able labour force is vital.

As previously demonstrated, projected drought, possible flood and even siltation conditions will negative impact that quality of water supply for the community council. This too could negative impact that health of the population by means of water borne diseases such as typhoid and cholera.

Secondary impacts from other sectors are also likely to impact the health of the population. For example, decreases agricultural yields and quality result in subsistence production having a low nutrient content and this not being sufficient to adequately sustain the population.

b) Basotho Culture

The Basotho culture is based only based on the natural assets of the country, but cultural wealth which is measured in livestock. For this reason, the culture sub-components are directly affected by the negative implications that climate change projections are likely to have on the agricultural (livestock) vulnerability. In addition, cultural practices stem from the use of indigenous plants species and thus the sector is susceptible to the vulnerability of the natural resources (especially biodiversity) sector.

For this reason, the vulnerability of the cultural component is likely to be susceptible to the vulnerability of the livestock (agriculture) and natural resources sectors.

c) Economics

Economic implications of projected climate changes stem from the implications that changes are likely to have on the key sectors. One of the most prominent implications stems from the vulnerability of the agricultural sector, which the majority of the population are highly dependent on from both a subsistence and income generating perspective. This sector currently contributes to 19% of the county’s GDP and thus a reduction in crop outputs will have severe implications. As only a small portion of the community council is used for crop production, negative implications on the sub-sector are likely to several affect the income it generates.

Livestock is the most dominant for of agriculture in the community council, and thus a vital component of the populations’ subsistence and economic profile. As a result, the vulnerability of this sector is likely to dramatically affect the region’s economy either directly through decrease yields, or indirectly as farmers are forced to sell livestock (assets) in times of economic stress and low crop yields.

8. Hotpot Vulnerability Analysis

This section aims to reveal the overall projected climate change implications for the community council by producing a hotpot vulnerability map. This is produced by overlaying the vulnerabilities of all the key sectors and projected climatic changes to pin point the most vulnerable areas for management and planning purposes. This enables the identification of priority areas in terms of hazard prone areas. The hotpot vulnerability map has been produced by overlaying and weighting the climate change projection and hazard vulnerably maps displayed in Section 7.

8.1. Hotpot Vulnerability Mapping: Linakeng Community Council

The Linakeng hotpot vulnerably map demonstrated below (Figure 24) instantly provides a clear understanding of the areas in the community council that have the highest level of risk (red/orange). Displaying similar patterns to those of the sector vulnerability analysis conducted in the previous section (Section 7.1: Overview of Climate Change Projection), it is evident areas in the western portion of the CC are most vulnerable. Such areas are predominately in the low-lying, flat and valley portions, which are likely to be used for grazing and cultivation, placing such areas at a higher risk. The remaining western, the majority of the central regions, are considered to have moderate to high vulnerability. Finally, the eastern, highland regions demonstrate the least overall vulnerability, due to their low risk level in the face of projected climate change.

Those areas classified as “high risk” consist of settlements, cultivated crop lands and heavily utilised grazelands that are in close proximity to the main towns. Therefore, the risk level does not only stem from on the projected shift of rainfall and temperature patterns and hazard implications, but also due to the heavily reliance that the population place on those low-lying and valley areas. These high level areas need to be prioritised in terms or risk management and planning, to avoid projected implications on all the key sectors.

The majority of the central regions of Linakeng are classified as having an overall “moderate to high risk” level, demonstrating that they too are susceptible to projected changes. These regions are not as highly utilised as those in the lower lying areas, however they are particularly important from a grazing perceptive. As livestock is such key subsistence, economic and cultural assets, these areas need to be addressed in terms of their vulnerability to likely climate change projections.

Lastly, the eastern portion of the community council displays “low to moderate risk” area thus is not particularly vulnerable to climate change implications. This is primary due to its location in the highland regions, which are unlikely to experience the increase in temperatures and decrease in rainfall patterns that are projected. In addition, these areas are largely underutilised due to their remote location and inaccessibility, resulting in there being little to no risk to the majority of the key sectors. There are small portions of the eastern region that demonstrate a small level of risk, predominantly in the valley regions. This is likely due to the vulnerability of these low lying areas implications such as hazards and water shortages.

In conclusion, the projected climate change hotspot vulnerability areas for the Linakeng Community Council are primarily centred around the two main towns, incorporating agricultural lands where exiting pressure is evident. This, combined with the climate change projections in terms of changing rainfall and temperature patterns and the likely hazard events, results in areas that need to be prioritised for disaster and risk management planning.

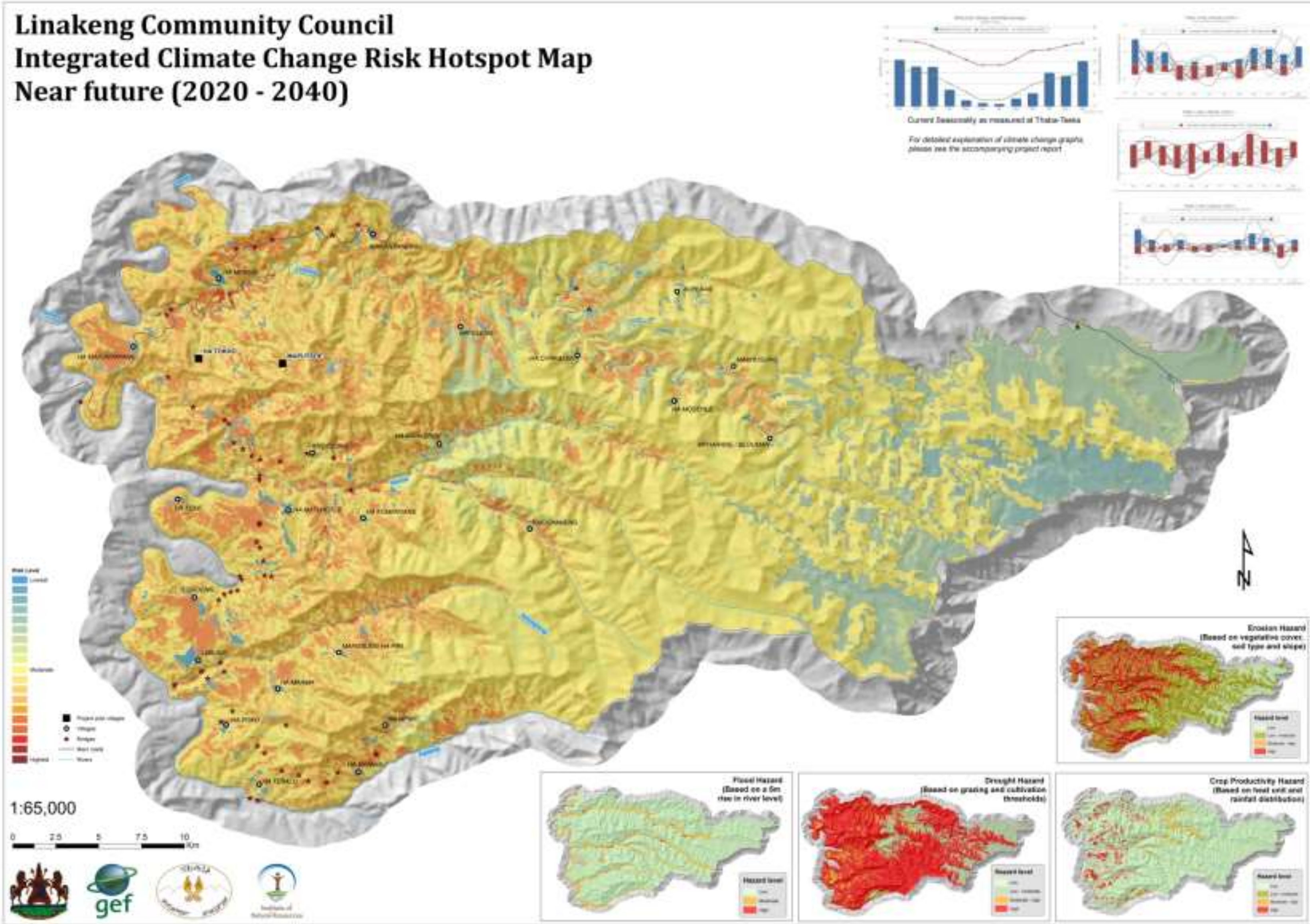


Figure 24: Linakeng Community Council projected climate change hotpot vulnerability map for the 2020-2040 Period (worst case projection)

9. Planning and Prioritisation to Reduce the Impacts and Vulnerability to Climate Change

Stakeholder engagement was conducted through which members of target community council were initially engaged, after which district level stakeholder were consulted. The stakeholder engagement process was conducted through a series of workshops and meetings with the following stakeholders:

- District Level Stakeholders: District Administrators (DAs), District Council Sectaries (DCs) and Head of Departments (HoDs) from various sectors including civil society organisations (CSOs) and the media in the project pilot sites.
- Community Level Stakeholders

Summary of Observations

- It was evident from multi-stakeholder consultation processes that the impacts of climate change on the biophysical environment and the livelihoods of Basotho have been quite severe. Specific examples to cite in this regard include inter-alia; reduced agricultural yields over the years, declining livestock productivity, accelerated soil erosion and general degradation of rangelands, arable land and wetland ecosystems. Most of the issues contained in the contingency plans (from which priority adaptation actions identified and incorporated into concepts for fundable projects), highlight the fact that Basotho now realize that they need to make the necessary adjustments in order to cope and adapt to the rapidly changing climatic conditions.
- The district level consultations revealed that in order for Lesotho to successfully implement its programme of action towards adapting to the potential impacts of climate change, and to effectively integrate climate change into its development plans and policies across the various sectors; it is imperative for the country to rely on feedback from scientific research and climate modelling to guide her development efforts. This is justified by the fact that stakeholders, especially from district level, highlighted the need for LMS to produce the developed vulnerability maps and tools, and make them available to assist in planning processes in various sectors. These tools shall assist the various government departments to justify why certain developments are recommended for selected priority hotspots, as informed by the vulnerability mapping process.

Challenges

- The recent development by the government of Lesotho to newly demarcate the Community Council boundaries in respect of aligning with the Constituency boundaries has caused uncertainty in data and about jurisdiction.
- In areas where the delineation of authority between Local and Central Government authorities is not clearly outlined, or due to ill-defined working relations between the two parties, especially at district level; the process of disseminating information to the target audiences can potentially be challenging and risky. For example, in scenarios where the District Administrator (DA) and

District Council Secretary (DCS) do not get along well; it may become a challenge for either party to have full authority over either local government staff or central government personnel.

- From consultations with the project stakeholders, the following recommendations can be made by the project team, in view of improving service delivery to the ordinary Basotho citizens:
  - Accessibility of the relevant policies and guidelines to the Community Councils, in the language they understand best, is critical to enhance their operational effectiveness. This coupled with the necessary trainings and capacity building efforts can go a long way towards deepening the decentralization process so eagerly anticipated by the masses, to improve the socio-economic and political development pathway for Lesotho.
  - Stakeholders recognize the importance of integrating Indigenous Knowledge Systems (IKS) to the Early Warning System promoted by LMS in respect of climate change and towards implementation of the necessary early actions.
  - Stakeholders recognized the importance of external influence from non-state actors in influencing policy review and form. The involvement of civil society organizations in climate change issues should therefore not be overlooked in stakeholder profiling.

9.1. Contingency Planning

Contingency planning is a management process conducted to analyse the potential events or conditions that a society or environmental are likely to be susceptible to. The aim is to establishing agreements in advance to enable effective, appropriate and timely responses to such situations. This process enables key actors to anticipate, envision and solve problems before they occur, enhancing their preparedness.

Using the information from awareness creation, the developed vulnerability maps, training cards and the planning matrix; the CCs were able to develop contingency plans. The contingency plans were then taken to district level stakeholders (HoDs) for validation and further refinement.

Linakeng Community Council has most parts of the council nested in the mountains while some villages are along the Senqu River. Both zones are characterized by very fragile ecosystems and therefore are highly vulnerable to erosion. Thus, the vulnerability maps depict a serious problem of soil erosion, with predictions painting a gloomy picture in the near future if the status quo is maintained especially regarding land use and land management practices. Depletion of rangelands also came strongly as another major concern especially because most people in the highlands derive livelihoods from livestock production. With predicted drought conditions rangelands will continue to be under threat and livestock production will decline. This goes as well for crop production where the problem will be compounded by loss of arable land. All these are envisaged to culminate in chronic food shortages and hence food insecurity for many households dependent on subsistence agriculture. Furthermore, with predicted decrease in average annual rainfall as well as drought, water resources are also expected to be severely affected. It is against this backdrop that the Linakeng Community Council has planned to address problems of land degradation as a result of increased rate of soil erosion; desertification due to loss of biodiversity and vegetative cover; food insecurity as a result of declining agricultural output both in terms of animal and crop production and diminishing water resources.

Planned Interventions based on mapped vulnerabilities:

1. Strengthening Watershed Management Plans for soil erosion control and Rangeland Management
    - Construction of stone lines across dongas
    - Tree planting
    - Reseeding denuded rangelands with palatable species
    - Terracing steep slopes along cropping lands
    - Development of grazing plans with stakeholders
    - Formation of grazing schemes
    - Development of land use plans
2. Protection of Wetlands and other Water Resources
    - Identify and map wetlands and other sources of water throughout the Community Council
    - Develop water resources management plan with stakeholders
    - Implement Water Resources Management Plan
3. Improvement of Crop Production
    - Promote application of indigenous knowledge to protect crops
    - Promote Conservation Agriculture
    - Promote Protected Agriculture Technologies such as Greenhouse & cold frames/hotbeds for vegetable production
    - Promote low-cost Irrigation Methods
4. Improvement of Livestock Production
    - Promote fodder production on marginal lands
    - Improve breeding stock for production of quality wool and mohair
    - Lobby for establishment of District-level Livestock Breeding Centres
5. Improvement of Water and Sanitation Facilities
    - Protect natural springs and wells
    - Construct boreholes at village level for better access to clean drinking water
    - Construct water storage tanks and improve supply of piped water to villages
    - Promote construction of Ventilation Improved Pit-latrines

9.2. SWOT Analysis

A SWOT analysis (strengths, weaknesses, opportunities and threats) was conducted for the site to address identified climate change vulnerabilities including early warning and early actions. The district level stakeholders conducted a SWOT analysis based on the contingency plans to assess the level of preparedness of to address the identified climate change vulnerabilities including early warning and early actions. The aim of this analysis is to assess the level of preparedness to address the vulnerabilities. A SWOT analysis was conducted for the spatially mapped climate change hazards, as demonstrated in the tables below.

Table 9 - SWOT Analysis - Drought

STRENGTHS **Helpful –** *Status of the internal driving forces enhancing achievement of the objective*	***WEAKNESSES*** **Harmful –** *Status of the internal driving forces impeding achievement of the objective*
• Strong technical capacity within the Lesotho Meteorological Services • Involvement of different Line Ministries in Disaster Management Working Groups • Good communication infrastructure for information dissemination • Availability of Drought Disaster Preparedness Plan • Existence of Departments such as Disaster Management Authority and Department of Crops • Establishment of a Multi-sectoral National Climate Change Committee	• No clear mechanisms to plan with and report back to communities (highly centralized services-decentralization not effective) • Ineffective communication and information sharing with local authorities and other grassroots level structures • Inability to use available water resources effectively and efficiently • No mechanism in place to enable collaboration between the different sectors and therefore uncoordinated efforts • Poor governance practices/systems • Inherent culture of spending resources on developing plans that are never implemented
OPPORTUNITIES **Helpful** – *Status of external driving forces enhancing achievement of the objective*	***THREATS*** **Harmful –** *Status of external driving forces impeding achievement of the objective*
• Good water resources enhancing the position of the Country for transboudary water transfer schemes in support of IWRM • Possibility of increasing crop production coverage for certain crops • Topography that supports relatively low cost gravity-fed type of irrigation • LMS Climate Change Section which can source funds to go beyond point of implementation of the current Improvement of Early Warning Systems Project • Climate Change Policy yet to be developed • Expansion of block farming presenting an opportunity for irrigated crop production • MAFS & EIF promoted protected agricultural production practices (greenhouse tunnels) to enhance high value cash crops production.	• Lack of financial resources to build infrastructure to support irrigation • High possibility of outbreaks of water-borne diseases such as cholera and typhoid • Possibility of continued land transformation as the maps point to non-arable, high lying areas receiving better rains in future • Non-existence of legally constituted national coordinating bodies such as the National Research Council, National Planning Board etc, which in essence have to be mandated to coordinate and oversee emerging development issues. • Reduction in water quality and quantity due to siltation of water bodies and eutrophication • Loss of fish and other aquatic organisms • Loss of opportunity to use water for recreational activities i.e. fly fishing and canoeing. • Potential water resources use conflicts

Table 10 - SWOT Analysis - Floods

STRENGTHS **Helpful –** *Status of the internal driving forces enhancing achievement of the objective*	***WEAKNESSES*** **Harmful –** *Status of the internal driving forces impeding achievement of the objective*
• Good Communication infrastructure • Presence of the Disaster Management Authority • Presence of the Disaster Management Working Groups involving the different line ministries • Presence of Village Disaster Management Teams	• Poor land use planning • Unsustainable land management practices • Under preparedness in terms of establishment and capacity building of structures to deal with disasters • Poor public awareness and education services
OPPORTUNITIES **Helpful** – *Status of external driving forces enhancing achievement of the objective*	***THREATS*** **Harmful –** *Status of external driving forces impeding achievement of the objective*
• Presence of UN Agencies and international NGOs providing support in emergency operations and relief services • Topography of the Country and therefore lower risks of floods • Deposition of fertile alluvial soils on the flood plains	• Lack of financial resources to address anticipated disasters • Lack of technical capacity to respond timely and adequately to disasters • Possibility of damage to water bodies • Current NSDP not informed by predictions to inform appropriate and responsive measures • High possibility of damage to the already unstable roads infrastructure and networks

Table 11 - SWOT Analysis - Increasing Temperature (Heat Units - based on crop productivity)

STRENGTHS **Helpful –** *Status of the internal driving forces enhancing achievement of the objective*	***WEAKNESSES*** **Harmful –** *Status of the internal driving forces impeding achievement of the objective*
• Existence of decentralized Agricultural Resource Centers across the country • Expertise within the Departments of Crops and Agricultural Research	• Poor agricultural research facilities to take advantage of the situation and make trials on different crops • Weak agricultural extension services due to lack of capacity of the extension officers • Poor linkages among the different departments within MAFS at National level • Inadequately resourced Agricultural Resource Centers
OPPORTUNITIES **Helpful** – *Status of external driving forces enhancing achievement of the objective*	***THREATS*** **Harmful –** *Status of external driving forces impeding achievement of the objective*
• Presence of many role players such as NGOs supporting the agricultural sector • Possibility of production of a variety of food crops	• Possibility of introduction of unknown plant pests which will take time to put under control. Moreover, need to increase use of pesticides to control pests, which will pose a threat to water bodies and aquatic life forms. • High possibility of extinction of indigenous flora and fauna

Table 12 - SWOT Analysis - Soil Erosion

STRENGTHS **Helpful** – *Status of the internal driving forces enhancing achievement of the objective*	***WEAKNESSES*** **Harmful –** *Status of the internal driving forces impeding achievement of the objective*
• Good collaboration among MFLR departments enhancing holistic implementation of Integrated Watershed Management plans • Strong engagement of MFLR in the implementation of the project on Improvement of Early Warning Systems • Engagement of communities in implementation of Watershed Management Plans • Good collaboration between LMS, MFLR and other stakeholders	• Inadequate legislation addressing range management which is the main contributing factor to land degradation through overgrazing • Poor law enforcement • Poor land use planning • Unsustainable land management practices • Politicized watershed management activities • Catchment management strategy highly linked to cash for work results in overshadow of the importance of land rehabilitation and sustainable utilization of natural resources.
OPPORTUNITIES **Helpful** – *Status of external driving forces enhancing achievement of the objective*	***THREATS*** **Harmful –** *Status of external driving forces impeding achievement of the objective*
• Availability of watershed management plan within the Ministry of Forestry and Land Reclamation • Good collaboration of the different Departments in the Ministry of Forestry and Land Reclamation on issues of Watershed Management • MTICM perceived introduction of market centres to possibly include livestock auction centres (promote marketing of livestock)	• Fragile mountainous ecosystem and topography that gets easily eroded • Lack of political will to address legislation & policies • Improper infrastructure planning and inability to counteract negative externalities of certain projects on the environment e.g. quarrying and roads construction

9.3. Fundable Projects

The district level stakeholders conducted a SWOT analysis based on the contingency plans to assess the level of preparedness to address the identified climate change vulnerabilities and hazards. The national and district level properties and needs were then evaluated to identify fundable project concepts that could be implemented at council level (Table 13).

Table 13: Fundable Projects Associated with National and Regional Priorities

PRIORITIES	FUNDABLE PROJECTS
1. Water Resources Management	• Water harvesting (roof water harvesting, construction of earth dams/ponds, spring protection, stone built tanks – gravity fed etc.) • Fisheries projects • Irrigation • Wetlands protection & rehabilitation • Domestic water supply • Water supply infrastructure rehabilitation & network expansion • Trainings & capacity building
2. Livestock Production & Range Management	• Animal health & nutrition • Wool & mohair marketing • Improvement of breeding stock • Establishment of abattoirs • Rangeland rehabilitation & management • Fodder production
3. Crop Production	• Research & development investments • Plant protection • Horticulture (market oriented production) • Crop diversification • Fruit production (stone and pome fruits) • Strengthening of Agric. Extension Services • Promote Conservation Agriculture (CA)
4. Biodiversity & Soil Conservation	• Protected areas conservation (national parks, botanical gardens, Transfrontier Conservation Areas (TFCAs), nature reserves etc.) • Ecosystems approach & sustainable utilization • Policy reform and law enforcement • Implementation of IWRM plans
5. Clean Energy Technologies & Early Warning	• Promote widespread use of solar technologies • Introduction of wind power • Hydropower generation • Awareness campaigns • Capacity building – climate change and early warning, including early actions • Strengthening of institutional mechanisms

10. Toolkit

The outcomes of this project are used to generate a toolkit, which can be used for planning, management and training purposes. The toolkit consists of the following:

- **Vulnerability Mapping Report** (this report): provides an in-depth overview of the project (background, process, findings)
- **Downscaled Climate Change Projections**: CSAG website link with step-by-step instructions and background user guide
- **Metadata**: all maps generated for the project.
- **Basic GIS program** which allows minor GIS functions (such as pan, zoom and query) as well as the ability to overlay data on Google Earth© imagery.

In addition to the above, the *Vulnerability Mapping Training Kit* which was used to conduct the training and stakeholder consultation is included, which comprises:

- **Training Cards**: English and Sesotho
- **USAID Booklet**: *Benefiting from the Environment in a Changing Climate*
- **LMS Climate Change Awareness Posters**
- **LMS Climate Change Brochures**
- **LMS Climate Change video**
- **Introductory PowerPoint Presentations**
- **Contingency Planning Matrix**

This toolkit is compiled on the CD attached to this report.

References

Bisaro, S. (2007). Formal and Informal Institutions in the wetlands of the Lesotho Highlands, *Potsdam Institute for Climate Impact Research,* Potsdam, Germany

Cheke, R. A. (November 2012). Report on a Consultancy for the Africa Adaptation Programme on Possible Climate Change Effects on Health in Lesotho: Technical Report, *Natural Resources Institute*, University of Greenwich at Medway

CSAG. (2014). Climate Information Platform, *Climate System Analysis Group*, University of Cape Town, accessed on 16 April 2014 at: http://cip.csag.uct.ac.za/webclient2/app/

CSAG[1]. (January 2014). Background to Using the Climate Information Portal: User Focus Lesotho, *Climate System Analysis Group*, University of Cape Town

Dejene, A., Midgley, S., Marake, M. V., and Ramasamy, S. (2011). Strengthening Capacity for Climate Change Adaptation in Agriculture: Experience and Lessons from Lesotho, *Food and Agriculture Organization of the United Nations*

Du Plessis, J. (2003). Maize Production, *ARC-Grain Crops Institute*, Department of Agriculture, South Africa

FAO. (2010). Global Forest Resources Assessment 2010: Country Report - LESOTHO, *Food and Agriculture Organization of the United Nations: Forestry Department*, Rome

First Country Report to the COP. (no date). Biological Diversity in Lesotho: Convention on Biological Diversity.

Global Environmental Facility. (January 2013). Strengthening Capacity for Climate Change Adaption through Support to Integrate Watershed Management, Food and Agriculture Organization of the United Nations

Gwimbi, P., Thomas, T. S., Hachigonta, S., and Sibanda, L. M. (2013). Chapter 4: Lesotho, *Southern African Agriculture and Climate Change: A Comprehensive Analysis*, International Food Policy Research Institute (IFPRI)

Hall, D. and Jennings, G. (2007). Demographic and Economic Activity in the four Orange Basin States, *Orange River Integrated Water Resources Management Plan*

Heath, R. and Brown, C. (2007). Environmental Considerations Pertaining to the Orange River, *Orange River Integrated Water Resources Management Plan.*

Kirkman, K., and Lewis, F. (2013). Rangelands of Lesotho: Community Based Rangeland Management to Protect and Restore a Critical National Resource and an International Asset, *Draft Report*

Lesotho Meteorological Services. (April 2000). National Report on Climate Change: Lesotho, *Ministry of Natural Resources*, First National Communication to the Conference of the Parties to the United Nations Framework Convention on Climate Change

Lesotho Meteorological Services. (July 2007). Lesotho's National Adaptation Programme of Action (NAPA) on Climate Change, *Ministry of Natural Resources*, United Nations Framework Convention on Climate Change

Lesotho Meteorological Services. (November 2001). Climate change in Lesotho: A Handbook for Practitioners

Matarira, C. H., Pullanikkatil, D., Kaseke, T., Shava, E., and Manatsa, D. (2013). Socio-Economic Impacts of Climate Change on Subsistence Communities: Some Observations from Lesotho, *International Journal of Climate Change Strategies and Management*, Vol. 5:Iss. 4, pp.404 - 417

MFLR. (March 2014). Types of Forests in Lesotho, *Ministry of Forestry and Land Reclamation*

Mhlanga, M. L. (June 2004). Adaptation to Climate Change: Technology Needs in Lesotho*, Lesotho Meteorological Services,* Ministry of Natural Resources: Energy and Land Use Change and Forestry

Ministry of Forestry and Land Reclamation. (2011). National Range Resources Management Policy

Ministry of Natural Resources. (2010). Interim Strategy for the Water and Sanitation Sector

Mokorosi, P. and Matete, M. (March 2009). IWRM Survey and Status Report: Kingdom of Lesotho, *Global Water Partnership: South Africa*

SADAC. (2013). Assessment of the Regional Water Policy: Country Report, *Global Water Partnership: South Africa,* Kingdom of Lesotho

Schulze, R.E., Maharaj, M., Warburton, M. L., Gers, C. J., Horan, M. J. C., Kunz, R. P., and Clark, D. J. (2008). South African Atlas of Climatology and Agrohydrology, *Water Research Commission*, South Africa.

Schulze, R. E. (2010). Atlas of Climate Change and the South African Agricultural Sector: A 2010 Perspective, *Department of Agriculture, Forestry and Fisheries*, Pretoria, South Africs

Smith, B. (2006). The Farming Handbook, *the Technical Centre for Agricultural and Rural Cooperation (CTA),* University of KwaZulu-Natal Press, South Africa

UNISDR. (2009). Terminology on Disaster Risk Reduction, *United Nations International Strategy on Disaster Risk Reduction*

Water Commission Report. (2007). Roadmap to Completing Integrated Water Resources Management and Water Efficiency Planning in Lesotho.

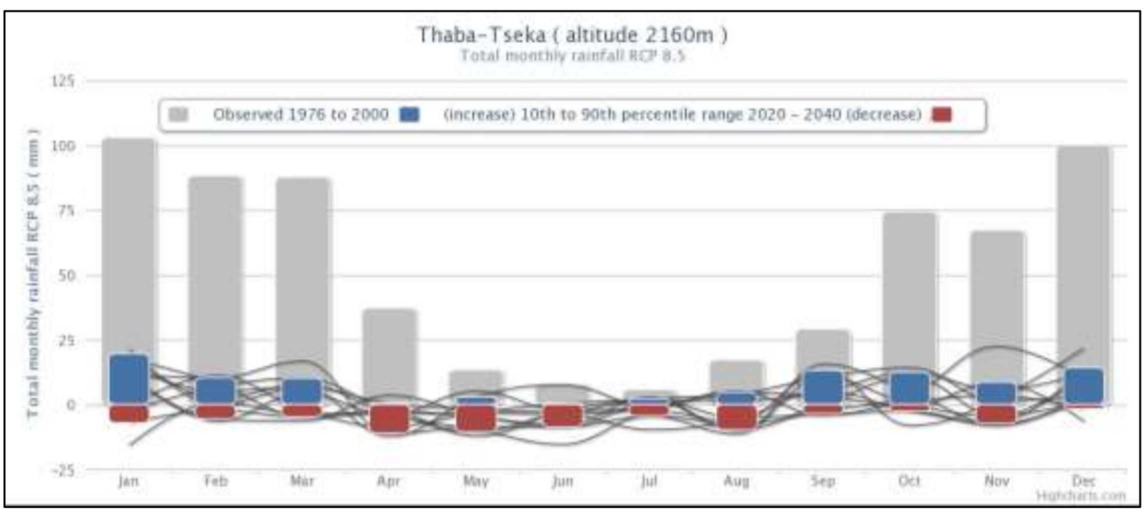
WMO. (2014). Natural Hazards, *World Metrological Organisation*, accessed at: http://www.wmo.int/pages/publications/showcase/documents/hazards_wmd.pdf

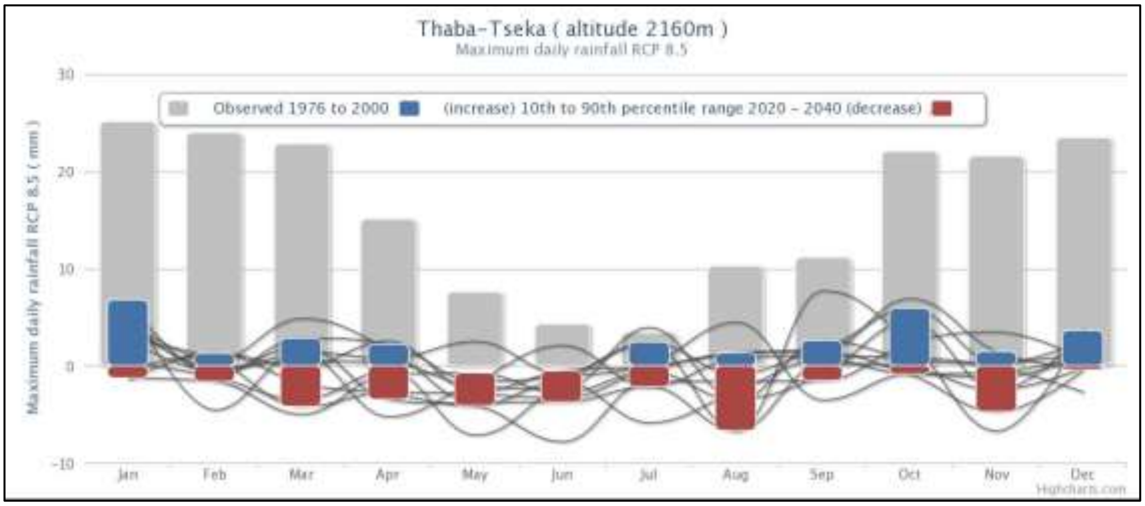
Annex 1: Downscaled Climate Change Projections

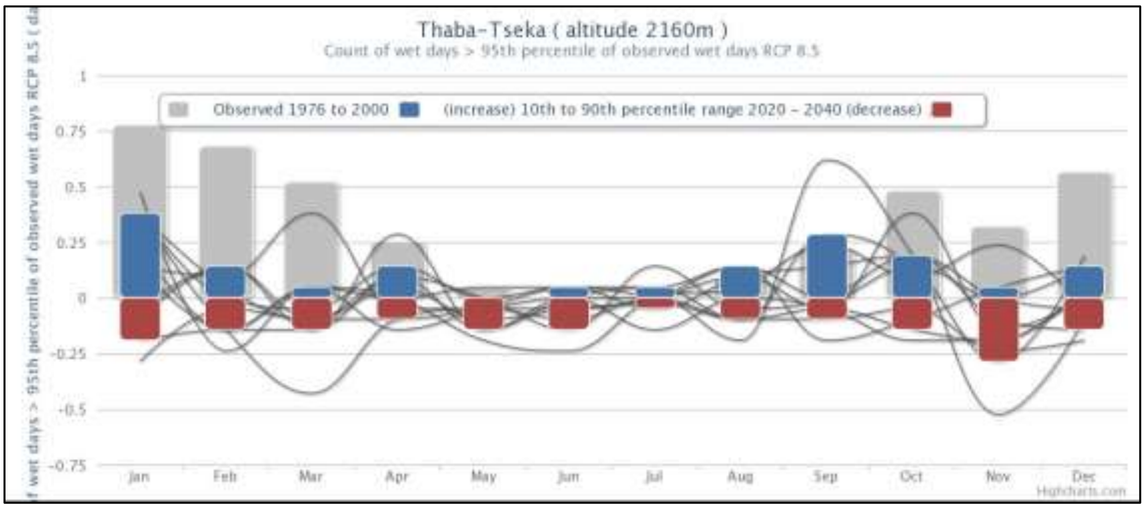
The CSGA (2014) downscaling climate change projections were used to identify the likelihood of hazards occurring in the Linakeng Community Council. The graphs justify this likelihood to determine which maps are produced for the vulnerability analysis. Each graph demonstrates the projected monthly increase or decreases of the climatic variable, for the 2020-2040 periods, give the worst case projection. The historical (current) climate anomalies are also demonstrated on the graphs as a comparison against projected changes. The graphs extracted for each Community Council were:

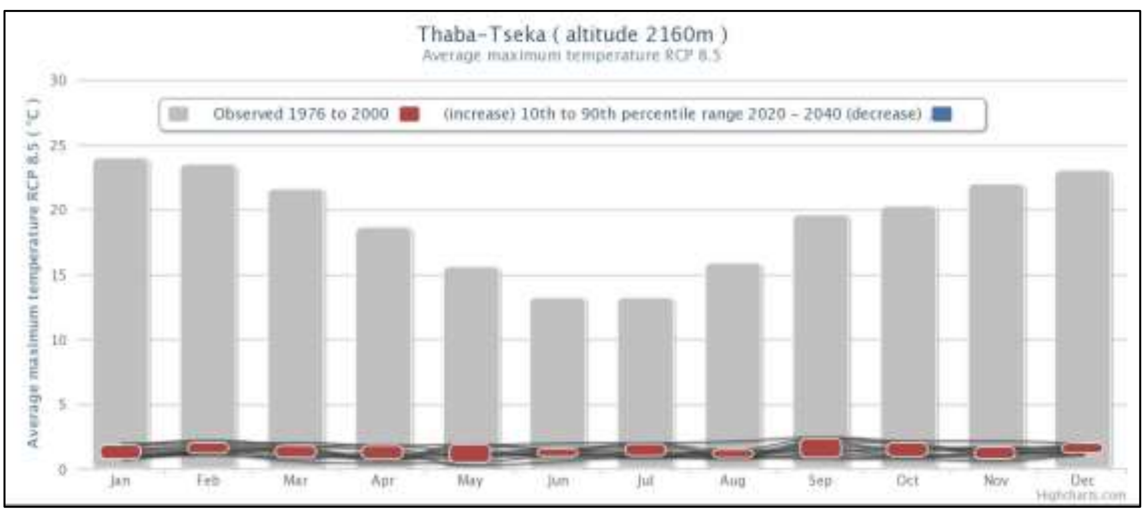
- Total monthly rainfall
- Maximum daily rainfall
- Count of Wet Days (95th Percentile)
- Average Maximum temperature
- Average Minimum temperature
- Count of Hot days (>32°C)
- Mean dry spell durations
- Frost Days (<0°C)

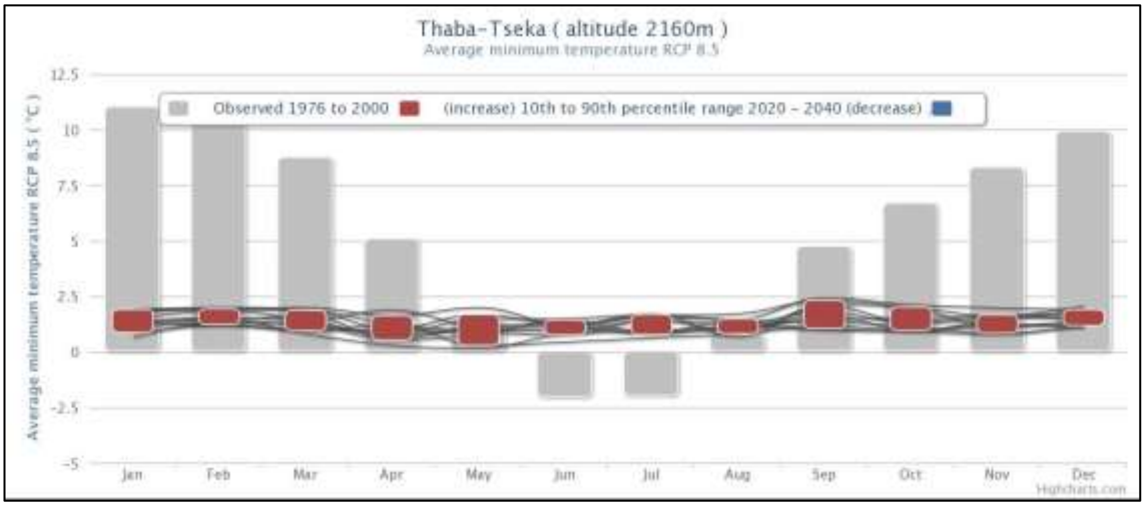
An analysis of each graph is conducted to evaluate if the identified climate change hazards are likely to be experienced, and which sector they are likely to impact. The outcomes of this analysis are summarised in the table in the main report (Table 3).

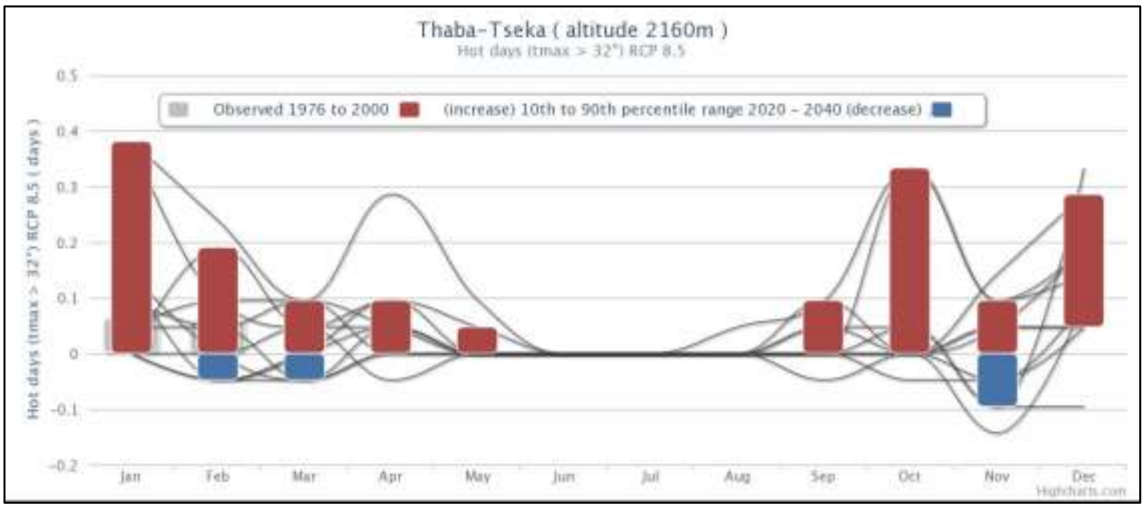


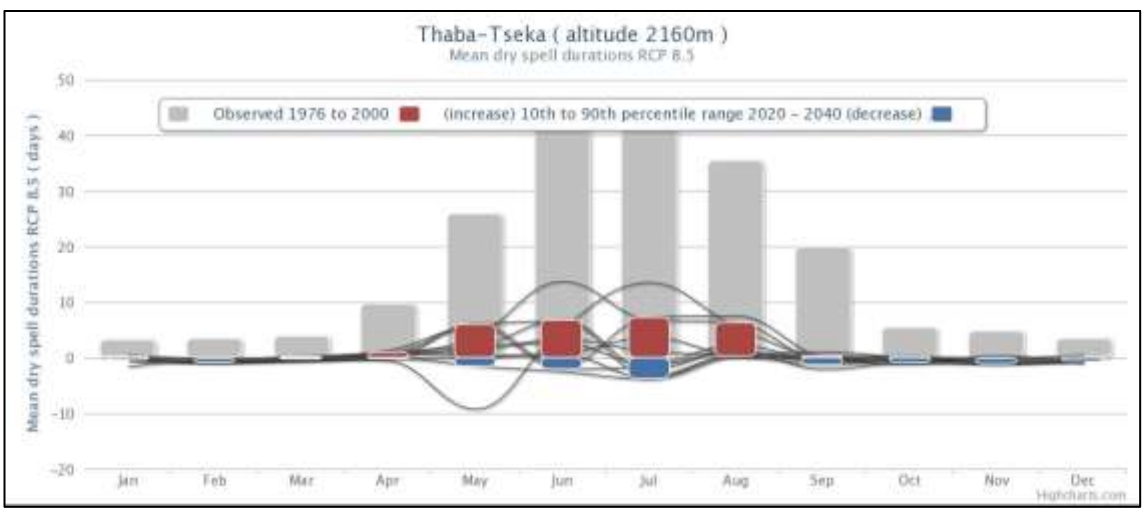

Thaba-Tseka (altitude 2160m)
Maximum daily rainfall RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Maximum daily rainfall RCP 8.5 (mm)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Highcharts.com

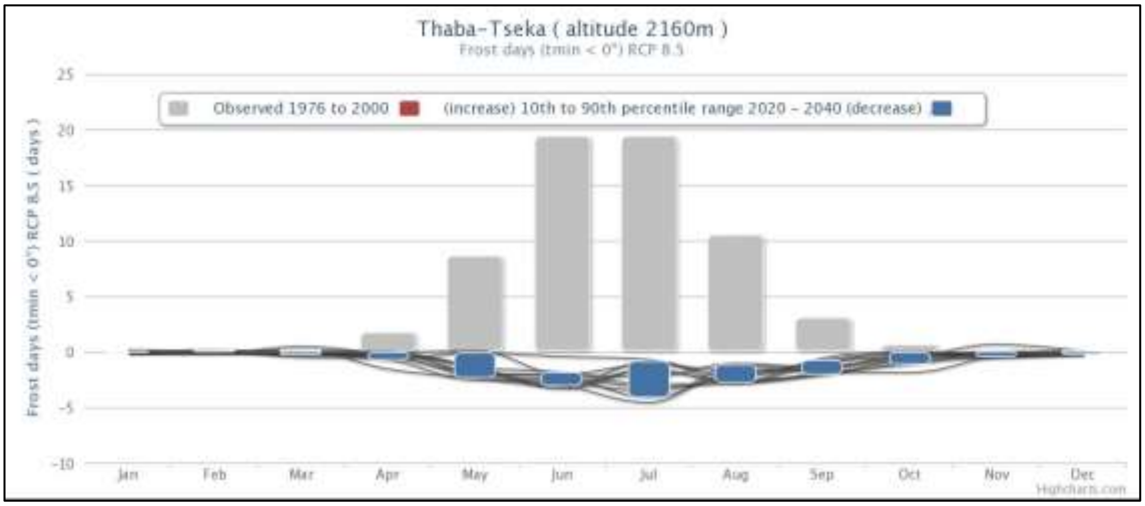

Thaba-Tseka (altitude 2160m)
Count of wet days > 95th percentile of observed wet days RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Highcharts.com


Thaba-Tseka (altitude 2160m)
Average maximum temperature RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Average maximum temperature RCP 8.5 (°C)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Highcharts.com


Thaba-Tseka (altitude 2160m)
Average minimum temperature RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Average minimum temperature RCP 8.5 (°C)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Highcharts.com


Thaba-Tseka (altitude 2160m)
Hot days (tmax > 32°) RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Hot days (tmax > 32°) RCP 8.5 (days)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Highcharts.com

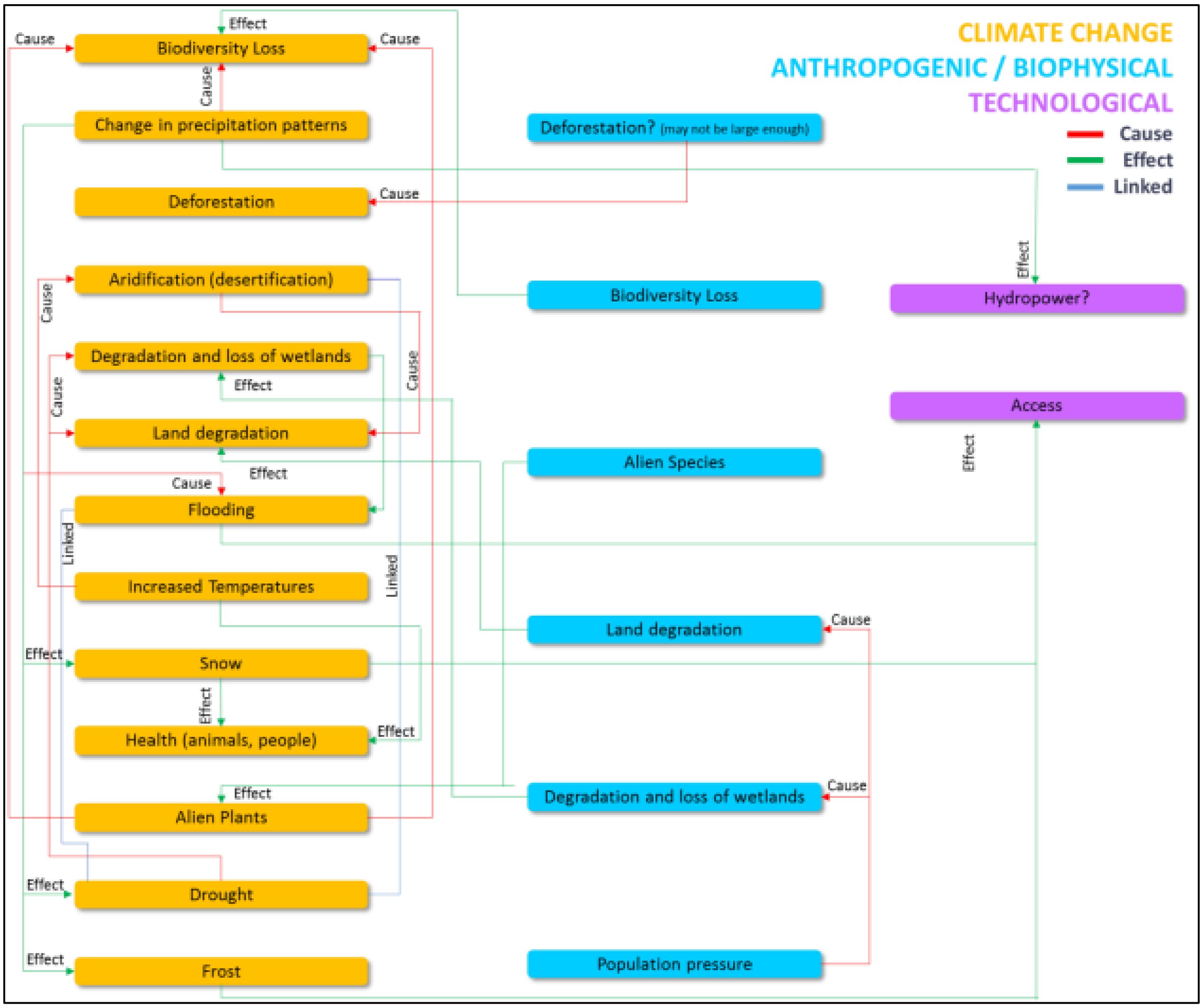

Thaba-Tseka (altitude 2160m)
Mean dry spell durations RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Mean dry spell durations RCP 8.5 (days)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Highcharts.com


Thaba-Tseka (altitude 2160m)
Frost days (tmin < 0°) RCP 8.5
Observed 1976 to 2000
(increase) 10th to 90th percentile range 2020 - 2040 (decrease)
Frost days (tmin < 0°) RCP 8.5 (days)
25
20
15
10
5
0
-5
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Highcharts.com

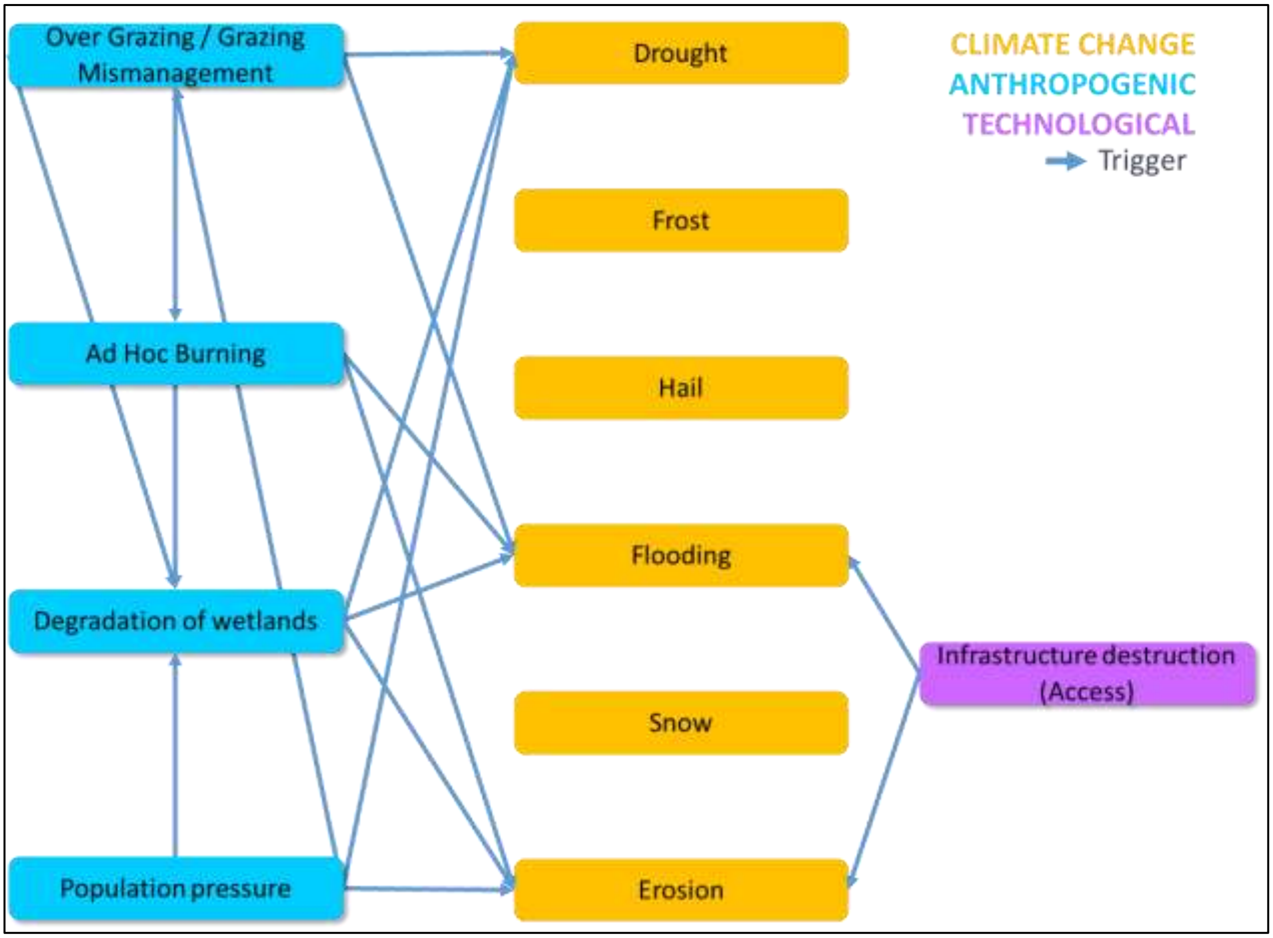
Annex 2: Understanding Hazards

The following mindmaps were generated through the literature review as a means of identifying hazards and understanding their relationships and dynamics.

Understanding Categorisation and Links of Hazards

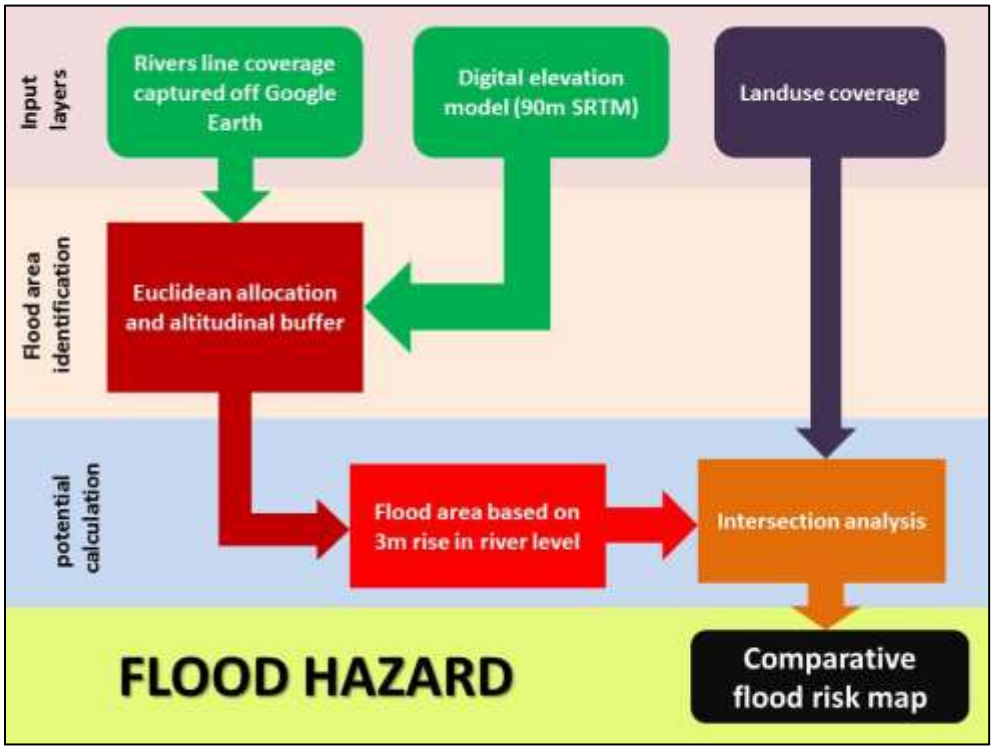


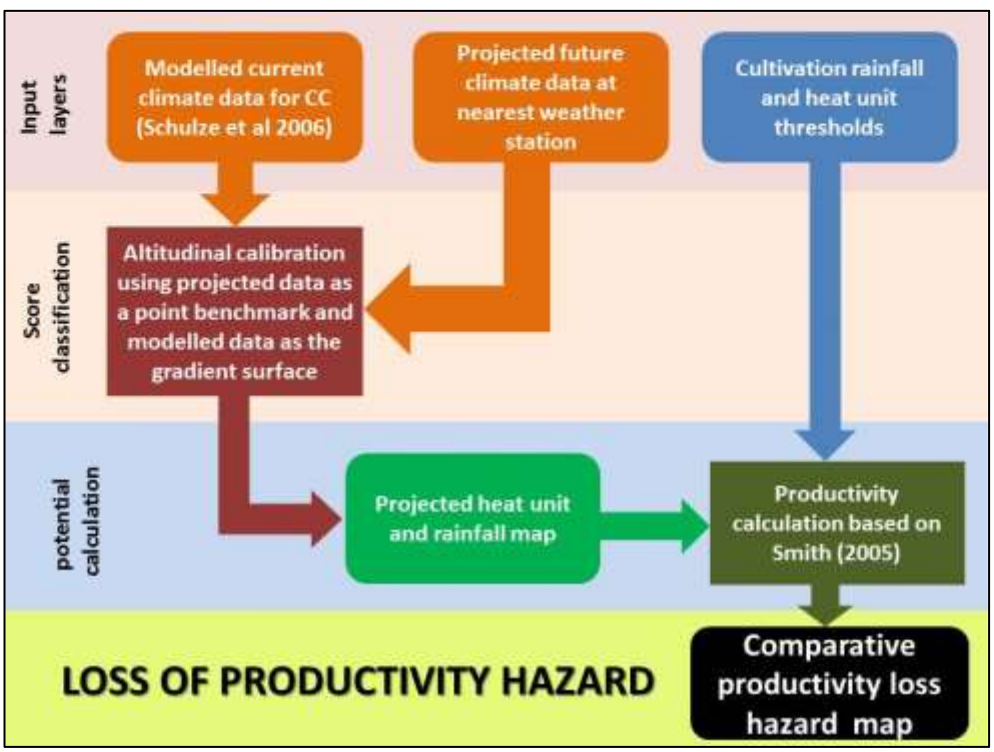
Relationships of Types of Hazards

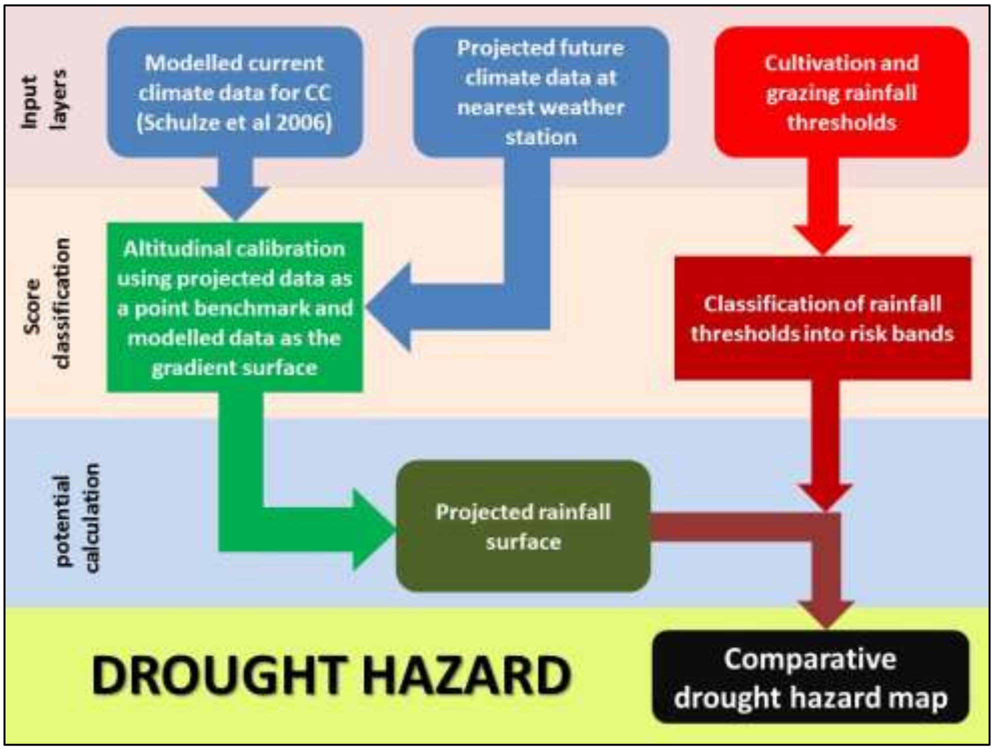


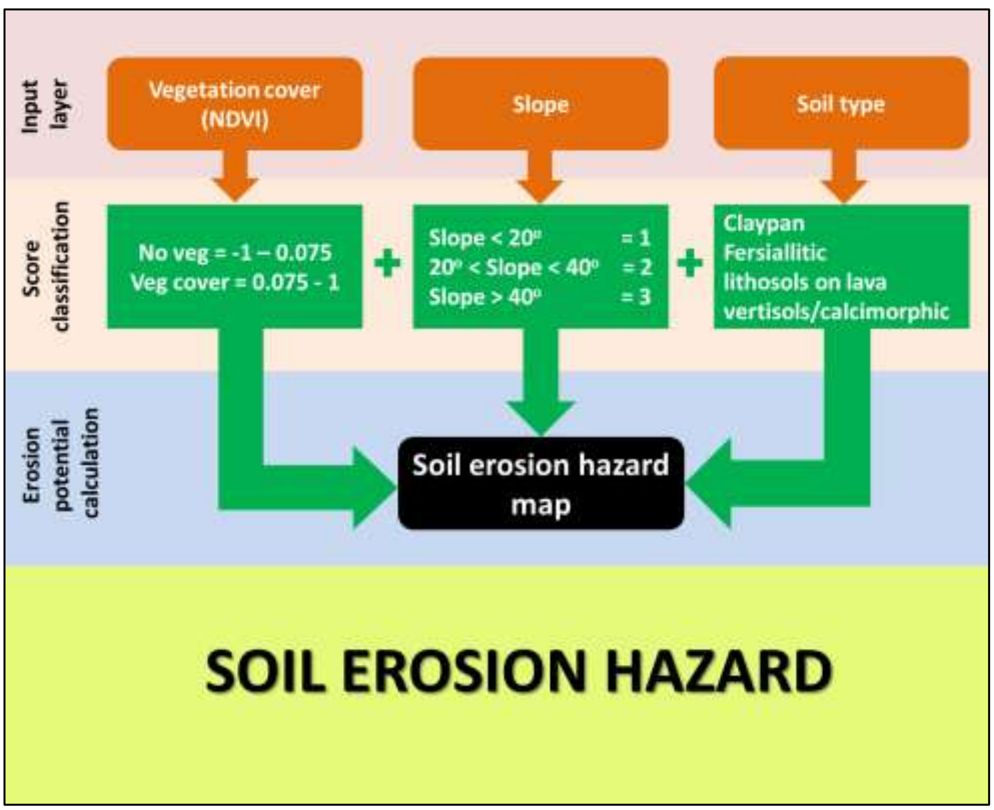
Annex 3: Methods for Spatial Vulnerability Mapping

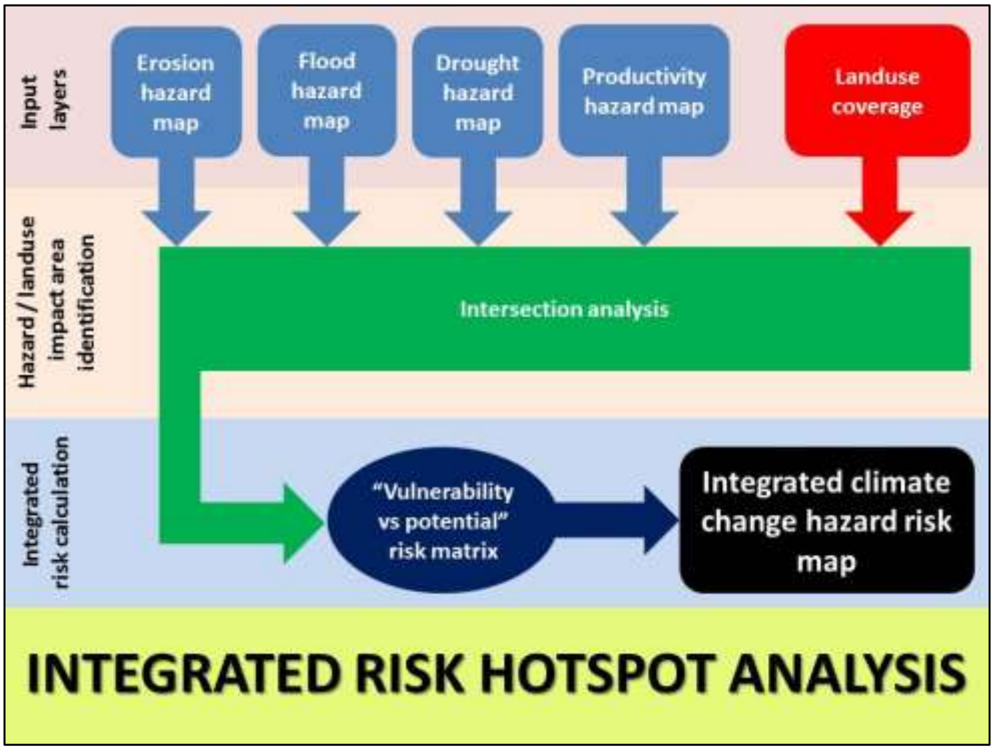
The following figures present input data used and processes taken to generate the climate change vulnerability maps.






Input layers
Modelled current climate data for CC (Schulze et al 2006)
Projected future climate data at nearest weather station
Cultivation and grazing rainfall thresholds
Score classification
Altitudinal calibration using projected data as a point benchmark and modelled data as the gradient surface
Classification of rainfall thresholds into risk bands
potential calculation
Projected rainfall surface
DROUGHT HAZARD
Comparative drought hazard map


Input layer
Vegetation cover (NDVI)
Slope
Soil type
Score classification
No veg = -1 – 0.075
Veg cover = 0.075 - 1
+
Slope < 20° = 1
20° < Slope < 40° = 2
Slope > 40° = 3
+
Claypan
Fersiallitic
lithosols on lava
vertisols/calcimorphic
Erosion potential calculation
Soil erosion hazard map
SOIL EROSION HAZARD


Input layers
Erosion hazard map
Flood hazard map
Drought hazard map
Productivity hazard map
Landuse coverage
Hazard / landuse impact area identification
Intersection analysis
Integrated risk calculation
"Vulnerability vs potential" risk matrix
Integrated climate change hazard risk map
INTEGRATED RISK HOTSPOT ANALYSIS