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AN ASSESSMENT OF PLACE VULNERABILITY TO NATURAL HAZARDS IN SOUTH-WESTERN LESOTHO (QUTHING AND MOHALE'S HOEK DISTRICTS)

Moipone `Mantŝebo Amelia Letsie

A thesis submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

Johannesburg, February 2015

DECLARATION

I declare that this thesis is entirely my own work, except where otherwise stated in the text. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree of examination by any other university.

_____

(Signature of Candidate)

_____Day of _____2015 in _____

ABSTRACT

Due to its geographical location, poor economic situation and geological features that are characterised by mostly mountainous terrain, Lesotho is vulnerable to hazardous events associated with climate, such as drought, floods, heavy snow, and severe frost. This research explores factors underlying spatial vulnerability of places to natural hazards in south-western Lesotho. Prior vulnerability assessments in Lesotho have investigated vulnerability in terms of identifying populations that are most food insecure and vulnerable to hunger. By broadening the scope of vulnerability to include biophysical and socioeconomic characteristics, the study emphasises the concept of place vulnerability as a foundation for understanding Lesotho's vulnerability to natural hazards. Spatial orientation of vulnerability within a geographical area provides an easy way for planners and decision makers to identify areas that may require additional resources in order to prepare for disasters. To date, no quantitatively based vulnerability assessment has been undertaken in Lesotho, so this study is one of the first to assess place vulnerability to natural hazards in Lesotho using GIS and it emphasise the role of geography of a place.

Using two districts in Lesotho as the study region, the study examines which district and community council has the greater level of vulnerability to natural hazards, and why. Place vulnerability is thus investigated through examining vulnerability distribution and by identifying the underlying causes of vulnerability in the study area. The study used a modification of the 'Hazards of Place Model' of vulnerability to assess place vulnerability to natural hazards. Using this model, a combination of social and physical variables was examined to assess place vulnerability. Social vulnerability was developed from indicators of demographic, social and economic variables of households and communities. In contrast, physical vulnerability was developed from the history of natural hazard, biophysical and environmental characteristics. The study results reveal that communities are affected differently through a range of natural hazards, based on their past experiences with natural hazard events and social and physical characteristics. Generally, physical vulnerability is high in the lowlands and river valleys, but lower in the high mountains. Social vulnerability varies across the study area, yet without a strong spatial pattern. Aside from heightened levels of place vulnerability in the lowlands and along the river valleys, mapping vulnerability values reveals the influence that social and physical vulnerability has on the overall place

vulnerability. For this research, place vulnerability is mostly physically constructed, through the influence of the biophysical characteristics of a place, particularly topography and relief.

Keywords: Vulnerability assessment, natural hazards, Lesotho, place vulnerability, social vulnerability, physical vulnerability.

In memory of my father

Sebete Solomon Letsie

1937-2001

ACKNOWLEDGEMENTS

My research interest in vulnerability and disaster management issues has been influenced by my mother Mamoipone Letsie who served the Government of Lesotho as the District Disaster Management Officer for the past 17 years (retired in May 2014).

I would like to express my sincere gratitude to all the government officials whom I interviewed (Mr Moletsane, Mr Letsie, Mrs Letsie, Mr Tsikoane and Mr Lekota). My gratitude goes to the chiefs, community leaders, communities and families who participated in the household interviews and focus group discussions. I am grateful for the assistance of Mr Letuma and Mr Tongwa from the Lesotho Meteorological Services for making Lesotho climate data available to me. Thanks to the late Professor Adelani Ogunrinade, the former Vice Chancellor of the National University of Lesotho for fostering the academic drive to continue with my education. For financial assistance, a very special thanks to the Government of Lesotho, Canon Collin Trust, and the National University of Lesotho – Kellogg Foundation Project.

To my friends scattered throughout the world, colleagues an NUL, and the other geography graduate students at Wits, you have been my support system throughout this process. You have provided emotional, academic, and technical assistance and support when I needed it most. You encouraged me to push forward and succeed, and also persuaded me to take a break sometimes. Thank you for keeping the friendship bonds alive and strong through visits, calls, SMSs, Skype calls, messages, Whats app. messages, Facebook and emails. Thank you to my pastors for their encouragement and prayers.

To my in-laws, thank you for your love and support and for understanding that *makoti* had to study. To the Molete's thank you for being there. To my brothers and sister Maama, Seahle, Tsepo and Senate thank you for your support and encouragement. To my mother, your love, prayers and support have given me the strength I needed to get through this process. Thank you for taking care of the twins from the day they were born till now. *Kea leboha Lekholokoe*!

To my husband and best friend, thank you for your love, support, patience, encouragement and providing for me and the twins. To my twins Bokang and Relebohile, your birth (which happened in the middle of writing this dissertation) was the push I needed to finally complete this stage of my life's journey. Mommy loves you with all her heart.

Finally to Professor Stefan Grab, there is no way this research could have been completed without your efforts, guidance, time and patience. You have taught me how to be a scholar and a researcher. I am thankful for your guidance, leadership, training, and support over the past years. You have played a vital role in my life and helped me to find my niche in geography. Thank you for everything you have done for me. You are a great academic adviser, servant and truly an inspiration. 1 Peter 4:10 "*As each has received a gift, use it to serve one another, as good stewards of God's varied grace*".

Above all, glory be to GOD for making this work possible, because with God all things are possible. Psalm 116:12 (AMP) *"What shall I render to the Lord for all His benefits toward me? [How can I repay Him for all His bountiful dealings?]."*

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ACRONYMS AND ABBREVIATIONS USED IN THIS STUDY

AIDS	Acquired Immune Deficiency Syndrome
BBC	Bogardi Birkmann and Cardona
CBL	Central Bank of Lesotho
COP	Conference of the Parties
DEM	Digital Elevation Model
DMA	Disaster Management Authority
DDMO	District Disaster Management Officer
FAO	Food and Agriculture Organisation
FANRPAN	Food Agriculture and Natural Resources Policy Analysis Network
FIVIMS	Food Insecurity and Vulnerability Information Mapping System
GDP	Gross Domestic Product
GIS	Geographic Information System
GoL	Government of Lesotho
GNI	Gini-coefficient
HDI	Human Development Index
HEA	Household Economy Approach
HIV	Human Immunodeficiency Virus
ICSU	International Council for Science
ICPAC	International Climate Prediction and Application Centre report
IFPRI	International Food and Policy Research Institute
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
LVAC	Lesotho Vulnerability Assessment Committee
m.a.g.l	Meters Above Ground Level
m.a.s.l	Meters Above Sea Level
m/s	Meters per Seconds
NAPA	National Adaptation Actions Programmes
SADC	Southern Africa Development Community
SAVI	Southern African Vulnerability Initiative
PCA	Principal Component Analysis
RVAC	Regional Vulnerability Assessment Committee
UNDP	United National Development Programme

UNFCCC	United Nations Framework Convention on Climate Change
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
UNISDR	United National International Strategy for Disaster Reduction

CHAPTER ONE

BACKGROUND TO THE STUDY

1.0 INTRODUCTION

Vulnerability research has received significant attention from the geographical community, particularly in the sub-fields of disasters, risk and hazards (Blaikie *et al*., 1994; Hewitt, 1997; Tobin and Montz, 1997; Alexander, 2000; Cutter, 2006). Vulnerability is also implicated in discussions on food security and hunger as well as in global environmental change research (Kasperson *et al*., 1995, Hewitt, 1997; Kasperson and Kasperson, 200l; Turner *et al*., 2003; Hawkes and Ruel, 2006; Adger *et al*., 2007). According to the International Council for Science (ICSU, 2008), globalisation, population growth, widespread poverty (particularly in hazardous areas), and a changing climate will increase place vulnerability associated with natural hazards in the future. In many parts of the world, especially hazard-prone areas, poverty and population growth indicate that more people and communities are at risk from natural hazards. Place vulnerability assessments of natural hazards help to address some of the aims outlined by the International Strategy for Disaster Reduction in Africa, which calls for improving the assessment and identification of natural hazards and populations at risk (ISDR, 2004; Cardona *et al*., 2012 IPCC, 2012).

Thus, understanding place vulnerability to natural hazards has recently become an imperative issue, as natural hazards have increased in frequency and intensity as a consequence of climate variability. The potential for loss, both in material possessions and loss of life, is worsened by ever increasing human development, especially in susceptible locations such as flood plains. People historically have been and will always be vulnerable to natural hazards, and researching the root causes of what makes communities vulnerable may assist in reducing losses and recovery time from natural hazard events. Place vulnerability to natural hazards is based on social and environmental processes (Cutter *et al*., 2001), both of which manifest differently on the landscape, thus requiring a need for a place-based approach to understanding their relationship. A major gap in vulnerability and hazards literature exists in the area of place vulnerability assessments that takes into account the geography of a place (social and biophysical characteristics) and its influence

on overall place vulnerability. Better understanding of these aspects will lead to more appropriate and efficient strategies for disaster resilience and adaptation in the long run.

1.1 RATIONALE

With the emergence of sustainability science and climate change there has been considerable attention paid to the unique nature of developing and landlocked countries and their vulnerability to climate change and associated natural hazards (UN-OHRLLS, 2009; Karki and Gurung, 2012). The issue of specific need for these countries is covered in Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) clause 8, which provides for parties to "*give full consideration to meet specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures* [especially on countries that are highly vulnerable to climate change, including] *countries with fragile and mountainous eco-systems* [as well as] *land-locked and transit countries*". Following this, the current PhD study assesses Lesotho's situation in relation to the above statement and seeks to identify vulnerable places and populations in the Mohale's Hoek and Quthing districts. Lesotho is one of the least developed of mountainous, landlocked countries and is vulnerable to a range of natural hazards, however, no place-based, multi-hazards assessment has previously been conducted using GIS. Considering Lesotho's status as a poor and particularly vulnerable small country with fragile ecosystems that are prone to natural disasters, it is timely to assess the extent to which it is vulnerable to natural hazards. Losses from natural hazards are increasing and have both human and economic consequences (Disaster Management Authority, 2010). Previous vulnerability assessments conducted in the country focused mainly on food insecurity, HIV/AIDS, gender, rural livelihoods and vulnerable children (Slater, 2003; Gill-Wason, 2004; LVAC, 2005, 2008, 2009, 2010; Corno and de Walque, 2007; CRS-Lesotho, 2009; Sloth-Nielsen, 2014).

1.2 GLOBAL AND REGIONAL CONTEXTS

Over the last few decades, place vulnerability assessment has emerged as an alternative approach to evaluating vulnerability to natural hazards in developing countries, also implicated in discussions on food security and hunger, risk and hazards (Kasperson *et al*., 1995; Hewitt, 1997; Birkmann, 2007), as well as in global environmental change research.

Globalisation, population growth, widespread poverty (especially in hazardous areas) and a changing climate will increase the risk to people and communities from natural hazards (International Council for Science, ICSU, 2008; Yoon, 2012; Siagian *et al*., 2014).

Previous studies that have incorporated vulnerability metrics have focused on human-environmental systems at different sub-national scales. For instance in India, O'Brien *et al*. (2004) investigated regional vulnerability to climate change by examining multiple stressors in the Indian agricultural sector, whilst Hurd *et al*. (1999) developed measures for assessing the vulnerability of regional water resources and water-dependent resources to climate change in the United States of America (USA). Additionally Polsky (2004) investigated impacts of climate change on agriculture and explored how human-environment relationships associated with climate sensitivity vary over space and time on the Great Plains of the USA. A more comprehensive and place based vulnerability assessment was undertaken in South Carolina (United States of America) which employed vulnerability metrics on human-environmental systems at the sub-county level and used socioeconomic and demographic data to construct an index of social vulnerability to environmental hazards (Cutter *et al*., 2000).

However, in the African continent, especially the sub-Saharan African region, there is limited research on place based vulnerability assessments to natural hazards. Some studies have been conducted in several countries to identify of vulnerable populations through hazard mapping focusing mainly on physical vulnerability and food insecurity. For instance, Thornton *et al*. (2006) used the sustainable livelihood framework to study the impacts of climate change on temporal and spatial livelihood changes in Africa. While in the Southern African Development Community (SADC), the Regional Vulnerability Assessment Committee (RVAC now, the RVAA) uses a livelihoods approach to assess vulnerability in terms of welfare perspectives such as education, health, water and sanitation, and HIV/AIDS, food security and vulnerability (Makoae, 2006,SADC, 2012). On the one hand, the majority of RVACs were primarily on collecting information and data to provide an in-depth understanding on food security in the SADC region, prompted by the apparent food crisis and drought of 2002 (Vogel *et al*., 2007). The Southern African Vulnerability Initiative (SAVI), not operational currently, has investigated how multiple stressors interact to generate vulnerability in southern Africa. A key objective of SAVI was to understand how and why processes of change (such as climate change and food

prices) interact to generate stressors for some and opportunities for others (Quinlan *et al*., 2005). Currently, the RVAC is building understanding and strategies that integrate short-term responses to food emergencies with broader, longer-term approaches to chronic poverty, food insecurity and climate-resilient livelihoods in the SADC Region.

1.3 LESOTHO'S CONTEXT

Due to its geographical location, poor economic situation and geological features that are characterised by mostly mountainous terrain, Lesotho is vulnerable to hazardous events associated with climate, such as drought, floods, heavy snow, and severe frost. This thesis seeks to explore factors underlying spatial vulnerability of places to natural hazards in south-western Lesotho, this part of the country was chosen because it represents the four ecological and livelihood zones (lowlands, foothills, Senqu River valley, and the mountains). This region is also considered as the poorest, vulnerable and food-insecure zone by the government, largely a result of poor agricultural production influenced by unfavourable climatic conditions (drought and poor soil). By broadening the scope of vulnerability to include biophysical and socioeconomic characteristics, the study emphasises the concept of place vulnerability as a foundation for understanding Lesotho's vulnerability to natural hazards. Spatial orientation of vulnerability within a geographical area provides a useful way for planners and decision-makers to identify areas that may require additional resources in order to prepare for disasters. Prior vulnerability assessments in Lesotho have investigated vulnerability in terms of identifying populations that are most food-insecure and vulnerable to hunger. This study is the first to assess place vulnerability to natural hazards in Lesotho and emphasises the role of geography of a place.

Lesotho is to a certain extent vulnerable to the adverse effects of climate change and variability and thus requires a comprehensive vulnerability assessment (LMS, 2001; LMS, 2005; Obiaha, 2010). Recently, Lesotho has experienced an increase in the frequency of natural disasters associated with climate, such as drought from 2002 to 2006, heavy snow in July 2007, severe windstorms in 2006, 2007 and January 2009, and recently the 2010/2011 floods. There is a general recognition that Lesotho's vulnerability to natural hazards is compounded by the wide prevalence of poverty in the country. The livelihoods of over 85% of the population are exposed to high environmental hazard risks, due mainly to environmentally sensitive subsistence agricultural practices (LMS, 2005). Marginalised

groups are often the ones who suffer most in highly variable climates as they often do not have the resilience either to prepare for or to recover from shocks that climate extremes tend to bring (Ziervogel, 2001).

Considering Lesotho's status as a poor and particularly vulnerable small landlocked country with fragile ecosystems that are prone to natural disasters, it is timely to assess the extent to which Lesotho is vulnerable to natural hazards. The majority of vulnerability assessments carried out in Lesotho originate from research on entitlements in livelihoods. Previous ones were mainly related to food aid with a strong focus on physical vulnerability, as with Chakela and Stocking's (1988) erosion hazard map, and others on food insecurity (e.g., Moseley and Earl, 1997; Sechaba consultants, 2007; Turner, 2007; One World, 2009, 2010 LVAC, 2010). A study was undertaken by Ziervogel (2004) in one village in southern Lesotho to evaluate processes associated with vulnerable and marginalised smallholder farmers in rural areas in relation to seasonal climate information and its adaptation to agricultural planning and decision-making. The study also assessed how seasonal climate information was disseminated and how the farmers adopted and utilised it to improve their natural resource-based livelihoods. The study results suggested that the climate forecasts might be integrated into rural livelihoods to increase resilience of marginalised groups to the negative impacts of climate variability (Ziervogel, 2004, Ziervogel and Calder, 2003).

This study moves away from the livelihoods approach which has been used for several years in Lesotho to explain vulnerability of communities to food insecurity. By harnessing geographic techniques such as GIS and spatial statistics, it investigates the spatial nature of multiple hazards and the specific communities that are affected differently in Lesotho. The study therefore identifies areas within the Quthing and Mohale's Hoek districts which are most physically and socially vulnerable to natural hazards as opposed to vulnerable to food insecurity. This is appropriate and most relevant for a country that is prone to recurring hazard occurrences and is experiencing declining agricultural production, increasing poverty levels, food insecurity and a rising number of vulnerable households (e.g., Mwakabolo, 2007; FANRPAN, 2010; LVAC, 2011).

This study seeks to address the gaps in methodology used in the previous vulnerability assessments and the type of data collected in Lesotho. It employs GIS-based spatial analysis of vulnerability to help identify locations and populations that may be at higher

risk due to natural hazards. The research combines social vulnerability data with biophysical and climate data so as to build an understanding of the geography of place within the broader vulnerability context. It further explores the feasibility of using the 'Hazards of Place Model' of vulnerability, which is a GIS based model to map socioeconomic and physical vulnerability in Lesotho, and ultimately produces a place vulnerability map for the study region.

1.4 OBJECTIVE

The underlying aim is to explore factors underlying spatial vulnerability of places to natural hazards in Mohale's Hoek and Quthing districts. Using two districts as the study region it examines which district and community council has the highest level of vulnerability to natural hazards, and why. Place vulnerability is thus investigated through examining vulnerability distribution and by identifying the underlying causes of vulnerability in the study area. The primary objective, providing a focal point to this assessment, is to determine how the hazard profile, socioeconomic makeup and physical environment vulnerabilities differ spatially in the study region.

1.5 RESEARCH QUESTIONS

The research was guided by three specific questions which need to be answered for a better understanding of place vulnerability to natural hazards in Lesotho:

1) What are the biophysical characteristics of communities that make them more vulnerable to natural hazards?

2) What are the socioeconomic characteristics of communities that make them more vulnerable to natural hazards?

3) What factors, including social and physical, are responsible for spatial variation in overall place vulnerability?

The study uses the hazards of place model of vulnerability approach in Lesotho to frame the research and uses site specific parameters unique to Lesotho.

1.6 ORGANISATION OF THE THESIS

Chapter two presents an in-depth review of the literature pertaining to vulnerability concepts, theories and models. Chapter three provides a brief description of the study area. Chapter four details methods undertaken in the analysis of place vulnerability in the study region then presents research limitations. Chapter five discusses the results of physical vulnerability assessment of the study area and focuses on physical factors influencing place vulnerability. It further identifies the most vulnerable communities. Chapter six presents the results of social vulnerability assessment and identifies the factors contributing most to place vulnerability. Chapter seven presents the overall place vulnerability assessment of the study region and identifies the most vulnerable communities and underlying factors behind their vulnerability. Chapter eight presents major research findings and makes recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter presents an overview of natural hazards vulnerability research, its evolution and implications within disaster research. It first defines key concepts then describes the history of vulnerability science is placing this research within the broader context of scientific writings. Understanding both vulnerability and hazard settings helps to justify the chosen variables for constructing the vulnerability indices. Lastly, a review of vulnerability assessments in Lesotho builds an argument for developing a multi-hazards vulnerability assessment at both district and community council levels which integrates social and biophysical characteristics of vulnerability. The literature and theoretical frameworks offer useful theoretical and conceptual links which were employed and adopted as a basis for a vulnerability assessment of natural hazards in Lesotho.

2.1 DEFINITION OF CONCEPTS

In order to understand the relationship between natural hazards and society it is important to understand the key elements: hazards, risks, disasters and vulnerability. Though not mutually exclusive but often interchangeable, these concepts mark the progression and impacts of natural hazards within an explicit spatial domain. Each of these elements has its place in the literature, for example, hazards, risk and disasters in geography and vulnerability with a multi-disciplinary approach, and there has often been ambiguity relating to the definitions. An understanding of these elements is important in place vulnerability research. As a result of differing perspectives, the hazards literature allows for a range of definitions of these terms in relation to vulnerability research (Cutter, 1996; White *et al*., 2001; Miller *et al*., 2010).

2.1.1 Natural hazards and disasters

'Natural hazards' are usually related to extreme events that have the potential to harm people, property, livelihoods and places (Cutter *et al*., 2009). Tobin and Montz (1997:5)

argued that a natural hazard "represents the potential interaction between humans and extreme natural events". Consequently, it can be defined as a threat to society, existing because of human activities that are continually exposed to natural forces. The impact of climate (including both change and variability) and the frequency and intensity of hazardous natural events in the above definition can be understood in terms of hazard exposure and sensitivity to climate extremes and the extent to which communities are exposed in relation to their location.

'Disasters', meanwhile, are unusual large-scale events that devastate the local capacity to effectively respond to and recover from an event (National Research Council, 2006). In the Special Report of the IPCC (2012:5) on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, disasters are defined as:

> Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

2.1.2 Risk

'Risk' is the probability of sustaining harm or the likelihood that some type of injury or loss would result from a hazardous event (Cutter *et al*., 2009). Differences in approaches to vulnerability among the disciplines can be explained by their tendency to focus on different components of risk, household responses to risk and welfare outcomes. Based on the definition referred to in many studies (Mileti, 1999; Wisner *et al*., 2004; Adger, 2006; Eakin and Luers, 2006; National Research Council, 2006), the risk from natural hazards is the interaction of hazard and vulnerability which can be described as the probability of the harmful event, including loss of life, personal injury, damage to property, and disruption of economic activity. The elements at risk consist of populations, communities, the built environment, the natural environment, economic activities and services, which are under the threat of disaster in a given area (Alexander, 2000). Risk is equated when vulnerability and hazards combine, encapsulated in the formula: (Risk = Hazard x Vulnerability).

2.1.3 Resilience

Literature on hazard mitigation and climate change defines 'resilience' as the ability "to withstand short-term or long-term shocks and be able to return to pre-shock or pre-trauma conditions" (Petrillo and Prosperi, 2011). The United National International Strategy for Disaster Reduction defines resilience as "the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner" (UNISDR, 2009). Resilience has further been defined as the capacity of a system to absorb disturbance and reorganise while undergoing change so as to retain essentially the same function, structure, identity, and feedback (Adger *et al*., 2011). Because this study focuses on climate change and variability, it applies the IPCC (2007) definition of resilience as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation and the capacity to adapt to stress and change.

2.1.3 Vulnerability

The UN International Strategy for Disaster Reduction (ISDR, 2007) defines 'vulnerability' as the conditions determined by social, economic, physical and environmental factors or processes that increase the susceptibility of a community to the impact of a hazard. This would include characteristics of an individual, community or built environment that are susceptible to risks and natural hazards and influence the ability to anticipate, cope with, resist and recover (Wisner *et al*., 2003). These are a combination of factors that determine the degree to which an individual's life, property, livelihood, and other assets face risk from hazardous events. In the literature, vulnerability is generally defined as the "potential for loss" (Mitchell, 1989) or the ability to experience harm and react adversely (Kates, 1985). Depending on the research perspective, many other definitions exist that focus either on a single underlying factor, such as biophysical vulnerability or exposure (Alexander, 1993), social aspects such as gender, race and age (Fothergill *et al*., 1999; Lowe, 2010), or a combination of both (Smith, 1992; Blaikie *et al*., 1994). Many definitions also possess a spatial dimension, given the place-dependent manifestation (Liverman, 1990; Cutter, 1993; Montz *et al*., 2003). A broad definition of vulnerability includes the spatial elements and susceptibility to harm from the risk posed by hazardous

events at a specific location, as well as the potential for social disruption (Borden *et al*., 2007).

Recently, the notion of vulnerability has received increased attention in environmental and climate change research, particularly in assessing the impacts of natural hazards (Eriksen, 2005; Fuchs *et al*., 2011; Birkmann *et al*., 2013). The challenge is that vulnerability has no universally accepted definition and even within the IPCC assumes different meanings. A broad review of the vulnerability terminology was undertaken by Thywissen (2006) and comprises a comprehensive list of definitions that mainly differ according to the school of thought in which they are developed and used. These different schools of thought are grouped into: political economy, social ecology, holistic vulnerability, disaster reduction assessment and climate change science. Several approaches and frameworks have been developed to assess vulnerability based on these schools of thought (Birkmann *et al*., 2013; Depietri *et al*., 2013).

Although there are different definitions of vulnerability, it generally refers to the potential to be adversely affected by an event or change (Kelly and Adger, 2000). The confusion around the different interpretations arises from the differing meanings and normative attributions assigned to it. While the term is used in a number of contexts (e.g., medical science and biophysical sciences) it is increasingly being viewed through the lens of the social sciences (Vogel, 2004). The uncertainty in definitions is a common challenge in science (Cannon *et al*., 2003; Füssel, 2007; Feynman, 2007).

2.1.4 Exposure

The IPCC (2012) defines ‘exposure’ as the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected. Thus, it is the presence of susceptible elements within a zone affected by a hazard.

2.1.5 Susceptibility

'Susceptibility' contains the passive characteristics of humans that render them generally disadvantaged in the face of disaster. It is hazard-independent.

2.2 INTERPRETATIONS OF VULNERABILITY

According to O'Brien *et al*. (2004) there are two key interpretations of vulnerability in the climate change literature. The first interpretation is called "the end point" approach and views vulnerability as a residual of climate change impacts minus adaptation. According to this perspective, vulnerability embodies the net impacts of climate change and serves as a means of defining the degree of the climate problem and providing input into policy decisions regarding the cost of climate change versus costs associated with the greenhouse gas mitigation efforts (Kelly and Adger, 2000; Fussel, 2007). Research within this viewpoint assesses distribution of some hazardous conditions, the human habitation of the hazardous zones, and the extent of loss of life and property emanating from a particular hazardous event. The second approach regards vulnerability as a "starting point" and views vulnerability as general characteristics created by multiple factors and processes and examines the pre-existing conditions and focuses more on potential exposure to hazards (Cutter, 1996; Wu *et al*., 2002; O'Brien *et al*., 2004; Cutter, 2009). Thus researchers from different disciplines use these interpretations and different meanings and concepts of vulnerability, which, in turn, have led to diverse methods of measuring vulnerability. Additionally, recent research interest is now on empirically measuring vulnerability (Armas, 2008; Myers *et al*., 2008; Mendes 2009; Chen *et al*., 2013a), especially social vulnerability.

2.3 THEORETICAL CONSTRUCTS OF VULNERABILITY

The concept of vulnerability is essential to human-environment research (Wu *et al*., 2002). Several conceptual models, frameworks and vulnerability assessment techniques have been developed to increase understanding of theoretical emphasis and practical applications of vulnerability (Adger, 2006; Bankoff *et al*., 2004; Eakin and Luers, 2006; Gallopin 2006; Fussel, 2007; Green and Penning-Rowsell, 2007; Manuel-Navarrette *et al*.,

2007; Polsky *et al*., 2007; McLaughlin and Dietz, 2008). Although, these models and frameworks are different, they have a number of elements common to all: (1) the assessment of vulnerability from a social-ecological perception; (2) the significance of place-based studies; (3) the conceptualisation of vulnerability as an equity of human rights issue (Sarewitz *et al*., 2003) and the use of vulnerability assessments to identify hazard zones, thus establishing the base for pre-impact and hazard mitigation planning (Cutter *et al*., 2000; O'Brien *et al*., 2004; Brooks *et al*., 2005; Cutter *et al.,* 2008). Because vulnerability manifests itself spatially, a geographical perspective that integrates the particularities of place is vital. Thus, different views and definitions surrounding the concepts of hazard, vulnerability and risk have led to the development of various conceptual models and frameworks in order to demonstrate the interaction of these conditions in vulnerability research.

2.3.1 The Bogardi, Birkmann and Cardona (BBC) framework

The first framework is that of Bogardi, Birkmann (2004) and Cardona (1999, 2001) (BBC), which addresses various vulnerabilities in the environmental, social and economic spheres. It posits that vulnerability assessment goes beyond the estimation of deficiencies and assessment of disaster impacts in the past (Birkmann, 2006), and distinguishes the systems' conditions between the response before a disaster occurs (preparedness/risk reduction) and afterwards (disaster emergency management). This framework has three main components: (a) it links vulnerability to human security and sustainable development; (b) it is a holistic approach to disaster risk assessment; and (c) it measures environmental degradation in the context of sustainable development. Thus, the BBC frameworks views vulnerability as a dynamic process which changes with time. Its main advantage is that it consists of feedback loops which emphasise current vulnerability status and the ability to reduce it, and adaptive capacity of places (Birkman, 2006). It adopts elements from other schools of thought and focuses on the concept of sustainable development, with exposed and susceptible elements and coping capacity. Vulnerability is regarded as a process and should be examined from social, economic, and environmental perspectives. The BCC framework is based on a view that vulnerability goes beyond damage assessment towards being a dynamic process that continuously evaluates it as a combination of social, environmental, and economic aspects that link to risk reduction and

sustainable development (Green *et al*., 2000). However, this framework and its variants do not take into consideration environmental vulnerability and only define the environment as an event sphere (passive). This model has recently been applied to assess social vulnerability to river flooding in Germany (Fekete, 2011), to identify how the social components of susceptibility together with exposure construct a certain degree for different population groups.

2.3.2 Risk-hazard (RH) model

A second modelling framework by Turner *et al*. (2003) elucidates causality using a risk/hazard approach, and presumes that vulnerability is a function of proximity to the source of risk or hazard (Burton et al., 1993; Davidson and Lambert, 2001; Dilley *et al*., 2005). The risk-hazard (RH) model considers the impact of a hazard as a function of exposure and sensitivity. It is commonly used in geographical studies to examine the effects of natural hazards and food insecurity on the biophysical environment (Fussel, 2005; Eakin and Luers, 2006; Vincent, 2007). This approach is appropriate for assessing the risks to certain valued elements ('exposure units') that emanates from their exposure to hazards of a particular type and magnitude (Fussel, 2007). The IPCC definitions of vulnerability are indicative of this theoretical paradigm to climate change research (Eakin and Luers, 2006), however, the main disadvantage is that it does not show how the system under study (underlying conditions) amplifies the impacts of hazards. Thus, it is not easy to implement in communities and populations whose exposure to hazards mostly depends on their behaviour, as determined by socioeconomic factors. This model is often applied by engineers and economists in technical literature to disasters, and used in environmental and climate impact assessments, for example in studies modelling ecological systems. It is used in examining climate change risks in different regions, such as Mexico (Eakin and Luers 2006), Australia (Sposito, 2005), Norway (Tyler *et al*., 2007), Ghana (Westerhoff and Smit, 2009), and Canada (Ford and Smit, 2004; Ford *et al*., 2006).

2.3.3 Pressure release model

The third model is the pressure and release (PAR) model developed by (Blaikie *et al*., 1994; Turner *et al*., 2003), which views vulnerability as an interaction between physical

exposure to natural hazards and the underlying processes that cause vulnerability at various levels of society. Turner *et al*. (2003) presume that vulnerability is nested in endogenous and exogenous factors acting on the place. This model implies that an evolution of vulnerability interacts with hazard impacts and specific root causes, such as political and economic systems and inadequate access to power, structures, and resources (Wisner *et al*., 2004). Thus, the model identifies the root causes of vulnerability and some aspects of society that amplify vulnerability (economic, demographic and political processes), dynamic pressures (population growth, rapid urbanisation, financial pressures, global environmental change and land degradation), and unsafe conditions (groups living on marginalised land and crowded urban areas), as the main determinants in resource allocation and distribution (Wisner *et al*., 2004; Burton and Cutter, 2008; Fekete, 2011). This model has been used mainly in social vulnerability assessments to address social groups facing disasters, as it emphasises distinctions in vulnerability by different exposure units, such as ethnicity and social class. This model has been used to assess flooding impacts in Pakistan and Norway (Mustafa, 1998; Rauken and Kelman, 2010) and typhoons in the Philippines (Gaillard, 2010), as well as to examine how vulnerability to HIV/AIDS relates to the root causes of its transmission (Tsasis and Nirupuma, 2008).

The main advantage of this model is that it explicitly highlights vulnerability by taking into account both physical and social components. For instance, from the social point of view, it focuses on how population growth and access to resources increase vulnerability. However, it is based only on a single hazard and factors that influence vulnerability to that particular hazard. Thus, it does not allow for a multi-hazard analysis and does not address physical vulnerability associated with proximity to the source. Another limitation is that it does not address the coupled human-environment systems or consider vulnerability of the biophysical sub-systems (Kasperson *et al*., 2003). It does not cater for the feedback of policy or mitigation initiatives that may reduce place vulnerability.

2.3.4 The hazards of place vulnerability model

The fourth approach is the methodical spatial combination of biophysical and social components into a place-specific assessment of vulnerability, known as the hazards of place vulnerability model (Cutter, 1996; Cutter *et al*., 2000; Preston *et al*., 2011). The

development of spatially explicit vulnerability assessments which clearly identifies those locations and characteristics of populations with the greatest risk from natural hazards remains subtle. Geographically based in assessing multi-hazards vulnerability, it stems from natural hazards research and the human ecological perspective, initially developed for a multi-hazard assessment of Georgetown County of South Carolina in the USA. This initial assessment used social characteristics of the population, the physical nature of the environmental hazards and indicators of the built environment to assess place vulnerability to multiple hazards (Cutter *et al*., 2000).

The model and its modified versions have been used to assess vulnerability to sea-level rise and global change (Wu *et al*., 2002), coastal erosion hazards (Rashed and Weeks, 2003; Boruff *et al*., 2005), earthquake and tsunami hazards (Wood and Good, 2004), ecological vulnerability (Jackson *et al*., 2004), evacuation assistance needs (Chakraborty *et al*., 2005), multi-hazards assessment in New Zealand (Montz, 2000), and natural hazards vulnerability assessments in Europe (Kumpulainen, 2006). By using a local level approach such as the hazards of place vulnerability model, several attributes and their influence on overall place vulnerability can be examined. Its main advantage is the incorporation of both social and physical factors in the overall vulnerability of a place. This conceptual model shows how the hazard potential interacts with the geographic context and social fabric to produce both biophysical and social vulnerability. Its simplicity allows for flexibility in empirical applications. However, because of its simplicity the model also has some disadvantages.

The concepts used to construct the model are very broad and could be defined very differently, depending on who is adopting the model. It also fails to scrutinise the root causes of social vulnerability and does not include the external drivers of vulnerability, such as urbanisation and political processes. Though it has been used as a basis for a multi-hazard assessment of Georgetown County in South Carolina (Cutter *et al*., 2000), its adaptability outside the USA has only been tested in a few countries, and once in Africa. Kienberger (2007) used GIS and remote sensing to assess vulnerability of communities in Mozambique to drought and floods because of lack of data. This place-based perspective fits well within the purposes of this dissertation.

Considering the large number of approaches to vulnerability research it is not surprising that conceptual models differ in explaining the root causes of vulnerability, as summarised in Table 2.1 (below).

Table 2.1: Vulnerability models and their characteristics.

Author/s	**Model**	**Characteristics**	**Weaknesses**
Blaikie and Wisner *et al.,* 2004	Pressure and release model	Tracks the progression of vulnerability from root causes to dynamic pressures to unsafe conditions.	Fails to adequately address the coupled human-environment system associated with the proximity to a hazard.
Turner *et al*., 2003	Risk / Hazard	Uses a place-based approach locating local vulnerability within the larger contexts that influence it.	It fails to clearly differentiate between exposure and sensitivity and also does not include a temporal dimension that shows where vulnerability begins and ends.
Cutter 1996, Cutter *et al*., 2000	Hazards-of-place model	Integrates systems exposure and social vulnerability.	Fails to account for the root causes of the antecedent social vulnerability, larger contexts, and post-disaster impact and recovery.
Bogardi and Birkmann, 2004 Cardona 1999, 2001	BBC framework	Defines vulnerability with regard to different hazard impacts related to the economic sphere and the social sphere.	Does not take into consideration environmental vulnerability.

2.4 VULNERABILITY RESEARCH

Vulnerability literature has grown immensely over the past few years. There have been significant articles from earlier research on development and sectoral perspectives (Bohle and Watts, 1993; Chambers, 1989; Gencer, 2007, 2008; Tao *et al*., 2011; Massmann and Werhahn, 2014). Studies related to natural hazards (Blaikie *et al*., 1994; Clark *et al*., 1998; Stephen and Downing, 2001; Cannon, 2008; Peduzzi, 2009; Dunno, 2011); climate change studies (Bohle *et al*., 1994; Adger and Kelly, 1999; Handmer *et al*., 1999; Leichenko and O'Brien, 2000; Downing *et al*., 2001; Kasperson *et al*., 2002; Fuchs *et al*., 2011), and an increasing number of researchers are thus calling for more research on vulnerability and adaptation in both developing and developed nations (O'Brien, Eriksen *et al*., 2006; Moser

and Luers, 2008; Adger *et al*., 2009). Current research follows a trend that provides key assessment of the elements at risk, as a result of climate change (end point approach), at various levels: household, community, regional to global (Füssel and Klein, 2006; Füssel, 2007; Fuchs *et al*., 2011; Armas and Gavris, 2013).

When outlining the history of vulnerability research, Cutter (1996) highlighted various definitions of vulnerability and descriptions of the factors that contribute to the impacts of natural hazards. This was a result of many theoretical approaches to the same challenges and that the vulnerability concept was applied in the global change research as well as in the traditional hazards research. In her review, Cutter (1996) clustered vulnerability studies and their approaches into three groups: vulnerability as pre-existing conditions; vulnerability as hazards of place; and vulnerability as tempered response. Additional literature points out that there are different justifications for the causal structure of vulnerability, some that it results from underlying social conditions (Birkmann, 2006; Chen *et al*., 2013b). In this case, exposure to hazards is treated as given, and studies from this viewpoint examine patterns of differential access to resources or differential susceptibility to loss.

Another vulnerability perception explains causality by modelling potential exposure to hazard events, assuming it as a function of proximity to the source of risk or hazard (Heyman *et al*., 1991; Alexander, 1993). The final approach integrates social and biophysical perspectives, seen as a function of biophysical risk and social response and the way in which these two manifest themselves locally. This is referred to as hazardousness of place (Hewitt and Burton, 1971; Cutter *et al*., 2008). Two principal goals currently driving the field are the design of models which explain vulnerability as well as the root causes which create it, and the development of indicators and indexes that attempt to map vulnerability over time and space (Villágran de León, 2006; Islamn *et al*., 2013).

2.5 VULNERABILITY INDICATORS

The use of indicators to inform policy decisions dates back to the mid-1960s in the USA, when there was a growing interest in the measurement of social change by the social scientists and civil servants (Wong, 2000). Within recent natural hazards and vulnerability research, the Hyogo Framework for Action (2005) appealed for the development of

vulnerability indicators at national and sub-national levels as a fundamental activity in disaster risk reduction to "enable decision-makers to assess the impact of disasters on social, economic and environmental conditions and disseminate the results to policy-makers, the public and populations at risk" (cited in Birkmann, 2005). Indicators are quantifiable constructs that provide information either on matters of wider importance than that which is actually measured, or on a process or trend that otherwise might not be apparent (Hammond *et al.*, 1995). Vulnerability is a relative measure and does not exist as something that can be observed or measured in isolation from context. Hence, developing and using indicators one needs awareness of a number of technical issues, including their sensitivity to change, standardising indicators for comparison, reliability of the data, mapping of indicators, and coverage of relevant dimensions of vulnerability (Downing *et al*., 2002; Gall, 2007; Cutter *et al*., 2009).

There is increasing research initiatives on the development of quantitative indicators of climate change and adaptation to climate-related hazards at different scales of analysis (Leichenko and O'Brien, 2002; Moss *et al*., 2002; O' Brien *et al*., 2004; Brenkert and Malone, 2005; Brooks *et al*., 2005; Sullivan and Meigh, 2005; Deressa *et al*., 2008; Torresan *et al*., 2008; Hahn *et al*., 2009; Khajuria and Ravindranath; 2012; Halsnæs *et al*., 2014; Vincent and Cull, 2014). While there is substantial research and policy interest in the development of vulnerability indicators and indices, particularly in climate change research, general consensus on measuring vulnerability (data, variables, and index construction) remains vague.

Within the natural hazard research, vulnerability indices have been developed at national and sub-national levels and this approach is being gradually applied in countries such as the USA (Clark *et al*., 1998; Cutter *et al*., 2000; Wu *et al*., 2002; Rygel *et al.*, 2006; Yarnal, 2007); the United Kingdom (UK) (Tapsell *et al*., 2002); Spain (Weichselgartner, 2002); Latin America (Cardona, 2005); Australia (Dwyer *et al*., 2004); the Philippines (Acosta-Michlik, 2005); Germany (Kropp *et al*., 2006; Fekete, 2009; Fekete, 2011); Pakistan (Khan and Salman, 2012), or generally for regions worldwide (Mustafa *et al*., 2011; Ramieri *et al*., 2011). In Lesotho, there has been a general lack of such efforts, except for the few attempts that have been made to develop food insecurity and poverty mapping indices (Sechaba Consultants, 2002; LVAC, 2006-2012).

2.5.1 Two types of vulnerability

As a distinction between physical vulnerability and social vulnerability has been made in Cutter (1996), Adger (1999), Wisner *et al*. (2003) and Miller *et al*. (2010) whereby the former denote exposure to stress resulting from physical hazards and the latter refer to the capacity of people to respond to physical impacts. Thus, physical vulnerability is the susceptibility of a given system or place to harm from exposure to a hazard which directly affects the ability to prepare for, respond to, and recover from hazards and disasters (Cutter *et al*., 2009). Physical vulnerability, therefore, assesses the risk of exposed elements from a hazardous event and their propensity to suffer damage (Douglas, 2007; Mazzorana *et al*., 2012).

2.5.2 Social vulnerability

'Social vulnerability' describes the characteristics of the population that influence their capacity to prepare for, respond to and recover from disasters (Cannon, 1994; Tate, 2012). The major objective of vulnerability assessment is to provide indications where, when and how people are vulnerable, and what kind of people and associated assets are likely to be affected by a certain hazard (Aubrecht *et al*., 2012). Thus, social vulnerability assesses both the sensitivity of a population to natural hazards and its ability to respond to and recover from their impacts (Cutter *et al*., 2008). Social vulnerability is the product of social inequalities, namely those social factors that influence or shape the susceptibility of communities to harm and that govern their capacity to respond (Cutter *et al*., 2003). In disaster research, social vulnerability assessments look at the most vulnerable groups in society and examine different types of vulnerabilities between and within geographical units (Downing and Patwardhan, 2003; Azad *et al*., 2013). Socially vulnerable communities and individuals are less likely to have access to essential services during disaster events (e.g., transport, medical care, shelter and food). Therefore, understanding social vulnerability helps to explain why different communities and households can experience the same hazard event differently (Morrow, 2008; Armas and Gavris, 2013). Hence, the extent to which populations and communities are vulnerable to natural hazards is determined not only by a population's proximity to the source of risk but also by its social vulnerability status (Yoon, 2012; Cutter *et al*., 2013). Understanding social

vulnerability in Lesotho is essential for quality public initiatives to be implemented for preparing for, mitigating and responding to natural hazard events.

In line with this study, social vulnerability to hazards is a measure of the potential for loss and is a complex interaction among risk, mitigation, and the social fabric of a place. Social fabric includes community experience with hazards and the ability to respond to, cope with, recover from and adapt to the hazards (Cutter *et al*., 2003). Social vulnerability may be assessed differently in different geographical settings (*ibid.*), provided there are the following generally accepted factors:

1. Lack of access to resources, such as information, knowledge and technology
2. Limited access to political power and representation
3. Social capital, including social networks and connections
4. Beliefs and customs
5. Building stock and age
6. Frail and physically limited individuals
7. Type and density of infrastructure.

Additionally, there are principal components of social vulnerability factors observed in the literature. The community's literacy level, employment status, income levels, housing ownership, age and sex distributions, religious beliefs, kinship levels and informal social support networks are some of the examples of social vulnerability components: (Tierney *et al*., 2001; Cutter, 2001; Cutter *et al*., 2003; Wisner *et al*., 2004; Wood *et al*., 2010). In other studies, social vulnerability includes employment (type and stability), income, savings and education levels (Morrow, 1999; Dwyer *et al*., 2004; Cutter, 2006; Zahran *et al*., 2008). Social vulnerability is therefore an amalgamation of marginalisation factors. Generally, the literature review demonstrates that social vulnerability is high for low income and low status persons, females, the elderly, young children, the rural poor and those dependent on extraction economies, large families, single parent families, female-headed households, and special needs populations (Morrow, 2008; Fekete, 2010). Vulnerability also increases in societies with rapid population growth and loss of employment or infrastructure after a disaster, weak housing and a lack of nearby medical services.

Current indices of social vulnerability differ in indicator selection and statistical downscaling as well as the incorporation of scale and time (Hill and Cutter, 2002). Extensive research exists on single indicators such as gender, income or education, as well as multidimensional indicators such as urbanisation and culture (Table 2.2, below). Gender is an indicator of vulnerability due to unequal access to resources between men and women (Enarson and Morrow, 1997; Mileti, 1999; Morrow, 1999; Dwyer *et al*., 2004; Wisner *et al*., 2004). Females are associated with poverty and inequality. Within the African context, poor population consists mainly of female-headed households (Frankenberger *et al*., 2003). Gender inequality is subject to increasing unequal distribution of resources among males and females, contributing to increased vulnerability of female-headed households to shocks and hazards. Gender inequality also contributes to insecurity and lack of opportunities or empowerment, resulting in lower quality of life for female-headed households (Anderson, 2000; Babugura, 2005).

In addition, the relationship between indicators and social vulnerability is sometimes based on functional relationships with specific outcomes such as agricultural productivity (Polsky, 2004), environmental inequality (Pulido, 2000) or hazard related mortality (Adger *et al*., 2004). Regardless of the general consent of what influences social vulnerability to natural hazards, scientists and professionals disagree on selecting broadly representative indicators. This is not a unique phenomenon in the field of vulnerability science but a recurring problem associated with the generation of indices in general (UNDP/BCRP, 2004; Dunno, 2011). As a result, there is no generally accepted set of indicators to assess social vulnerability, nor is there empirical evidence for the connectivity or their relative importance in vulnerability assessments. Vulnerability indicators can only be selected based on choices by a researcher.

Table 2.2: List of dimensions contributing to social vulnerability to natural hazards

Social vulnerability dimension	**Author**
Income	Morrow (1999), Cutter *et al*. (2003), Adger *et al*. (2004), Burton *et al*. (1993), Cutter *et al*. (2000), Devereux (2006), Leichenko (2002), Cutter and Finch (2008), Cutter and Morath (2013)
Gender	Cutter *et al*. (2003), Fothergill (1996), Vincent (2004), Cutter and Finch (2008), Dunno (2010), Cutter and Morath (2013)

Race, ethnicity	Cutter *et al*. (2003), Pulido (2000), Fothergill *et al*. (1999), Cutter and Finch (2008), Cutter and Morath (2013)
Age	Cutter *et al*. (2003), Cutter *et al*. (2000), Cutter and Finch (2008), Crooks (2009), Cutter and Morath (2013)
Unemployment, dependence on social services	Cutter *et al*. (2003), Adger *et al*. (2004), Heinz Centre for Science, Economics and the Environment (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Housing conditions	Cutter *et al*. (2003), Heinz Centre for Science, Economics and the Environment (2000), Cutter *et al*. (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Infrastructure	Cutter et al. (2003), Adger *et al*. (2004), Heinz Centre for Science, Economics and the Environment (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Family structure, social networks	Cutter *et al*. (2003), Heinz Centre for Science, Economics and the Environment (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Education	Cutter *et al*. (2003), Adger *et al*. (2004), Heinz Centre for Science, Economics and the Environment (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Culture	Cutter *et al*. (2003),
Place (rural/urban dichotomy)	Cutter *et al*. (2003), Adger *et al*. (2004), Cutter *et al*. (2000), Cutter and Finch (2008), Cutter and Morath (2013)
Population growth	Cutter *et al*. (2003), Adger *et al*. (2004), Heinz Centre for Science, Economics and the Environment (2000), Cutter *et al*. (2000)
Special needs population (marginalised, disabled, elderly, under 5)	Cutter *et al*. (2003), Adger *et al*. (2004), Blaikie *et al*. (1994), Cutter and Finch (2008), Cutter and Morath (2013)
Commercial and industrial development	Cutter *et al*. (2003), Heinz Centre for Science, Economics and the Environment (2000), Cutter and Finch (2008), Borden *et al*. (2007).
Built environment	Cutter *et al*. (2003), Cutter and Finch (2008)

2.5.3 Biophysical vulnerability

Biophysical vulnerability refers to the susceptibility of the natural environment to the effects of natural hazards as a result of its exposure (Brooks, 2003; Smit *et al*., 2005). According to Cutter (1996), biophysical vulnerability has distinct spatial outcomes and varies over time. Thus, biophysical vulnerability is orientated towards the ultimate impacts of a natural hazard event and is often perceived in terms of the amount of damage experienced by a system as a result of an encounter with a hazard (engineering research)

(Douglas, 2007; Agrawal, 2010; Mazzorana *et al*., 2012). Biophysical vulnerability operates on two scales: internal vulnerability (driven by local climatic and environmental conditions) and external vulnerability (driven by global scale environmental impacts such as rising sea levels) (Fussel, 2005). According to O'Brien *et al*. (2004), the biophysical vulnerability perspective regards vulnerability to be a fairly stagnant view of the impacts of climate change. In this sense, vulnerability assessment studies are based upon a linear relationship between hazard and impact as consequences of climate change. The trend of assessing impacts based on physical vulnerability has been highlighted in the IPCC processes (McCarthy *et al*., 2001; Vincent, 2005).

Biophysical vulnerability is also influenced by the proximity of elements to the natural hazard, rapidity of onset, duration, areal extent and the probability (risk) with which a hazard of specific magnitude and frequency occurs (Cutter, 2005). Thus, biophysical vulnerability assessments are based mainly on historic information of hazard occurrence and impact. Generally, this allows for a reliable risk assessment of a single hazard or multiple hazards (Cannon, 1994; Hill and Cutter, 2002). Nonetheless, this approach has been criticised by assuming that human beings are passive recipients of climate change and failing to capture their adaptive and coping capabilities (Stonich, 2000).

Even though the concept of vulnerability has some negative implications, the definition of social vulnerability is relatively more positive as it concentrates on the coping capacity of the society, i.e., resilience. This is different from physical vulnerability, in which one of the main focal points is the degree of loss (Cutter and Corendea, 2013). Another important difference between social and physical vulnerability is that the latter changes depending on the type and magnitude of the natural hazard, while the former assessment does not usually consider these factors and so on the whole is not hazard-specific.

Vulnerability of a place to natural hazards is based on both the social and physical processes (Cutter *et al*., 2001), which manifest themselves differently on the landscape, thus suggesting a need for a place-based approach towards understanding their relationship. Many researchers argue that climate change will worsen the severity and frequency of extreme weather events (Mazzorana *et al*., 2012; Busby *et al*., 2013) and consequently increase vulnerability of communities and places. Since vulnerability is place-specific, many researchers call for more local-level analysis to acquire better understanding of the main factors underlying place vulnerability (Mano and Nhemachena,

2007; Below *et al*., 2012; Garcia and Fearnly, 2012; Nasif and Jeroen, 2014). Overall, place vulnerability to natural hazards is thus a function of physical exposure (physical vulnerability), poverty, marginalised groups, lack of access to infrastructure and services (social vulnerability). Identifying where physical exposure to natural hazards conjoins with other dimensions of vulnerability (social and economic) is an important area of research, with significant policy relevance. Spatial differences in these characteristics give rise to differentiated vulnerabilities to environmental threats as well as variations in the resilience or the ability to respond to and recover from them.

In agreement, Vogel and O'Brien (2004) emphasised that vulnerability is: (a) multi-dimensional and differential, that is it differs for different dimensions of one element or group of elements and from a physical context to another; (b) scale dependent, in relation to the unit of analysis, for instance global, regional, national, local and individual; and (c) dynamic, in that the factors that influence vulnerability are continually changing over time and space. Therefore, a spatial orientation of vulnerability within a geographical area is a useful tool for decision-makers. In addition, in order to build resilient communities that can adapt and respond to natural hazards, both physical and social vulnerabilities must be understood, planned and mitigated for. This current study looks at vulnerability from sub-national and local levels. The local level is important as vulnerability is location-specific and because a large share of decisions affecting vulnerability are local (O'Brien *et al*., 2004).

2.6 MAPPING PLACE VULNERABILITY

A spatial analysis of vulnerability helps to identify locations and populations that may be at higher risk due to natural hazard events, for example, drought zones and heavy snowfall prone areas. Cutter (2003) argues that vulnerability manifests geographically in the form of hazardous places, such as floodplains or hurricane routes, thus spatial solutions are required, especially when comparing the relative levels of vulnerability between places or between different groups of people who live and work in them. Generally, vulnerability of a place is characterised by many potentially inter-related factors, for example, hydrological, meteorological, geophysical, social, political and economic. The best way to assess vulnerability is spatially, hence the geographical information system (GIS) has been

used as a tool to understand and map vulnerability. For instance, Emani *et al*. (1993) investigated vulnerability to extreme storm events and sea-level rise using GIS, whilst Lowry *et al*. (1995) carried out a spatial examination of vulnerability to hazardous chemical releases, Rashed *et al*. (2007) used an integrative GIS and remote sensing model for place-based urban vulnerability analysis, whilst Fotis *et al*. (2012) employed GIS for flood vulnerability mapping, and Kumar *et al*. (2014) carried out a GIS based assessment of groundwater vulnerability using a drastic model. These examples underscore the increasing interest in spatial analytical approaches to vulnerability assessment.

This research is theoretically situated in the findings of key several researchers in the fields of hazards and disasters. The theoretical framework is based on the general understanding of vulnerability as a two-part process which includes factors that contribute to an initial lack of the ability of a community to defend against the impact and effect of a hazard or disaster even and also characteristics of place or community that hinder the ability to adequately recover from a hazardous event in a timely manner. It is a multi-step process involving the spatial delineation of characteristics of the biophysical, socioeconomic and built environment characteristics. The methodology is theoretically based on Cutter's (1996), hazards of place model of vulnerability.

Mapping with GIS allows for the ease of data editing, analysis, manipulation, storage, and visualization (DeMers, 2005), and by using a GIS framework, various geophysical patterns and social vulnerability indicators were combined to determine the spatial distribution of place vulnerability. In undertaking place vulnerability to natural hazards, GIS has been used extensively (Chakraborty *et al*., 2005; Rygel *et al*., 2006), and is particularly well-suited for vulnerability assessment because it allows for the integration of multiple data sources that include hazardous locations and vulnerable populations, the geographic representation of complex data in a map form, and the application of spatial analytical techniques, including buffering and overlaying. To analyse social vulnerability, variables that represent socioeconomic characteristics were normalised then combined to create quantitative indicators of vulnerability (discussed in detail in Chapter 4). Equally, data layers that represent various aspects of the biophysical factors, including topographical and hazard profile, were combined. The integration of these sets in a GIS environment provided a composite view of place vulnerability to hazards.

The use of GIS for analysis allowed the researcher to explore spatial statistical outputs that would otherwise be difficult to interpret, for example, hot spots and cold spots. Spatial statistics have been used for many years in various fields, but the most significant contribution that GIS technology has brought to spatial analysis is linking map-based analysis of spatial patterns with well-developed quantitative analytical methods. With appropriate measurements of map features, interpretation of spatial patterns is no longer subjective (Chou, 1997; Chakraborty *et al*., 2005; Rygel *et al*., 2006). Spatial analytical techniques are committed to the analysis of the spatial order and associations of a phenomenon or variable (Fuchs, 2012). Spatial order outlines how geographic entities related to the phenomenon in question are organised in space, while spatial association describes the geographical relationships among phenomena. Therefore, a requirement of spatial analysis is that the phenomenon examined can be mapped (Chakraborty *et al*., 2005; Rygel *et al*., 2006).

2.7 VULNERABILITY ASSESSMENTS

According to Fussel and Klein (2006), vulnerability assessments help in understanding socioeconomically and ecologically climate-sensitive populations and areas. Thus, vulnerability assessments are systematic examinations of who is vulnerable, to what and why. They are widely used instruments comprising a broad group of tools with varying characteristics and goals. The origins lay in the areas of impact assessment, hazard research and food security studies (Schroter *et al*., 2005; Patt *et al*., 2005), and their goals have over the past decade changed from mapping potential climate change impacts to an increased focus on strategies to facilitate adaptation. Current vulnerability assessments help in understanding the impacts of climate change and variability and in identifying measures for adaptation policies (Smit *et al*., 2000; Moser, 2010). This is particularly significant as adaptation has become topical through the UNFCCC.

The International Panel on Climate Change (2012) also urges that selecting the right tool to evaluate risk and vulnerability is dependent on the decision-making setting and that the methods taken in these assessments differ depending on the resources and technologies available. Some approaches may employ global data or downscaled local data, while others may choose more participatory avenues at local level. What is clear, however, is

that quantitative approaches and spatial data need to be supplemented with qualitative inputs at the local level to inform adaptation planning.

2.7.1 Regional vulnerability assessments

The desire to understand geographic, historic and socioeconomic characteristics of vulnerability of places motivates much contemporary research around the world. Recent studies incorporating vulnerability metrics have focused on human-environmental systems at different spatial scales. Globally, Wheeler (2011) measured vulnerability to climate change for 233 countries, using indicators for increasing weather related disasters, sea level rise and loss of agricultural productivity. Additionally, the Global Vulnerability Assessment (2013), an initiative of the IPCC, identified populations and resources at risk from higher sea level as a result of climate change and investigated the cost and feasibility of possible counter measures in response to adverse impacts and examination of institutional capabilities to implement them.

In Africa, climate change is expected to intensify vulnerability, as a consequence of high levels of poverty and dependence on natural resources (IPCC, 2007; 2014). Thus, it is likely to place considerable stress on the economic, political, biophysical and social systems that determine livelihoods (Leary *et al*., 2008; Ziervogel and Zermoglio, 2009). As a result, there have been a number of vulnerability assessments on the continent, with southern and eastern Africa, Eriksen *et al*. (2008) seeing a multiple stressor assessment in several countries, which comprised liberalisation, HIV/AIDS pandemic, trade, competing pressures for land, agricultural policy changes, insecurity of land tenure, conflict and migration, all of which are affected by global environmental change, urbanisation and low agricultural productivity. The authors concluded that all of these shocks impact people in various ways and at different places, depending on socioeconomic factors.

The development literature has increasingly stressed the role of climate variability in shaping rural communities, particularly in southern Africa (Leichencko and O'Brien, 2002; O'Brien and Vogel, 2003; Matyas and Silva, 2013). Evidence shows that in sub-Saharan Africa, natural hazards and disasters have increased in frequency, magnitude and impact in recent past (FANRPAN, 2010), Additionally, whilst compound and interdependent forms of vulnerability co-exist in many African countries and have the

potential to transform even minor hazard events into human disasters. Poor health status, in particular the high prevalence rates of HIV/AIDS in sub-Saharan Africa and the southern African region specifically, has significantly increased underlying vulnerability of households and communities to the impacts of natural hazards (Drimie, 2002; Mwakabolo, 2007). All these factors and processes have resulted in a number of vulnerability assessments at all levels, from regional to household.

The background paper on impacts, vulnerability and adaptation to climate change in Africa is a predecessor to the IPCC Fourth Assessment Report (Elasha *et al*., 2006) and includes a review of key impacts and vulnerabilities to future climate change by sector, for instance, water resources, health, agriculture, food security, biodiversity, coastal zone and marine areas and Millennium Development Goals, as well as of adaptation in African countries. The Intergovernmental Authority on Development (IGAD) and the Climate Prediction and Application Centre report (ICPAC) (2007) reviewed vulnerabilities to the impacts of climate change across major domains, notably energy, water, agriculture, livestock, food security, health, coastal and marine resources, environment, biodiversity and human settlements, in Kenya, Malawi and Ethiopia. This paper further summarised downscaled regional climate projections for 2030 and 2050 and discussed options for mainstreaming climate information in development activities.

Vincent (2004) created a social vulnerability index to climate change for Africa and assessed relative levels of human vulnerability to climate change in relation to water availability. Her index allowed for a cross-country comparison of social vulnerability in Africa. The index was developed from several indicators, including economic, demographic, institutional stability, strength of public infrastructure, global connectivity and dependency on natural resources. The Mapping Climate Vulnerability and Poverty in Africa, a report by Thornton *et al*. (2006), highlighted vulnerability mapping for Africa and used downscaled climate data from several GCMs with biophysical and social vulnerability indicators. Their report further identified the "hotspot" areas in which high exposure to climate change intersects with high biophysical and social vulnerability, in the Sahel, eastern Africa and in southern Africa.

Whilst the identification and assessment of vulnerable populations in Africa has made some advances in the last few years, much of the research has focused on social vulnerability, livelihoods and food insecurity. Numerous case studies have been

undertaken in southern Africa to examine various components of vulnerability. For example, the Regional Vulnerability Assessment Committee (RVAC) uses a livelihoods approach and welfare indicators such as education, health, water, sanitation, HIV/AIDS in relation to food insecurity and vulnerability (Makoae, 2006). Additionally, some vulnerability research has been undertaken across southern Africa on a local level in relation to climatic variability and change (Smith, 2001; Babugura, 2005; Gandure, 2005; Mpandeli, 2006; Vincent, 2007; Eriksen and Da Silva, 2009; One World, 2009; 2010; Bell, 2012).

2.7.2 Lesotho's context

While vulnerability assessments at the global and regional national scales can provide an indication of generic risks and vulnerabilities and of their comparative spatial significance, the impacts of natural hazards are likely to be felt locally in very specific ways that cannot be adequately captured in national assessments, and so require local vulnerability assessments (Hill and Cutter 2002; Birkmann 2006; Cutter *et al*., 2009). Measuring vulnerability at the national level is recognised for its importance in guiding policy and decision-making, which often occur at the national level with the assumption that if vulnerable communities can be identified then comparisons between communities can also be made. A series of (multi-agency) rolling vulnerability assessments have been conducted in Lesotho to provide sub-national food aid targeting details, as well as to inform and guide food security monitoring at the sub-national level and to reassess estimated needs in the light of new food insecurity events. In 1996, Save the Children (UK) used a food economy approach to carry out a risk map project, which indicated areas vulnerable to food insecurity in Lesotho. This was not a vulnerability assessment as such, but it provided baseline information on annual production and market access data to indicate areas vulnerable to food insecurity (Moseley and Earl, 1997).

Lately, the concern with vulnerability in the post-2000 period in Lesotho and southern Africa as a whole has its origins in the food crisis that hit the region at the beginning of the decade (LVAC, 2003). In 2003, the LVAC, in collaboration with SADC FARN vulnerability assessment committee, conducted an assessment to review the food security situation and response in 2002, to develop projections for food security for 2003–2004,

and to identify appropriate food and non-food interventions. This was a nationwide assessment which employed a household economy approach (HEA) to generate baseline information and risk mapping analysis. The broad aim was to incorporate an understanding of livelihoods in emergency and development programming and broaden early warning systems. Thus, the HEA approach has been used in the SADC countries to provide an in-depth understanding of how and to what extent a combination of external and internal factors affects livelihoods. The HEA is a food and livelihood insecurity assessment methodology developed to improve food aid and agriculture decision making (Alexander *et al*., 2013). The HEA was developed in the 1990s by Save the Children (UK) in order to improve the ability to predict short-term changes in access to food and how people might be affected by an environmental 'shock'. This methodology is often used in countries in which people suffer from lack of access to food and income (Frankenberger, 1996; Boudreau, 1998; Seaman, 2000; Stephen and Downing, 2001; Jaspars and Shoham, 2002; Save the Children, 2009; Alexander *et al*., 2013).

There have been very few efforts from SAVI and LVAC to understand vulnerability in terms of who is vulnerable and where the most vulnerable communities are located, with most assessments having been biased towards food insecurities. This is the result of mechanisms that are used to diagnose vulnerability being designed to facilitate implementation of food emergency interventions (LVAC, 2012). The concern to facilitate relief planning and targeting of beneficiaries for emergency assistance has meant that less effort has been made to understand natural hazards vulnerability in southern Africa (Verduijn, 2005), and Lesotho in particular. Although Bell (2011) studied vulnerability of household livelihoods to climate change in the Butha Buthe district (northern Lesotho), he used participatory rural appraisal methodology and did not take into consideration the biophysical characteristics of communities or the underlying social factors contributing to vulnerability.

Hence, previous vulnerability assessments in Lesotho have not generated sufficient information concerning vulnerability beyond livelihoods and food emergencies. The majority of vulnerability assessments carried out in Lesotho originate from research on entitlements and livelihoods, with few efforts made to better understand the factors underlying vulnerability of places to natural hazards. Places that are the most vulnerable to environmental hazards and the factors contributing to their vulnerability have thus been

understudied in Lesotho. The current PhD study seeks to address some of the gaps in methodology used in the previous vulnerability assessments and the type of data collected in those assessments. The study seeks to assess the spatial patterns of vulnerability in the Quthing and Mohale's Hoek districts of Lesotho by testing the suitability of the 'hazard of place vulnerability model'.

2.7 CONCLUSION

This chapter has defined the term 'vulnerability' and related concepts. It further provided a review of existing methods to assess vulnerability and reviewed a number of vulnerability assessment studies. As indicated, these methods have been developed from diverse disciplines. Within the larger theoretical body of vulnerability research the dimensions of vulnerability have been addressed by several studies, however, in only few cases does a model of vulnerability exist that allows for the integration of both physical and societal characteristics of vulnerability. In general, vulnerability assessments in Lesotho have used the livelihoods and entitlements approaches and mainly focused on vulnerability to food insecurity. These assessments usually under emphasise the physical susceptibility of communities and the characteristics of a society that attenuate the effects of extreme natural hazards. Therefore, this literature provides an argument that, in order to improve vulnerability assessments in Lesotho, a more integrated approach must be embraced. By combining physical and social vulnerabilities to a variety of natural hazards at the district and community council levels a better understanding of place-based vulnerability assessment will hopefully be attained. The research thus attempts to advance the body of vulnerability research by developing a multi-hazards assessment method for Lesotho, allowing for spatial comparisons.

CHAPTER THREE

THE STUDY AREA

3.0 INTRODUCTION

Formerly a British protectorate of Basutoland, the Kingdom of Lesotho adopted its new name on independence in 1966, and covers an area of 30 588km^2. According to the 2006 Population and Housing Census, Lesotho had about 1,876,633 inhabitants, made up of 912,798 males and 963,835 females, with a population density of 61 people per km2 (Bureau of Statistics 2007; Coburn *et al*., 2013). It is landlocked and completely surrounded by South Africa (Figure 3.1), the present boundaries following in part a series of rivers, Tele, Senqu (Orange River), Makhaleng and Mohokare (Caledon River). Between Makhaleng and Mohokare, the south-western boundary follows a beaconed boundary fence, while between the sources of the Mohokare and Tele, the long eastern and southern boundaries follow a high mountain watershed. This section of the boundary is for much of its distance the continental divide between the Atlantic and Indian Oceans, and it is the dramatic escarpment cliffs which make access to Lesotho on this side extremely difficult (Chakela, 1999). Lesotho is underlain by sediments and basaltic lavas of the Karroo System with numerous dolerite dykes and sills (Bawden and Carroll, 1968; Bordy *et al*., 2004). There is consensus in research findings that the soils of Lesotho (derived from sedimentary and basaltic rocks) are highly erodible (Staples and Hudson, 1938; Carroll and Bascomb, 1967; Bawden and Carroll, 1968).

3.1 ECOLOGICAL ZONES

Lesotho has a varied geomorphology and topography, including micro-climatological influences which have a significant impact on the ecology and economy of the country. These factors characterise the formation of distinct ecological zones in Lesotho which include the lowlands (17%), foothills (15%), mountains (59%) and Senqu River Valley (9%) (Figure 3.2 and Table 3.1). The mountains rise to a height of 3,482 metres above sea level (m.a.s.l.) at Thabana-Ntlenyana in the Drakensberg, which forms the eastern boundary with KwaZulu-Natal. The mountain ranges extend from north to south and those

in the central area (Maluti Range) are spurs of the main Drakensberg, which they join in the north forming a high plateau varying in height from 2,700 to 3,400 m.a.s.l. It is in this area that two of the largest rivers in southern Africa, the Orange (Senqu) and the Tugela as well as the tributaries of the Caledon have their source.

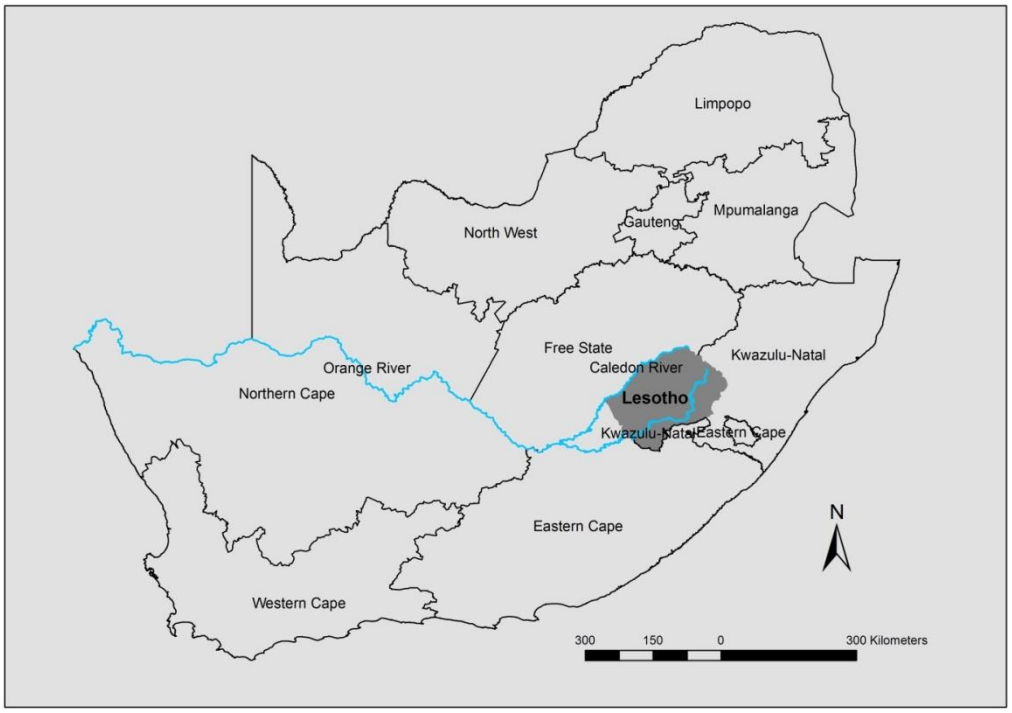

Figure 3.1: South African map

Source: Own data

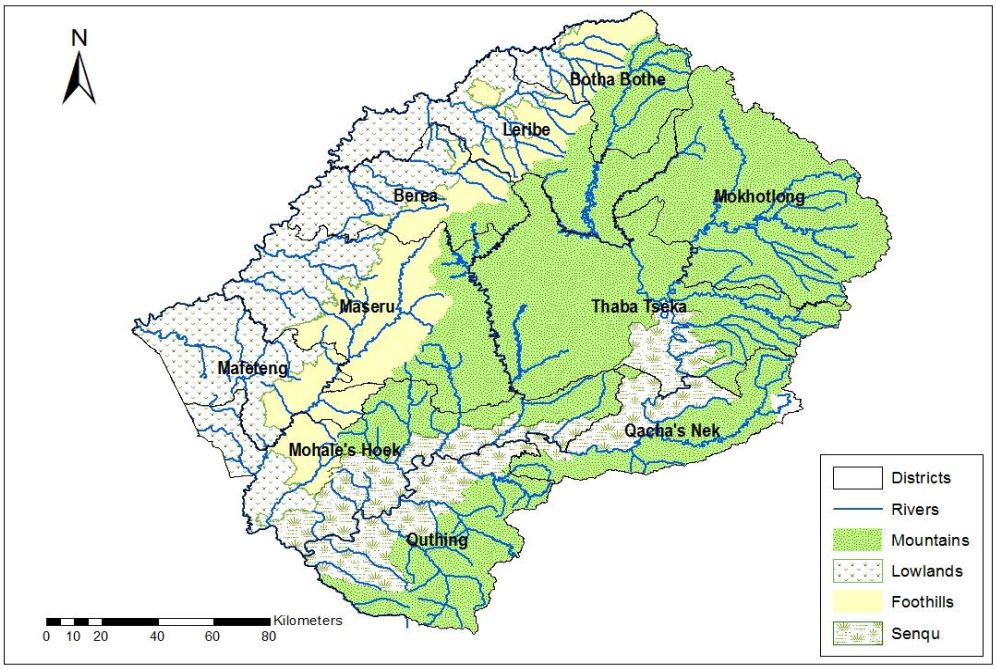

Figure 3.2: Map of Lesotho

Source: Own data

Table 3.1: Summary of the characteristics of ecological zones

Parameter	**Mountains**	**Lowlands**	**Foothills**	**Senqu River Valley**
Area (km^2)	18, 047 (59%)	5,200 (17%)	4,588 (15%)	2,753 (9%)
Altitude (m)	2,000 – 3,482	1.388 - 1,800	1,800 - 2,000	1,388 – 2,000
Topography	Very steep bare rock outcrops and gentle rolling valleys	Flat to gentle rolling	Steeply rolling	Steeply rolling
Soils	Fragile, thin horizon of rich black loam except on valley bottoms.	Sandy textured, red to brown in the north, clayey in the south	Rich, alluvial along valleys, thin and thick on slopes	Calcareous/lime soil, clayey red soils with poor penetration by rain
Climate	Cold and moist	Moist in the north, moderately dry in the south	Moist, sheltered	Dry
Risks	Long period of frost, snow, hail, high soil	Parching sun, strong winter winds, hail, periodic droughts, and	Floods, high soil erodibility	Severe drought, moderate soil erodibility.

	erodibility	high soil erodibility.		
Vegetation	Denuded grassland, indigenous shrubs in some river valleys, stunted peach trees near homesteads	Crop stubble, reforestation on some hills, fruit trees near homesteads	Poplar and willow trees along streams and gullies, crop stubble, a lot of fruit trees near homesteads	Denuded dry shrubs, brush, few trees in valley

Source: Ministry of Natural Resources 2000; FAO, 2006.

3.2 CLIMATE

Lesotho's rainfall, the bulk of which falls between October and April, varies from 700 millimetres (mm) to 1,000mm, depending on years and the location, with the northern part of the country (Oxbow) receiving the highest and the southern part (Quthing, Mohale's Hoek and the Senqu River valley) receiving the lowest (Wilken, 1978; Hyden, 1996, Hyden and Sekoli, 2000; Hyden, 2002). According to Saha (2011), the mean annual precipitation in the Lesotho lowlands over the 107 year period from 1886/87 to 1992/93 was 735mm and the mean annual precipitation varied significantly between years from 426 to 1,097mm. For this study the current mean annual rainfall is 775mm (1938-2011) indicating a slight increase from 1886/87. Mountainous topography in southern Africa has both positive and negative impacts on the regional climate through orography and by blocking inland infiltration of humid south-easterlies from the Indian Ocean (Schulze, 1997). Orography generally affects rainfall amounts, rates, frequency and distribution around the mountains and their surroundings. High elevation areas often receive higher rainfall than surrounding areas and rainfall is higher on the windward side of the mountains whilst leeward side receives less rainfall (Grab, 2004) in the Drakensberg and Lesotho highlands.

Monthly mean minimum temperatures in winter range from −6.3 °C in the highlands to 5.1 °C in the lowlands; sub-zero temperatures are frequent in the winter months (May to July) but low temperatures can also occur during summer. Monthly mean maximum temperatures (16.5 °C at high altitudes and 29 °C in the lowlands) occur from November to February. The highest temperatures are usually recorded in January (Dyer, 1982; Mason, 1996; Mason and Jury, 1997; Lesotho Meteorological Services, 2000). Summers are cool (average temperature 11˚C) and winters cold (average temperature 0˚C) at

~3000m, whereas the highest summits >3400m have an estimated mean annual temperature of 4˚C (Sene *et al*., 1998; Grab, 1999). At this elevation, around 200–225 annual frost days occur (Schulze, 1997; Moeletsi, 2010; Moeletsi and Walker, 2013). In addition, ground freezing has been reported in the Lesotho highlands (Grab, 2004) and the Drakensberg region has been specifically classified as slightly periglacial and a range of active and inactive periglacial landforms has been observed, such as earth hummocks, sorted patterned ground and stone and turf-banked lobes (Grab *et al*., 2012; Knight and Grab, 2013).

3.3 NATURAL HAZARDS

Lesotho suffers from highly variable and extreme weather conditions and exposure to a wide range of natural hazards, including severe wind, hail storms, floods, extreme cold, severe frost, heavy snow and drought (LMS, 2002; Ziervogel, 2004; Showers, 2005; Obiah, 2010; Nash and Grab, 2010; Moeletsi and Walker, 2013). Natural occurring events and hazards are often not confined to specific areas within the country. However, land size and the fragility of the environment influence hazard occurrence, distribution and impacts. Vulnerability to natural hazards, though influenced by natural occurrences, is also a consequence of unsustainable human activities such as land degradation caused by inappropriate farming practices, unplanned development and improper land use (Maro, 2011). A potential risk to such hazards is people, field crops, livestock, buildings, transport infrastructure and economies, all of which are greatly influenced by space and location. While the entire country of Lesotho is vulnerable to natural hazards, some natural ones, such as severe frost, flooding and drought, are more prevalent in the southern districts of the country (Mohale's Hoek and Quthing). Geographic exposure, low household incomes, low rainfall, topography and greater reliance on climate sensitive sectors such as agriculture, are factors that increase people's vulnerability and reduce their productivity (LVAC, 2009).

3.4 LAND USE

Land-use patterns in Lesotho have largely been determined by historical circumstances and agro-ecological conditions. During territorial wars of the 19th century, hilltops and mountain sides were used as fortresses hence many settlements were confined to these strategic locations while flat plains and fertile valleys were used for crop farming and the remote mountains for grazing (Ferguson, 1990; Mbata, 2001). This has largely remained the pattern of land-use in the country although population pressure and urbanisation have forced widespread encroachment of settlements onto areas that were traditionally reserved for agriculture (Chakela, 1999). The shortage of arable agricultural land has also tended to concentrate cultivation on mountain slopes (marginal lands) with devastating results for slope and soil stability, a decrease in the quality of rangelands and reduced agricultural productivity (Ferguson and Lohmann, 1994; Keketso, 2003). Table 3.2 (below) shows land-use and land classification categories in Lesotho, and it is evident that the prime land-use is ranges for grazing. The second most dominant land-use is crop lands, which occupies 24.7% of the total acreage, notwithstanding that arable land is estimated at 9% or less in the country. There is serious land degradation, with about 1.9% of the land area classified as 'dongas' (dry valleys). It is widely believed that the classified area of "rock outcrops" is a consequence of soil erosion (Showers, 2005, Majara, 2005). Additionally, although villages occupy 3.2% of the land area, they are rapidly encroaching onto croplands, resulting in increases in landlessness and cultivation of marginal lands (Chakela *et al*., 1986; Maro, 2011, 2012). Soil erosion and expansion of settlements have thus contributed to extreme forms of land degradation. It is estimated that the country loses a total of 40 million tons of soil per year through gully, sheet and rill erosion (Chakela and Seithleko, 1995).

Table 3.2: Land classification in Lesotho

Land Classification/Use	Area (Ha)	Percentage of Total
Croplands	754,002	24.7
Rangelands	1,981,896	64.8
Forest	12,118	0.4
Rock outcrops	103,798	3.4
Gullies	59,572	1.9
Villages	98,802	3.2

Roads	12,118	0.4
Water	33,179	1.1
Other	1,581	0.1
Total	3,057,066	100.0

Source: Majara (2005)

3.5 ECONOMIC SETTING

Being entirely surrounded by the Republic of South Africa, Lesotho has an internally weak economy that is highly dependent upon external sources of revenue. Its political system has been historically marked by incessant conflict and instability. Since the demise of apartheid and the Cold War, Lesotho's political system has also changed, although economic conditions have not fundamentally altered (Kimble, 1978; Ferguson and Lohmann, 1994; Coplan and Quinlan, 1997; Matlosa and Sello, 2006).

Agriculture and migrant labour, with many citizens seeking work in South African mines, have formed the mainstay of Lesotho's economy for decades. A decrease in migrant labour has resulted in increasing poverty levels through a reduction in purchasing power, particularly in rural areas (Mohanoe-Mochebelele *et al*., 2009). Analysis of official data provides evidence of a gradual decline in agricultural production in the country, a feature that had dominated food security policies since the 1970s (GoL, 2009; CBL, 2013). Once based on subsistence agriculture and animal husbandry as well as migrant workers' salaries from the South African mines, the economy has changed substantially as a result of growth in the manufacturing sector in Lesotho. In the 1980s, nearly half of Lesotho's GNP was based on the earnings of about 120,000 mine labourers, whilst recently less than half that number has been employed in the mines (Mohanoe-Mochebelele *et al*., 2009). There has also been increasing investment in the local mining sector (BoS, 2009).

Lesotho's main economic pillars are remittance from the Southern African Customs Union (SACU), which comprises Botswana, Lesotho, Namibia, South Africa and Swaziland. It is estimated that about US$4 billion is generated from SACU, representing over 60% of the GDP. Other sources of revenue are through the African Growth and Opportunity Act (AGOA) and water sales to South Africa. Thus, the main sources of government revenues are the country's share in the South African Customs Union (SACU) and the sale of water to South Africa. It is estimated that about US$4 billion is generated from SACU,

representing over 60% of the GDP. Other sources of revenue are through the African Growth and Opportunity Act (AGOA), an agreement with the United States government to offer favourable export conditions for African textile exports. Lesotho has benefitted from AGOA through sales of textiles, which generate 10% of Lesotho GDP, whilst the sale of water generates 5%. The country has abundant water, which is currently being tapped for export to South Africa through the Lesotho Highlands Water Project (LHWP) (Matlosa and Sello, 2006), signed between the Kingdom of Lesotho and the Republic of South African in 1986, and which supply water to the Gauteng province of South Africa. Lesotho's abundance of water has been referred to as its "white gold (Mochebelele, 2000; Braun and McLees, 2012) and it is estimated that the sale of water to South Africa contributes 14% of the government's revenue, 25% of Lesotho's total annual export revenue, and 5% of its GDP (Matli, 2005; Manwa, 2014). Lesotho's limited natural resource base, a mountainous topography, limited arable land, unreliable climate and severe soil erosion, limit the agricultural sector to create sufficient levels of employment and income to support the country's population.

In 2012, Lesotho had a Gross Domestic Product (GDP) per capita of US$ 4795 and an annual growth rate of about 4.4% (UNICEF, 2013). Over the last decade it has made modest progress in terms of economic growth and economic wellbeing, and has been able to transform from subsistence to a modern economy with per capita income of US$ 2,426 billion in 2011 and annual per-capita GDP growth of 2.2% registered in 2010 (UNICEF, 2013). Lesotho's economy showed signs of economic recovery in 2009, following the global financial crisis, however, the impacts of floods during early January 2011 slowed the pace of the expected recovery (Central Bank of Lesotho, 2011).

Although Lesotho's GDP has increased it has not been equally distributed across the country. The gap between the rich and the poor has remained similar over the past decade, hence inequality and poverty remain the greatest challenges to the government. For instance, in 1994/95 income inequality as measured by the Gini-coefficient (GNI) was estimated at 0.57, whereas in 2003/04 it was estimated at 0.52. In 2011, the GNI was estimated at 0.62, suggesting an increase in inequality across communities, and this has placed more people in Lesotho below the poverty line (Mohanoe-Mochebelele *et al*., 2009; Central Bank of Lesotho, 2011). Lack of economic resources is a driving factor of poverty and economic vulnerability, as they are essential for appropriate response to hazards. The

extent to which people have sufficient economic resources to meet their basic needs, to anticipate and respond to inevitable change and disruption is a core factor in resilience and varies considerably among households and communities in the country. When significant segments of the population are poor and live with daily risk and insecurity, they usually cannot cope or respond to hazards and threats effectively without outside assistance.

3.5.1 Poverty and livelihoods

Poverty in Lesotho is deeply rooted in rural areas, in which about 70% of the people reside. More than half of rural people are poor and more than one quarter lives in extreme poverty (Mohanoe-Mochebelele *et al*., 2009; BOS, 2010; Central Bank of Lesotho, 2011). Major causes of poverty in Lesotho include lack of income, unemployment, inadequate distribution of assets and power, reliance on government to provide economic and social services, as well as to severe degradation of the natural resource base on which the livelihoods of many rural poor depend. The significant drop in remittances from migrant labourers in South Africa has worsened poverty levels for many rural households (BOS, 2010). These factors make the poor more prone to natural hazards and exacerbate their poor economic status, thus increasing vulnerability. The issues of underdevelopment, landlessness and unemployment have earlier been raised by Copland and Quinlan (1997).

Of the 1,876,633 people in Lesotho in 2006, 17.3% were classified as very poor and an additional 32.5% as poor, resulting in a total of 49.8% of the population living below the poverty line (BoS, 2010). By 2009, with the rapid increase in deaths due to HIV/AIDS, low agricultural productivity and the decline in remittances from South African mines had increased poverty in the country (*ibid.*). Additionally, nearly all national household surveys in Lesotho show prominent variations of poverty in relation to gender, household size, livelihood patterns, access to basic services and geographic location (Sechaba Consultants, 2006; BoS, 2009; LVAC, 2009). Of these, the greatest determinant of economic differences is geography. Several studies have consistently shown that the mountain areas of Lesotho, which are home to approximately one-third of the population, are significantly poorer (Turner, 2005; Sechaba Consultants, 2006; LVAC, 2009; Letete and Paramaiah, 2009; Mohanoe-Mochebelele *et al*., 2009; One World, 2010). Extreme poverty is thus concentrated in the rural areas not only as a proportion of the population

but also in absolute numbers. A weak and limited agricultural/natural resource base (due to mountainous terrain and unproductive soils), inaccessibility and scarce income opportunities in rural areas are the main causes of rural poverty.

Second to geography in explaining poverty in Lesotho is gender. According to the 2006 Census, about one third of households were headed by women who were single, divorced, widowed or abandoned by their husbands, a proportion higher than in most sub-Saharan African countries (BoS, 2006; Mapetla, 2011). Female-headed households often have the highest incidences of poverty, about two thirds, and are particularly poor and vulnerable because they are typically headed by ageing widows, who may have lost the productive assets they once possessed and are less likely to own agricultural assets such as livestock (field observation). Thus, female-headed households are more prone to poverty than male-headed households.

Focus group discussions also confirmed that female-headed households are considered poorer because they are typically headed by young single women and/or ageing widows, with fewer assets and greater difficulties securing cash incomes. Turner (2005) noted that the historically patriarchal structure of gender relations in Lesotho has resulted in women's lack of rights caused poverty and hindered women's empowerment and capability to build sustainable livelihoods. Land ownership remains a major challenge for rural women with the percentage distribution of land tenure by households between male and female heads, according to 2006 Census, showing that men own almost 70% of land relative to 30% owned by women, limiting access to land and leaving women poor and economically dependent (Bello *et al*., 2009; Bureau of Statistics, 2009). However, the situation is expected to change with recent legal reforms having brought about women and men's equal rights in marital power and access to land, thus improving their household status and decision-making powers (Mapetla, 2011).

At the national level, social protection and social safety nets in terms of food aid are very common as a consequence of recurrent droughts. Although Lesotho does not face famine because of the droughts, the ability of many households to maintain a minimum livelihood has either been put in jeopardy or completely failed. This is particularly the case for those who need some form of assistance even in 'normal' economic circumstances, and those who depended most on paid labour or the market for their food (Levine, 2007). The entire country has experienced a more than 70% drop in domestic agricultural production, putting

more than 725,000 people, over a third of the population, at serious risk of food insecurity over the past decade (Obiah, 2010; Saha, 2011; DMA, 2012). Figure 3.3 illustrates that more than 200,000 people require humanitarian assistance in Lesotho annually. Recurrent droughts, severe frost and floods often result in crop failure and property losses that limit the ability of households to cope. Thus, humanitarian assistance is often required to feed communities devastated by such events. For instance, in 2012/13 it was estimated that about one third of the country's population (725,519) required humanitarian assistance, the highest number since 2005.

Additionally, Lesotho has a child grant programme which is an unconditional social cash transfer targeted to poor and vulnerable households, to improve the living standards of orphans and vulnerable children (OVC), so as to reduce malnutrition, improve health status and increase school enrolment among OVC (Taylor *et al*, 2014). Lastly, Lesotho has a universal old age pension for people aged 70 and above, which has been a primary source of income for the elderly. Though Lesotho does not have any formal social protection system, old age pension is playing a critical role in enhancing the welfare of the elderly (Dhemba, 2012). Though typically a small amount (M450.00), the availability of a non-contributory universal old age pension paid monthly in Lesotho allows for basic living needs to be met. It plays a significant role in reducing poverty not only for older people but also for their households (Pelham, 2007; Bello *et al*., 2008).

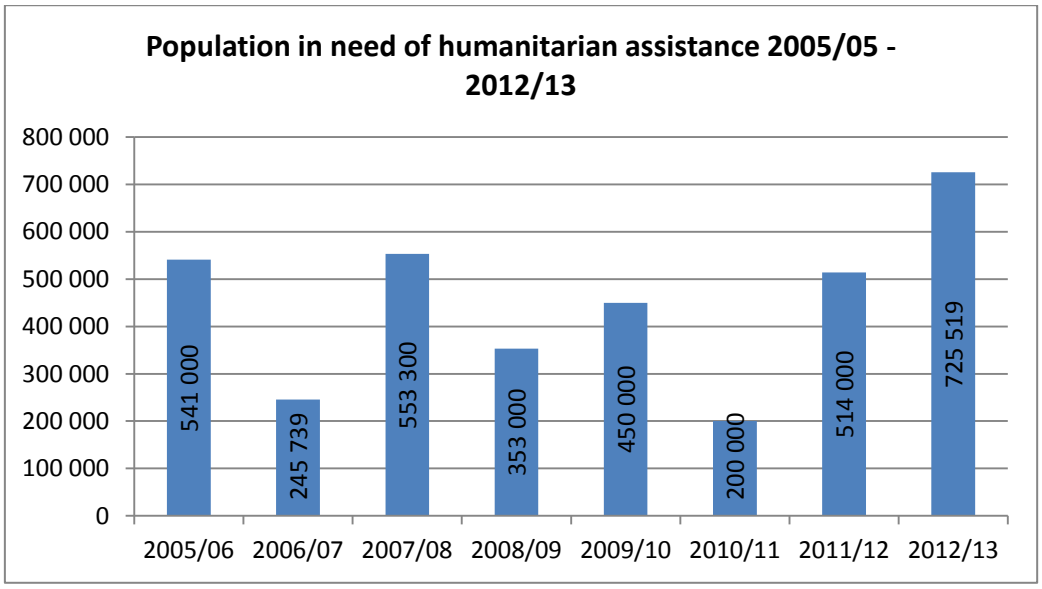

Figure 3.3 Population in need of humanitarian assistance 2005/06 – 2012/13.

Source: DMA. (2012)

3.5.2 Agriculture

Lesotho's geographical position, topography and latitude contribute to the country's biophysical and socioeconomic landscape and influence livelihood options. Of the 30 300km^2, making up Lesotho's total land area, about 25% has agricultural potential (NES, 2009). Less than half of this is suitable for arable farming, with the remaining agricultural land supporting livestock farming. Crop cultivation is generally performed in the foothills and lowlands. Being a grassland region, the country is more suitable for livestock farming (Maro, 2011), thus the terrain favours livestock farming over crop farming. Agriculture contributes about 16.6% of Lesotho's GDP and is a major source of employment, however, a larger proportion of the country's population is involved in subsistence agriculture. Crop production accounts for 70% of agricultural GDP, and livestock production 30% (CBL, 2012). The agricultural sector employs between 70-80% of the total labour force and over 50% of these are resource-poor rural households who engage in small-scale farming primarily for subsistence purposes. The remainder are small-scale semi-commercial and commercial farmers, on both medium and large farms (BoS, 2012).

Climate variability and land degradation have contributed to the consequent decline in agricultural production and have worsened the coexisting problems of food shortages and poverty (Lesotho Review, 2009; Maro, 2012). The consequent reduction in the total arable land coupled with population growth rate has resulted in landlessness and increased poverty and subsequent rural urban migration (GoL, 2008; Bisaro *et al*., 2010). Environmental degradation is a major problem and is threatening to negatively affect the country's socioeconomic gains and weaken government's ability to provide agricultural extension services. Declining agricultural production and loss of biodiversity are not unique problems to Lesotho, but are also a concern in other countries in sub-Saharan Africa (Muchena *et al*., 2005; Rutherford and Powrie, 2010).

3.5.3 Unemployment

According to the Lesotho Integrated Labour Force Survey of 2008 the unemployment rate was 22.7%. Unemployment is a concern as it affects household income, vulnerability and food security, and has left many households unable to purchase food during drought periods. Unemployment, especially among the youth, remains a serious challenge to the

country's economy. The employment to population rate stands at 54.1% and it is estimated that only 15.3% of the youth (25-29 years) are unemployed (Bello *et al*., 2008). In 2009, the overall unemployment rate was higher for females, 24.6%, than for males 21.2% (Figure 3.4). As evident from the graph, Quthing had the highest unemployment rate of 30% among females and 24.6% for males, while Mohale's Hoek had 26% and 19% for females and males respectively.

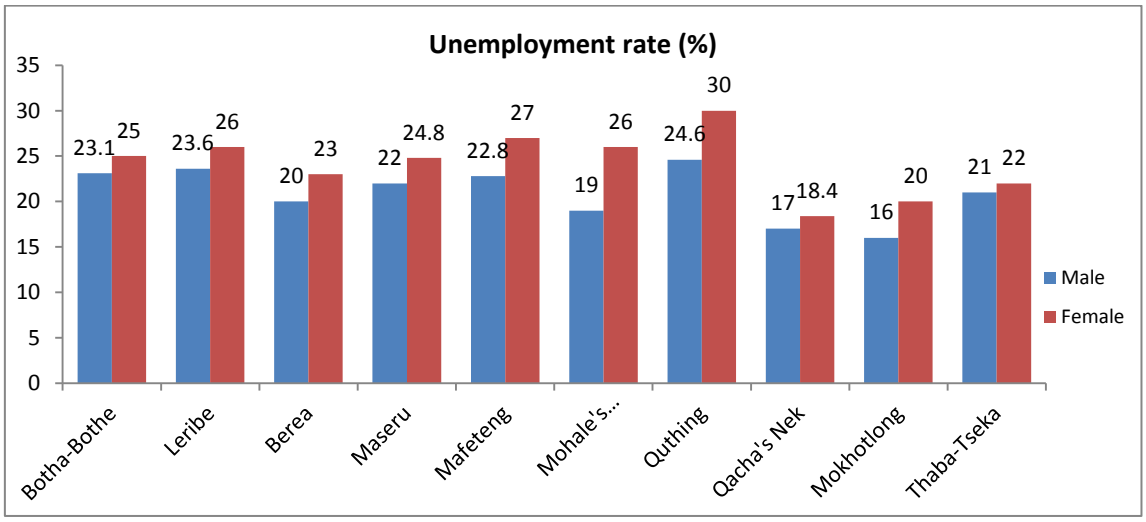

Figure 3.4: Unemployment rates in Lesotho.

Source: Bureau of Statistics 2009.

3.6 DEMOGRAPHY

Data from consecutive population censuses show that the population of Lesotho is predominantly rural. However, the proportion living in urban areas increased from 12% in 1986 to 17% in 1996 and to 25% in 2006 (Table 3.3). Similarly, life expectancy at birth has increased from 55 years in 1986 to 59 years in 1996. Recently, the increased morbidity and mortality of economically active population caused by the HIV/AIDS pandemic has brought wide ranging socioeconomic impacts on all aspects of livelihoods, including erosion of income, reduction in livelihood asset base and decreased access to education, all thereby exacerbating poverty (Turner, 2005; Mapetla, 2011). As a weakening illness, HIV/AIDS not only increases vulnerability to shocks among those affected but also increases the vulnerability of the aggregate population by further diverting scarce financial

resources into healthcare provision and funeral expenses. Though poverty in Lesotho is very closely associated with the absence of wage employment and income, the worsening HIV/AIDS pandemic is undermining the economic resource base, especially of the weaker strata of the economy in rural areas. This generally results in lack of labour for essential agricultural activities and as a result some fields are being left idle, deepening the poverty and increasing food insecurity and vulnerability. HIV/AIDS has reduced availability of family labour, which is becoming a major constraint in subsistence farming. Table 3.4 presents the HIV/AIDS situation in Lesotho. As a devastating illness, prevalence of HIV/AIDS increases vulnerability to shocks amongst those infected and affected and the vulnerability of the aggregate population by further redirecting insufficient financial resources of households.

Table 3.3: Basic demographic indicators

Selected demographic indicators for Lesotho: 1976, 1986, 1996 and 2006				
Indicator	**1976**	**1986**	**1996**	**2006**
Population (millions)	1.2	1.6	2.1	1.8
Inter-Census growth rate (%)	2.3	2.6	1.5	
Population density (per km^2)	60	53	61	63
Percentage urban	11	12	17	25
Crude birth rate	39	37	30	
Crude death rate	17	11.6	12.8	
Total fertility rate	5.4	5.3	4.1	
Infant mortality rate (per 1,000 births)	113	85	74	
Life expectancy (years)	51	55	59	
Male	49.3	49.3	58.6	
Female	52.7	56.7	60.2	

Source: Bureau of Statistics (BoS), 1976, 1986, 1996, 2006 (Census reports).

Table 3.4: Key HIV/AIDS indicators

Indicator	**2005**	**2007**	**2008**
Adult HIV prevalence rate	23.2%	23.2%	23.6%
Total number of HIV infected people	266, 000	270, 000	281, 000
Adult HIV incidence rate	2.9%	2.35%	2.1%
Number of new infections	26, 000	21, 558	21, 000
AIDS mortality	24, 000	18, 000	11, 000
AIDS related OVCs	97, 000	108, 700	122, 000
Projection of ART needs	42, 640	81, 270	117, 903

Source: Lesotho National AIDS Commission 2010. www.nac.org.ls

The HIV/AIDS prevalence rate, significantly increasing from 4% estimated in 1993 to 23.4% in 2004 (Ministry of Health and Social Welfare, 2005), has played a crucial role in increasing the number of orphans. About 2,697 households in Quthing were identified by the district administrator as hosting single orphans, of which about 1,568 were considered vulnerable. A further 1,208 households were identified to be hosting double orphans, of which 739 were considered vulnerable. Over 9% of the interviewed households were considered to have a high burden of care, hosting two or more double orphaned children. Lastly, this study discovered that there were 86 child-headed households in Quthing district and 56 in Mohale's Hoek. Orphan-headed households often lack economically active adults who might otherwise provide income to support them (field observation). According to the 2006 Lesotho Census, HIV/AIDS has been the main contributory factor in the increase in the number of orphans from 130,245 in 1996 to 221,403 in 2006. This implies a 70 % increase over the ten-year period. During field visits it was observed that the majority of orphans were often left with one surviving parent to raise them, or in the case of the death of both parents in the care of aged grandparents or other relatives. Alternatively, they might simply be left on their own. Orphans often tend to drop out of school to assume household responsibilities, which sometimes include household

headship. Despite the rising number of orphans in the country and the complexity of challenges they face, the government has been implementing a number of programmes and initiatives to address and mitigate vulnerability of orphans. One such programme is the child grants programme (CGP), which is a cash grant of M360 per quarter allocated to poor householders who are responsible for taking care of vulnerable children, including orphans.

3.7 THE STUDY REGION

The study region is situated in the south-western districts of Mohale's Hoek and Quthing in Lesotho (Figure 3.5) and comprises the four ecological zones of Lesotho, namely, the lowlands, foothills, Senqu River valley and the highlands. The lowlands have an altitude of 1520-1820m and cover a small portion of Quthing and Mohale's Hoek. Most parts of the lowlands have soils derived from cave sandstones and the rocks of riverbeds (Moeti, 1996). The foothills run along the western side of the Maluti Mountains, creating a transitional zone between the lowlands and the highlands with an altitude ranging from 1,388-2,200m. The Senqu River Valley comprises a narrow strip of land that borders the banks of the Senqu River which originates from the Mokhotlong highlands and stretches into lower parts of the main tributaries of this river. The soils in the Senqu River valley range from fair to very poor, making this the most infertile region in the country (Moeti, 1996; Chakela, 1999; Moeletsi and Walker, 2013). The highlands are widely divided by the headwaters of the Senqu River and its tributaries which flow down in a north-south direction and in conjunction with a wide network of mountain wetlands, they form a significant part of the southern African region's water resources (Chakela, 1999; Lannas and Turpie, 2009). Each of the major river systems in Lesotho forms a part of the Senqu drainage basin. The flow of these rivers depends on the seasons. In winter the flow is very low and in dry years the rivers dry up (Moeti, 1996). This drainage pattern of the highlands region has resulted in deep river valleys, gorges and gullies that in general make this region and its population vulnerable to a wide range of natural hazards, such as frost, heavy snowfall and flooding.

Of the two districts, Mohale's Hoek is the larger, covering approximately 3,530 km² with a population density of 65.8 (Table 3.5). Villages are spread throughout the district, with a

concentration of settlements, schools and commercial establishments in Motletjoeng community council (Mohale's Hoek) town. Motlejoeng is also the most densely populated (25,096) community council in the district. The total population of Mohale's Hoek is 173,781 with just over 88,522 of the population being females (51%). Quthing covers approximately 2,916 km² of land with a population density of 73.4 and a population of 119,592 (Table 3.6). Just over half of the population in Quthing were female (52%). Liphakoe, the urban community council and the administrative centre of the district had 14,537 inhabitants. Mohale's Hoek had an average household size of 7, while Quthing had an average of 5.9. This is in contrast to the national average household size of 4.4 persons in Lesotho (Bureau of Statistics Lesotho, 2009). Most of the community councils with large households were located in the rural and mountain areas of the country. The majority of households in Lesotho have large families, which often affects the ability of some households to cope with the effects of natural hazards, as there are more people to feed and take care of.

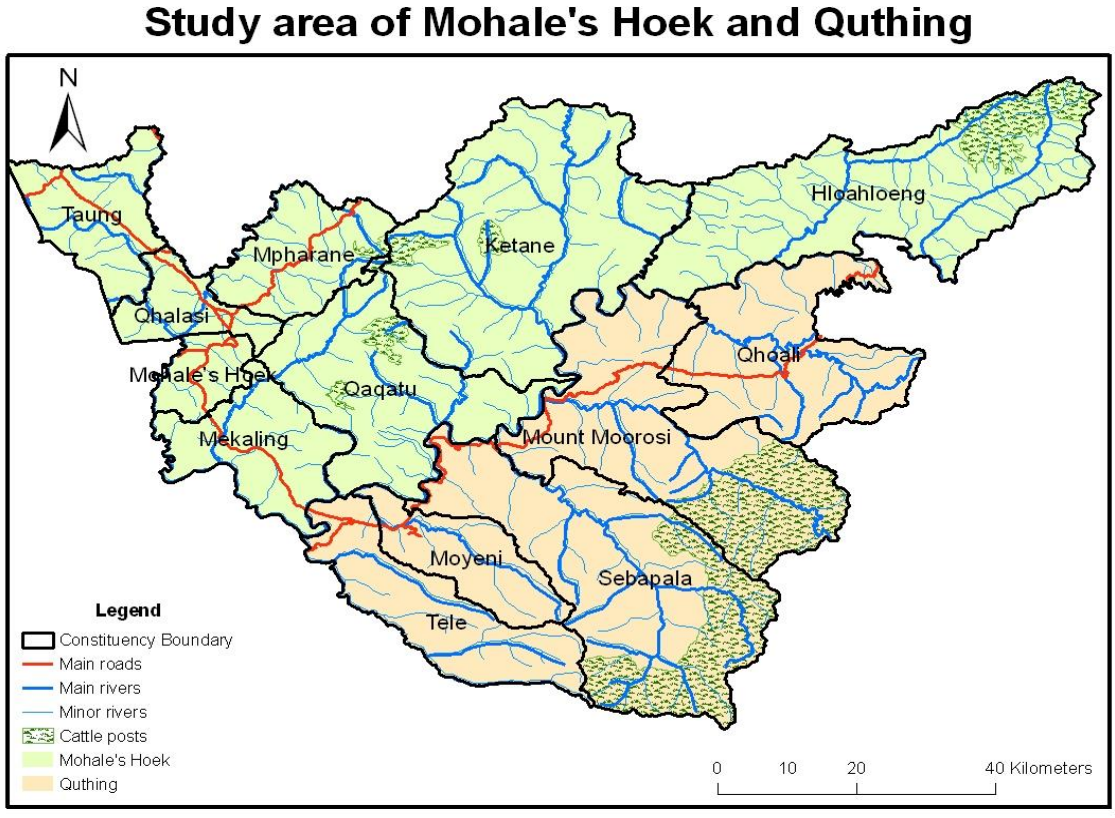

Figure 3.5: Map of the study area.

Source: Own data

Table 3.5: Mohale's Hoek district profile

Community Council	Populat-ion	% of District Population	Male	Female	Km2 surface	Population density	House-hold size
Siloe	18261	10.5	9295	8966	262.96	69.4	5
Mashaleng	21869	12.6	10658	11211	146.25	149.5	5
Motlejoeng	25096	14.4	11839	13257	109.93	228.3	7
Khoelenya	22424	12.9	10873	11551	297.97	75.3	8
Teke	5403	3.1	2722	2681	174.32	31.0	5
Mootsinyane	9995	5.8	4743	5252	183.16	54.6	10
Phamong	8402	4.8	4113	4289	142.45	59.0	5
Thabana Mokhele	18135	10.4	8851	9284	267.33	67.8	4
Qobong	9324	5.4	4747	4577	205.57	45.4	12
Qhobeng	3083	1.8	1604	1479	211.13	14.6	7
Seroto	7836	4.5	3950	3886	313.84	25.0	6
Likhutloaneng	7937	4.6	3945	3992	304.32	26.1	8
Nkau	9092	5.2	4462	4630	226.68	40.1	8
Qabane	6924	4.0	3457	3467	198.69	34.8	4
Total	**173781**	**100.0**	**85259**	**88522**	**3044.6**	**65.8**	**7**

Source: Ministry of Local Government (2008).

Table 3.6: Quthing district profile

Community Council	Population	% of District Population	Male	Female	Km2 surface	Population density	Household size
Likhohlong	7,455	6.23	3671	3784	219.5	34	5
Matsatseng	18,713	15.65	9108	9605	190.1	98.4	6
Qomoqomong	6,760	5.65	3288	3472	151.2	44.7	6
Liphakoe	14,537	12.16	6864	7673	49	296.7	4
Nkoebe	10,487	8.77	5073	5414	363.2	28.9	5
Tsatsane	9,452	7.90	4637	4815	235.8	40.1	7

Mkhono	9,840	8.23	4796	5044	235.8	41.7	5
Mokotjomela	12,340	10.32	6044	6296	226.7	54.4	7
Mphaki	20,288	16.96	9956	10332	400.1	50.7	5
Seforong	9,720	8.13	4700	5020	196.9	44.4	9
TOTAL	**119,592**	100.00	**58137**	**61455**	120,502	73.4	5.9

Source: Ministry of Local Government (2008).

3.8 SUMMARY

This chapter has provided a detailed description of the physical and socioeconomic landscape of the study area. It also set the scene for the study by giving the physical and socioeconomic challenges facing the study area and the country as a whole. Issues of interest within the research, climate, topography, demographics, livelihoods and poverty, have been discussed within the context of the study area, as well as their likely impacts on vulnerability. With the study area being described, the next chapter presents the methodologies employed to address the research questions outlined in chapter one.

CHAPTER FOUR

METHODOLOGY

4.0 INTRODUCTION

The main aim of this chapter is to present the methods and data used in this PhD research. The study adopted mixed quantitative and qualitative methods which combined data from different sources as a means of triangulation. This allowed for a complementary research strategy with the aim of assessing place vulnerability from different perspectives as well as integrating the viewpoints of different stakeholders. This triangulation enabled insight not possible with only one data type. The study was based on an extensive review of literature pertaining to vulnerability and natural hazards in both developed and developing countries. Primary and secondary data was collected[1] in order to develop vulnerability indicators. The main data sources used for this study included questionnaire-based interviews with household heads, key informants and focus group discussions at community level, census data, biophysical and climate data. The questionnaires developed covered key topics such as demographic, socioeconomic characteristics, hazard occurrence, effects of the most recent hazard events and coping strategies.

4.1 SAMPLE SIZE AND SELECTION

Table 4.1 presents basic information of the study area, comprising two districts and 23 community councils, which were used as the spatial units of analysis for this study. Community councils were the most appropriate unit of analysis because of the administrative structure in Lesotho, availability of demographic data and the statistical requirements for the creation of the social vulnerability index (SoVI). Community councils constitute an entity whose residents share ideas, have similar livelihoods, values and risk culture. They are also meant to represent the area with fairly homogenous population with respect to population characteristics, economic status, and living conditions. Additionally, many government functions and decisions begin at the community council administrative

[1] Although 'data' is the Latin plural of datum it is generally treated as an uncountable 'mass' noun and so takes a singular verb (*Concise Oxford English Dictionary*, 2011, Eds. Stevenson and Waite).

level. As a way of influencing decision-making at the local level and the district level, the researcher considered the community council as a unit of analysis to be the most appropriate. A small proportion (3%) of the total households in each district was used as the sample size population for household interviews. A small sample size of 250 households in both districts was used for the questionnaire administration. The households were randomly selected making sure that they provided a true representation of each community council. The key informants (e.g., community council members, village chiefs and village disaster management team members) were used to identify participants for focus group discussions. Prior to data collection process a preliminary visit to the study area (Mohale's Hoek and Quthing districts) was undertaken and meetings held with district community council member and community leaders in each district, during which this study was introduced.

Table 4.1: Basic information of the study area

District	Population	Male	Female	Km2 surface	Population density	Number of house-holds	Household size
Mohale's Hoek	173781	85259	88522	3044.6	65.8	4354	7
Quthing	119,592	58137	61455	120,502	73.4	4053	5.9

4.2 PRIMARY DATA

The study relied mostly on the 2006 Census data at the community council level for the creation of social vulnerability index. Because studies on individuals and households confirmed good results for the quantification of social vulnerability (Levine, 2004), a small set of household interviews was used to confirm the accuracy of indicator selection at census level. The primary data collection was based on field visits and primary data was collected between December 2009 and April 2012 in both Mohale's Hoek and Quthing districts. Fieldwork was carried out in the 23 community councils consisting of several villages. The information was gathered by interviewing 250 household heads. Four research assistants were engaged for both household interviews and for focus group discussions. The household interviews were semi-structured and based on a questionnaire prepared for this research (Appendix A). A structured questionnaire composed of six

sections was designed to obtain information through household interviews. The interviews were approximately 45 minutes in length, although this ranged from 30 minutes to 1.5 hours, depending on the interviewee.

A pilot survey was undertaken in November 2009 to pre-test the questionnaire before the actual data collection. The pilot survey was conducted using the convenient sampling of six households in each district, in order to determine the effectiveness of the questionnaires and the duration of administering them. Additionally, it helped determine the types of questions asked, their content and wording. The pre-testing of the questionnaire revealed unanticipated problems such as wording, repetition and instructions to skip questions. After the pilot survey, the questionnaire was revised.

4.2.1 Sampling method

The researcher adopted a multistage sampling technique (Agresti and Finlay, 2008) which included stratified sampling of respondents based on their geographical location, from the district level to the village level. A stratified random sampling technique was then employed at the village level to select households to which the questionnaires were administered. This was to ensure that the selected sample was representative and to also allow each household an equal chance of being selected. Secondly, it ensured that accurate results were obtained for purposes of making generalisations and inferences, thus, the sampling technique facilitated the compilation of a study sample which was reflective or representative of properties and attributes of the entire population.

In fulfilling research ethics and standards of the University of the Witwatersrand, permission was sought from the District Administrator and the local area chiefs. All interviews were conducted in Sesotho, the language with which the respondents, research assistants and the researcher were comfortable. However, about 16 interviews were conducted with the help of an interpreter as respondents were Xhosa-speaking in the Quthing district. Through the fieldwork, in-depth interviews and informal conversations were conducted with households and community leaders, such as area chiefs and local councillors.

4.2.2 Focus group discussions

Apart from household interviews, a total of 12 focus group discussions of two- to three-hour sessions were conducted (six in each district) with farmers and the elderly in the community. The focus groups were composed of eight to twelve people, consisting of both males and females. A digital voice recorder was used during the focus group discussions during which two research assistants took notes. Focus groups discussions are a qualitative data collection method, meaning that the data is descriptive and cannot be measured numerically (Rabiee, 2004). They were also conducted to gather additional information to supplement quantitative data. In contrast to the quantitative data methodologies, focus group discussions gathered more in-depth information on perceptions, insights, attitudes, experiences and beliefs of the communities in relation to vulnerability to natural hazards (Appendix C). On average, a focus group comprises six to twelve people with similar characteristics or common interests (Babbie, 2001; Rabiee, 2004, 2007). Group discussions produce data and insights that are less accessible without the interaction found in a group setting, listening to others' verbalised experiences, stimulate memories and ideas in participants (Steward and Shamdasani, 1990; Krueger, 1994; Kleiber, 2004; Babbie, 2011; Liamputtong, 2011). Similarly, work by Tapsell *et al*. (2002) used focus groups to determine vulnerability indicators for a social flood vulnerability index.

4.3 SECONDARY DATA COLLECTION

Vulnerability studies often rely on indicators from available data sources such as the decadal population or housing censuses, or geophysical data related to hazard risks (Chester *et al*., 2000; Dunno, 2011). Additional secondary data collected for this study included:

- Topographical maps at a scale of 1:50,000, used as a base for delineating the study area and obtained from the Lesotho Surveys and Physical Planning Department.
- Digital Elevation Model data, available from the Department of Geography of the National University of Lesotho.
- Climate, weather related and natural hazards data, obtained from the initial recording time to-date from the Lesotho Meteorological Services.

- Additional climate and hazard related information, obtained from the District Disaster Management Authority offices, missionary diaries and newspapers from the Morija Museum, and recent newspapers.
- Literature (journal articles, official reports, research reports and the Internet) on hazard occurrences in Lesotho.

4.3.1 Historical climate data

The historical climate data relied upon two major sources: the available measured climate data for both Mohale's Hoek and Quthing districts and all available documentary sources, including travel writings, administrative, colonial and government reports, missionary journals, correspondences and newspapers. For both districts, the earliest measured meteorological data available was from 1825, used to identify periods of extreme climatic events and to verify the data set compiled using the documentary evidence. All descriptions, statements or discussions mentioning extreme climatic conditions, as well as impacts on livelihoods, infrastructure, or other relevant socioeconomic aspects of livelihoods in Lesotho, were transcribed. From the documentary sources, all references to extreme climatic factors were transcribed (Table 4.2).

Table 4.2: Indicators for extreme climatic events

Hazard	**Indicator used**
Flooding	Heavy rainfall, flooding, extremely wet, water logging, heavy downpour, torrents of rains, fields eroded, roads impassable, people drowned and killed livestock.
Drought	Drought, prolonged drought, severe drought, crop failure, famine, weak livestock, livestock deaths, poor pastures and low yields.
Severe frost	Severe frost, extreme cold, severe early frost and damaging frost.
Heavy snowfall	Heavy snowfall, prolonged heavy snowfall, killed livestock, killed people, houses collapsed, mountain passes impassable and herd boys trapped/ killed.
Strong winds	Terrible storm, strong winds, whirlwinds, violent wind, gale storms, tornado, buildings damaged, people injured, infrastructure damaged

	and wind ripped off roofs.

Historical documentary climate records include severe frosts, droughts, strong winds, and snowfall, heavy and prolonged rainfall. Historical and documentary climatic sources have been used by other researchers to reconstruct the climate of particular areas for periods when little or no detailed instrumental data was available (Vogel, 1989; Grab and Nash, 2010; Nash and Grab; 2010, Kelso, 2010). Documentary climate data in Lesotho is, however, generally limited to regions with available archival records. In this study, such data was interpreted with caution, as it was not equivalent in reliability to actual instrumental measurements of meteorological variables. Furthermore, historical information often emphasises extreme conditions (Jones and Mann, 2004) and so present a misleading picture as there are no categories of extreme events reported in archival data. For instance, there is no distinction between severe and extreme events. Additionally, such data often leads to a subjective description of climatic conditions, which often involves generalisation for a prolonged time period or a large area. The spatial extent covered by the references was also varied. Some sources related to Quthing and Mohale's Hoek specifically, while others dealt more broadly with the whole of Lesotho. The researcher believes that reporting of climate data has improved in Lesotho in recent years, in terms of data quality, time resolution and spatial coverage, hence an increase in the number of reported extreme climatic events.

4.4 DATA PROCESSING

Several steps were followed to construct a GIS-based place vulnerability index. The first included the gathering of spatial, for example, satellite images, topographic maps, climate data; and non-spatial, for example, statistical records, and socioeconomic parameters. They involved primary data collection in the field, from analysis of scientific literature, existing GIS databases and documentary and instrumental climate data.

Topographical maps and other geographic data were used to assess physical characteristics of the study area. This was aimed at estimating the overall exposure and susceptibility in different communities. Fieldwork made it possible to geo-reference data from satellite imagery and aerial photographs, and to confirm the results obtained from the remote

sensing image analysis. The processing of the household questionnaires involved creation of a data entry form, data entry, verification, data editing and cleaning. The data were entered and analysed using *Microsoft Excel* and *Statistical Package for the Social Sciences* (*SPSS 22*). The raw data from the census data and the district handbooks were imported into *Microsoft Excel* and SPSS for processing and standardisation. Some variables did not require standardisation because they had already provided a percentage (e.g., percentage female population). The variables were imported from *SPSS* in a .dbf format into *ArcMap* then spatially joined with the community council layer shapefile.

Non-spatial data, notably census data and social vulnerability index scores, were then geo-coded, a method by which any information provided in a tabular format is converted into spatial coordinates (Zandbergen, 2009). The non-spatial datasets were thus entered into a GIS to create different layers which were overlaid and used to produce a place vulnerability map. The data was subsequently exported into *ArcGIS 10.1* (Geographical Information Systems) software and overlaid with other spatial data sets (census data and topographic data) to produce social, physical and place vulnerability maps.

A systematic coding method was used to analyse data gathered from the focus group discussions using the coded key word approach (Rabiee, 2004). The researcher read thoroughly the focus group discussion notes and assigned a code/key word to each comment in order to identify themes within the text. This coding set the stage for systematic analysis of focus group comments through the application of text management programme using *nvivo* software.

Socioeconomic data from the 2006 National Census and the District Handbooks were entered into *SPSS* programme and used to extract socioeconomic vulnerability indicators. These sets of data were used in conjunction with the interviews and focus group discussion data to create vulnerability indicators. Usually, census data contains information about income levels, educational status, age or sex differentiations, which can be used as indicators of social vulnerability. However, indicators such as kinship levels or social support networks, which are more powerful indicators of social vulnerability, are not included in the census data and these were obtained from the focus group discussions and household interviews.

These different datasets were integrated in a GIS as follows: in the first step, attribute information was associated with three basic concepts (points, lines or polygons) that describe features occurring in the real world using a unique identifier assigned to each spatial element (community council). From a database design point of view, attribute information was stored in two-dimensional tables linked with a relational join. The database was then developed on the GIS platform as spatial and non-spatial data. The spatial data (maps) was created by onscreen digitising the geo-referenced scanned paper maps then stored as vector and raster files in the digital format using *ArcGIS 10.1* software. The non-spatial data or the attribute data such as population and household variables for the community councils was added to the spatial data (maps). These datasets were manipulated and used to create different layers which were overlaid to produce social, physical and place vulnerability index maps. Figure 4.1 shows a GIS data model that was developed for this research.

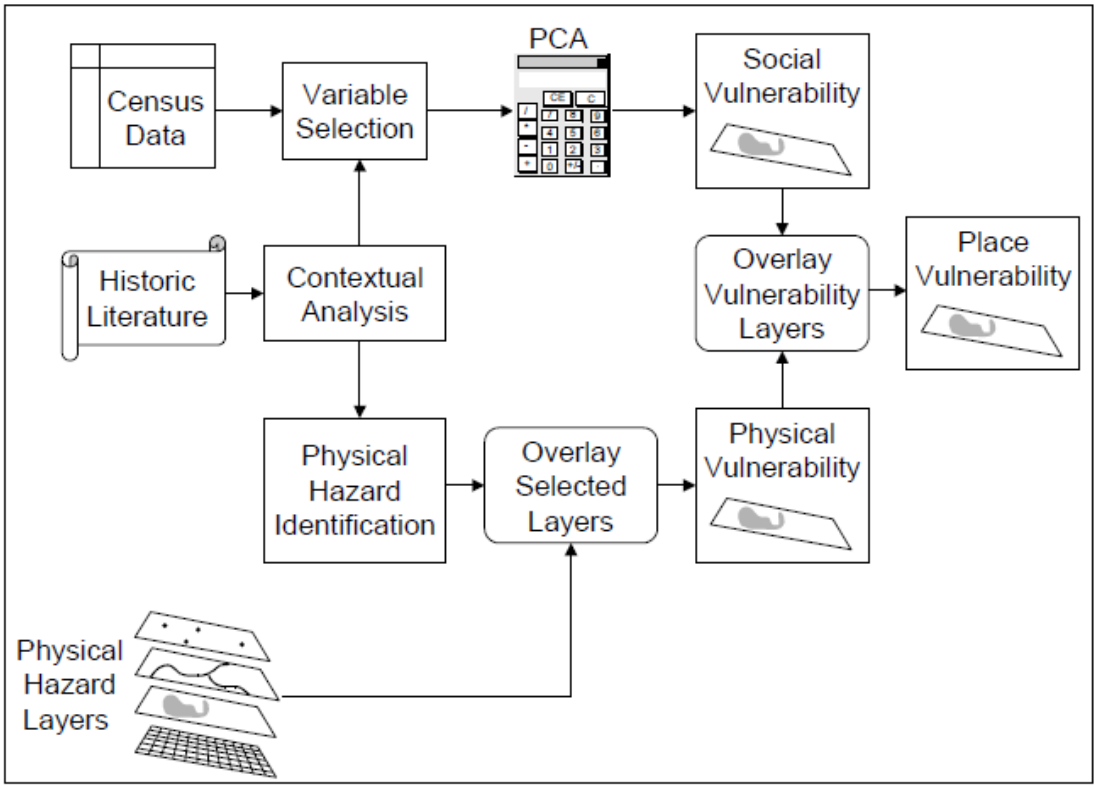

Figure 4.1: Flow diagram of the geospatial implementation of the vulnerability of place model in the study area.

4.5 SOCIAL VULNERABILITY CONSTRUCTION

This study adopted the methodology for measuring social vulnerability, as used in the USA, the Caribbean, Germany, Australia and New Zealand, with census data as proxies for social vulnerability variables (Cutter *et al*., 2003; Boruff *et al*., 2005; Finnis and Johnston, 2007; Fekete, 2009; Lowe, 2010). The method analyses pre-disaster vulnerability as a snapshot in time, effectively creating a checklist of vulnerable characteristics that can be mapped. This method identifies socioeconomic characteristics of communities, households and individuals, and measures the underlying causes of social vulnerability.

4.5.1 Data

Although social vulnerability may be assessed differently in different geographical settings, Cutter and Morath (2013) provide generally accepted factors affecting social vulnerability. These include socioeconomic status, gender, race, ethnicity, age, development, unemployment, rural/urban, residential property, infrastructure and lifelines, renters, occupation, family structure, education, population growth, medical services, social dependence and population with special needs. The literature review by Cutter *et al*. (2003) demonstrated that social vulnerability is usually high for low income and low status persons, females, the elderly, young children, the rural poor and those dependent on extraction economies, large families, single parent families, female-headed households and special needs populations. Vulnerability also increases in societies with rapid population growth and with loss of employment or infrastructure after a disaster, weak housing and a lack of nearby medical services. To examine the applicability of these indicators as measures of social vulnerability for the Lesotho context, their applicability was first assessed.

The question then arises as to the applicability of Cutter's methodology to the present analysis, given the difference in place, scale and variable selection, since the availability and type of data may differ from one country to another. In this regard, Schmidtlein *et al*. (2008) examined the sensitivity of the quantitative features of the social vulnerability index (SoVI) created by Cutter *et al*. (2003) to changes in place and scale at which the model is applied and the set of variables used in its construction. They found that, across

scales, the identification of the underlying drivers of social vulnerability remained constant within a particular study area. With respect to the adequacy of variable selection, Lowe (2010) applied this model to the Virgin Islands with a modified set of variables and produced similar results to those from the original study (Cutter *et al*., 2003), both in terms of representation of vulnerability and the identification of highly vulnerable areas. Overall, the SoVI approach was found to be robust to minor changes in scale and variable selection (Schmidtlein *et al*., 2008; Cutter and Morath, 2013), and thus it was applied to the current study on social vulnerability in Lesotho.

Although the social vulnerability index is a valuable tool for assessing social vulnerability within a community it was considered necessary to adjust the variables so that they accurately reflect the underlying social fabric of Lesotho. Based on the recommendations from the disaster management authority officials and drawing from existing literature and knowledge of the study area, the variables were grouped according to the social vulnerability research (Twigg, 2001; Cutter *et al*., 2003; Blaikie *et al*., 2005; Cutter and Morath, 2013), as well as on the perceptions of disaster management officials in Lesotho, focus group discussions and household interviews. The additional socioeconomic variables for this study that had not previously been considered in other studies are percentage of orphans and child-headed households to represent vulnerable groups, and percent of households receiving public assistance as an additional measure of dependent populations within the study region. Percentage of households using electricity for cooking and lighting is an additional variable representing economic status, as is percentage of population that has completed primary and secondary education. The original social vulnerability index and the recent index (Cutter *et al*., 2003; Cutter and Morath, 2013) present a number of mobile homes as an indicator of vulnerability within the community. However, given that there are no mobile homes in Lesotho, the percentage of housing type (thatched, iron, tile roofing and mud and brick walls) was a better representation of housing structures heavily impacted by natural hazards.

Preparedness is a significant component of vulnerability assessment that is not dealt with in the Social Vulnerability Index model (Cutter *et al*., 2003; Cutter and Morath, 2013). The degree of a household's preparedness has the capability either to intensify vulnerability to natural hazards or to improve upon it. The more prepared a household is the less vulnerable it will be. These particular variables adopted for this research were percentages

of: orphans and child-headed households; the population dependent on social protection and food aid (thought to increase vulnerability in the study area); households using alternative fuel (cooking and lighting with electricity); villages with cell phone reception; and villages with no access to roads. Percentage of villages with existing water systems were categorised within infrastructure development and socio-demographic indicators. These variables are not among the characteristics generally accepted by social scientists as typical of social vulnerability, yet they are significant from a preparedness point of view. Vulnerability indicators used to represent race and culture in the original social vulnerability index methodology did not accurately reflect the social fabric of Lesotho, a homogeneous country, therefore they were excluded from the analyses.

4.5.2 Data processing

All of the variables collected at the community council and district levels were standardised using percentages, per capita or density (per square kilometre) functions. To combine multiple variables in the assessment of social vulnerability, the arithmetic mean of social vulnerability indices was calculated by dividing the sum of index values of all variables by the number of variables. Finally, the 37 selected variables were transformed into z-scores, maximum value (ratio of value) and minimum-maximum rescaling techniques. When standardised in this way, values of social vulnerability index range from 0 to 1 and are not affected by the number of variables integrated in the calculation (Cutter *et al*., 2003; Schmidtlein *et al*., 2012; Ward, 2012). The z-scores provide a standardised value so that data is on a relative scale and can be used more effectively in statistical analysis (Nardo *et al*., 2008). Since the variables were demarcated in a range of statistical units with varying ranges or distributions, they were also standardised to avoid problems inherent when mixing measurement units and to avert having extreme values skew a statistical analysis (Nardo et al., 2008; Fekete, 2010).

The SoVI scores were then imported into SPSS 22 and ArcGIS 10.1 for mapping and further analysis. A comparative assessment of social vulnerability among the community councils and districts was then conducted. By mapping the social vulnerability index scores, the most and the least vulnerable community councils were identified and the underlying social processes contributing toward this vulnerability enabled. Thus, this study

analysed social vulnerability at district and community level, the spread providing a more comprehensive overview on vulnerability in the study region as well as a better understanding of the processes that shape vulnerability at multiple spatial scales. In line with the SoVI methodology, variables were entered into SPSS and descriptive statistics for the variables were run to ensure the normality of the data and to inspect for data errors.

4.5.3 Social vulnerability assessment methodology

The social vulnerability index (SoVI) is a quantitative measure of social vulnerability to environmental hazards. Originally developed in 2003 and applied to the USA, it allows for an empirically based comparative measure that facilitates the geographic examination of relative variations in the levels of social vulnerability across space (Cutter *et al*., 2003). The SoVI synthesises socioeconomic variables known to influence vulnerability (National Research Council, 2006) into multiple dimensions using a principal components analysis (PCA). These dimensions are equally weighted and summed to create the overall SoVI score for a study region. As the model was initially intended for assessment of counties in the USA it was modified to fit the Lesotho context.

Relative community council level social vulnerability was modelled for the study area following the methodology outlined by Cutter *et al*. (2003). The initial model applied a Principal Components Analysis (PCA) to a set of 42 census variables illustrating social contributions to vulnerability at the county level for the USA. The researcher adopted the same model and used the Lesotho 2006 Census data and District Handbooks to extract social vulnerability variables specific to the country's context. Once extracted, the variables were processed using PCA in *SPSS*, with the resulting components then summed up using an equal weighting scheme to create an overall SoVI score for each spatial unit of analysis. Higher scores indicated more socially vulnerable areas, lower scores, less vulnerable ones. The SoVI construction is a three-tiered process: standardise input data, use factor analysis (plus rotation) and an additive modelling methodology. The end result is a univariate score that broadly represents the relative levels of social vulnerability within the study area. The resulting factors or components are linear combinations of correlated variables that represent a broader measure of how certain factors contribute to vulnerability. A methodological step for the construction of indices includes identifying

aspects that make people vulnerable to natural hazards, using factor analysis to generate a social vulnerability index score, standardising the social vulnerability scores, and mapping social vulnerability index. Figure 4.2 illustrates the main steps involved in the creation of the SoVI.[2] The following steps were involved in the creation of SoVI in this study:

- Collect the input variables. SoVI variables were derived primarily from the 2006 Lesotho Census data and district handbooks.
- All variable were normalized as percentages, per capita values or densities (i.e., per square kilometre).
- The input variables were standardised using z-scores standardisation. This generates variables with a mean of 0 and standard deviation of 1.
- A PCA was then performed using a Varimax rotation and Kaiser Criterion for component selection. The Varimax rotation reduces the tendency for a variable to load highly on more than one factor. The parameters were then set for the extraction of factors. This was done by examining the scree plot for significant drops in *eigenvalue* as the number of components included in the analysis increases (Velicer *et al*., 2002; Lance *et al*., 2006). It was then determined whether a factor has a tendency to decrease or increase social vulnerability, and in instances where a factor decreases social vulnerability, a negative sign was assigned to the factor score, and if it increases vulnerability a positive sign was assigned.
- The resulting factors were examined to determine their broad representation and influence on social vulnerability (i.e., whether factors increase or decrease vulnerability) for each factor by scrutinising the factor loadings (i.e., correlation between the individual variable and the entire factor) for each variable in each factor.
- Factors were then named based on variables with significant factor loadings (or correlation coefficients) usually greater than .500 or less than -.500, then a directional adjustment (cardinality) was applied to an entire factor to ensure that the signs of the subsequent defining variables were appropriately describing the tendency of the phenomena to increase or decrease social vulnerability.

[2] The procedure for duplicating the SoVI can be found at http://webra.cas.sc.edu/hvri/products/sovi.aspx

- All the components were placed with their directional adjustments into an additive model and summed to generate the overall SoVI score for each community council.
- The SoVI scores were then mapped in ArcGIS using an objective classification (standard deviations) with 3 or 5 divergent classes to illustrate areas of high, medium and low social vulnerability.

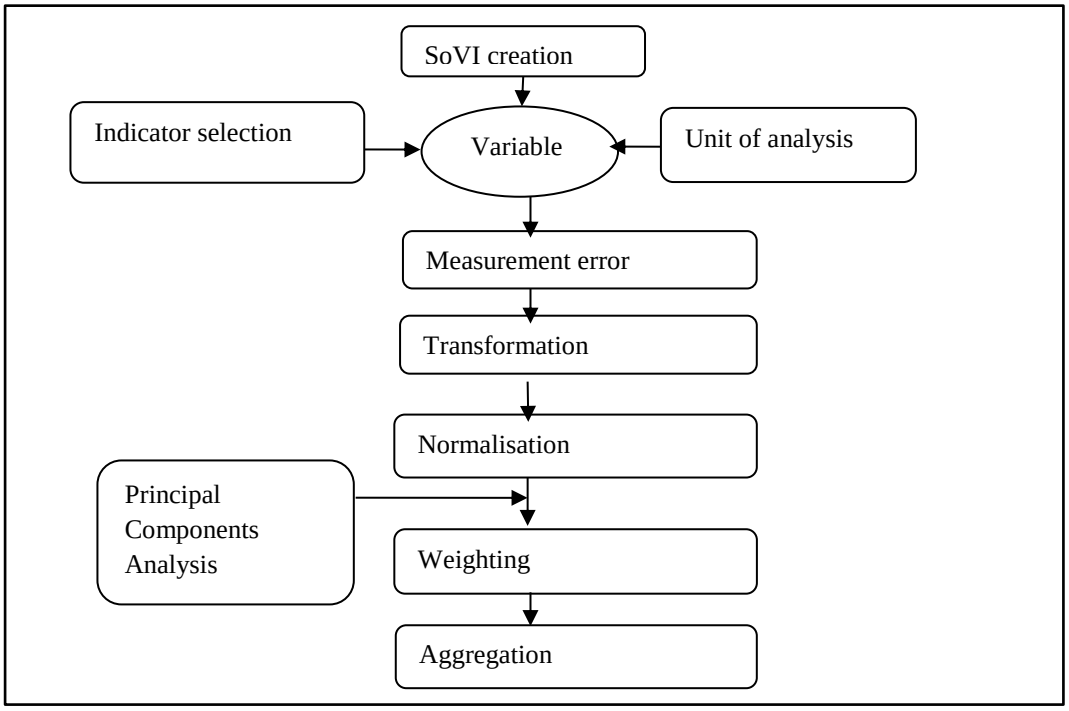

Figure 4.2: Social vulnerability index construction flowchart

4.5.4 Construction of the SoVI

All the variables collected at the community council for the study area were normalised using percentage, density or per capita (per square kilometre) functions. Data accuracy was explored using descriptive statistics and then normalised using z-scores (Appendix F). The normalised scores were then input into *SPSS* for PCA to reduce the number of variables into a smaller number of multidimensional factors/ components. The PCA is a data reduction method of factor analysis which was used in this study to simplify the interpretation of a large multivariate data set by identifying groups or categories of variables that behave in a similar manner (Field, 2012). The PCA was conducted so as to arrive at a minimum number of components that adequately account for the co-variation

among the larger number of analysed variables. In addition, PCA assists in determining a meaningful interpretation of the component groups that gives insight into the data for use for further analysis. The Kaiser criterion was used as an extraction method (eigenvalues greater than 1) and a Varimax rotation. The Varimax rotation minimises the number of variables that load high on a single factor, increasing the percentage of variation between each.

Finally, the overall social index scores were mapped as standard deviations from the mean to allow for a visual representation of the spatial variability in social vulnerability. Mapping vulnerability in this way outlines the extent to which some places are more vulnerable than others, and highlights those geographic units that are at the ends of the distribution, for example, high and low social vulnerability. It should however be noted that the SoVI is not an absolute measure of vulnerability but a comparative one, allowing one to visually or numerically see how similar or how different places are relative to each other.

This same basic approach was employed in this study to create a community council level SoVI for this analysis, but using only variables relevant to the Lesotho's context. A resulting set of 27 variables were extracted using the Lesotho 2006 Census data. These 27 variables were first standardised to z-scores and then entered into a PCA. Following the procedures in the original construction of SoVI, a PCA was undertaken to define the underlying, independent, dominant components of social vulnerability for the study area (see Cutter *et al*., 2003 and http://sovius.org for specific details on the construction). Eight components explaining 80.95% of the variance in the census data were extracted from the PCA using the Kaiser (1960) criterion for component extraction (eigenvalues greater than 1.0 selected) and a Varimax rotation (Kaiser, 1958).

The majority of indicators used in this study are based on indicators that international literature has shown to affect social vulnerability (Cutter *et al*., 2003; Dunno, 2011; Cutter and Morath, 2013). However, there were relatively few indicators available for the study area based on the original indicators, therefore additional indicators were adopted. Table 4.2 lists the indicators used in the construction of SoVI for the study area, with more detailed definitions and the rationale for their inclusion. Selection of these variables was based on their relevance to the characteristics of the population considered important from

the vulnerability perspective. The three characteristics identified were general population and structural attributes, access to resources, and special needs population.

Using district and community council data from the 2006 Lesotho Census and district profile data, 27 indicators of social vulnerability were extracted (Table 4.3). Although, the social vulnerability index is a valuable tool for assessing social vulnerability within a community, it was considered necessary to adjust the variables so that they more accurately reflect the underlying social fabric of Lesotho. Based on the recommendations from the disaster management authority officials, and drawing from existing literature and knowledge of the study area, the following vulnerability indicators presented in Table 4.3 were used. All these variables were standardised using percentages, per capita or density (per square kilometre) functions. Data accuracy was explored using descriptive statistics and then normalised using z-scores (Appendix G). Listed in Table 4.3 are the 27 variable used in this study to measure social vulnerability in the study area. It should be noted that these variables adjusted so that they could more accurately reflect the social fabric to the study area and differ from the 42 original variables used in Cutter *et al*. (2003). Thus, Table 4.3 presents additional socioeconomic variables for this study that are not considered in other studies.

Table 4.3: Socioeconomic variables

No	**Variable name**	**Description**
1	Total population	Identifying large population densities is an important variable to consider when combining known hazard occurrence areas (Cutter *et al*., 1997). More assistance from local and emergency officials is required to notify these large population groups (*Ibid*.).
2	Number of households	Like total population, the number of households identifies where the greatest number of people live (*Ibid*.). This variable is important to show the intersection of hazard zones because it shows how many people are potentially more prone to hazard damages.
3	Percent female population	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities (Blaikie *et al*., 1994; Cutter, 1996; Enarson and Morrow, 1998; Enarson and Scanlon, 1999; Morrow and Ennerson, 1999; Fothergill, 1996; Morrow, 1999;

		Cutter et al., 2003).
4	Population density	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
5	Average population per village	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
6	Number of households per community council	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
7	Average household size	Large families, with many dependents often have limited financial resources and this affects their resilience to and recovery from natural hazards (Cutter *et al*., 2003; Chen *et al*., 2013b).
8	Percent of household with toilets	Households that lack basic sanitation facilities such as toilet and piped water are social vulnerable and often live in poor housing conditions (Chen *et al*., 2013a; Sajjad and Jain, 2014).
9	Population with no income	People that have no incomes and live in poverty are less capable of recovering from hazard impacts (Cutter *at al*., 1997, 2003). According to Cutter *et al*. (2003), wealthy populations are able to absorb losses more quickly due to insurance and social safety nets (Cutter *et al*., 2003).
10	Percent of households with over M1000 income per month	People that work tend to have higher incomes, larger social networks, and are better off. Those with formal jobs have relatively better job security in times of crisis (Cutter *et al*., 2003).
11	Percent households with agricultural fields	Agriculture is vulnerable to natural hazards (Cutter *et al*., 2003).
12	Percent households dependent on farming income	Agriculture is vulnerable to natural hazards and households that are dependent on farming are more vulnerable (Cutter *et al*., 2003).
13	Percent households with	Some occupations, especially those involving resource extraction, may be severely impacted by a hazard event (Heinz

	trade as source of income	Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2003).
14	Percent households with formal employment	People with formal employment tend to have regular incomes, educated, and are better off. Those with formal jobs have relatively better job security in - times of crisis (Cutter *et al*., 2003, Thomas *et al*., 2013).
15	Households with no access to radio	Radios serve as a tool for communication. Households without radios are limited to current knowledge and updates on potential disasters (Clark *et al*. 1998).
16	Households with no access to cell phones	Like radios, cell phones serve as a tool for communication. Households without cell phones are limited to current knowledge and updates on potential disasters (Clark *et al*. 1998).
17	Households dependent of social support	Those people who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Hewitt, 2000, Cutter and Morath, 2013).
18	Percent dependent on home-based care	Populations on home-based care consist of AIDS and TB patients under supervised care and are on chronic medication. Individuals with chronic illness have unique needs that require more detailed planning in the event of a disaster (Clark *et al*., 1998; Cutter *et al*., 2003; Cutter and Morath, 2013). Clark *et al*. (1998) states that illness can intervene with any actions taken to reduce vulnerability.
19	Percent aged five years or below	Children and infants are one of the most stressed demographic groups affected the most by disasters (Cutter *et al*., 2003). For example, parents lose money when caring for the children when day care and school systems are affected (Boruff *et al*., 2005; Finch *et al*., 2010).
20	Percent aged 65 years and above	Elderly populations are the one of most affected demographic groups (Cutter *et al*., 2003). Elderly populations require more attention because they have more mobility constraints than other age groups (Cutter *et al*., 1997, Cutter *et al*., 2003).
21	Percent households with orphans	Childcare is a critical activity during a crisis and the resources available to a household are affected by the number of children in that household therefore social vulnerability increases with many child-headed households (Fothergill, 1996; Heinz Center for Science Economics and the Environment 2000; Cutter *et al*., 2003).

22	Percent child-headed households	Childcare is a critical activity during a crisis and the resources available to a household are affected by the number of children in that household therefore social vulnerability increases with many child-headed households (Fothergill, 1996; Heinz Center for Science Economics and the Environment 2000; Cutter et al., 2003). Children, especially in the youngest age groups, cannot protect themselves during a disaster because they lack the necessary resources, knowledge, or life experiences to effectively cope with the situation (Martin *et al*., 2006; Flanagan *et al*., 2011).
23	Percent female-headed households	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities (Blaikie *et al*., 1994; Cutter, 1996; Enarson and Morrow, 1998; Enarson and Scanlon, 1999; Morrow and Ennerson, 1999; Fothergill, 1996; Morrow, 1999; Cutter *et al*., 2003; Finch *et al*., 2010).
24	Primary education	People with higher levels of education are likelier to have access to and act upon varied hazard information from preparation to recovery (Tierney, 2006; Cutter and Morath, 2013). Education is thus linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings (Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*, 2003; Tierney, 2006).
25	Secondary education	Different occupations require different education levels and skills and produce different levels of income. Lower education constrains the ability to find good jobs and understand warning information and access to recovery information (Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*, 2003; Tierney, 2006).
26	Access to piped water	Households that lack basic sanitation facilities such as toilet and piped water are social vulnerable and often live in poor housing conditions (Chen *et al*., 2013a; Sajjad and Jain, 2014).
27	Access to roads	Access to roads is important during and after disasters. Effective disaster response needs good infrastructure (Rygel, 2006)

Table 4.4: Principal components analysis communalities

Variables	Initial	Extraction
1. Total population	1.000	0.780
2. Average population per village	1.000	0.755
3. Number of villages per community council	1.000	0.854
4. Population density	1.000	0.806
5. Average households size	1.000	0.734
6. Number of households	1.000	0.872
7. Percent female population	1.000	0.779
8. Percent female-headed households	1.000	0.944
9. Percent child-headed households	1.000	0.925
10. Percent population aged 5 years and below	1.000	0.936
11. Percent population aged 65 years and above	1.000	0.912
12. Percent total orphans	1.000	0.911
13. Percent households receiving social support	1.000	0.660
14. Percent dependent on home-based care	1.000	0.622
15. Percent of households with agricultural plots	1.000	0.831
16. Percent of households with toilets	1.000	0.885
17. Percent primary education	1.000	0.761
18. Percent secondary education	1.000	0.753
19. Percent of households with access to piped water	1.000	0.750
20. Percent of villages without road access	1.000	0.790
21. Percent of households with electricity connection	1.000	0.713
22. Percent households with radios	1.000	0.892
23. Percent of households with mobile phone	1.000	0.766
24. Percent of households with no income	1.000	0.662
25. Percent of households with trade income	1.000	0.898
26. Percent of households with formal employment income	1.000	0.902
27. Percent of households farm income	1.000	0.772
28. Percent households with over M1000 income per month	1.000	0.845

Extraction Method: Principal Component Analysis.

Source: Author's own data

The multidimensional components and level of explained variance in this present study were consistent with other SoVI studies for different countries and the USA in particular (Crooks, 2009; Rod *et al*., 2010; Emrich and Cutter, 2011; Cutter and Morath, 2013). Component loadings were examined to determine whether each component increased or decreased vulnerability. Where necessary, components were adjusted to ensure that positive loadings indicated increasing vulnerability and negative loadings decreasing vulnerability. The eight components were then summed to create the final social vulnerability index scores. The SoVI scores were then mapped using standard deviations (Std. Dev.) as the classification algorithm to highlight the extremes (low and high) in social vulnerability in the study area. Areas of low vulnerability (less than -0.5 Std. Dev. from the mean) and high vulnerability (greater than 0.5 Std. Dev. from the mean) were identified. The component groups were named in accordance with their broad representation of social vulnerability and assigned a cardinal direction, positive if the majority of variables in the component increase vulnerability, negative if the majority of variables decrease vulnerability and the absolute value if the component variables have a mixed impact on vulnerability. The main function of this PCA analysis was to determine the social vulnerability characteristics that were represented and if they had a tendency to increase or decrease social vulnerability. The SoVI scores were then imported into a GIS for further analysis.

The methodology of the factor analysis follows a standard procedure (Nardo *et al*. 2005; Field, 2012). First, the PCA was intended to find a linear combination of variables that accounts for as much variation in the original variables as possible. A Varimax rotation with Kaiser Normalisation was applied to the component matrix in order to facilitate the interpretation (Schneiderbauer, 2007) by rotating the axes of the components so they are perpendicular to each other. This step places the respective components as far apart from each other as possible (Field, 2009). The extracted communalities are all above 0.5, which indicates that the extracted components represent the variables well. For the interpretation, only *eigenvalues* greater than one are considered and absolute loading values below 0.30 are suppressed (Miller *et al*., 2002; Nardo *et al*. 2005; Bernard 2006; Field, 2012). The *eigenvalue* is the standardised variance associated with a particular factor. The *scree* plot serves as another criterion to limit the number of factors (Field, 2009; Field, 2012). The

factors on the steep slope up to the 'scree elbow' in the curve are able to explain most of the data (Figure 4.3). As the plot line becomes more level the components contribute less to the overall variance (Field, 2012). The SoVI algorithm (Cutter *et al*., 2003) requires that Varimax rotation and Kaiser Criterion be used for component selection with *eigenvalues* greater than 1.0.

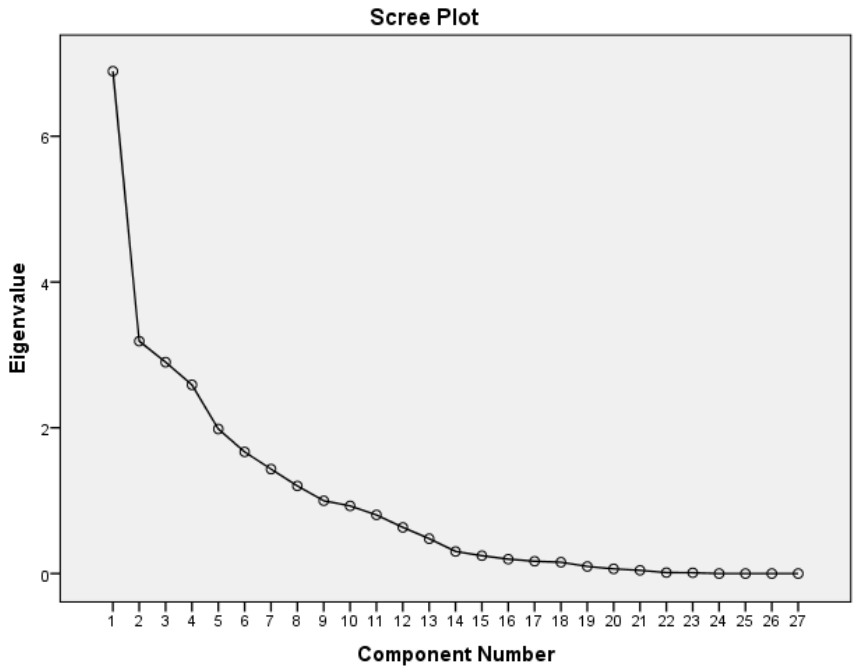

Figure 4.3: Scree plot for Quthing and Mohale's Hoek SoVI factor analysis showing the *eigenvalues* (y-axis) explained by the resulting factors (x-axis).

4.6 PHYSICAL VULNERABILITY

Physical vulnerability in this study was computed as a function of the physical environment, hazard frequency, intensity and impact by each hazard; firstly in the entire country, secondly in each district and then at community council level. All reported natural hazards from 1825 to 2012 were used to construct a physical vulnerability index. Historical information on the occurrence of previous hazardous events is given emphasis in this study. This was achieved by interviewing elderly people and referring to documentary sources such as past newspapers and missionary diaries. The document titled "*Reconstructing nineteenth century climate histories in Lesotho using documentary evidence*" by Nash and Grab (2010) provided invaluable information for this study. Nonetheless, a serious limitation with historical data from documentary sources is that it is

not place-specific and it is thus a challenge to carry out spatial vulnerability analysis using historical data. However, additional information was also collected from the national and district government officials. This information was augmented through local fieldwork, by conducting household interviews and focus group discussions. The study also used instrumental data such as rainfall, snowfall, temperature, wind speed and topographic data.

The components of physical vulnerability (natural hazard occurrence, frequency and impact) were processed to create individual hazard vulnerability maps for the study area. Finally, these maps were then overlaid to produce an overall physical vulnerability map of the study area. The resulting maps enabled the researcher to identify places within each district that exhibit either high or low levels of physical vulnerability. This methodology for determining the physical vulnerability of each district follows previous research by Cutter *et al*. (2000, 2003, 2007).

4.6.1 Data sources

Monthly temperatures, wind speed, rainfall data and topographic features of the study region were used in order to identify high risk areas of extreme hydro-climatological events. A topographic map served as baseline information for the study area and provided information such as physical geography, including river networks and topographic relief as well as road networks. This information was digitally extracted from the topographic map for integration into a GIS. Using visual clues of the landscape, such as settlements and road networks, the floodplains of major rivers were identified and digitised. High resolution topographic data or more particularly high resolution digital elevation models (DEMs) have been used for flood mapping over the past years as an important topographic data source (Kellens *et al*., 2013). For this study, the DEM thus provided the topographic data for the assessment. To further assist in delineating areas prone to natural hazards in both districts, disaster management officers were asked to draw and identify on the topographic maps areas previously affected by flooding, strong winds, heavy snowfall and severe frost. Household interviews and focus group discussions also identified areas susceptible to flooding, strong winds and heavy snowfall in both districts. All this information was mapped to produce individual hazard maps and finally a multi-hazard map of the study area.

4.6.2 Statistical analysis

Rainfall data was used as a proxy to illustrate drought and flood years in the study region. Detection of changes in hydrological records can be used for drought and flood monitoring purposes (Marengo *et al*., 2013). Low annual rainfall is usually accompanied by drought, while high daily rainfall is associated with flooding. Low flow statistics computed for monthly and annual values were used to identify trends in the magnitude and timing of drought studies (Wi, 2012). Temperature and wind data were analysed using extreme value statistics and block maxima techniques (Kunz *et al*., 2010). Snowfall data was gathered from satellite imagery and documentary sources.

For temperature, wind speed and rainfall data analysis, the study used the annual maxima/minimum of daily wind speed, temperature and rainfall data to indicate strong winds, severe frost and to establish likely flooding events. The extreme rainfall is defined as the maximum rainfall within each month, while the extreme minimum temperature is the minimum temperature within each month. This method has been used previously to define extreme climate data values (Gumbel, 1958; Nadarajah, 2005). One of the most commonly used forms of extreme value sampling is the selection of the highest/lowest value per year, hence it generates annual maximum/minimum series whose sample size is identical to the number of years (Ntegeka and Willems, 2008; Katz, 2010; Saidi *et al*., 2013). This approach is effective because it extracts information concerning true extreme events. There is a tradition of applying the statistics of extremes to weather and climate, starting in the early 1940s (Gumbel, 1942, 1958). Extreme events have a very low probability of occurrence, but are associated with high impacts and can lead to substantial damage and losses due to their magnitude. Extreme rainfall, strong winds, floods and severe frost are examples of extreme events that occur less frequently than the average event and often have severe impacts in Lesotho (UNICEF Lesotho, 2011).

4.6.3 Biophysical vulnerability

This study constructed a biophysical vulnerability index by restricting the hazard frequency analysis to damaging hazard events and the historical documented losses. Biophysical vulnerability was assessed at the community council level through the

calculation of hazard frequency for floods, droughts, heavy snowfall, severe frost and strong winds events. The individual hazard frequency maps were overlaid to create an aggregated multi-hazard frequency map. The historical context information additionally assisted in the selection of the natural hazard types necessary to develop a comprehensive multiple hazards assessment of the study area. Each natural hazard affecting Mohale's Hoek and Quthing were overlaid using a GIS, summing physical vulnerability values as polygons of intersecting hazards. The final result was a single GIS layer representing the overall physical vulnerability in the study area. Lastly, using the same method, the overall physical vulnerability layer was merged with the index of social vulnerability to produce a spatial representation of place vulnerability of the study area.

4.7 OVERALL PLACE VULNERABILITY

Indicators are quantifiable constructs that provide information either on issues of wider significance than that which is actually measured, or on a process or trend that otherwise might not be apparent (Hammond *et al.*, 1995). Therefore, vulnerability indicators were used in this study. However, indicators usually only capture intangible process and they were validated by household and key informant interviews as well as focus group discussions. Data was categorised into subgroups according to the type of vulnerability they represented; social, biophysical environment and natural hazard profile. Taken together these components were combined to form an overall place vulnerability index. As indicated above, the theoretical constructs of vulnerability were initially identified through a review of relevant literature.

After initial pre-processing, data was standardised for each component of place vulnerability, that is, social and biophysical by calculating standardised variables (z-scores with zero means and unit variances) for each variable. When standardised in this way, the values of vulnerability index range from 0 to 1 and are not influenced by the number of variables included in the calculation (Borden *et al.*, 2007). Though each socioeconomic and physical indicator can be examined separately, the average of all measures gives a general idea of vulnerability for any region within the study area and is more useful for the disaster management and emergency community and decision-makers than are individual factors. Therefore, the overall vulnerability index combined socioeconomic and physical

factors into a single standardised measure of vulnerability to provide an overall place vulnerability index score. In order to apply the place vulnerability model in the study area the two components were integrated to arrive at the end result (place vulnerability index). An historical context analysis of the past natural hazard events affecting Lesotho and the study area in particular, a social vulnerability index and a physical vulnerability index were produced (Figure 4.4). The final step in the analysis was to combine data on physical vulnerability and social vulnerability to create place vulnerability index. To obtain the overall place vulnerability index scores, physical and social vulnerability index scores were added together following a simple additive model.

Once the index values were computed, they were entered into a GIS as data layers. The index values for each variable were summed to arrive at a composite index score for each community council, which represents an aggregate measure of place vulnerability. These values were visually displayed as five categories on the maps. Each individual indicator was examined independently; however, it is the summary of all the measures that produced a broad overview of the spatial distribution of vulnerability in a community council. This broad overview has a greater functionality for emergency and disaster management, which requires both the generalised information and the specifics.

The index was further computed in order to rank places on a comparative scale of vulnerability, a process that yielded three aggregate indices, and a social index (SoVI and a physical vulnerability index) which includes the biophysical environment and overall place vulnerability index. Finally, the two sub-component indices were combined into a single index of place vulnerability following the modified hazards of place model and methodology (Cutter *et al*., 2003; Boruff *et al*., 2005; Boruff and Cutter, 2007; Wood *et al*., 2010; Schmidtlein *et al*., 2011).

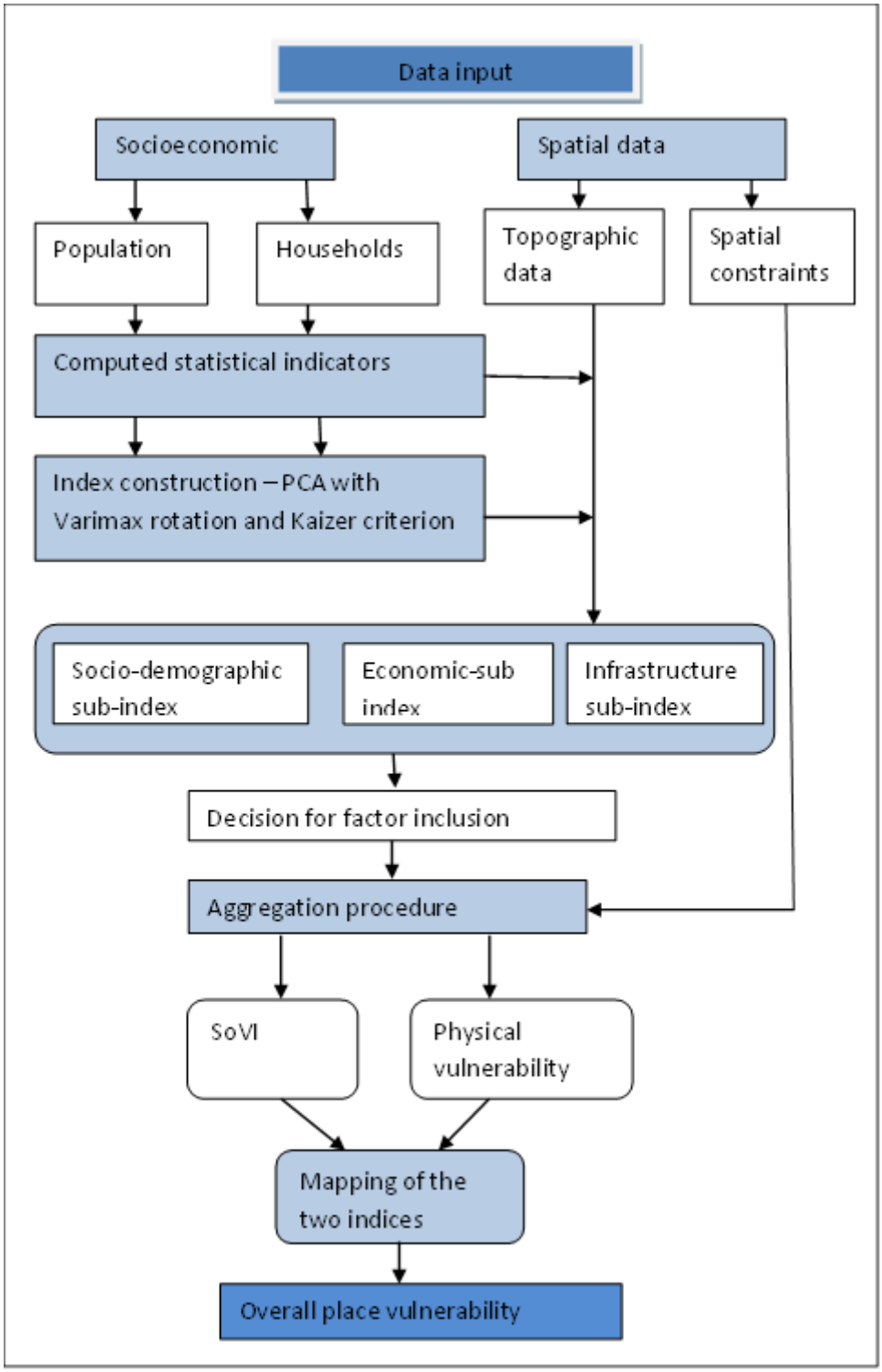

Figure 4.4 : A general framework for building the place vulnerability indices

4.7.1 Comparative assessment of vulnerability using GIS

A comparative assessment of place vulnerability between the two districts was then conducted. The place vulnerability index scores were computed by adding together the individual component scores for each community for an overall score for each community council. In order to rank the community councils in terms of place vulnerability, the mean vulnerability scores for each community council were mapped using *ArcMap*. The scores were then ranked from highest to lowest to determine the most to least vulnerable community councils. Those with the highest and lowest place vulnerability index scores were then identified.

A map was created to compare the place vulnerability index scores for all the community councils in the study area, presenting place for each community council using the standard deviation classification scheme. Mapping standard deviation revealed how much a feature's attribute value varies from the mean. A colour ramp was chosen to highlight community councils with values above the mean (in red) and below the mean (in blue). In this case, the dark red values represented the areas farthest from the mean in the positive direction, indicating that they were the most highly vulnerable, and the dark blue values showed the areas farthest from the mean in the negative direction, indicating that they were the least vulnerable. The colour ramp (dark red to dark blue) portrayed the areas from highest to lowest vulnerability in Quthing and Mohale's Hoek.

Statistical and visual analyses illustrate considerable variations in the patterns of vulnerability to natural hazards across the study area. To demonstrate how vulnerability varies across space, basic spatial cluster analysis was undertaken on physical and social vulnerability. Spatial autocorrelation techniques were therefore employed to establish the extent to which a spatial phenomenon is correlated to itself across space (Burt *et al*., 2009). To illustrate this phenomenon, a Moran's I statistic was performed to identify vulnerability clusters. According to Hung and Wang (2011), "hot spots" of spatially correlated areas have significant implications of why and where the clustered areas are vulnerable. To obtain an overall impression of the spatial clusters in the study area, a *Getis-Ord general G statistics* was used to examine autocorrelation in the spatial distribution of place vulnerability and to measure if vulnerable communities were clustered or scattered across the study area.

4.8 WEIGHTING AND AGGREGATION OF VULNERABILITY INDICATORS

The social vulnerability index scores and the physical vulnerability index scores were created by summing all the independent component loadings for each community council. Each component was then assessed to determine which variables demonstrated the strongest relationship. The greater the number (either positive or negative) the more strongly related the variable to the overall component (Manley, 1994; Miller *et al*., 2002). By concentrating on the greatest values, trends were apparent in each of the components. All vulnerability indices used a standardisation of data as well as equal weights and ranking of variables. There is no theoretical justification for assuming the relative importance of one factor over another in the construction of the index (Cutter and Finch, 2008; Fekete, 2009).

Therefore, all variables were treated equally and it is assumed that each had the same relative importance to the overall place vulnerability. Most researchers decide not to weight variables to allow for dissimilar effects (Mahendra *et al*., 2011; Prasad, 2012; Huang *et al*., 2013), given that the mechanisms used to explain how vulnerability variables influence place vulnerability and associations amongst them are complex and still not clear. Therefore, determining appropriate weighting is a challenge for most vulnerability assessments. Hence, the sub-components of vulnerability used in this thesis were given equal weights in terms of their overall contribution to place vulnerability in the study region. Thus, no prior weights were assigned to the individual layers or in the final index. It is acknowledged that this itself will not reflect realistic scores through time, but rather reflect 'relative' vulnerability. Given that impacts of hazards such as drought, floods or snow will change according to the magnitude of the event, or over longer time periods in response to climate change or infrastructure development, it is not possible to assign different weights to different hazard types in the current study.

Therefore, in the absence of such a theoretical basis, the factors were equally weighted to produce the overall vulnerability index for both districts. This study did not assign weights to variables because it created a context-specific composite index of place vulnerability. Assigning weights in a complex and highly dynamic biophysical and socioeconomic landscape, as is the case in the study area, is difficult especially during natural hazard occurrences, as vulnerability changes quickly over time and space, rendering many indicators useless (Rygel *et al*., 2006). For instance, road construction in the rural

highlands is likely to increase accessibility to services, markets, information and economic activities, thus reducing place vulnerability. Therefore, in order to carry out an accurate weighted place vulnerability assessment, large scale research would be necessary, as well as interviews and discussions with experts, decision makers and other stakeholders.

The rationale behind weighting is to estimate the importance of each variable. Nevertheless, without theoretical or empirical validation, allocating weights to the indicators is often arbitrary and subjective (Ward 2012). The majority of composite indexes do not apply weights and indicators are usually considered to be independent and equally significant (Babbie, 2007; Booysen, 2002; Dwyer *et al*., 2004; Fekete, 2009; Ward 2012). In most cases, weighted and unweighted indexes yield similar results (Lowe, 2010; Ward, 2012).

4.9 LIMITATIONS

Vulnerability is determined by local, regional and global conditions, and as a result a good understanding of physical, economic and social characteristics is required, together with climatological data. Whilst realising its importance, developing countries such as Lesotho often lack reliable information and basic data of this kind, or where it does exist the challenges of acquisition, storage and accessibility are often immense. In Lesotho, for instance, data collection is a neglected and under-resourced activity because it has to compete with more important economic and social development priorities, such as poverty eradication, HIV/AIDS, education and unemployment. For this reason, climate data networks are very sparse, data series are short and sporadic and data quality problematic, due to varied instrumentation or methodologies used in data collection.

Lesotho lacks complete and generally accessible data on disasters and disaster management, and lack of data, expert analysis and integration of planning are a major challenge. There is generally a lack of accessible hazard information or maps in the country, yet a detailed and complete hazard data are crucial for spatial vulnerability assessment at the local or community council level. For instance, historical and documented climate records were not place-specific as they generalised hazard occurrences for the entire country, and therefore the geographical distribution of documentary records, have implications for the wider applicability of a place-based

vulnerability assessment. According to Grab and Nash (2010), Lesotho's complex topography allows for significant altitudinal, latitudinal and longitudinal climatic diversity over fairly short distances, thus highly variable hazard distributions are likely. Hazard occurrence in a given area may not reflect hazard occurrence across the wider study area. Applying the hazard of place model to assess place vulnerability in the Lesotho context, as an underdeveloped country, presents a challenge because of lack of relevant place specific data, for example, snowfall data, long-term wind data and daily rainfall and temperature data. Additionally, generalisation of climate data across the study area was another challenge, as there are only two climate stations in the study area, representing different geographical settings with different physical characteristics.

Lack of detailed population data on a small scale and unavailability of land-use and land cover data for the study region further hindered the calculation of the percentage of the population residing in physically vulnerable zones. The study could therefore not have a hazard-by-hazard comparison of the percentage of the population at risk in the study area. This kind of data could have allowed for a calculation of the percentage of population living in areas susceptible to flooding, heavy snowfall, strong winds, drought and severe frost zones. Without population and land-use data it was difficult to determine whether or not people were actually vulnerable, since there was no indication of where they were located in proximity to the hazard sources. According to Varazanashvili *et al*. (2012), vulnerability assessment requires a detailed GIS based maps of elements at risk (physical, social and environmental), and also in-depth information on how such elements are susceptible to natural hazards under consideration. However, this kind of data is lacking in many developing countries, as shown in this study, taking Lesotho as an example.

The social vulnerability index is a helpful tool for measuring social vulnerability in a community. The model was used as guidance for selecting the appropriate variables for this analysis, however, only dominant variables identified in Cutter *et al*. (2003) were chosen. This is a limitation because the dominant variables explaining the variation in social vulnerability in the USA are different from those that explain the variation within districts in Lesotho, and were incorporated because they were found to have been important by local disaster management officials. Therefore, the input variables had to be adjusted in order to accurately reflect the underlying social fabric of the communities in Lesotho. The added variables more accurately reflected the social and economic fabric of

communities. Variables that were not explicitly used in the social vulnerability index model were incorporated because they were found to have been important by local disaster management officials. Subsequent to consultation with disaster management officials, review of existing literature and knowledge of the study area, it was discovered that some indicators of preparedness were significant predictors of vulnerability in Lesotho. Thus, this research included several variables that were thought to represent preparedness in Lesotho.

Finally, the initial step of the process, that of selecting indicators of vulnerability, raised questions of who decides which variables and why. The prejudice and potential bias of the process was the limitation met in this research. Some studies use theory and statistical procedures to determine indicators of vulnerability (Boruff, 2005; Borruf, 2011).

4.10 SUMMARY

The choice of a method for studying place vulnerability presents several methodological and practical challenges. Methodological limitations often relate to the availability of data and the complexity of the indices used. This chapter has drawn an outline of the methodologies and data used for the construction of place vulnerability index. The subsequent chapters deal with the results derived from the data analysis using the above mentioned methodologies. Chapter 5 will analysis physical vulnerability, while Chapter 6 will explore social vulnerability and Chapter 7 presents overall place vulnerability assessment.

CHAPTER FIVE

VULNERABILITY TO NATURAL HAZARDS

5.0. INTRODUCTION

In a natural environment characterised by climatic variability, humans are continually exposed to natural hazards at different scales in time and space (IPCC, 2007; UNISDR, 2008; IPCC, 2012). Geological, hydro-meteorological and geophysical hazards negatively affect human life and health and have a dramatic impact on the sustainable development of societies. The impact that extreme events may have on developing nations could result in severe consequences on the life and economic development of these nations and developmentally set them back many years (O'Brien *et al.,* 2006; Djalante *et al.,* 2013). Many societies have experienced human fatalities and injuries, property damage and economic and social disturbance as a consequence of natural hazards such as drought, floods, earthquakes, hurricanes, volcanic eruptions and landslides. These have brought major challenges to both developing and developed countries, killing thousands of people and destroying billions of dollars' worth of habitat and property each year (UNISDR, 2008; Wang *et al*., 2013).

The rapid growth of the world's population has escalated both the frequency and severity of natural disasters (GRID, 2009), with the 2013 Global Assessment Report on Disaster Risk Reduction finding that the global economy's transformation over the previous 40 years had led to a growing accumulation of disaster risk. Annually, economic losses amount to hundreds of billions of dollars and are anticipated to double by 2030 (UNISDR, 2013). In agrarian societies, livelihoods and food security have become vulnerable to changes in the atmospheric system, which have caused major shifts in precipitation patterns, leading to droughts and floods (IPCC, 2007; Boko *et al*., 2007; Collins, 2012; Jury, 2013). Global climate change is likely to increase temperatures, change precipitation patterns and probably raise the frequency of extreme events (IPCC, 2007, 2012). Additionally, recent literature addresses concerns over the impact climate change may have on the frequency and magnitude of extreme weather events (Francis *et al*., 2011; IPCC, 2012; UNEP, 2012).

Evidence shows that in sub-Saharan Africa, natural hazards and disasters have increased in frequency, magnitude and impact during the recent past (FANRPAN, 2010). The majority of natural hazards affecting sub-Saharan Africa are climatological and hydrological in nature. UNISDR (2009) reports that, on the whole, these hazards affect 12.5 million people annually, with drought having the greatest human and socioeconomic impact, thus making households and communities more vulnerable, given that the majority depend on agriculture for survival. Thus, it is widely accepted that developing countries are greatly affected by and suffer more from extreme natural events than developed countries, as they are already environmentally and socioeconomically vulnerable before the extreme events take place.

Additionally, compound and inter-dependent forms of vulnerability co-exist in many African countries and have the potential to transform even minor hazard events into human disasters. For instance, in most societies, extreme poverty and food insecurity contribute to land degradation as the poor and hungry overexploit natural resources to meet their urgent needs (food) for survival. The 2001-2003 food security crisis in southern Africa was characterised by a lack of availability and access to food for large proportions of the population in six countries, Lesotho, Malawi, Mozambique, Swaziland, Zambia and Zimbabwe. It is generally accepted that the crisis was triggered by extreme weather conditions, but there were deeper underlying circumstances that made people vulnerable to the negative effects of these weather conditions (Whiteside, 2002; Drimie, 2002; Harvey, 2004; Mwakabolo, 2007). Furthermore, development literature has increasingly stressed the role of climate variability in shaping rural communities, particularly in southern Africa (Leichencko and O'Brien, 2002; O'Brien and Vogel, 2003; Matyas and Silva, 2013). Kurukulsuriya and Mendelson (2007) raised concern that African agriculture is sensitive to climate change with associated increased warming, flooding and drought leading to net revenue losses (Benhin *et al*., 2010).

Southern Africa is a largely semi-arid region with high rainfall variability, characterised by frequent droughts and floods. Therefore, a change in the magnitude and distribution of extreme rainfall events associated with rainfall variability, such as flooding and drought, are likely to have negative impacts on natural and human systems (William *et al*., 2010; Kong *et al*., 2013). The region is also widely recognised as one of the most vulnerable to climate change, because of low levels of adaptive capacity, particularly among rural

communities, combined with a high dependence on rain-fed agriculture (IPCC, 2012). The majority of southern African national economies, apart from South Africa, are dependent on agriculture; with precipitation having a great influence on these economies. This is particularly relevant to Lesotho, where intra-annual and inter-annual precipitation may vary considerably (Davis, 2011; Moeletsi and Walker, 2013). Consequently, drought and flooding events are relatively common and possibly linked to climate change.

5.1 HAZARD IDENTIFICATION AND FREQUENCY

Lesotho is prone to natural hazards and the country is regarded as highly vulnerable to climate change (Turkey, 2007; Chubbier and Bajaj, 2008). Natural hazards, which include floods, drought, severe frost, strong winds and heavy snowfall, have affected many people and many sectors of the society. According to disaster management officials, floods, severe frost, heavy snowfall, strong winds and drought are the most damaging as they affect food security, damage property and infrastructure and affect the economy directly, phenomena on which this study will focus. This therefore, provides a premise for the investigation into understanding the causes, frequency, distribution and physical impacts of these hazards on the communities at risk.

Arguably, the country is already experiencing the growing impact of severe weather conditions, as measured by the increasing frequency of natural disasters such as droughts, floods, strong winds, heavy snowfall and severe frost (LMS, 2002, 2010). Return period statistics show that there have been some variations in the frequency of prevailing natural hazards in Lesotho over the past century or more. Heavy snowfall is the most common type of hazard, with a return period of 3.1 years, followed by severe frost, floods, drought and strong winds with return periods of 3.3, 3.5, 3.5 and 4.8 years respectively (Figure 5.1, below). Figure 5.2 shows that there has been an increase in the number of documented hazard occurrences in the study area from 1980-2012, perhaps attributable to climate change or improved recording of events. The period between 1863 and 1901 also recorded increased natural hazard occurrences. Generally, there has not been a significant increase in the frequency of natural hazard occurrences between 1825 to 1862 and 1902 to 1979.

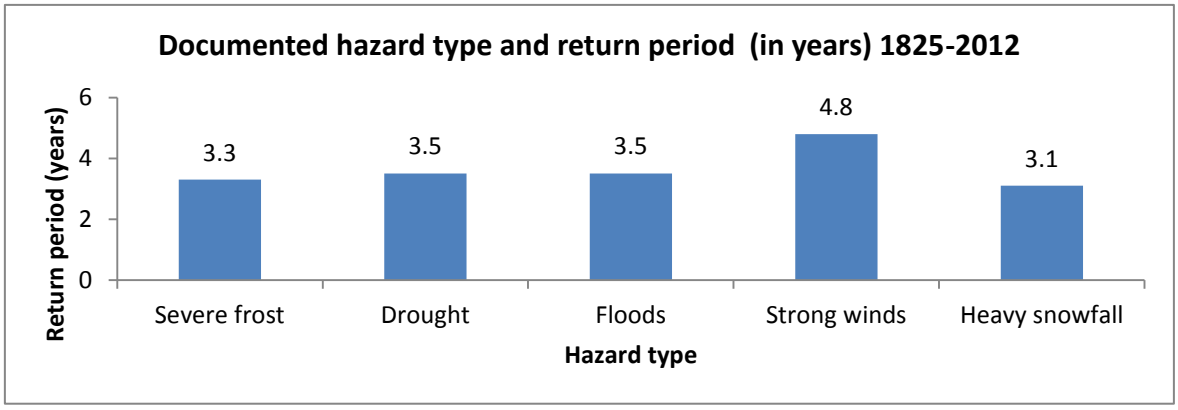

Figure 5.1: Hazards return period: 1825 - 2011in Lesotho (based on reported hazards)

Sources: Eldredge, 1987; Goliger *et al*., 1997; Showers, 2005; Nash and Grab, 2010; Disaster Management Authority, 2011.

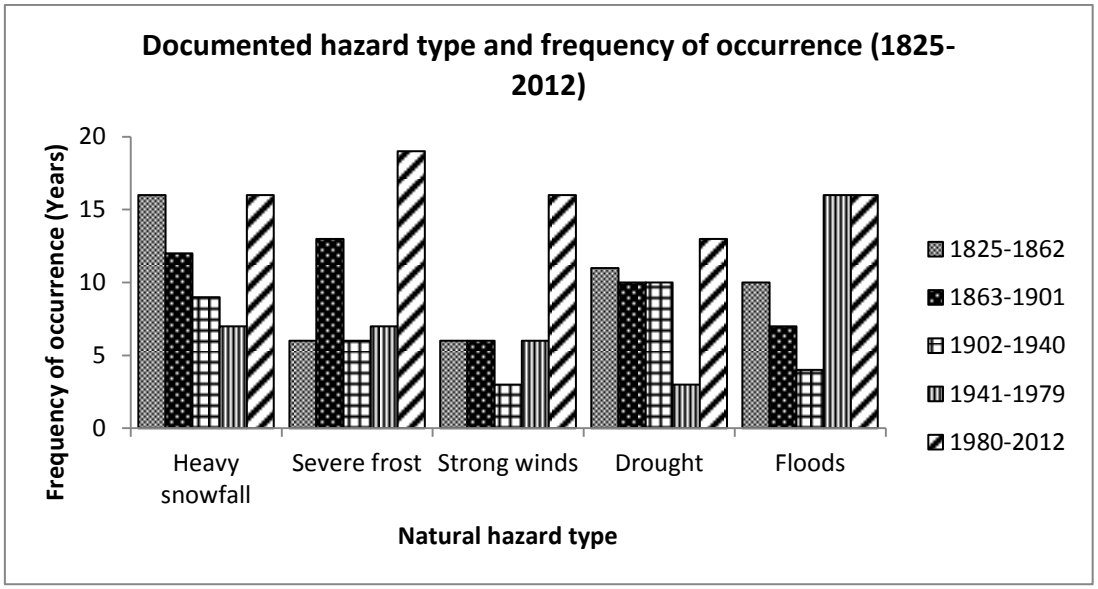

Figure 5.2: Documented natural hazards and frequency of occurrence over time (1825-2012).

Sources: Eldredge, 1987; Goliger *et al*., 1997; Showers, 2005; Nash and Grab, 2010; Disaster Management Authority, 2011.

For the purpose of this study, severe weather refers to any dangerous meteorological or hydro-meteorological phenomena of varying duration, with risk of causing major damage, serious social disruption, and loss of livelihoods, property or human life. While types of severe weather phenomena can vary with the latitude, altitude, topography, and

atmospheric conditions of a region (Bennett, 2010), general forms of severe weather in Lesotho include wind storms, hailstorms, flooding, severe frost and heavy snowfall. Emerging evidence from archival research shows that there have been several past events when human lives were lost, livestock killed, crops destroyed and buildings and infrastructure damaged or destroyed, notably between 1825 and 2011. The primary causes have been drought, flooding, severe frost, heavy snowfall and strong winds (Eldredge, 1987; Showers, 2005; Grab and Nash, 2010; Nash and Grab, 2010) (Figure 5.3).

Using the frequency of occurrence for the abovementioned natural hazard types affecting Mohale's Hoek, Quthing, and Lesotho in general, an understanding of the level of threat posed by each hazard is provided. However, it should be noted that this information provides a general overview about hazard occurrences and consequences, and is representative of the entire country rather than specific to the study region. Relevant comments on each natural hazard event are reflected in Figure 5.3, includes impact/damage information, loss of life and injury, damage to property and livelihoods, including structural damage, livestock losses and damage to crops. It was not possible to quantify property or infrastructural damage in monetary terms, or the number of human/livestock deaths or injuries for each event, as most reports do not provide precise or detailed information.

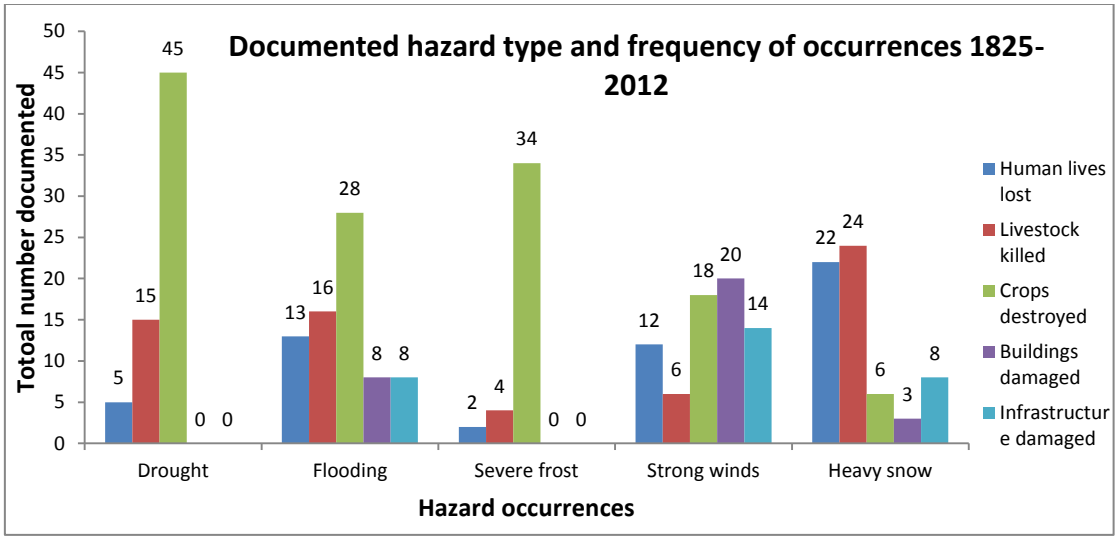

Figure 5.3: Documented natural hazard type and frequency of consequences in Lesotho (in years):1825-2011.

Sources: Eldredge, 1987; Showers, 2005; Disaster Management Authority, 2010; Nash and Grab 2010; Grab and Nash, 2010.

5.2 FLOOD OCCURRENCES

Floods and droughts are climatic events that occur at variable frequencies in many areas of the world (Seiler *et al*., 2002; IPCC, 2013; Campion and Venzke, 2013). Floods are some of the most common and costly natural disasters around the world. Under the influence of climate change and economic development, the extent of flooding is expected to increase (Jonkman and Kelman 2005; IPCC, 2012), consequently, most parts of the world will experience an escalating flood risk and exposure, particularly less developed countries (Speakman, 2008; Nie *et al*., 2009; Lee *et al*., 2012; Campion and Venzke, 2013). The likelihood of a flood is a composite problem, which depends on a number of variables. Areas with similar characteristics, for example those with high rainfall, lower altitude, and flat surfaces, are most prone to flooding, while those areas with lower rainfall, higher altitude and steep slopes are rarely affected by floods. Thus, through an indirect approach, one can use precipitation to estimate the possibility of a flood hazard (Messner and Meyer 2006; Lee *et al*., 2012).

Two types of flooding are particularly common to Lesotho, namely flash flooding and river-line flooding, which are among the most devastating types as they occur rapidly with little warning, and in addition transport tremendous amounts of water and debris at high velocity (Schad *et al.*, 2012). Flash floods are caused by very localised and stationary thunderstorms, where an exceptionally deep layer of unusually humid air is present, and where the amount of potential perceptible water in the clouds is very high (Valentin *et al.*, 2008; Schad *et al.*, 2012). Flash floods and river-line floods affect many households and communities in Lesotho every year, through the loss of lives, homes and livelihoods, along with extensive infrastructural damage. In remote areas, the threat of flash flooding is high, as advanced early warning systems are poorly developed or even absent (no radio frequency reception).

The researcher asserts that this is often the case in many rural areas in Lesotho. In the study area, river-line floods occur along the river valleys (Tele, Sebapala, Senqu, in Quthing and Makhaleng, Maphutseng and Senqu, in Mohale's Hoek) and cause the mountainsides to become unstable and consequently contribute to landslides and slope instability, which damage and impact on infrastructural developments, such as road networks, buildings, and communication networks, and natural resources, such as water. In both districts, tremendous amounts of erosion are observed to occur along river and stream

banks during flood events, washing away crops and productive land. At times, sediment is deposited over agricultural fields and settlements, as also reported in other parts of the world (Buchele *et al.* 2006; Brody *et al.*, 2012; Rawat *et al.*, 2012). Thus, the impacts of floods are multi-dimensional, affecting environmental, social and economic systems (Jain *et al.*, 2005; Campion and Venzke, 2013). In Lesotho and elsewhere, flash flooding is an environmental problem that decision-makers have to deal with, because it causes more deaths, economic loss and social destruction than any other type of natural hazards worldwide (Mileti, 1999; Messner and Myer, 2006; Nethengwe, 2007; Nie *et al.*, 2012).

The historic data presented in Table 4.1 show 54 flood-related incidences in Lesotho during a period spanning close to a century, however, the historic data is for the entire country and thus not place-specific. Associated with these occurrences were human (20) and livestock fatalities (26), destroyed crops (34) and damage to infrastructure (14). Buildings shelter people and protect them against physical and health hazards, and in communities that are prone to flooding, loss of shelter leaves people vulnerable to the after-effects of floods, including illnesses. The real impacts and frequency of floods are likely to be greater than those provided by the reports and official records. The reports do not indicate the total number of human lives and livestock lost, or the economic value to damaged buildings and crops, nor do such reports indicate spatial coverage and exact location of these occurrences in the entire country or within particular districts. The absence of locational information in historic data is a major limitation of place vulnerability analysis.

In the recent past, the 1988 floods in Lesotho resulted in a number of human tragedies, including 12 incidences of drowning, two of whom were young boys from Makhaleng in Mohale's Hoek. Many houses, 87 in Mohale's Hoek and 54 in Quthing, were damaged by these heavy rains, nonetheless, the official reports only stated the number of affected houses in the whole district and did not indicate the villages affected. During the same event in Quthing (Mphaki), rock falls caused damage to eleven houses and resulted in one human death (www.trc.org.ls). According to officials, the 2007 heavy rains resulted in fatalities and drowned three people in Quthing and five people in Mohale's Hoek. This flood also caused extensive damage to crops and infrastructure, leading officials to believe that subsequent reduction in damage attests to improved disaster preparedness activities during more recent years, whereby communities are informed of probable flooding

incidences over the radio across the entire country. Recently, the general post-disaster assessment after the early 2011 floods in Lesotho estimated the total cost of flood impacts at 462.7 million Maluti or 66.1 million US$ (Disaster Management Authority, 2011). Table 5.1 presents a historical account of flood episodes and their impacts on societies and the environment, which includes damage caused by flooding and those caused by the disruption and malfunctioning of services and systems associated with flooding. However, the spatial distribution of damage caused by heavy rains could not be disaggregated at district to community council level, thus, an equal distribution of damage has to be assumed.

Table 5.1: Documented flood incidences in Lesotho from 1825 to 2012 (incidences are not place-specific).

Year	**Comments**
1825	Heavy rainfall, ground over flooding
1828	Heaviest rain
1833	Abundant rainfall led to flood
1835	Extremely wet, flooding (rain fall abundantly, rivers flooded, buildings collapsed)
1838	Extremely wet
1840	Extremely wet, extraordinary rains (rained for a few weeks, floods)
1849	Heavy rains caused flooding
1852	Heavy rains (rivers flooded)
1855	Several storms caused extraordinary floods
1860	Torrents of rains (flooding killed people, animals and destroyed crops)
1863	Super abundant rain, heavy and prolonged rains (killed livestock) rivers flooded
1873	Heavy rains (washed away fields, swept away houses on river banks)
1878	Flood (fields washed off)
1881	Season unusually wet (destroyed crops)
1885	Disastrous rains (rivers over flooded, livestock died, fields eroded, damaged roads)
1887	Heavy summer rains, floods
1891	Abnormal summer rains (roads impassable, fields eroded)
1898	Heavy rainfall (river banks flooded)
1924	Heavy rainfall (river banks flooded)
1933	General flood
1934	Heavy summer rains, floods

1939	Heavy summer rains, floods (destroyed housed and crops)
1942	Torrents of rains
1943	Flood
1944	Heavy downpour, flooding
1955	Flooding
1956	Water logging, floods (damaged crops)
1958	General flood
1961	Heavy rainfall
1963	Heavy down pour
1966	Flood
1967	Heavy rainfall (people drowned)
1971	Heavy rainfall
1972	Very heavy rains
1973	flooding
1975	Flood
1976	Flooding
1978	Heavy rainfall resulted in flooding
1985	Flood
1987	General flood
1988	Flooding, Senqu river overflowed
1989	Flood
1990	Flood
1995	Flooding (heavy rainfall caused rapid fill of Katse Reservoir)
1998	Heavy rainfall resulting in floods (4 people drowned in Quthing)
1999	Exceptionally heavy rainfall and severe flooding
2000	Heavy rains
2001	Wettest summer since 1933-4
2002	Flooding
2006	Floods (Mohokare and Makhaleng Rivers rose to their highest levels)
2007	Heavy rains, people drowned
2009	Heavy rains and floods
2010	Flooding
2011	Flooding, major rivers overflowed, killed livestock and people drowned

Sources: TRC, 1999, 2006; Showers, 2005; Nash and Grab, 2010; Nash and Grab, 2010; Disaster Management Authority, 2011; www.em-dat.net

5.2.1 Extreme daily rainfall events

The analysis of extreme events is currently one of the lead research topics in climatology because of the potentially dangerous character of the phenomena (Katz, 2010; Halmstad *et al*., 2012). Extreme precipitation events are the major cause of severe floods in Lesotho. A number of record-breaking and devastating rainfall extremes previously occurred in the study region, some of which might be attributable to climate change. The 114 year-long daily rainfall series for Mohale's Hoek from 1889-2012 is presented in Figure 5.4. The annual maximum daily rainfall indicating flooding events is extracted for each year. It is worth noting that the only available daily rainfall data used for this analysis is only from one climate station for Mohale's Hoek, and it is thus difficult to represent the entire study region, allowing for temporal but not spatial analysis. Extreme precipitation is usually defined as the maximum daily precipitation within each year (Feng *et al*., 2007), however, spatial analysis of rainfall extremes and flooding remains a challenge in Lesotho. There are very few climate stations and, given that rainfall extremes are local events they should be examined using a dense observational network. To evaluate the characteristics of extreme rainfall events, statistical extreme value theory is commonly used in hydro-climatology related studies (Katz *et al*., 2002; Halmstad *et al*., 2012).

The extreme daily rainfall event of 1988 (107.7mm) was of the most severe magnitude recorded in the district, followed in 1905 by an event which measured 101.6mm of rainfall in a day. The analysis finds that the 1970s recorded the highest number of flood events, six, followed by the 1920s, five. According to the study results, extreme rainfall occurs mostly as single-day events, however, there are instances when these events occur sequentially and could continue for two or more days. The 1905, 1933, 1967, 1976 and 1988/9 and 2000s records show multi-day extreme precipitation which lasted for two to six days. The frequency of extreme events occurring sequentially was higher during the 1970s. On 18 February 1988, 107mm of rainfall was recorded in Mohale's Hoek, the highest rainfall ever recorded in a single day in the district (following the 14 December 1905 event). During this event, the Senqu River reached its highest level since 1933, causing devastating flooding. 1988 was a La Niña year, which resulted in above average rainfall in the southern African region (Nicholson and Selato, 2000).

The variations of extreme inter-annual rainfall exhibit some evidence of changing extreme rainfall patterns in the study area over time. Decreasing extreme rainfall events were

mainly observed from the 1990s onwards, whilst between the 1950s and late 1970s extreme events were more substantial. Contrary to climate change projections, which suggest an increasing magnitude and frequency of extreme events (IPCC, 2012), the trend is one of slightly decreasing extreme rainfall events.

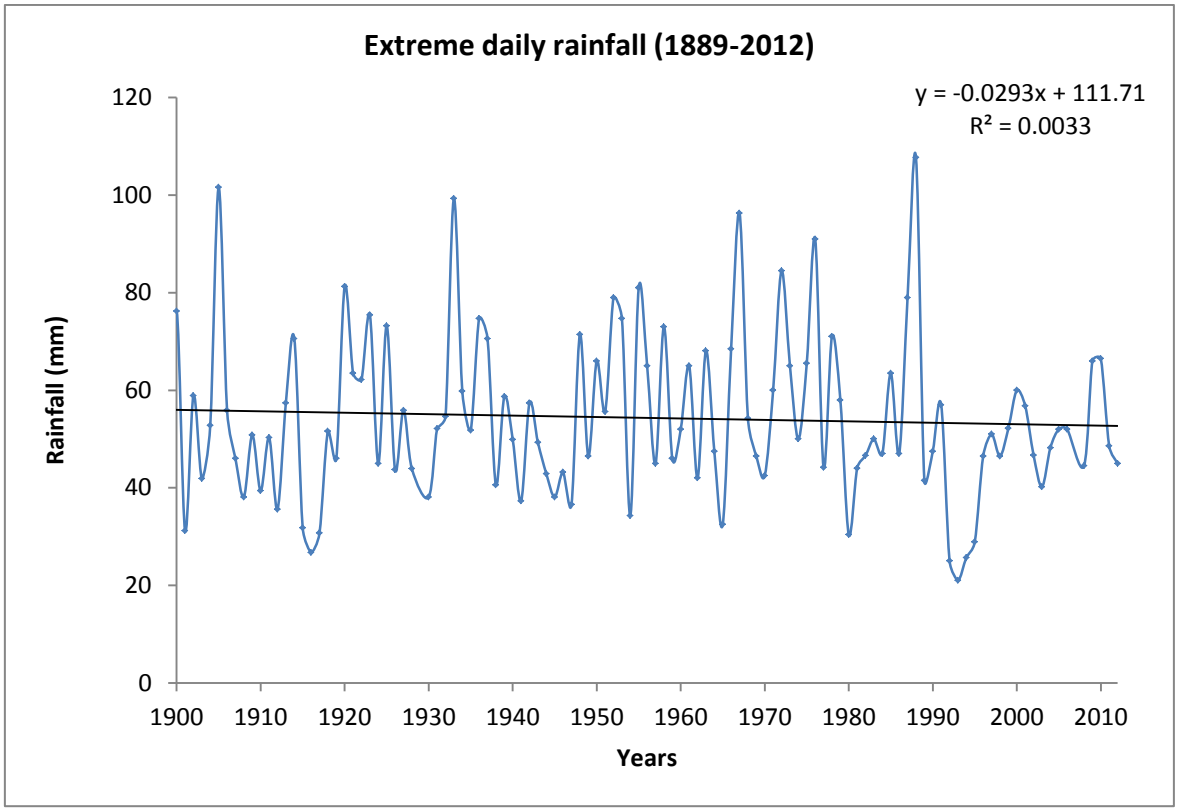

Figure 5.4: Annual daily rainfall maxima from 1889-2012.

Source: Data from Lesotho Meteorological Services

The data were further divided into two time periods of equal length (1900-1955 and 1956-2012), so as to compare the return periods and intervals of extreme events for both time periods (Figures 5.5 and 5.6). The results indicate that there has not been any change in the frequency and magnitude of damaging flood events during the study period. From 1898-1955 there were 17 extreme flooding events, whilst between 1956 and 2012 there were 16 extreme flooding events recorded. The return period and return interval were similar between the two time series.

The significance of changes in rainfall extreme events was assessed by comparing the differences in the intensity of high rainfall events with the difference expected under the

null hypothesis: that there is a difference in the intensity of high rainfall events between 1898 to 1955, and 1956 to 2012. Changes in the intensities of rainfall events between 1898-1955 and 1956-2012 are illustrated in Figures 5.5 and 5.6. Decreases in the intensities of the high annual maxima are evident from the 1980s. Decreases in intensities of high rainfall have been experienced in the study area. According to Mason (2001) and Tadross *et al*. (2005), most parts of southern Africa have experienced a decrease in annual rainfall totals since the late 1970s, which is also reflected in a decrease in extreme rainfall events in a study area.

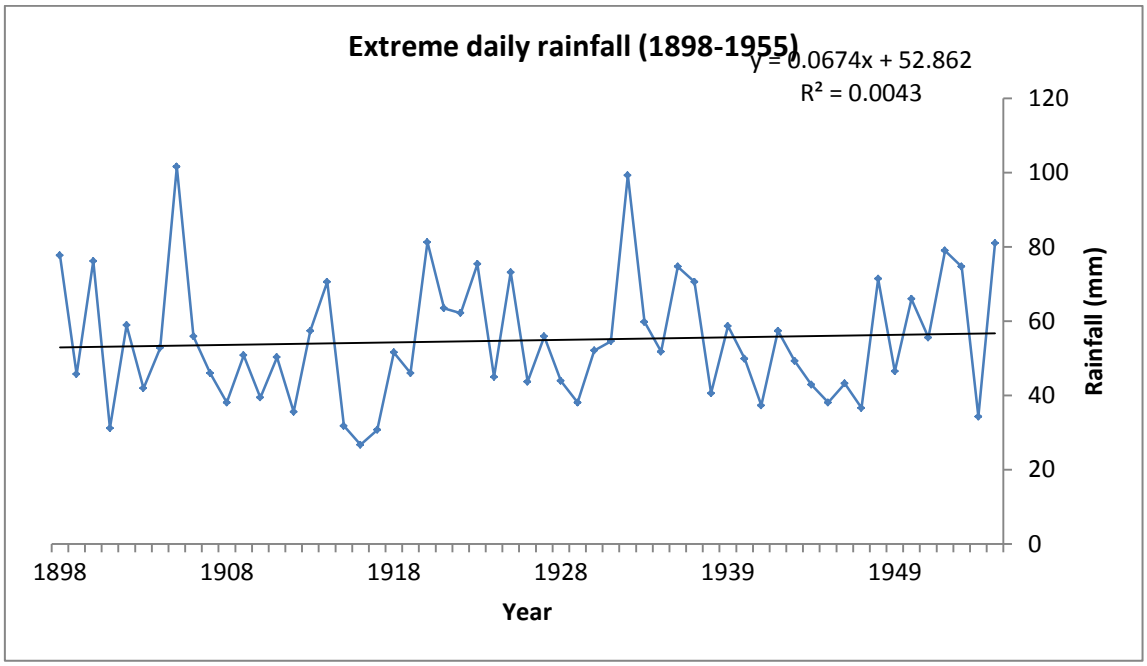

Figure 5.5: Annual daily rainfall maxima for Mohale's Hoek 1898-1956.

Source: Data from Lesotho Meteorological Services

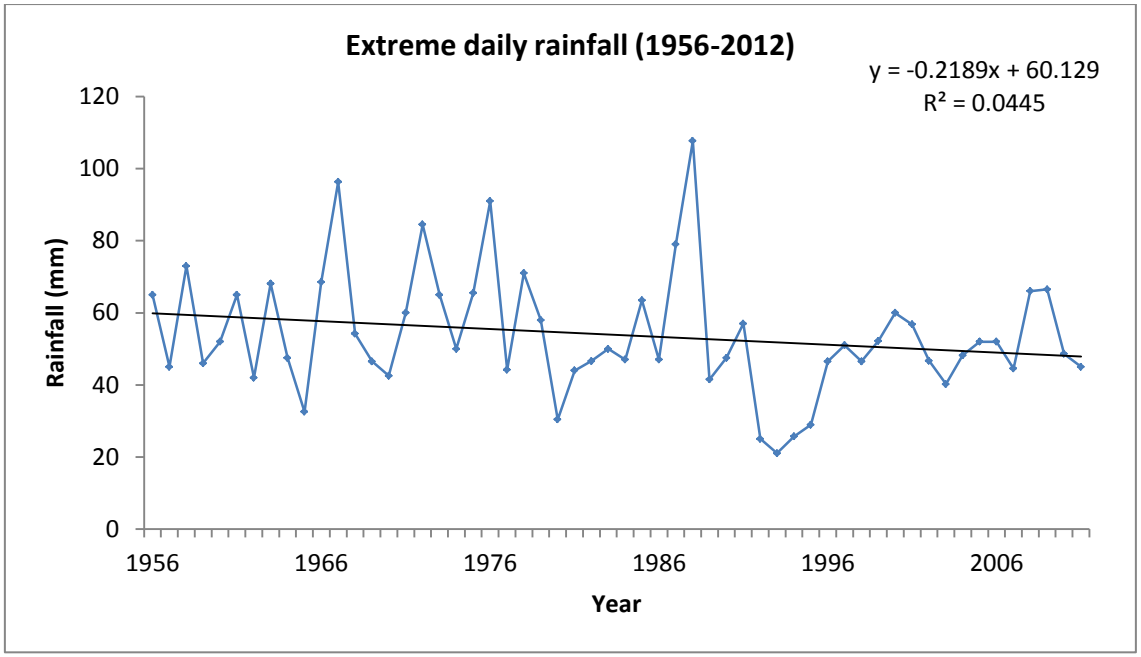

Figure 5.6: Annual daily rainfall maxima in Mohale's Hoek 1956-2012.

Source: Data from Lesotho Meteorological Services

The second half of the study period recorded 16 cases of extreme (more than 60mm/day) daily rainfall events, while the first half recorded 17 such events. There has thus not been a significant increase in flood (extreme rainfall) events over time. Relative to the changes in total rainfall amounts there is a slight indication of disproportionate changes in the precipitation extremes. The data presented here suggests that the recent trends in rainfall extremes of rainfall have been marginally decreasing since the early 1990s.

5.2.2 Flood monitoring of hazard surface

An important component in hazard assessment is the identification and delineation of flood-prone areas. Topography has been used extensively to highlight areas prone to flooding (Murphy *et al*., 2009; Stephen *et al*, 2012) and to determine how rapidly water will travel and where it will collect (Vogt *et al*., 2003; Degiorgis *et al*., 2012). Flood-prone areas, for the purpose of this study, are those subject to inundation as a result of a flood. In Lesotho, floods have been occurring at different places and times with varying magnitude. In Lesotho, flood disasters are attributed to rivers that overflow or burst their banks and

inundate downstream valleys, rising water tables and water logging. Particularly large-scale flooding, riverine, is common in the lowlands due to high intensity rainfall occurring in the highlands. In the study area, the major river basins that have serious flood problems are the Senqu and Makhaleng Rivers.

A digital elevation model (DEM) for the study area was acquired to provide elevation data. DEMs are used in flood mapping to identify and determine parameters and features such as elevation, surface area, slope, aspect and curvature (Wilson *et al*., 2003; Hengl and Reuter, 2009). According to Zhou and Chen (2011), digital terrain analysis techniques have been used extensively to derive terrain (hydrological or morphological) for flood assessments. Therefore, the DEM was used to derive changes in terrain elevation and slope, as both are crucial to natural runoff direction and for the determination of flood prone areas. The DEM was also used to derive aspects to define and show the direction of runoff in the study region. The DEM demonstrates the study area's elevation as ranging from 1389m to 3218m above sea level (Figure 5.7). Low-lying areas 1389m-1682m are prone to flooding as runoff from higher elevations tends to flow towards areas of lower elevations. The areas with lower elevation include Siloe, Mashaleng, Khoelenya, Thabana-Mokhele and Phamong in Mohale's Hoek, while in Quthing the low lying areas prone to flooding are Liphakoe, Matsatseng, Ha Nkoebe and some parts of Mokotjomela. Areas ranging from 2528m to 3218m are more likely to experience erosion because runoff velocity towards low elevation areas has high erosion rates, showing greater inclination for increased degradation of top soil. These areas include Qhobeng, Seroto, Likhohlong and Qabane in Mohale's Hoek, and Mphaki and Tsatsane in Quthing.

The shape of the land surface determines how water will flow across the surface. The spatial routing of water over a terrain is greatly dependent on the shape of the downhill surface (Li and Wong, 2010; Degiorgis *et al*., 2012). Hydrologically, slope determines the amount of gravitational energy available to drive water flow, and hence influences the rate of water flow and flooding.

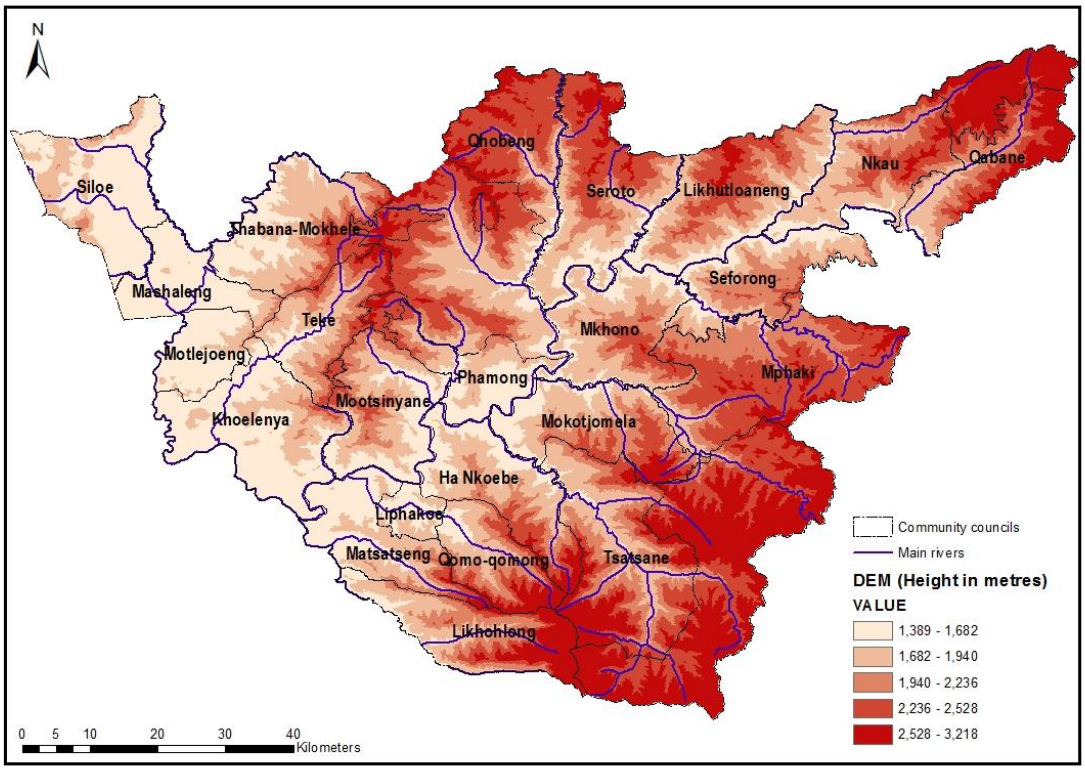

Figure 5.7: Study area elevation map

Source: Own data

Surface flooding is a temporary but damaging hazard associated with heavy rainfall and can last from a few hours to several days. It is a major contributory factor to flash flooding and waterlogging in the Lesotho lowlands. In the highlands, however, steep slope gradients generally provide sufficient drainage for excess water to flow over saturated soils and be accommodated in the stream channels below. In low-lying areas, the situation is reversed because of the flat nature of the ground, more especially in urban areas (in the study region). Urbanisation and settlement encroachment on agricultural lands increases surface runoff by reducing the ability of surplus water to infiltrate the ground in places such as in Moyeni (Quthing) and Motlejoeng (Mohale's Hoek). This results in increased flood vulnerability in low-lying urban areas and high exposure for buildings and agricultural fields.

For terrain and land surface analysis, the spatial analyst tool in ArcGIS 10.1 was used for surface curvature, which refers to convex and concave slope. Convex parts of surfaces,

such as ridges and foothills, are generally exposed and drain to other areas, hence they have high soil erosion rates, but are less susceptible to flooding. Concave parts of surfaces, such as river valleys and channels, are generally more sheltered and "accept" drainage and sediment deposition from other areas (mostly upslope) and are prone to flooding. Slope analysis is used primarily to interpret the effect of terrain on water flow and erosion (Istanbulluoglu *et al*., 2008), therefore, the concave and low curvature areas are likely to be flooded and have more deposition, such as river valleys and low-lying settlement areas and agricultural lands (Figure 5.8, below), including Siloe, Mashaleng, Khoelenya, Thabana-Mokhele and Phamong, Likhohlong, Liphakoe and Qomoqomong. On the other hand, the areas with convex profile curvature are less prone to flooding but susceptible to erosion, namely high elevation areas that include Hloahloeng, Qhoali, Seforong, Teke, Nkau, Tsatsane, Mphaki and Qobong.

Aspect, which defines the slope direction, can be used to establish the direction of water flow, which is the information required to determine other hydrologically significant variables such as upslope area (Zevenbergen and Thorne, 1987; Li and Wong, 2010). Aspect can be used to calculate the primary flow direction. The aspect map not only gives details of slope direction but also an overview of the topography of the research location (Figure 5.8). Therefore, surface features such as river channels and streams can be easily identified. River channels are shown as thin lines between the areas of two opposite directions of slopes on the map. Slope curvature measures the rate of change of the slope along the profile and is important for characterising changes in flow velocity and sediment transport processes. Therefore, the profile curvature is negative for slope increasing downhill (as convex) and positive for slope decreasing downhill (as concave).

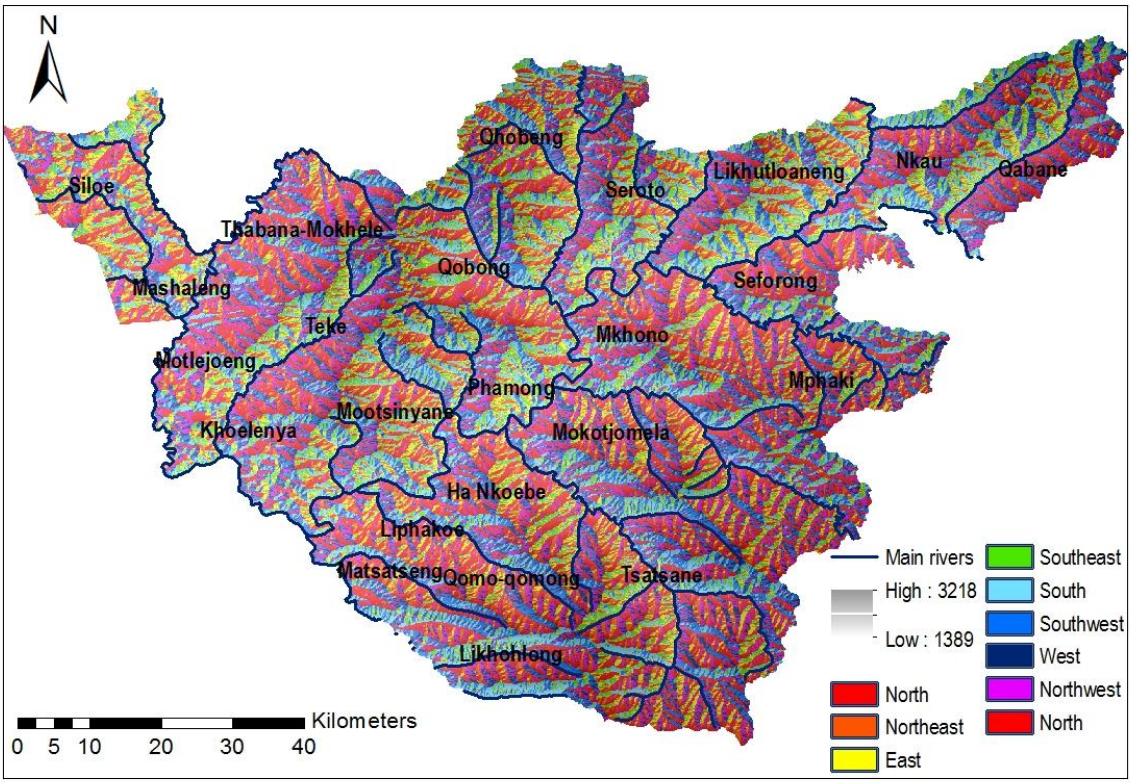

Figure 5.8: Aspect map

Source: Own data

Generally, slopes are steeper and vegetation cover more sparse in mountain areas than on surrounding foothills or lowlands, and such characteristics of a place can influence both flood frequency and intensity. Based on field observations (January 2011 to April 2012), areas with steep slopes, with a gradient of more than 38%, such as Likhohlong, Tsatsane and Mphaki in Quthing, and Mootsinyane, Nkau, Qabane, Likhutloaneng and Hloahloeng in Mohale's Hoek, were found to be less susceptible to flooding but most susceptible to erosion, rock falls and landslides resulting from intense rainfall and high water velocity, and thus had great potential for slope failure. It was also observed that land degradation, road construction, quarrying and farming on steep slopes could contribute to slope failure in these regions. Soil cover is very thin (between 14cm-29cm deep) on exposed mountain slopes to reasonably deep (between 48cm-64cm deep) in the river basins (Lopez, 2013).

Increased susceptibility to flooding is further increased by human-related activities (e.g., Yanda, 2011; Maro, 2011). The Lesotho population is predominantly rural and depends

mainly on traditional rain-fed agriculture. The country is experiencing rapid urbanisation and limited settlement areas in urban settings, consequently there is a problem of urban encroachment on arable agricultural land, particularly in Moyeni and Motlejoeng. Increasing exploitation of these marginal areas has been observed in different parts of the study region. Inadequate land and increased water demand from the growing population have led to changes in land-use patterns in urban areas, thus, more land is cleared to make space for these activities, leading to reduced land cover and modified soil surface properties. Subsequently, large land areas become exposed to erosion and flooding. Changes in land surface often lead to increased frequency and/or volumes of flash floods due to poor infiltration.

The location of an area determines potential for flooding. In rural areas of Lesotho, settlement and agricultural areas are generally established at the foot slopes, where there is an abrupt change in slope profile. These topographic features impact significantly on the formation of stream systems and flow directions, as well as the magnitude of soil erosion rates and flooding downstream. Agricultural fields and settlements are mostly located on riverbeds and these areas are naturally flooded during peak events. This situation is aggravated by the presence of very tight river channel curvatures and a high sediment load due to erosion occurring upstream during heavy rain. This has been identified by the disaster management officials in the study area as a major challenge in Tele and Phamong.

5.2.3 Flood risk mapping

This study adopted a simple definition of floodplain as a morphologic sector of a valley and a flat area adjacent to the river (Niculiță, 2013). A floodplain for the study area was delineated using Arc Hydro model in *ArcMap*, modelled with the study area's DEM on which a rivers layer was overlaid. Several steps were followed on the Arc Hydro model which produced a map of the flooded area both as a raster of water depth in the floodplain and as a polygon feature of the flooded area. Slope length and steepness are critical factors in enhancing flooding potential, since they determine, in large part, the velocity of runoff. The energy (thus the flooding potential) of flowing water increases as the velocity increases. Long and continuous slopes in the highlands allow runoff to gain momentum. The high velocity runoff tends to concentrate in narrow channels and produce rills and

gullies (Kellens *et al*., 2013). The shape of a slope also has a major bearing on flooding potential. The base of a slope is more susceptible to flooding than the top, because runoff has more momentum and is more concentrated as it approaches the base. A convex slope amplifies this problem whereas a concave slope reduces it. A relatively flat area at the base of a slope is also flood prone and allows sediments from the upper portion of the slope to settle there (Lindell and Hwang, 2008; Kellens *et al*., 2013).

Both main and minor river layers were mapped in *ArcGIS* and buffered, with a buffer distance of 500m created on both sides of the river channels, derived from field observations and from key informant interviews. The buffered layers were overlaid on the DEM. To determine flood risk areas, from the buffered river basin and DEM, spatial intersect and erase geo-processing techniques were applied in *ArcGIS*. Flood prone areas were then classified, based on elevation and distance from the rivers, because flood risk impact of rivers decreases with distance from the river channels. Elevation (DEM) on the other hand, has been used to assess the spatial distribution of potentially endangered flood areas (Taubenbock, *et al*., 2011, Ishaya *et al*., 2009).

The DEM or surface analysis of the study region illustrates elevation of the study area and different communities are located at different elevations. The DEM helped in determining the extent of inundation area, direction of flood flows, and changes in river channel through remaining flood evidences, relief features and sediment deposits formed by repeated floods, hence in understanding the nature of former floods and probable characteristics of floods occurring in the future. This approach of flood investigation has been verified significantly where the channel system and floodplain morphology of rivers change dynamically and have high erosive potential and substantial sediment supply (Lastra *et al*., 2008; Ho *et al*., 2010). The use of a DEM is known as a cost-effective and efficient method for mapping flood hazard in developing countries because of inadequate data sources (Wang *et al*., 2002; Ho *et al*., 2010).

The whole region was classified into different flood risk categories based on the DEM (Figure 5.8). Figure 5.9 therefore illustrates flood susceptibility and delineation of the study area into five different levels. Areas were also mapped based on their distance from the rivers and these were classified as *highly, moderately* and *less* vulnerable, within 0-200m of rivers, 200 and 500m, and 500m respectively (Figure 5.9). Thus, communities such as Phamong, Siloe, Mashaleng, Motlejoeng, Thabana-Mokhele, Khoelenya,

Liphakoe, Matsatseng, Ha Nkoebe, Mkhono and Tele are classified as highly vulnerable, while the communities of Qomoqomong Mokotjomela, Likhutlong, Seroto, Seforong and Likhohlong are moderately vulnerable, and those of Qabane, Qhobeng, Qobong, Mphaki and Tsatsane are least vulnerable to flooding. Therefore, increasing distance from the river and higher elevation values lowers the flood hazard risk. Figure 5.9 illustrates that a large portion of the study region is relatively highly susceptible to flooding.

It is necessary to distinguish between hill slopes and valley bottoms, as there are substantial differences in hydrological and geomorphological processes across such areas. Soils on hill slopes are normally shallower than in valleys and are characterised by erosion and deposition of materials (Gallant and Dowling, 2003). According to these authors, the hill slope flow paths are mainly driven by surface topography, while this connection between topography and water flow is not apparent in valley bottoms, where low gradients and depressions affect flow paths as a result of surface topography. Figure 5.10 shows a slope map of the study area and its topography and indicate that upper catchment areas correspond to the steepest and narrowest valleys, while the valley bottoms have relatively flat terrain. Slope aspect directly or indirectly influences flooding through increasing or reducing vegetation cover and soil moisture.

The slope map defines the rate of downstream movement of water from one point to another, which gives insight into the acceleration and deceleration of water movement, influencing flooding, erosion and deposition of materials. This means the higher the elevation the faster the downward flow of water. Figure 5.11 presents the slope steepness variation and thus potential overland flow velocity of storm water in the study area. The areas ranging from 12.41-21.03° and from 29.65-8.26° are susceptible to flooding, and to some extent erosional deposition. This may result from the slow movement of runoff during rainfall on shallow slopes. The areas with nearly level and moderate slope are more susceptible to erosion than flooding. Lastly, the areas with steep and very steep slopes are crucial and likely to produce flood of greater velocity downstream than moderate slopes. Topography is therefore one of the critical factors affecting the propagation of a flood wave downstream (Zhou and Liu; 2008; Creutzfeldt *et al.,* 2010; Manfreda *et al*., 2011).

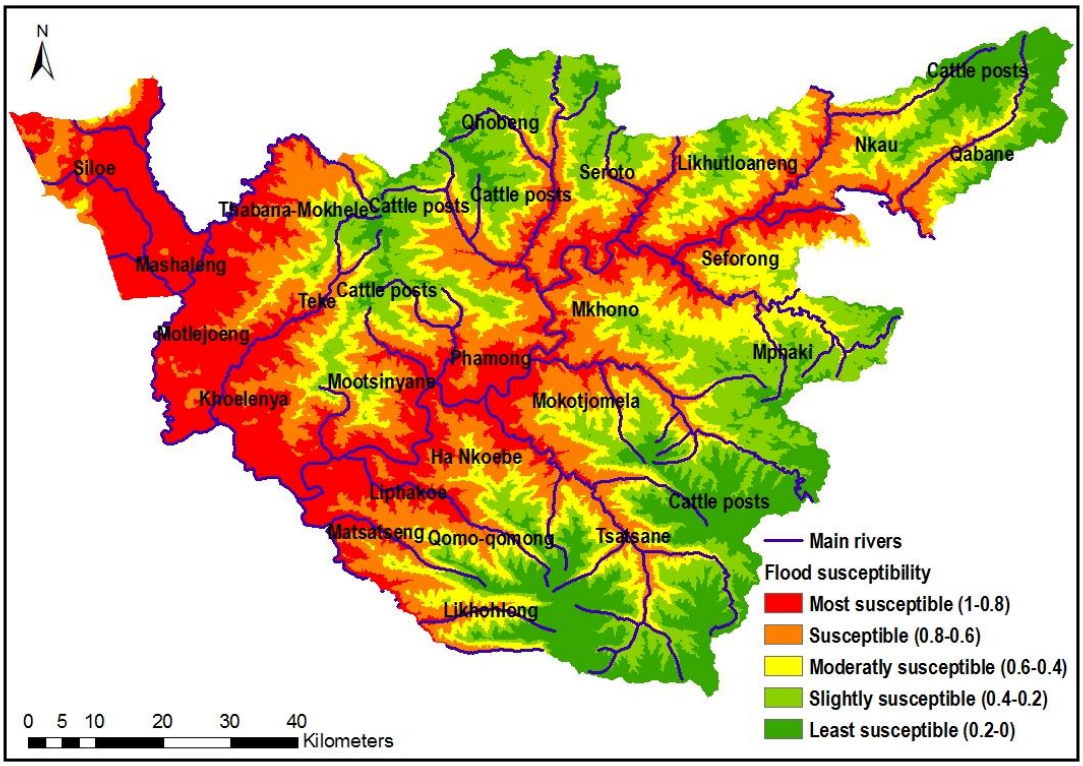

Figure 5.9: Potential flood vulnerability map
Source: Own data

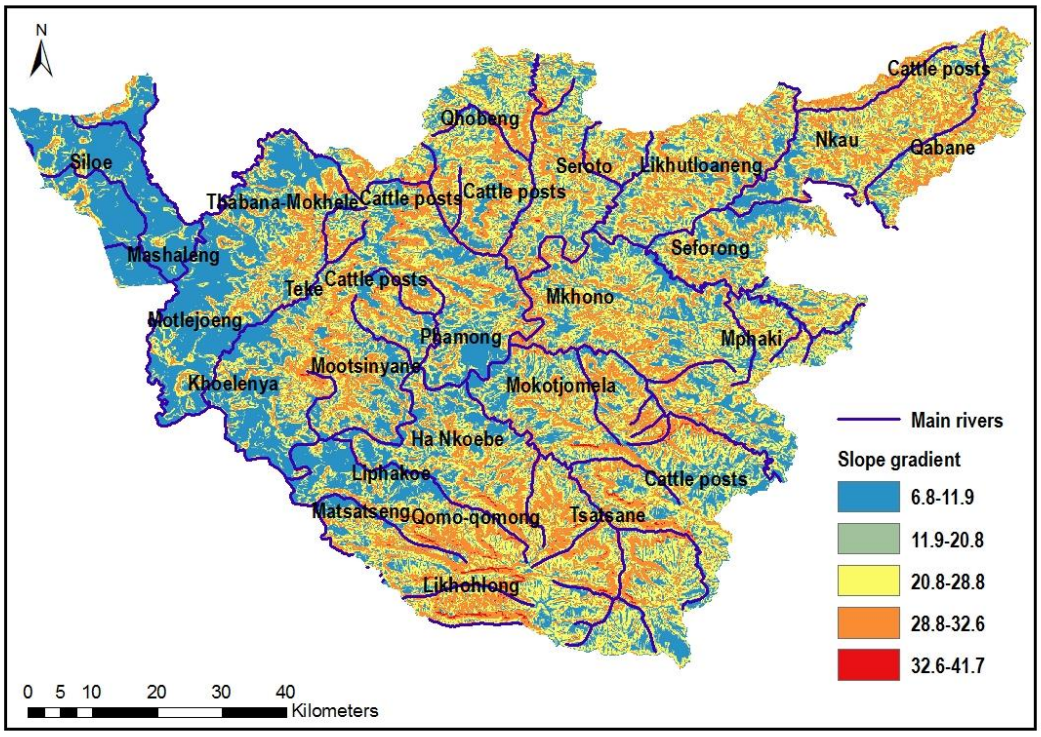

Figure 5.10: Slope gradient (degrees)
Source: Own data

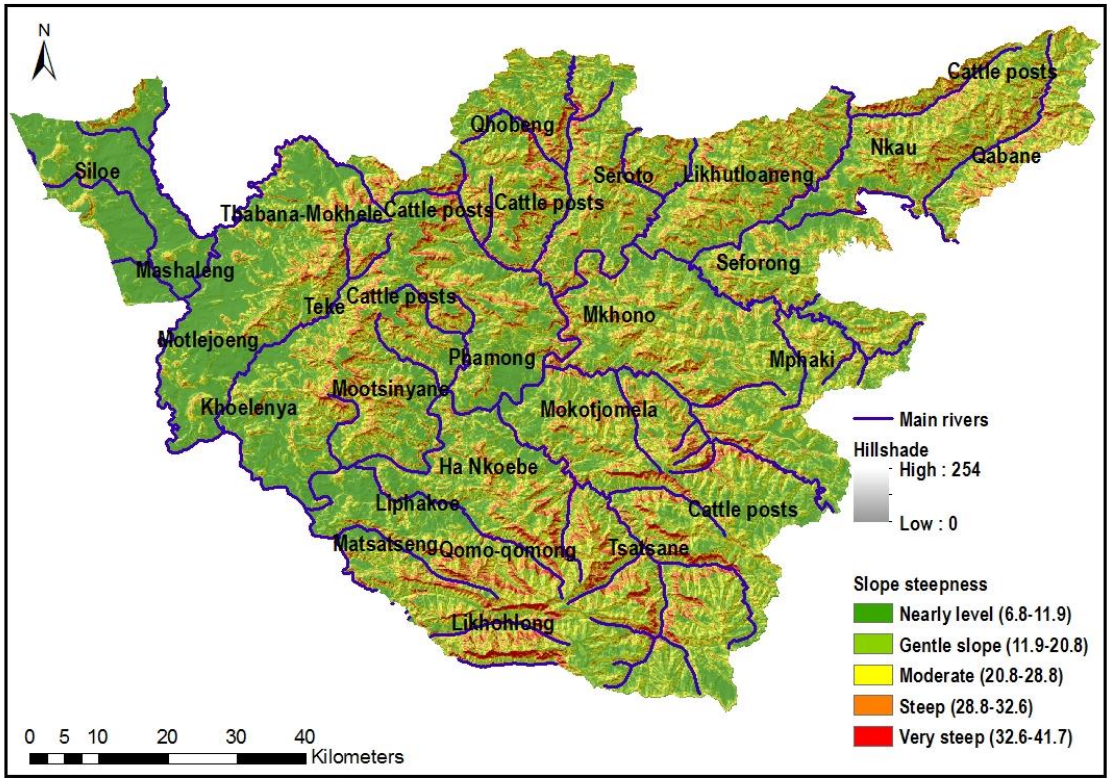

Figure 5.11: Slope steepness map
Source: Own data

5.2.4 Flood impacts and community vulnerability

Flood losses are essentially human interpretations of the negative economic and social consequences of natural events (Van Looy *et al.*, 2006; Maro, 2011). Evidence emerging from the study through interviews suggests that the negative impacts of floods have been greater than those reported in official records. Residents from both districts (Mohale's Hoek: 65% and Quthing: 43%) mentioned that they sometimes did not report flooding incidences to officials because they were not offered any recovery assistance and thus it was not worth the effort to report. The government reports and officials from both districts recorded and reported cases of heavy rains and destructive storms in 1943, 1957, 1958, 1967, 1976, 1988, 2001, 2006, 2010 and 2011, which caused severe and widespread flooding in communities along the river banks of the Senqu, Tele, Qhoali, Sebapala and Quthing Rivers (Quthing district), and along the Makhaleng, Mekaling and Senqu Rivers (Mohale's Hoek). The respondents confirmed that these rains swept away crops and bridges, caused human and livestock deaths, and caused damage to property and

infrastructure. The survey findings, referring to the recent events, validate the flood episodes deduced from rainfall data presented above.

Flood intensity and its impact are also influenced by the location of various elements at risk (fields, houses and infrastructure networks), their elevation, their proximity to rivers and associated flood return period (Messner and Meyer, 2006). In the study area, floods often affect essential services in remote rural areas. Some residents in Hloahloeng (67%) and Ketane (54%) in Mohale's Hoek reported that because of restricted movement during floods there are often shortages in medical supplies and vaccines, with consequent frequent high incidences of gastroenteritis after floods, owing to contaminated drinking water. These communities are adjacent to the Senqu River and there are no bridges connecting them to the rest of the district. In Quthing, the communities mostly affected by floods are in the relatively low-lying areas of Liphakoe, Matsatseng and Ha Nkoebe, adjacent to the Sebapala and Tele rivers, which have no bridges.

5.2.5 Effects of floods on agriculture

Although damage to housing and infrastructure is possibly the most fundamental and pressing impact of floods, a more established effect has been on agricultural land. In Lesotho, agricultural fields are generally situated in low-lying areas, flood plains and riverbanks, all of which are susceptible to flooding. As the majority of fields in Mohale's Hoek are situated along the river banks (Makhaleng and Senqu Rivers), a large proportion of land and crops is lost during floods (field observation). Due to their relatively fertile soils, the valleys are used for cropping. For one female-headed household at Qhalasi (Mohale's Hoek), the 2011 flood left the entire field waterlogged, thus reducing the area available for planting. Some 30% and 45% of households in Quthing and Mohale's Hoek respectively, reported having lost land in the previous ten years as a result of erosion caused by flooding (household interviews and focus group discussions). Floods destroy crops and wash away fertile soils, cause land degradation and soil erosion, consequently reducing the area planted, and lowering agricultural productivity and food security. Respondents reported that floods also caused waterlogging in agricultural fields and as a result delayed crop planting and destroyed existing crops (Figure 5.12). Globally, for

communities located in the river valleys and flood plains, flooding is a major threat to residents and their livelihoods (Matarira, 2010; Gwimbi *et al*, 2012).



Figure 5.12: Flooded maize crops in Mohale's Hoek. (January, 2011)
Source: Own photo

The livelihoods impact of floods in the two districts is felt most on the agricultural sector, which for many poor households is a major source of subsistence. The most fertile land is in close proximity to the rivers, particularly along lower river valley terraces, thus washing away crops and leaving households with declining and inadequate food stocks. The areas and fields near the Maphutseng, Makhaleng and Senqu Rivers (Mohale's Hoek), and Tele, Sebapala, Quthing and Senqu Rivers (Quthing), have historically experienced crop damage due to floods in seven events (1989, 1995, 1998, 2001, 2006, 2007 and 2011). Both the respondents and disaster management officials stated that these floods have resulted in reduced agricultural production and increased food insecurity for households. Official records (LVAC, 2008; DMA, 2010) further indicated that 400 households were assisted with food commodities in 2007 in flood affected areas, 126 in Mohale's Hoek, and 174 in Quthing (data was not place-specific but representative of the entire district). Figure 5.13 outlines fields and houses at Dili Dili (Tele), a village in the Quthing district, where it is evident that the majority of fields and houses are situated, making them particularly susceptible to flooding and fluvial deposition. The physical location of this village and its fields makes it more susceptible to flooding than other areas at higher elevations, such as

Tsatsane and Mphaki. In the event of excess rainfall, the houses and fields in this area are likely to be flooded. Residents confirmed that fields and houses are sometimes flooded or waterlogged for several days.

Geographical proximity to flood prone areas is a key factor to place vulnerability. Those living within or near river valleys and riverbanks are generally at greater risk of flooding. The strongest predictor of flood-related vulnerability is proximity to low-lying areas (Alcantara-Ayala , 2002; Liu *et al*., 2004; Lastra *et al*., 2008; Suriya and Mudgal, 2012).



Figure 5.13: Flood prone fields in Dili Dili, Quthing (circled with orange line).
Source: Google Earth (accessed January 2012)

5.2.6 Slope failure impacts on infrastructure

A number of floods in Lesotho have caused extensive damage to the built environment and infrastructure in the country, reversing the development efforts of infrastructure developments by the government. Activities such as road construction and quarrying have increased the use of transportation and vehicles that could eventually increase artificial vibrations on slopes (Borga *et al*., 2002; Lanni *et al*., 2013; Thanapackiam *et al*., 2012). Road construction in the highlands has greatly influenced slope failure and affected geomorphological and hydrological processes in Lesotho (Figure 5.14). In addition, reworked slopes face tremendous stress, through pressure release mechanisms, from these conditions in the study area, whereby deterioration in slope stability has contributed to

slope failure threats (Lebelonyane in Quthing and Ketane in Mohale's Hoek in Figure 5.14). Weathered material such as dolerite in Ha Lebelonyane in Quthing, is susceptible to slope failure. The changes in slope height and gradient on Lebelonyane Pass (Quthing) during excavation for road construction accelerated slope geomorphological processes (field observation). In Mphaki Quthing, landslides and unstable soils, which resulted from excessive rainfall, adversely affected communities by disrupting roads and communication lines, and damaging houses and properties.



Figure 5.14: Rock falls caused by excess rainfall at Mphaki Quthing. (25/06/2009)
Source: Own photo

During the 2010/2011 rainy season, roads and bridges in both districts were damaged and rendered unusable, affecting the movement of people, goods and services. In the Quthing district along the road that connects Quthing and Qacha's Nek district, a bridge was washed away and it was impossible for people to use for a week, until a make-shift bridge was constructed to ease movement (Figures 5.15 and 5.16). In the event of bridges being washed away, people cross flooded rivers on foot, exposing them to the risk of drowning. The communities most affected by such consequences are those of Sebapala and Mt Moorosi, in Quthing, the constituencies most affected as this road connects them with

Moyeni town, administrative centre for the Quthing district. The majority of these communities are in the foothills and rural mountain areas, with poor road networks and a lack of basic social services. They are situated along the major rivers, such as Sebapala, Senqu and Qhoali in Quthing.

In the rural communities of Lesotho (both in the highlands and foothills), and the study region in particular, people rely heavily on footbridges to cross flowing streams and rivulets. Residents in Ha Nkoebe, Matsatseng, Tsatsane and Mkhono in the Quthing district, and in Seroto, Qhobeng, Phamong, Teke, Likhutloaneng and Qabane in Mohale's Hoek, reported that if footbridges were destroyed there were associated risks of drowning and children being unable to attend school. In most cases, children would wait for several days for rivers and streams to subside, and thus be educationally disadvantaged. In recent times, as mobility determines one's exposure to livelihood opportunities, floods and flooding continue to isolate entire villages, with implications for essential services. For instance, the sick cannot access healthcare and government officials cannot reach people to offer them services.

In 2005 and 2006, torrential rains, which destroyed bridges and culverts and washed away roads, resulted in prolonged traffic interruptions and detours in the Motlejoeng, Mashaleng, Phamong, Mootsinyane and Qobong community councils in Mohale's Hoek along the Senqu and Makhaleng Rivers (Figures 5.17, 5.18 and 5.19). During a visit to the study area in Mohale's Hoek in January 2011, one of the bridges connecting Phamong and Seroto had not yet been repaired. Residents in Phamong and Seroto reported that their movement was severely restricted owing to this damaged bridge.



Figure 5.15: Bridge washed away in Ha Selaitara, Quthing during heavy rains (Jan 2011).
Source: Own photo



Figure 5.16: A make- shift road/bridge in Ha Selaitara, Quthing after heavy rains (Jan 2011).
Source: Own photo





Figure 5.17: Bridges and roads washed away in Mpharane, Mohale's Hoek during heavy rains (Jan 2011).
Source: Own photo



Figure 5.18: Road flooded in Motlejoeng, Mohale's' Hoek, disrupting movement of people and goods in January 2011.



Figure 5.19: A road destroyed by floods in Mashaleng, Mohale's Hoek in January 2011. Source: Own photo

When surface water enters the streams and when rivers exceed the capacity of the natural or constructed channels to accommodate the flow, water overflows the banks, spilling onto nearby low-lying areas. Figures 5.18 and 5.19 show this phenomenon along the Makhaleng River (at Makhaleng village in Mohale's Hoek), where water overflowed the river banks, and runoff submerged roads and properties. In Mohale's Hoek, most properties have developed on floodplains and near rivers, making them highly susceptible to flooding.

5.2.7 Determination of flood vulnerability

Annual rainfall data, topographical maps and digital elevation data were used to prepare the flood vulnerability layer, standardised to determine flood susceptibility, after which the values ranged from 0 to 1, where a higher value represents a higher vulnerability level. The flood vulnerability was evaluated under three categories: high, medium and low. To verify the results, flood-affected areas between the years 1898 and 2012 derived from rainfall data and interviews were overlaid into a final flood layer (Figure 4.20). It was determined that approximately 95% of flood-affected areas for the study period correspond to areas labelled with very high or high flood vulnerability.

The areas with high vulnerability levels are mostly in Mohale’s Hoek district (Siloe, Thabana Mokhele, Motlejoeng, Khoelenya, Mootsinyane and Phamong (Figure 5.20). In Quthing, areas with high vulnerability levels are Liphakoe, Matsatseng, Ha Nkoebe and some parts of Mkhono and Seforong. Most of these areas are low-lying or situated along the river valleys. In contrast, all the highlands (Tsatsane, Mphaki, Qabane and Qhobeng) are all above 2600m, and cattle posts in both districts are less vulnerable owing to their topography and low population densities, making them less vulnerable to flooding.

Under current climate conditions, flooding due to excess precipitation events is extensive in the country, but varies spatially across and even within districts, thus impacting on place vulnerability. The spatial distribution of floods tends to occur along the Senqu, Makhaleng, and Tele Rivers, as well as in lowland areas. The areas which suffer most losses in terms of infrastructure are high-density urban areas of Motlejoeng and Liphakoe. These areas are relatively vulnerable to flooding because they are located in flood plains and are populous, with relatively well-developed infrastructure. The damage resulting from seasonal storms and river flooding are partially caused by anthropogenic

activities such as construction of infrastructure and agricultural fields adjacent to rivers, location of settlements and agricultural fields in flood plains. In addition, changes in total precipitation appeared to have a direct relationship with flooding events.

Flood magnitude and damage in the study area seem to be increasing over time, mainly due to a growing vulnerability emanating from societal changes such as interference by occupying flood prone areas, infrastructural developments, investments and land-use changes. Recent studies have indicated that losses from flood hazards are expected to increase in coming years (IPCC, 2013). In many countries, flood vulnerability is also expected to increase as a direct consequence of population growth and spatial expansion (Kellens *et al.*, 2013). It should be understood that while disasters result from a combination of physical exposure and human vulnerability to the geophysical processes associated with flood hazards, human vulnerability reflects mainly on socioeconomic factors, such as the number of people at risk in flood plains (Abhijeet, 2011; Dang *et al*., 2011; Ho *et al*., 2013).

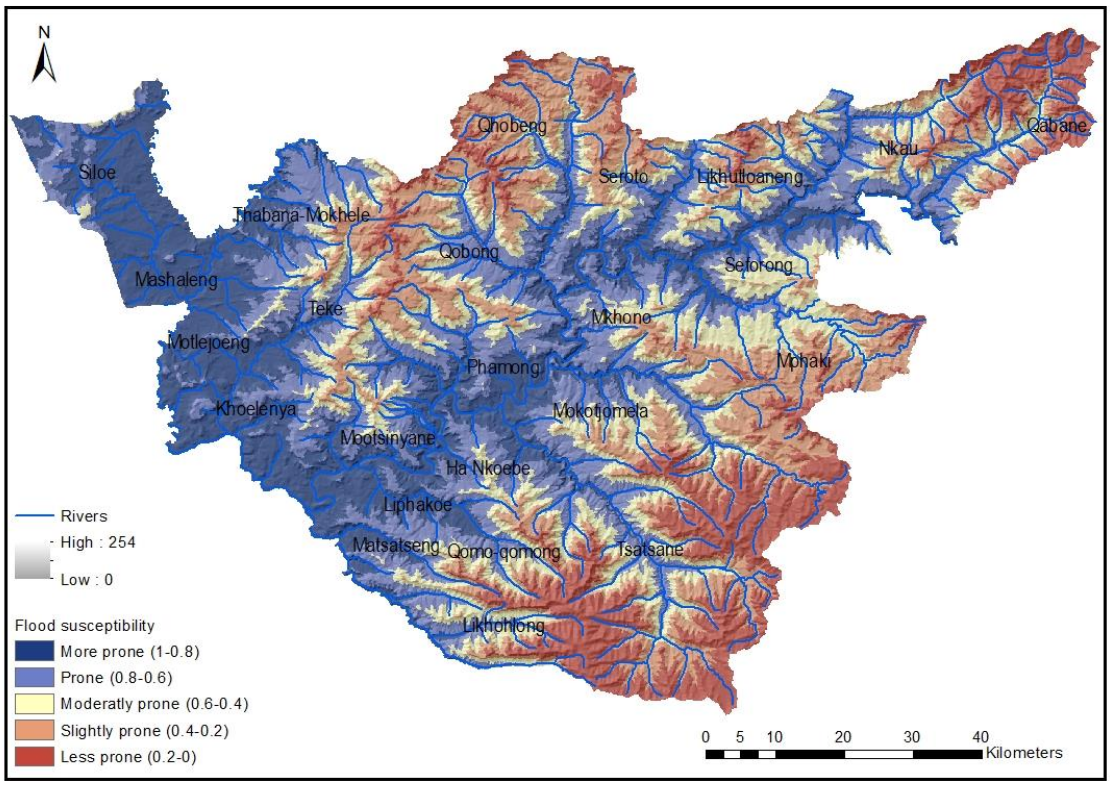

Figure 5.20: Flood prone areas in both Mohale's Hoek and Quthing.
Source: Own data

Drainage, topography and land-use patterns are significant factors contributing to flood-related place vulnerability, especially in urban areas. In Lesotho, poverty, topography, urban sprawl, rapid urbanisation, rural urban migration, uncontrolled land-use planning and the absence of settlement policies have resulted in unplanned human settlements in flood prone locations. The absence of building codes and standards, as well as unregulated land tenure systems in the country, has resulted in house-building in hazardous areas such as flood plains and in gullies (Leduka, 2006, 2007). These houses and settlements are thus susceptible to flooding, even in situations of moderate rains. For example, the urban areas of Thabana-Mokhele and Motlejoeng in Mohale's Hoek, as well as Liphakoe in Quthing, have witnessed settlement in flood plains. Respondents in these villages reported that the frequency of flooding has increased in recent years and this may be due to land-use changes, including building settlements on agricultural land. In Mohale's Hoek, higher population densities in the urban areas are associated with increased exposure (risk) to flooding. Poor land-use practices have increasingly been identified as a contributor to human induced hazard events in the study area (Leduka, 2000, 2004; Leduka and Setsabi, 2008). When people occupy hazard prone areas for livelihood subsistence and economic reasons, vulnerability is driven more by social than natural forces. The likelihood of a flood also increases as the elevation of a location decreases, making it a reliable indicator for flood susceptibility (Kellens *et al*., 2013).

This analysis illustrates that there has been an increase in the severity of flood events in the study region as a result of increasing population growth and urbanisation. About 60 devastating flooding events were reported between 1830 and 2012. Generally, there has been a significant change in the frequency and severity of flooding events in the study region, which points to possible vulnerability.

5.3 DROUGHT VULNERABILITY

At present there is no general definition of 'drought' and hence it is usually defined according to its impacts. There are different types of droughts, namely hydrological, agricultural, meteorological and socioeconomic. Wilhite and Svoboda (2000) described these different types of drought as: 1) meteorological - the degree of dryness in relation to the average amount and the duration of the dry period; 2) hydrological - related to effects

of precipitation deficit on surface and groundwater supply (Mishra and Singh, 2010a); 3) agricultural - associated with impacts on farming resulting from shortages in rainfall which leads to soil moisture deficit; and 4) socioeconomic - when the demand for an economic good exceeds the supply as a result of a weather-related shortfall in water supply.

Regardless of droughts being defined in association with their impacts, all these definitions highlight water deficit due to the absence of precipitation for prolonged periods. Therefore, drought can be defined as a condition of abnormally dry weather resulting in a serious hydrological imbalance with consequences such as losses of standing crops and shortages of water required by people, livestock and wildlife (Kizza *et al*., 2009; Mishra and Singh, 2010b). Drought occurrence is associated with severe damage of agricultural production and results in food shortages (Boken, 2009). Meteorological droughts defined as deficiencies in precipitation at a certain place over a period of time are the main focus of this section.

Drought is an unpredictable climatic phenomenon within the earth's climate system and is associated with a continued period of considerably low water availability relative to the normal condition, and has an extensive impact over broad geographical areas (Mokhtari *et al*., 2013). Many physical and empirical arguments along with General Circulation Model (GCM) experiments suggest that global warming may result in an increased number and severity of droughts (IPCC, 2012). Though drought occurs in many parts of the world, southern African countries are highly susceptible to them (New *et al*., 2006; Jury, 2013). They caused severe shortages in crop production in many parts of the region and highlighted the vulnerability of the region's food security and water resources to climatic anomalies (Harsh, 1992; Vogel, 1994; Hulme *et al*., 1996; Fauchereau *et al*., 2003; New *et al*., 2006; Jury, 2013).

5.3.1 History of droughts in Lesotho

Drought is a periodic feature of Lesotho's climate, as the entire country has been affected by about 51 droughts of varying magnitude and severity over the past 184 years. In recent years, it experienced recurrent droughts which affected more than 70% of the population, all dependent on rain-fed agriculture. Thus, farmers remain highly susceptible to drought events which severely impact on both quality and quantity of yields. Recent severe and

recurrent droughts have highlighted Lesotho's vulnerability to this natural hazard and caused the public, government and NGOs to be vigilant of a range of socioeconomic problems associated with droughts and the need for mitigating measures. This section presents drought assessment, its impact on Lesotho and the study area in particular. There have been a few studies which have focused on drought in Lesotho with Matarira (2008) using the standardised precipitation index (SPI) to examine incidences, and Nash and Grab (2010) documentary historical sources of information to show rainfall variability in Lesotho between 1824 and 1900.

Drought as a major disaster in Lesotho affects many people and results in huge economic losses, with a return period of 4.4 years for the entire country and is regarded as a typical climatic feature of the climate (LMS, 2000; IFRC, 2011, 2012). Most of the drought events reported in the country are agricultural and socioeconomic in nature, as they affect both livestock and crop farming, the mainstay of the country. Historically, they influenced migration and settlement patterns among the Basotho society (Chakela, 1997). Previously, communities would move from one place to another in search of pastures and water for their livestock. Historical records reveal that Lesotho experienced a particularly severe drought between 1801 and 1803 (Showers, 2005), during which period, there were general crop failures and widespread death of livestock, which resulted in mass starvation, and prompted migration of people and animals in search of food and water. In his summary of oral reports on drought events in Lesotho, Ellenberger (1912: 42) writes:

> This took place in the year 1803, the year of the terrible famine which was called *sekoboto* in Sesotho. It was a time of disaster and death. Family ties were suspended as well as those between chiefs and people, and the starving people gave themselves to anyone who could keep them alive. Men could not maintain their families, and turned off their younger wives to fend for themselves, with freedom for them to join anyone who could keep them.

According to Showers (2005 the 1803 drought was reported to be very severe and resulted in famine, which became known in Basotho circles as the ‘famine of the female servants’, a general reference to the freedom granted to polygamous married women by men who could not afford to feed them (Eldredge, 1987). The 1862 drought was also known as the “great drought”, or “red dust”, when the Caledon River ceased to flow for the only time in living memory (Eldredge, 1987). There were other droughts documented in the country,

with the longest lasting for five consecutive years, 1917/18-1921/21 and 1981/82-1985/86 (Hyden, 1996). The years 1922-23, 1933, 1946, 1949 and 1951 were some of the driest pre-independence years (Basutoland Department of Agriculture Annual Reports, 1942-1957), however, according to Pim (1935), the 1932-1933 drought was said to be an exception, because of its impact, and was believed to have led to enormous livestock losses and reduced household assets and wealth.

The severe droughts of 1833 to 2012 are presented in Table 5.2. Eldredge (1993) and Nash and Grab (2010) highlighted that severe droughts were recorded during the following years in Lesotho and surrounding areas of South Africa: 1841-43, 1851-52, 1858-59, 1860-63, 1865, 1877-80, 1883-85, 1887, 1890 and 1895-98). Showers (2005) also confirms recorded droughts in the following years: 1862, 1886-87, 1888-89, 1895-96 and 1897-98. The 1922 drought was regarded as the worst experienced in the country in living memory, and the 1932/1933 drought was remembered as the year of great dust, which caused total crop failure and widespread livestock loss (Eldredge, 1987). By 1951, severe food shortages were recorded, and an increase in food imports from South Africa was evident (Basutoland Department of Agriculture Annual Report, 1942/43-1957). These series wiped out household savings and productive assets and left people poor and households vulnerable to shocks (Eldredge, 1987; Ziervogel, 2004; Romero-Daza *et al.*, 2009; Jury, 2013). The marked effects of these droughts are poor agricultural performance, food shortages and weak livestock.

The drought chronology indicates that Lesotho has a long history of droughts. For agrarian households, livestock losses affect the asset base and physical capital, as it provides a buffer against future shocks. Among the Basotho society, cattle provide draft power for crop production and are a form of status and wealth, which households would usually draw on during periods of hardship. However, these historical records do not indicate the total number of deaths, human and livestock, or the total amount of crops destroyed by these events. The more recent drought years of 1949, 1979 and 1991 were years remembered as being the worst droughts in Quthing, whilst in Mohale's Hoek the respondents recalled the 1979, 1991-1995, 2002 and 2006 droughts as being the worst. Literature also confirmed the 1991/92 and 2002 droughts as some of the worst recent ones on record in the country, due to the far-reaching impacts felt through all sectors (Glantz *et al*., 1997; Vogel, 1997; Vogel *et al*., 2000; Matarira, 2010).

Table 5.2: Drought incidences in Lesotho from 1833 to 2012.

Year	Comments
1833	Severe midsummer drought
1834	Severe drought
1837	Drought in early summer
1838	Drought
1841	Severe drought
1842	Severe drought
1846	Severe drought and famine devastated the country
1849	Severe drought (terrible scourge of a long drought in whole country) no harvest for two years
1850	Severe summer drought
1851	Drought
1862	Severe and widespread drought
1863	Severe drought
1877	Severe midsummer drought
1878	Severe drought
1883	Widespread severe drought
1884	Severe drought
1885	Severe drought
1897	Drought, locusts, failure crops, failure wheat (shortage of draught animals, rinderpest)
1898	Drought
1900	Drought at planting, low summer yield, low wheat yield, pasture limited, weak cattle died
1901	Drought
1902	Summer drought, early frost, failure summer crops, begin four years drought Mafeteng
1904	Drought at planting, summer drought, pasture limited, weak cattle died, failure winter wheat
1912	Drought (failure summer crop, pasture limited, cattle weak, large stock losses due to drought)
1915	Drought, early frost, low wheat yield
1919	Drought conditions
1920	Drought conditions continued, low to failure summer crops
1921	Extremely dry conditions, low to failure all crops
1922	Most severe drought year on record (1922)
1928	Drought, limited pasture, cattle weak, worst drought on record for sheep
1932	"The year of the dust", total crop failure, livestock deaths
1949	Crop failure, pasture limited, cattle weak, drought can be compared with famine year of 1933
1968	Drought
1979	Drought, severe food shortages
1980	Drought

1982	Drought
1983	Drought
1984	Drought
1985	Drought
1986	Drought
1991	Prolonged drought, killed livestock because of poor of grazing lands
1992	Drought
1993	Drought
1994	Drought
1995	Drought
2002	Severe drought (the Prime Minister declared state of emergency in relation to food crisis)
2003	Severe drought
2004	Severe drought
2005	Drought
2006	Worst drought in over 30 years
2008	Drought

Sources: Showers, 2005; Nash and Grab 2010; Grab and Nash, 2010; Disaster Management Authority, 2011.

5.3.2 Drought monitoring using Standardised Precipitation Index (SPI)

This section focuses on extremely dry periods (drought) occurring in the study region between 1898 and 2012. There are only two climate stations in the study, one in Mohale's Hoek and the other in Moyeni, both of which recorded similar rainfall quantities during the study period. The main objective of this section is to apply the SPI as a drought risk indicator. The monthly mean rainfall data for the study region from 1898 to 2012 was acquired from the Lesotho Meteorological Services. This study therefore tests for trends in annual rainfall for the period 1898 to 2012 in the study region and the mean for each year is plotted (Figure 5.21). Mean annual rainfall in the study area ranges from 460mm to 1292mm, and a slight increase of a linear trend in mean annual rainfall in the study region is evident from 1955. However, the mean annual precipitation varies significantly between years, the lowest being 115mm in 1992 and the highest 1097mm in 1898. While the overall mean annual precipitation over the past 114 years is 693mm. Figure 5.21 demonstrates rainfall variability and highlights the years which experienced low rainfall (i.e., 1940, 1943/44, 1949, 1965, 1971, 1980, 1992 and 1995/96). The three major drought

episodes associated with ENSO are evident during the 1991/92 and 1994/95 seasons. The 1997/98 season also had a strong ENSO event linked to it (Clay *et al*., 2003).

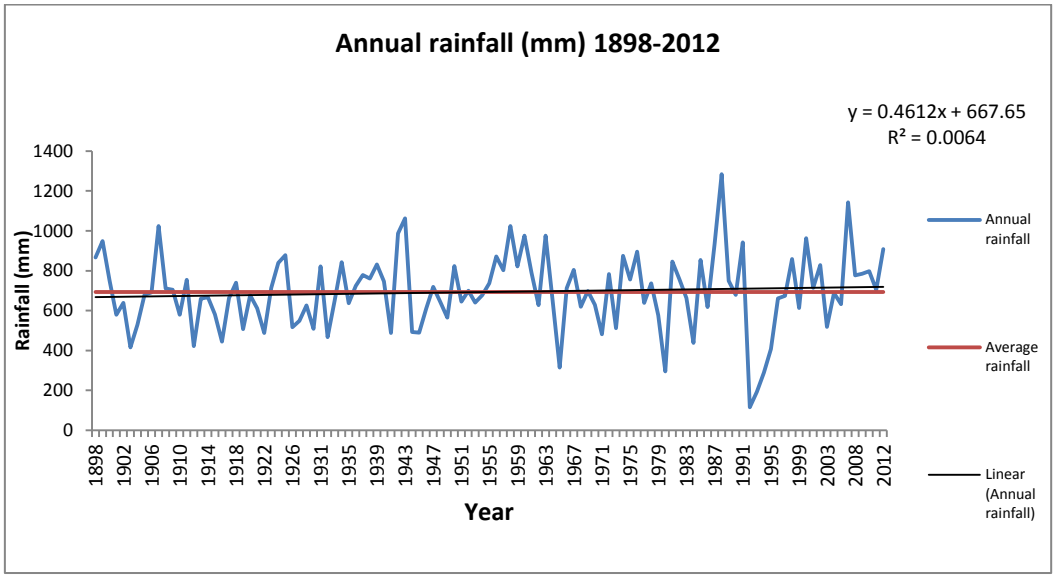

Figure 5.21: Annual mean rainfall (mm) for the study area from 1898 to 2012.
Source: Data from Lesotho Meteorological Services

The occurrence of dry spells is not easy to monitor or detect, however, there are some indices that allow for monitoring climatological conditions. The SPI is one of those indices (McKee *et al*., 1993), measuring the difference in precipitation from the mean for a specified time period divided by the standard deviation (McKee *et al*., 1993). The SPI is the number of standard deviations that a monthly rainfall would deviate from the long term mean. Negative SPI value indicates dryness (droughts) and positive value indicates wetness (floods), as categorised in Table 5.3.

The SPI is computed using the following formula:

$$SPI = \underline{(Xi - Xmean) \div \sigma}$$

Where:

- X_i is the accumulated (monthly) precipitation observation, X*mean* is the mean monthly precipitation, and σ is the standard deviation.

McKee *et al*. (1993) developed the SPI to quantify precipitation deficits on time scales, and is the transformation of the precipitation time series into standardised normal

distribution (z-distribution) (Lloyd and Saunders, 2002; Hayes *et al*, 2007; Hayes *et al*., 2011). After standardisation, the strength of the anomaly is categorized (Table 5.3). Extreme values in the SPI will, by definition, occur with the same frequency at all locations (Hayes *et al*., 2011).

Table 5.3: Drought classification and SPI categories (after McKee *et al*., 1993).

Moisture conditions	**SPI Value**
Exceptional drought	≤ -2.326
Extreme drought	-2.326 to ≤ -1.645
Severe drought	-1.645 to ≤ -1.282
Moderate drought	-1.282 to ≤ -0.935
Minor drought	-0.935 to ≤ -0.524
Near normal	-0.524 to 0.524
Slightly increased moisture	0.524 ≤ to 0.935
Moderately increased moisture	0.935 ≤ to 1.282
Considerably increased moisture	1.282 ≤ to 1.645
Extremely wet	1.645 ≤ to 2.326
Exceptionally wet	≥ 2.326

Understanding historical droughts in a given area is of paramount importance for drought assessment (Mishra *et al*., 2010; Gebrehiwot *et al*., 2011). This section evaluates the temporal occurrences of meteorological and hydrological droughts, where rainfall is the main parameter of interest. To define dry years, monthly and annual rainfall data were used to compute SPI for incidences of drought between 1898 and 2012 in the study region. This provides, for a time series of drought strength, the number and the duration of droughts and the trends. Conversely, there is a limitation to applying the SPI in this study. Because of a limited number of weather stations in the study region, the SPI is not capable of identifying areas that are more prone to drought than others at a local level, and therefore the results from this analysis assume drought to be widespread across the study region. The use of the SPI only makes it possible to make temporal comparisons, not spatial ones, thus allowing for historic construction of dry periods over time. The SPI has

been widely used to monitor drought in terms of their intensity, duration and spatial extent in the USA and Europe over several decades (Heim 2002, Lloyd and Saunders, 2002; Chen *et al*., 2013a), and China. In southern Africa, the SPI has been used in Lesotho, Botswana, South Africa and Zimbabwe to determine drought events (Moeletsi, 2004; Matarira, 2008; Fobo, 2012; Ambrosino *et al*., 2011; Batisani and Yarnal, 2010; Batisani, 2011; Gwimbi *et al*., 2012; Manatsa and Mukwanda, 2012; Moeletsi and Walker, 2013). According to Manatsa and Mukwanda (2012), the SPI is therefore capable of maintaining elementary parameters in the analysis of the occurrence of different drought events of varying time scales in terms of severity, magnitude, and frequency, regardless of topographical differences.

The annual series for the study period shows the worst single drought to be in 1965 (SPI=-0.98), with other major droughts in 1980, 1983, 1993, 1987, 1956, and 1901 with SPI values of -0.65, -0.62, -0.61, -0.6 and -0.5 respectively. It also indicates that 1973 (SPI=-0.23) and 1974 (SPI=-0.21) were less severe droughts, but when combined, they had a cumulative effect more serious than other droughts. For drought, one can conclude that the study area experienced extreme drought episodes in the early 1990s and moderate drought conditions between 1940 and 1953. The results, however, do not show any particular trend over time and drought frequency and magnitude have not changed significantly over the past 114 years. Figure 5.22 illustrates decadal trends in drought incidences during the 1980s, early 1970s and 2000s, and lesser drought incidences during the 1960s and 1990s.

Extreme droughts are less common and their duration tends to be shorter than less severe droughts. These results agree with the interviews with elderly people in the study area, who reported precipitation decrease in the study region from the 1970s to 1980s and the early 1990s. It can also be noted that there is a period extending 15 years from 1957 to 1972 which does not indicate any type of drought, but generally there seems to be a trend for severe and extreme droughts taking place near the end of the time series. The focus group discussions with the elderly and interviews with government officials indicated 1992, 1993 and 2005 as severely dry years during the recent past. However, the SPI results do not show 2005 to be a drought year. Trends in SPI values indicate that the probability of the study area experiencing extreme and/or moderate drought conditions has not changed significantly over the past 114 years. This analysis can provide a useful resource for assessing vulnerability to drought and the seasonal predictability of the phenomenon.

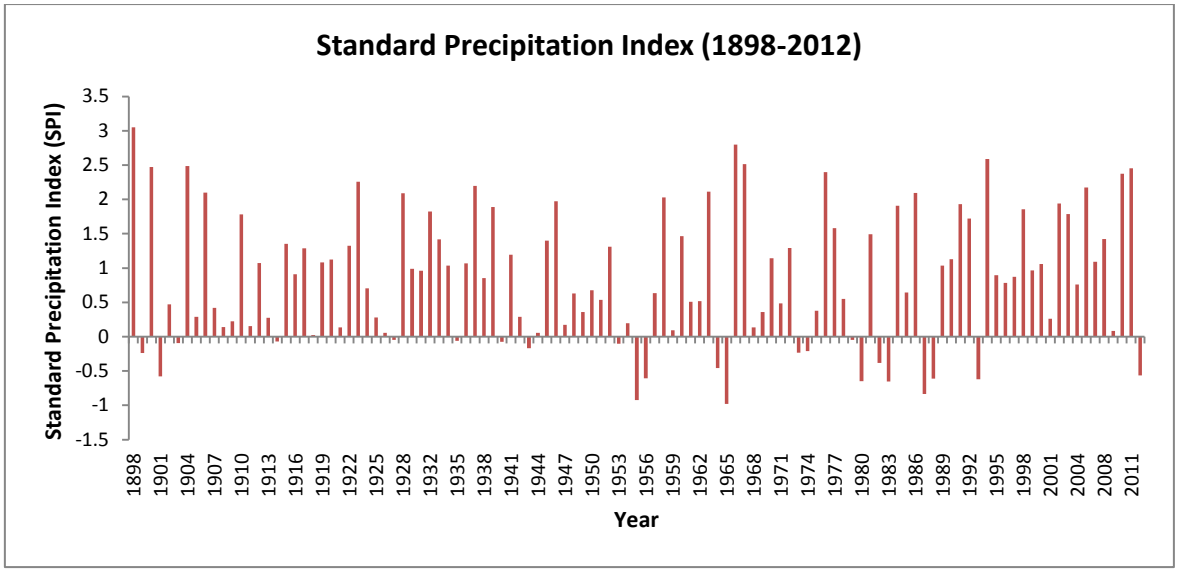

Figure 5.22: Drought monitoring using SPI
Source: Data from Lesotho Meteorological Services

5.3.3 Societal Impacts of Drought

Floods are one of the most common hazards which cause death, injuries, property damage, and contamination of drinking water and disruption to infrastructure facilities. This section assesses the socioeconomic consequences of flooding events, using data mainly collected from household interviews, focus groups discussions and official reports. The respondents in Quthing reported that there had been rainfall variability (meteorological drought) in recent years and an increase in the frequency and intensity of droughts over the previous 15 years. At Mt Moorosi, Quthing, one farmer reported that rainfall patterns had changed significantly, stating that a drought year was often followed by normal rains during the following year and heavy rainfall two years after. The farmer reported that these varying rainfall patterns affected their livelihoods, as they often experienced reduced crop yields as a result of drought and excessive rainfall (agricultural and socioeconomic droughts). During focus group discussions in both districts it was reported that the impacts of the 2001/02 and 2006/07 droughts were more pronounced owing to the combination of other factor, namely high unemployment rates, retrenchment of mine workers from South Africa and the HIV/AIDS pandemic. The effects of these droughts were more severe along the Senqu River Valley in both Mohale's Hoek (Phamong, Qaqatu, Hloahloeng and Ketane) and Quthing (Mt Moorosi, Mphaki, Qhoali and Seforong), because of low agricultural productivity and reduced precipitation prevalent in this region. However, the losses on the

actual effects of drought in some years have not been recorded, either in total production numbers or monetary value.

Droughts associated with ENSO variability were reported in the country during the past two decades (LMS, 2007; Matarira, 2008; Batisani, 2011). The 1991/92 drought, which also affected other countries in the region, was generally regarded by the respondents as the worst during the recent past. The first six years of the 1990s were years of drought although with differing severity (D. Ambrose, pers. comm., 2011). The recurrent 2002-2005 drought spells came when households were at their most vulnerable, having exhausted their assets during the drought periods in the 1990s. According to residents, these episodes were followed by years of moderate rains, however, coping mechanisms were severely tested and the majority of households had not fully recovered when another period of drought struck during the first five years of the new millennium. In 2001/2002, there were no crops in the two districts due to drought, and households were dependent on food relief (T. Letsie, pers comm., 2010).

In 2004, Lesotho only produced approximately 20% of its cereal requirements, leaving thousands dependent on food assistance (UNICEF, 2004). According to the LVAC report of 2004, the Senqu River valley (64%) was the most affected region in Quthing district while in Mohale's Hoek district the lowlands (52%) were the most affected by drought. These districts were the hardest hit by the effects of droughts, because they received least rainfall, and consequently farmers planted late or did not plough at all. Owing to this drought, food aid was distributed to about 13,402 people in these districts, about 6,000 (44.8%) people received food aid in Mohale's Hoek and 7,402 (55.2%) in Quthing, making Quthing the most vulnerable of the two districts, as it had a higher proportion of households affected. The 2006/07 cropping season was recorded as the most severe drought in over 30 years in Lesotho (LVAC, 2008), leaving households with little or no food and making them dependent on food aid.

Drought experiences were discussed in both household interviews and focus group discussions, and in both districts communities had similar experiences (Figure 5.23, below). The discussions disclosed that many households were vulnerable to drought and did not have enough of an asset base to buffer against the impacts of drought. Respondents mentioned that drought left them more vulnerable to other shocks, as they did not produce any food from the fields (Mohale's Hoek 89%). The communities in both districts

(Quthing 90%; Mohale's Hoek 87%) highlighted that drought worsen their food insecurity situation and pushed them deeper into poverty as all money was spent on food (Quthing 80% and Mohale's Hoek 76%). Respondents further mentioned that recurrent droughts reduced crop production, which often results in increased food insecurity. In both districts focus group discussions revealed that the drought hazard was particularly serious for the poor and the very poor because it affected them in various ways, such as reduced crop production, reduced casual labour opportunities for both cash and in kind payment, and reduced gifts from economically advantaged households. Two of these groups were found in the Quthing district at Mt Moorosi and Qhoali, both of which are situated along the Senqu River valley. In Mohale's Hoek district, Qaqatu was the most affected, which is also located along the Senqu River valley.

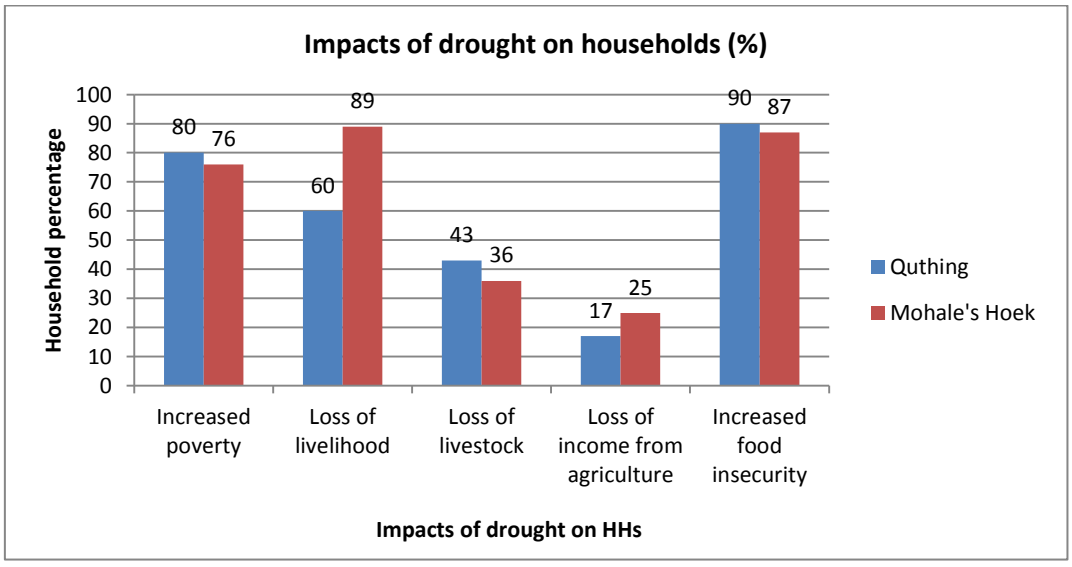

Figure 5.23: Responses relating to the impacts of drought on households.
Source: Own data

Elsewhere in the region, Zimbabwe's and Botswana's agricultural productivity has been declining as a result of drought, and the 1992 drought was recorded as the worst in recent decades (Maphosa, 1994; Reason *et al*., 2006; Batisani, 2011; Manatsa and Mukwada, 2012). Severe crop damage, decreased livestock numbers and widespread food shortages have often resulted from recurrent droughts in the region. Impacts of drought can be severe and are most significant in countries whose economies are dominated by agriculture. Apart from South Africa, most economies of southern Africa and rural livelihoods rely heavily on rain-fed agriculture, hence, drought events often turn into a natural disaster.

The prevalence of droughts has increased during the past two decades, mainly due to vulnerability of the whole southern African region to inter-annual climatic variability associated with changes in El Niño and the southern Oscillation (ENSO), leaving large populations heavily reliant on food relief (LMS, 2002; LVAC, 2009; Batisani, 2011). The loss of crops and livestock reduces household coping strategies and leaves them vulnerable to food insecurity. In southern Africa, food shortages are a continuing problem, and long-term projections suggest that regional food production per capita is likely to diminish further in future (Rogegrant *et al.,* 2001; Misselhorn, 2005; UNEP, 2006; Harrigan, 2008; Batisani, 2011; Manatsa and Mukwada, 2012; Ambrosino *et al*., 2013; Jury, 2013).

Since agriculture is mainly rain-fed in Lesotho, drought is believed to have a direct negative effect on crop production, a district agricultural officer explained in Mohale's Hoek:

> *In mid-1970s there were droughts, but not as recurrent and severe. They did not result in as much damage because soils were fertile and there was more land cover and good crops. Now, over the past thirty years, we see astonishing changes on the impacts of climate, as more recurrent droughts are experienced, coupled with a shift in planting season. Traditional Basotho planting season is August/September, but now people start planting in November as a direct response to rainfall shifts. This has shortened planting season and winter finds crops at their vulnerable stages.*

These results mirror official reports which have identified some of the effects of the 2002/03 and 2005/06 food crisis in Lesotho, being a result of drought induced weather conditions resulting in very poor livestock, low food production, a steep increase in staple food prices, loss of income, loss of livestock and widespread poverty, economic weakness and overall vulnerability of households and communities (LVAC, 2003).

It is clear that drought affects households both directly and indirectly. From a socioeconomic perspective, reliance on agriculture makes the two districts highly vulnerable to drought. Widespread drought has forced many people out of farming (45% in Quthing and 34% in Mohale's Hoek). In both districts, agriculture takes place mostly in the river valleys and elevation differences in both districts have permitted only rain-fed agriculture and livestock farming as the main rural livelihoods. The Senqu River valley

region is highly vulnerable to drought, primarily due to very low rainfall occurrence associated with rain-shadow effects, a lack of surface water storage, and poor soils with low water holding capacity, and high elevated topography. In the study area, very few farmers (two in Quthing and four in Mohale's Hoek) reported to be mitigating drought impacts through crop selection and tillage practice. To date, at the country level, the emphasis of disaster management has largely been the response and recovery from drought, with little or no attention to mitigation, for example, irrigation, preparedness, prediction and monitoring.

A number of studies (Moeti, 1996; Wilhelm and Wilhite, 2002) have indicated no consensus on whether irrigation reduces vulnerability to drought in Lesotho. Efforts to establish and improve agricultural productivity through irrigation date back to the early 1960's in Lesotho. Despite much surface runoff in Lesotho, the country lacks the resources and expertise to utilise it for irrigation purposes (Borris and Holland, 1986; Moeti, 1996). According to Moeti (2003), Lesotho's irrigation schemes have been characterised by a poor labour force, mostly consisting of old men and females. Furthermore, Tsikoane (pers. comm., 2010) who managed the Seaka irrigation project in the study region in the early 1990s explained that many irrigation projects in Lesotho have been characterised by lack of innovative management and insufficient supervision by farmers. On the one hand, farmers stated that they were not allowed to fully participate in the decision making processes and this had led to their views being neglected in the day-to-day running of the irrigation projects. Other technical problems highlighted as limiting factors for irrigation programmes in the country were poor irrigation designs, siltation of the river bed which caused damage to the pumps, and regular destruction and washing away of the pumps during floods (Moeti, 1996). In a number of the areas which were identified as potentially appropriate for irrigation, pilot projects were operated to determine the economic feasibility, with results being mostly negative.

The current study found that irrigation was not affordable to most subsistence farmers in the study area, given inadequate financial resources and a complex terrain. Even though both districts are situated along the Senqu and Makhaleng Rivers, with fields along the banks, irrigation potential is expensive, as reported by respondents from a focus group discussion at Phamong in Mohale's Hoek. In a focus group discussion at Seaka in Quthing, farmers reported that irrigation systems (mainly large sprinkler systems) had mostly been

inappropriate for operation by smallholders and were expensive to install and maintain. Consequently, farmer commitment and the overall sustainability of the irrigation works have been poor in both districts.

Figure 5.24 depicts a drought vulnerability map of the study area. Although drought vulnerability is prevalent across the study area there are some communities that are more vulnerable than others, based on topography, solar insolation, exposure to dry winds and distance from rivers and streams. Drought is a widespread phenomenon which affects all communities and sectors of the society, especially in a rain-fed agrarian society such as Lesotho. When droughts occur in Lesotho all residents are affected in one way or another. Food prices increase, agricultural production decreases and livestock is lost and stress is placed on the resident population, physically, financially and emotionally. Every community in both Mohale's Hoek and Quthing, without exception, has been exposed to droughts and their impacts. Drought vulnerability was determined by considering the natural geophysical factors such as soil type, distance from water sources, slope, and exposure to high evapotranspiration due to high solar insolation and exposure to dry winds. All these factors were grouped, weighted (multi criteria evaluation) according to a subjective judgement and combined to produce different vulnerability classes. A combination of unfavourable shallow soils with weak water holding capacity, complex topography, exposure to high evapotranspiration and high cost of irrigation due to vast distances from water sources resulted in high risk and vulnerability to droughts in the highland areas such as Qabane, Mphaki, Tsatsane and Likhohlong. While the lowlands and river valley areas (e.g., Siloe, Mashaleng, Khoelenya, Phamong, Liphakoe, Matsatseng and Ha Nkoebe) have lower risks and vulnerability levels to drought.

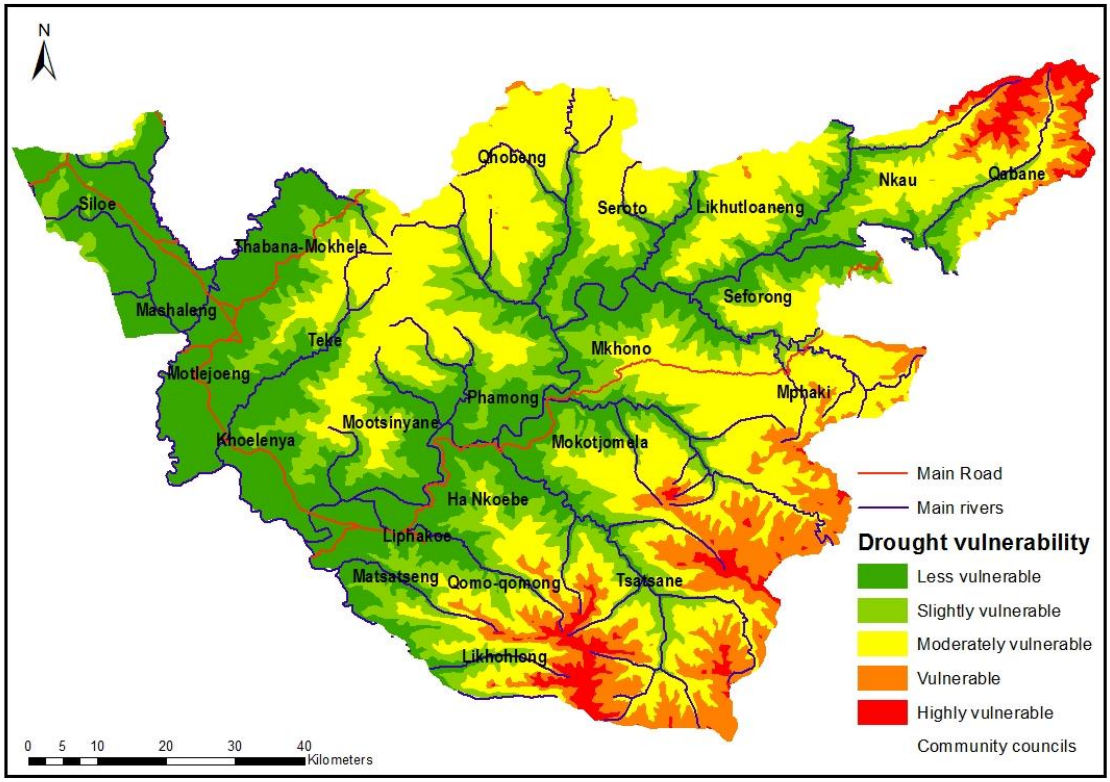

Figure 5.24: Drought vulnerability map
Source: Own data

Generally, the highlands and the foothills are the most vulnerable to drought because of their topography and distance from rivers, which makes irrigation efforts expensive or challenging to implement (Figure 5.24). Even though the majority of Basotho depend on rain-fed agriculture, have high levels of poverty, low levels of physical capital and poor infrastructure, some communities have a range of coping strategies. For instance, urban lowlands have more diverse livelihood strategies than rural highlands, yet the survey results demonstrate that the impacts of drought have been felt in all communities regardless of their location. Recent drought events in Lesotho and the magnitude of drought losses indicate the continuing vulnerability of the country to drought.

5.4 SEVERE FROST HAZARD

Varazanashvili *et al*. (2012) define frost as low minimum air or surface temperature below 0°C on the background of positive daily mean temperatures. Frost is a hazardous phenomenon for agriculture, and in some areas it affects infrastructure facilities.

Climatologically, it is defined as the occurrence of an air temperature of less than 2.2°C, and severe frost occurs when air temperature decreases below 0°C (Junhu *et al*., 2013). Severe frost encompasses socioeconomic and ecological effects of frost on communities and can cause injuries to sensitive crops (Moeletsi, 2012). The extent of damage depends on frequency and duration of the phenomenon. There is evidence that in Lesotho, altitudes above 3000m a.s.l experience seasonal frost and soil freezing (Grab, 2002; Sumner, 2004; Grab *et al.,* 2009; Moeletsi and Walker, 2013). These factors, coupled with shallow soils, lead to low agricultural productivity and associated increased food insecurity in the study area, particularly the highlands.

The occurrence of low temperature before a plant has started its growth does not necessarily present a problem, but damage to plants or even complete destruction could take place when temperatures decrease considerably after growth processes have commenced (Junhu *et al*., 2013). Thus, low temperatures occurring in spring could be hazardous to plants. Spatial patterns of frost are closely related to general weather conditions and regional/local topography. The two most common types of frosts are advective and radiation. Advective frosts occur as a result of a large scale influx of cold air during the day or night and are characterised by moderate-to-strong winds and a well-mixed atmosphere (Varazanashvili *et al*., 2012). Under such conditions, spatial differences in (minimum) air temperature at the local scale are usually small and are related to elevation, thus valleys and depressions are usually colder than hilltop sites (Laughlin and Kalma, 1990; Varazanashvili *et al*., 2012). In contrast, radiation frosts occur at night and results from strong, long-wave radiative cooling in calm clear and dry atmospheric conditions. Night time cooling of near-surface air during radiation frost is generally well understood and predictable for flat terrain (Junhu *et al*., 2013).

Of these two types, the most common in Lesotho is one caused by radiation heat losses. Such frosts could occur mainly between late autumn and early spring in the lowlands. Frost occurrence in the country can be related to a higher frequency of clear sky conditions. Generally, the lowlands experience frost on up to 80 days per annum but in the highlands it can be expected during most of the year. In most cases frost is most severe in the river valleys. Table 5.4 shows frost occurrences at two stations in the study region, these being the only two climate stations available to the entire study area.

Table 5.4: The average and extreme first and last dates of frost occurrences in the study region for the years 1970-2012.

Station	**Elevation**	**Avg. first day**	**Avg. last day**	**Extreme first day**	**Extreme last day**
Quthing	1740	09 May	30 Sept	02 Apr	05 Dec
Mohale's Hoek	1620	11 May	26 Sept	06 Apr	01 Dec

Source: Wilken, 1982, Moeletsi, 2012; Moeletsi and Walker, 2013

According to the table, Quthing has a slightly longer (by 6 days) frost season than Mohale's Hoek, demonstrating the sensitivity of spatial differences (altitude, proximity to rivers and slope curvature) to frost. In the study region, frost is predominantly problematic during the frost-free seasons, which may occur in late spring or early autumn in the highlands (Jayamaha, 1979; Moeletsi, 2004; Moeletsi and Walker, 2013). Such 'unseasonal' frost may have significant implications for agriculture.

Severe frosts occur between the months of May and September in Lesotho (Mulder, 2007; Grab and Nash, 2010; Linde, 2011), however, the research results suggest that extremely cold temperatures are prevalent in the study region from as early as April. At altitudes above 3000m, the first seasonal frosts can occur as early as March, but the Lesotho lowlands (such as Mohale's Hoek and some parts of Quthing) generally experience the first frost in April. In both Mohale's Hoek and Quthing, frost occurrence has even been reported by the respondents to have occurred in December (mid-summer). Many areas in the highlands experience ground frost on approximately 200 days per year, and significant diurnal changes in temperature result in the formation of frost related phenomena, including needle ice, patterned ground, and earth hummocks in the highlands (Grab, 1998, 2000, 2002, 2005). According to Moeletsi (2012), the cessation of frost in southern Africa marks the beginning of the growing season which often takes place during the months of September and October, while the onset of frost indicates that the growing season of most summer crops is coming to an end, usually in April, May and June.

The historical records for Lesotho report occurrences of severe frost which have destroyed crops. Table 5.5 presents severe frost incidences in Lesotho, including the study region, between 1842 and 2012. During this period, 51 cases of severe early and late frost were

recorded. Severe early frost and extreme cold are a common phenomenon in Lesotho and were historically reported in 1849, 1850, 1951, 1852, 1883, 1902 and 1903 (Table 5.5, below). During these incidences, total crop failure and loss of livestock were reported. Recently, in April 2004, below-normal temperatures were reported in Quthing and other highland districts and crops were reported to have been affected by frost. In the same year, gradual deterioration of maize crops resulting from low temperatures was reported (LMS, 2005). In 2007, very cold weather conditions occurred during the months of April and May, as successive cold fronts traversed the southern African region and minimum temperatures were below freezing, reaching values of -15.6°C in the highlands and -8 °C in the lowlands (www.wamis.org).

Table 5.5: Frost incidences between 1842 and 2012.

Year	**Comments**
1842	Severe frost
1849	Extreme intense cold and frost (people and livestock killed)
1850	Severe frost (cold lasted for two months, frost destroyed corn)
1851	Extreme cold and frost
1852	Extreme cold and ice and frost (destroyed corn and extreme cold killed livestock)
1861	Frost came on several occasions (very poor harvest) severe frost in October
1863	Severe early frost in the entire country (crops perished) (vegetables frost bitten in November)
1874	Severe cold and frost (crops destroyed by frost)
1875	Severe cold and frost (crops destroyed by frost)
1879	Early frost (blighted grain before it was ripe)
1883	Extremely cold winter (damaged crops and killed animals), heavy early frost
1884	Extremely cold winter (damaged crops)
1885	Early frost (crops frozen)
1886	Early frost, (so cold that all the fields froze) low summer yield
1888	Early frost, low summer yield
1889	Early frost, locust damage, low to failure summer crops
1890	Early frost, low summer yield
1891	Late frost, low yield
1900	Early frost, low summer yield
1904	Early frost, average wheat yield, failure summer crops
1906	Early frost, failure winter wheat

1907	Early frost, low summer yield, failure wheat
1914	Early frost, low summer crops yield, average wheat yield
1915	Late summer, early frost, low wheat yield
1939	Early frost, low wheat yield
1947	Early frost, poor summer crops (southern districts)
1948	Summer frost (low yields)
1951	Early frost lowlands, failure summer crops
1955	Early frost, cool summer temperatures
1956	Early frost, low crop yield
1971	Severe frost
1973	Early frost
1981	Very cold
1982	Extreme cold
1985	Early frost
1986	Severe frost
1990	Extreme cold
1991	Extreme cold (early frost)
1992	Early frost
1993	Extreme cold (crops damaged)
1994	Severe frost
1996	Severe frost (destroyed crops)
1997	Extreme cold and severe frost
1998	Severe frost
2002	Extreme cold
2004	Severe frost (damaged crops)
2006	Early frost (destroyed vegetables)
2007	Extreme cold resulted in early frost (low crop yield)
2009	Early frost
2010	Extreme cold in November (damaged crops)
2011	Early frost

Sources: Showers, 2005; Mulder, 2007; Nash and Grab, 2011; Grab and Nash, 2010; Linde, 2011.

5.4.1 Frost occurrences

This assessment uses extreme low temperatures (in °C) during the warm period to assess frost occurrence and magnitude. Figures 5.25 and 5.26 show the extreme daily minimum temperatures for April and December (extreme first and last frost occurrence months) from

1971-2012 for Mohale's Hoek district (which is a representative of the entire study region). The results also demonstrate a general increase in minimum temperature in the study region, an increasing trend evident from 1988. The late 1960s until the mid-1980s recorded the lowest minimum temperature for April (below the average of 8.7°C), indicating a general decrease in severe frost occurrences and severity in the region. Statistical results show that there is a significant positive linear correlation of minimum temperature over time. Several studies also reported positive temperature trends in the African region and the SADC region in particular (Hulme, 1996, 2001; Collins, 2011). Grab and Nash (2010) also identified a reduction in the duration of the frost season by about 20 days during the 19th century in Lesotho. These results are confirmed by the IPCC (2007), which observed decadal warming rates of 0.1 to 0.3°C in southern Africa (Kruger and Shongwe, 2004). In addition, in southern Africa and Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures (IPCC, 2012).

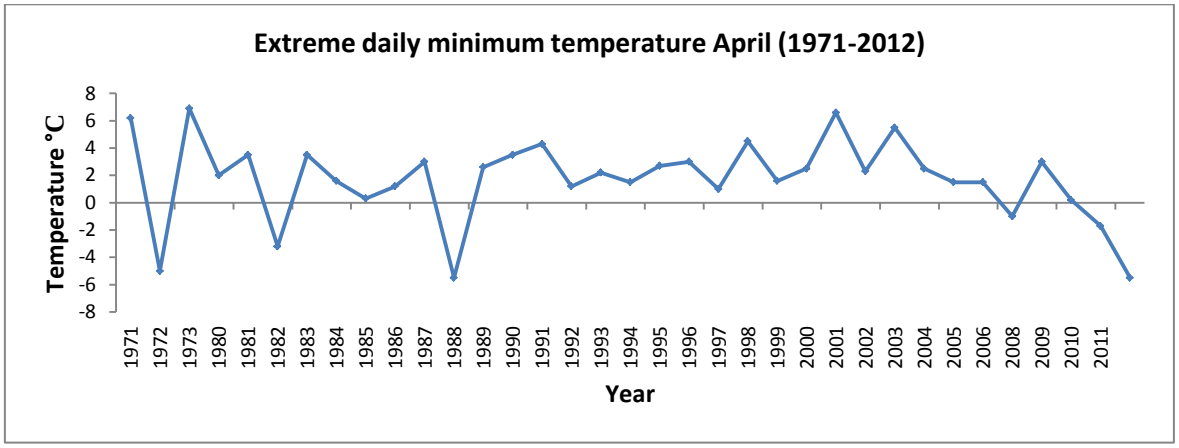

Figure 5.25: Minimum temperatures for April (1971-2012).
Source: Data from Lesotho Meteorological Services

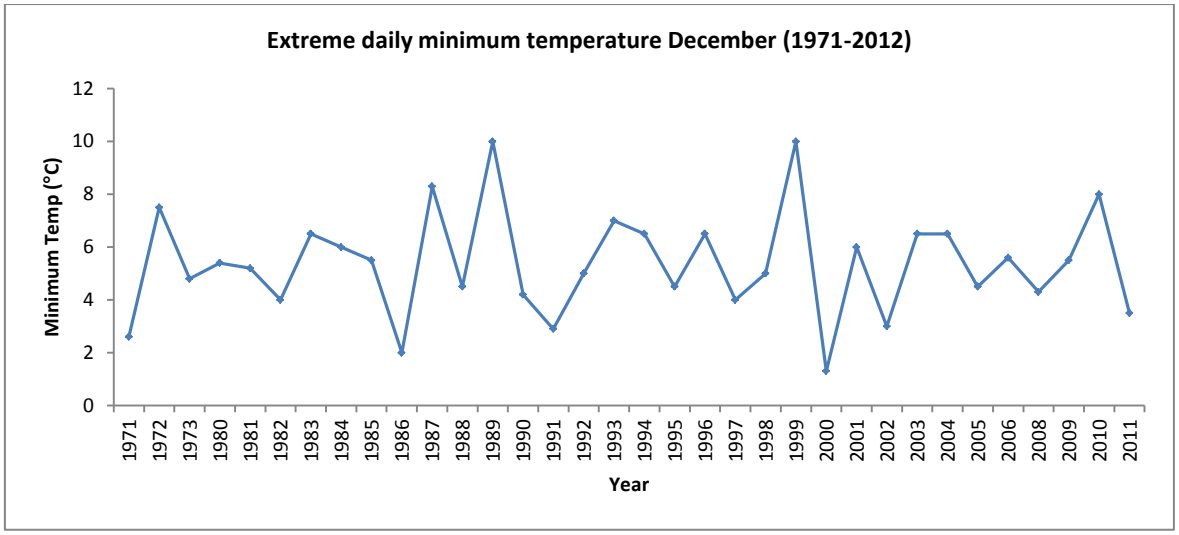

Figure 5.26: Minimum temperatures for December (1971-2012).
Source: Data from Lesotho Meteorological Services

5.4.2 Topographic influence on severe frost occurrence

In areas of complex topography, the majority of climate elements are influenced by topography (Wahl *et al*., 1987; Lindsay, 2004). Patterns of solar radiation received on the land surface and air temperature can influence frost occurrence in mountainous terrain (Cuxarta and Guijarrob, 2010). These variables are all interlinked through variations in slope angle, aspect and elevation. Slope aspect and angle create local variations in the amount of solar radiation received in areas with varying relief (Daly *et al*. 2003; Daly *et al*., 2007; Daly *et al*., 2009). According to Cuxarta and Guijarrob (2010), spatio-temporal variations in temperature are mainly dependent on topography (both elevation and relief), therefore, in high latitude and altitude areas temperature can be a restrictive factor for plant growth and development. These areas normally experience extremely low temperatures and severe frost occurrences. Wilken (1978) stated that although a number of lowland areas in Lesotho may have between seven and eight frost free months, the occasional occurrence of early or late frost reduces the growing season by more than a month. Furthermore, Moeti (1996) observed that temperatures that are considered as agricultural risk are not limited to cold temperatures because crops may die or stop growing when temperatures drop below minimum thresholds for individual crops.

This section examines and maps likely and reported occurrence of severe frost in the study region. Elevation, slope aspect, potential solar radiation and slope angle are used to determine susceptibility to severe frost occurrence in a GIS environment. Solar radiation

and aspect are the main factors controlling permafrost and frost formation in mountainous environments (Gruber, 2007). Similarly, the role of aspect on permafrost occurrence is well recognized (Rahimi *et al*., 2007; Dixit *et al*., 2011; Bonnefoy, 2013). Aspect and solar radiation are similar indicators because the amount of solar radiation depends on the direction a slope is facing. Topography is thus a factor which determines the exposure of a ground surface to incoming solar radiation during the day. For a large part of southern Africa, temperature variations in time and space are mainly dependent on topography, both the altitude and surface land formations (Hobbs *et al*., 1998). Topography has the effect of causing the southern slopes, in the Southern Hemisphere, to receive less radiation than the northern slopes and thereby permit them to become more prone to low temperatures and frost.

Slope aspect is associated with the amount of solar energy an area receives. Therefore, temperatures are typically warmer on north-facing slopes than on south-facing slopes in the Southern Hemisphere. In the study region, steep south-facing slopes receive the least amount of direct solar radiation throughout the year (field observation). Therefore, in most areas of Lesotho, severe frost can occur on south-facing slopes but less severe frost may occur on adjacent north-facing slopes. According to Cuxarta and Guijarrob (2010), adjacent topography also creates shading effects in dissected mountainous terrain, such as in the study region (Qhoali, Tsatsane, Likhohlong, Qobong, Qhobeng, Nkau and Hloahloeng). These shadow effects are most evident in the valley bottoms throughout the country and are likely to result in lower than expected amounts of solar radiation in these areas. The highland areas are characterised by cold air drainage, when a thin mass of cold dense air moves downhill under the influence of gravity. If the cold air remains in the valley bottoms for some time, or if these cold air drainage events occur frequently enough, it may result in frost. Differences in the thermal properties and soil moisture content can influence variations in frost occurrence in these areas. This study is motivated by the importance of the river valleys found in the study region being used mainly for agricultural purposes. The region is characterised by a complex topography constituting mountains and valleys. Agriculture is often carried out at the bottom of the valleys and on mountain sides, which are most frost prone (Figure 5.27).

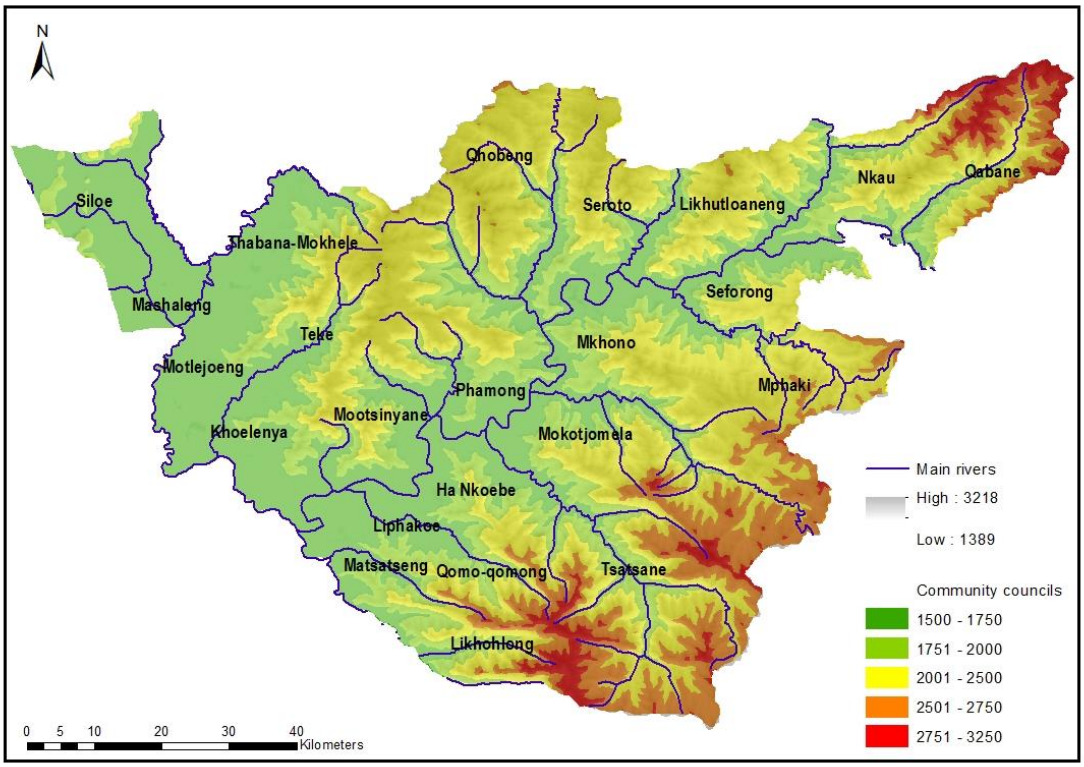

Figure 5.27: Elevation and relief map
Source: Own data

The main distinction in the climate of low and high latitude alpine environments is seasonal variations of received solar radiation. In the Lesotho highlands, differences in topographic shading are most apparent in winter when incoming solar radiation is low (Figure 5.28). Patterns of radiation frost, which is the most common type of frost in Lesotho, is known to be closely associated with topography. According to field observations in the study area, radiation frost tends to form earlier at night, is more frequent and more severe at sites located along valley floors, and was spread over a wide area in three consecutive days (Phamong, Siloe, Tele, Liphakoe, Qomoqomong and Ha Mopeli). In contrast, less frost was observed, once in over a period of four days, at Seroto, Nkau and Mokotjomela and Mkhono, which are areas located on open hill slopes or hill tops, over a period of a week in April/May 2010. It is thus evident that there is a link between frost severity and topography in the study area.

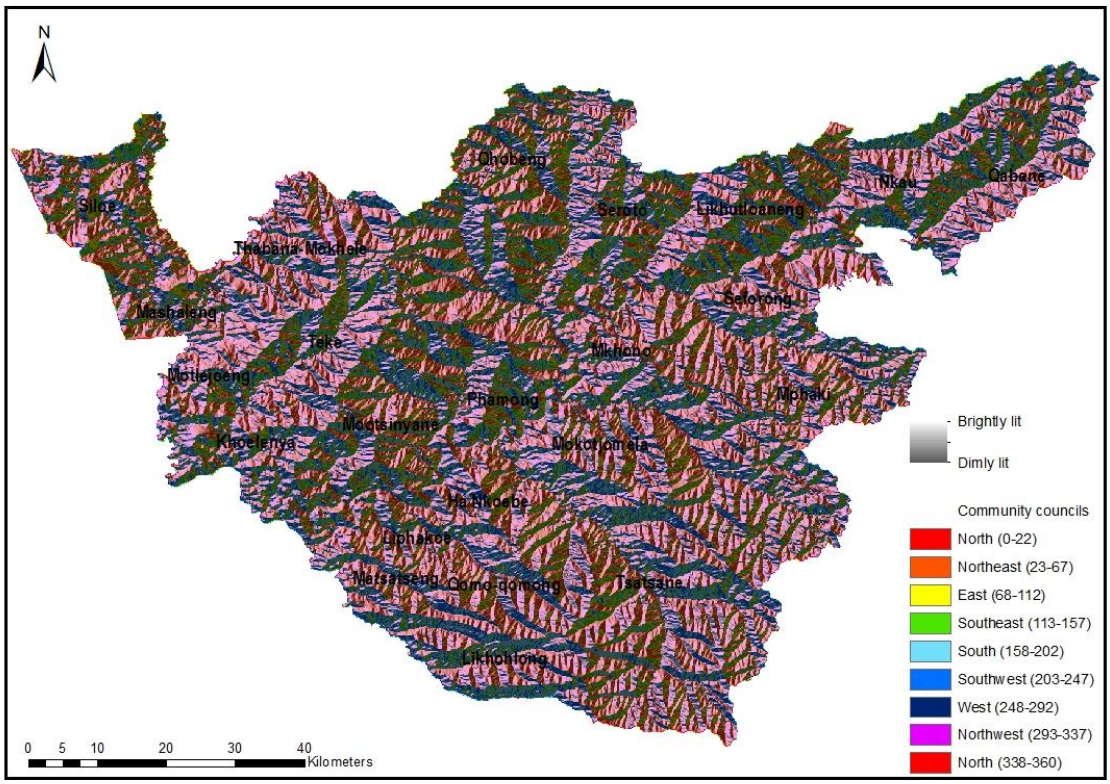

Figure 5.28: Incoming solar radiation map
Source: Own data

The aspect map was overlaid over the hill-shade map to show the intensity of lighting and solar radiation on a surface given a light source at a particular location. It illustrates the parts of a surface that would be shadowed by other parts, indicating the likelihood of frost occurrence. According to this map, places such as Phamong, Likhutloaneng, Qabane, Nkau, Seroto and Mootsinyane (in Mohale's Hoek), and Likhohlong and Tsatsane (in Quthing), are likely to receive less lighting and radiation, and hence are more susceptible to frost occurrences. In terms of solar radiation, the Mohale's Hoek district is more prone to severe frost than Quthing. The slope assessment suggests that a steeper slope causes a lower minimum temperature due to rapidly draining cold-air down-slope, whereas a flatter slope causes the opposite. This substantiates the findings from interviews which reported severe frost occurrences in low-lying river valleys and lesser occurrences on flat hilltops. Local and regional processes at different spatial scales determine minimum temperature variability (Rossi *et al*., 2002; Kruger, and Shongwe, 2004; Vosper and Brown, 2008; Mills *et al*., 2009; Fischer *et al*., 2011).

5.4.3 Frost impact on agriculture

Severe frost and frozen soil have been cited as major problems in Lesotho, as they can deter agricultural activities. Although respondents were not specifically asked about the prevalence of frozen soils/ground, but rather about severe frost occurrences, observations of frozen ground have been reported in several studies in the Lesotho highlands, though not particularly in the study region (Grab, 1997, 2002; Linde, 2011, Linde and Grab, 2013). Frost is thus considered as a major climatic hazard to agriculture, being responsible for reduced yields and damage to fruit trees, vineyards and crops (Moeletsi, 2004; Fischer *et al*., 2011; Moeletsi and Walker, 2013). The physical controls that govern frost variability and the spatial patterns in frost vulnerability are identified throughout the study area based on agricultural damage cited from interviews and in official reports. The length of the growing season in an agricultural area is important in determining the spatial patterns of different agricultural crops (Parnell, 2005). The spatial patterns of frost damage associated with the extreme frost events provide an understanding of the conditions that are necessary to produce agriculturally destructive frost events. The process of soil freezing and thawing also weakens soil bonds, increasing the risk of soil erosion.

Although frost is a common phenomenon during certain times of the winter season in Lesotho, severe frost destroys agricultural products, leaving households vulnerable to food insecurity. Other studies also highlighted the negative effects of severe frost on agriculture in Lesotho (Wilken, 1978; Moeti, 1996; Moeletsi, 2004; Moeletsi and Walker, 2013) and assert that there is great agricultural risk in relation to severe frost, which often cause severe destruction of fruits, vegetables and crops. The occurrence of low temperatures (early frost) after germination of plants can destroy them, particularly maize and vegetable crop. The sensitivity of a crop to low temperatures depends on many factors, including the severity of the temperature drop and length of time the cold persists, as plant species differ greatly in their susceptibility to chilling injury (Transmonte *et al.*, 2008).

Respondents in the highland areas in the Quthing district cited Qhoali (87.2%), Sebapala (61.3%), Hloahloeng (93.3%) and Ketane (89%) in Mohale's Hoek as the most frost prone areas (Figure 5.29, below). They also mentioned that early frost, in March and April, is a major concern in the highland regions (Seforong, Tsatsane, in Quthing and Ketane, Qobong, Hloahloeng in Mohale's Hoek), particularly for maize. This means that it may

have a direct impact on food availability and security, which varies spatially according to topography and locality.

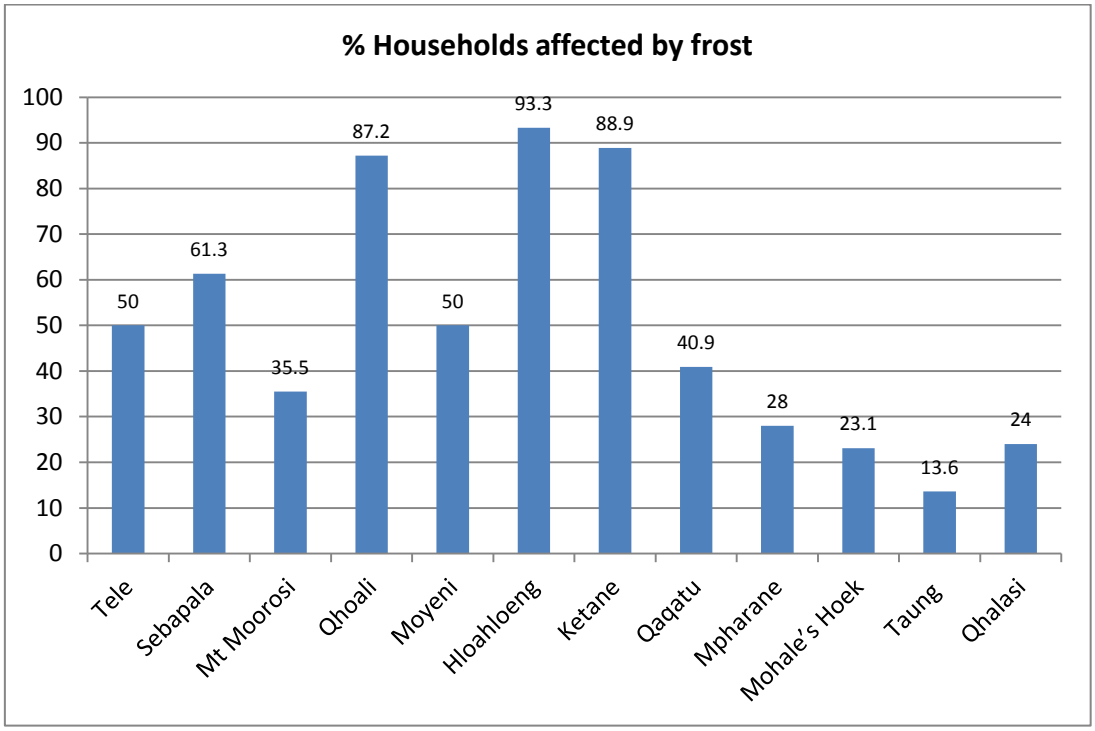

Figure 5.29: Households which reported to have experienced frost during the past two years.
Source: Own data

In the study area, frost is severe in the Senqu, Makhaleng (Mohale's Hoek), as well as Tele and Sebapala River valleys (Quthing), as presented in Figure 5.30 Frost occurrences in these areas impact negatively on crop yields, particularly in the highlands and river valleys (Makhaleng, Qhoali, Qomoqomong, Nkau, Qobong and Qhobeng). Susceptibility to frost hazards was determined based upon slope gradient, slope position, generalised frost basins and proximity to rivers. Based upon the combination of these attributes, frost hazard was classified from less susceptible to highly susceptible, as illustrated in Figure 5.30, which demonstrates frost susceptibility index in the study region. The red shaded areas denote areas with highest frost susceptibility index scores, these being the river valleys and some lowlands and they have a susceptibility index score of 0.9-1. The low-lying areas in which cold air is known to *pond*, based on field evidence and as reported by the respondents and agricultural extension officers, were: Mkhono, Mokotjomela, Ha Nkoebe, Matsatseng and Liphakoe (along Senqu and Quthing Rivers in Quthing), Phamong, Mootsinyane, Khoelenya and Mashaleng (Senqu and Makhaleng Rivers in Mohale's Hoek) and

Thabana-Mokhele (along Makhaleng River in Mohale's Hoek) all have index scores of 0.9-1. In contrast, the light shaded areas represent areas less susceptible to frost hazard, these being the foothills and some highlands (Mphaki and Tsatsane in Quthing, and Qhobeng and Qabane, in Mohale's Hoek), as well as the cattle posts (because of the absence of crop farming at the cattle posts) with a score of 0-0.3. The remaining areas have a medium susceptibility index score, these being mostly lowlands and foothills, with a score of 0.3-0.6, and include Likhohlong, Qomoqomong and Seforong in Quthing, and Teke, Nkau, Seroto and Likhutloaneng in Mohale's Hoek. These results affirm the spatial variability in frost occurrence and severity reported by Moeletsi (2004), who stated that the length of the growing season varies from 187 days in the mountains to 254 days in the lowlands.

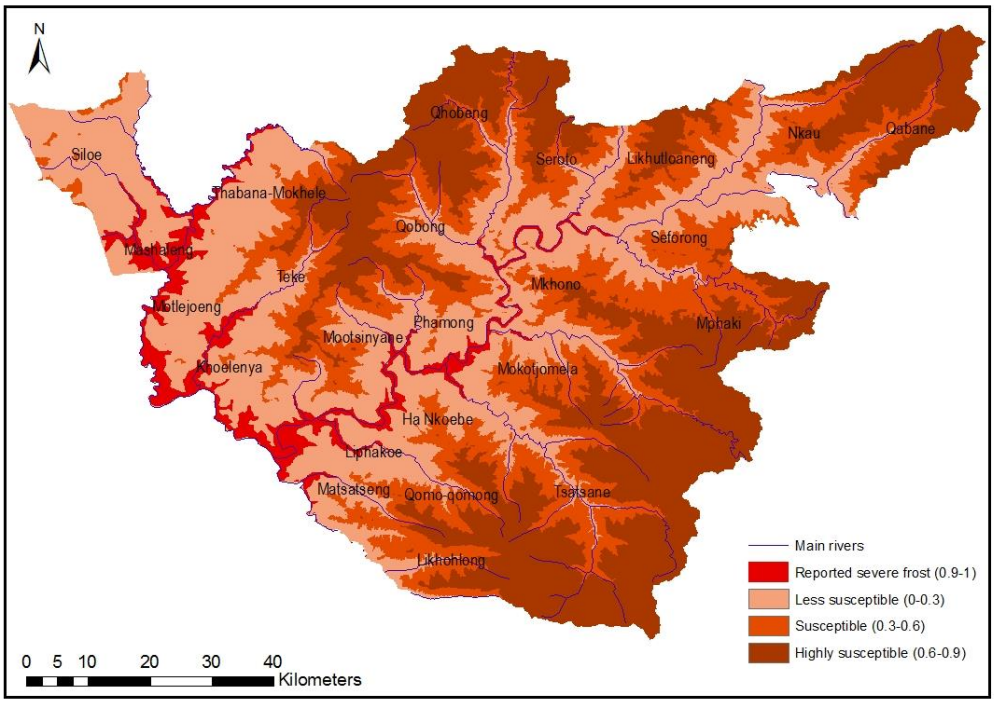

Figure 5.30: Frost hazard map
Source: Own data

Frost forecasts are essential in Lesotho as they can help farmers reduce any possible damage to their crops. There is a worldwide need for better spatial information on frost occurrence and its associated risk (Dai *et al.*, 2013). However, this is a challenge in Lesotho as only 35% of households in Mohale's Hoek and 26% in Quthing own radios and so do not have access to early warning broadcasts. Respondents from household interviews and focus group discussions in both districts stated that they often get notification on

natural hazards from school children (36% in Quthing and 56% in Mohale's Hoek), whilst others reported getting early warning information from neighbours who own a radio. A table showing radio ownership in both districts is presented in Chapter 6, under 'social vulnerability'. Apart from spatial variability in microclimate, notably extreme temperatures, the major factor responsible for a reduction in agricultural production in Lesotho is rainfall variability. Local variations in topography, i.e., elevation, aspect and slope, cause variations in temperature and frost incidence in the landscape, even with little variations in topographic relief. In other mountain environments, such as the Bolivian Andes, frost has also been reported as a limiting factor for agricultural production and is a major risk during the cultivation and growing period of potatoes (Franois *et al.,* 1999). There have been a number of studies on frost and extreme cold in South America and Iran, with a particular focus on its impact on agriculture (Astolpho, 2005; Rahimi *et al*., 2007; Rusticucci, 2012; Marengo *et al*., 2013).

5.5 HEAVY SNOWFALL VULNERABILITY

Snow hazard is defined as "comprising all the perils that snow and ice present, directly, both in themselves and in association with other earthly and atmospheric phenomena, and indirectly through snow melt and/or [re-]freeze" (Grab and Linde, 2013:1). Heavy snowfalls are often associated with extreme cold conditions and regularly result in a significant threat to people, livestock and property (Kaab, 2002; Prior and Kendon, 2011). On the one hand, light or normal snow is an event which may result in minimal to moderate impacts. Heavy snowfall in this study is referred to as snow which has negative impacts on human beings, livelihoods, livestock, crops and ecosystem functioning. Heavy winter snowfall in Lesotho often results in human and livestock fatalities (Grab and Linde, 2013).

However, with a significant lack of meteorological and precipitation data for Lesotho it is generally believed that snowfall in Lesotho occurs about eight times per annum (Mulder and Grab, 2009)., the heaviest and most widespread occurring over the three winter months (June-August), whilst May and September have fewer recordings (Tyson, 1986; Mulder, 2007; Mulder and Grab, 2009; Linde, 2011). Less frequent, heavier snowfalls

often leave high-altitude communities snowbound for several weeks in winter (Grab, 2005; Mulder and Grab, 2002, 2009).

Documentary evidence of heavy snowfall records and extreme cold has been explored for Lesotho for the period 1828-2012 (Table 5.6). Documentary sources indicate that in August 1849 there was extraordinarily cold weather in Lesotho, coupled with very heavy snowfall, and in some places the snow was about two feet deep. In 1850, again there was a severe winter and extraordinary snowfall for three days, which killed many people and livestock (Grab and Nash, 2010). Heavy snowfalls at higher altitude are more common in Lesotho, and snow can remain on the ground for several weeks (Boelhouwers and Meiklejohn, 2002). Table 5.1 indicated that heavy snowfall has a return period of 3.1 years in Lesotho. Of the 60 recorded major snowfall events that have occurred during the last 184 years, eight (1897, 1902, 1964, 1996, 2001, 2002, 2004 and 2007) were classified as the deepest and most extreme, as reported by the respondents and indicated in the official reports and literature (Showers, 2005; Mulder, 2007; Grab and Nash, 2010; Disaster Management Authority, 2011; Linde, 2011; LMS, 2011). The last two decades show increasing number of intense events, which could be a result of better reporting in recent years. In the majority of occurrences, there were incidents in which people and animals died from extreme cold in mountainous areas. On nine occasions human lives were lost, on ten livestock died.

In 1996, 2002 and 2004 heavy snowfalls caused disasters in the highland districts, particularly Mokhotlong, Quthing, Qacha's Nek and Thaba-Tseka (www.reliefweb.int). During these incidents, many villages were isolated and inaccessible because melting snow and heavy rainfall damaged roads and destroyed bridges. More tragically, human deaths were reported and an unknown number of livestock killed. There were also reported health problems including frostbite, snow blindness and typhoid in many highland communities across the country (DMA, 2012). Additionally, Linde (2011) reported that the 2004 heavy snow cover lasted for 12 days in the highlands. Local newspapers (*Public Eye*, 11 August 2006) reported a number of vehicles and buses trapped in mountain passes for more than two days. However, many deaths resulting from heavy snow in remote rural areas and cattle posts are only known by local villagers and are not reported to government officials. Despite the observed increase in mean winter temperature in the study area, reported in the

severe frost section, over the past 184 years, the frequency of abundant snowfalls in the study area has not declined.

Table 5.6: Severe snowfall and extreme cold incidences in Lesotho 1828-2012.

Year	Comments
1828	Heavy snowfall (3 inches thick)
1837	Snowfall in lowlands (harsh winter)
1839	Heavy snowfall (lasted for more than a week)
1842	Heavy snowfall, made it impossible to travel
1843	Abundant snowfall
1847	Much snow and cold in the lowlands (livestock losses)
1848	Very cold and lots of snow (killed livestock)
1849	Snow abundant and cold rigorous (killed livestock)
1850	Extraordinary snowfall for three days and extreme cold (killed many people and livestock)
1851	Severe snowfall (cold lasted for two months, frost destroyed corn)
1852	Extreme snowfall and ice and frost (destroyed corn and extreme cold killed livestock)
1853	Heavy snow fell continuously for three days (A year of extraordinary snows)
1854	Extraordinary snowfall is September (killed livestock, damaged houses)
1856	Snowfall for four days (killed people and livestock), it was impossible to travel
1858	Heavy snow
1859	Heavy snowfall and extreme intense cold (people and livestock killed)
1863	Heavy snow fall and severe cold (crops perished and frost bitten in November)
1869	Extensive and heavy snow in the mountains and severe late frost (caused damage to crops)
1871	Extremely cold (cattle died)
1874	Heavy snow (killed livestock)
1876	Heavy snowfall
1883	Extremely cold winter (damaged crops and killed animals), heavy early frost
1886	Heavy snowfall (killed livestock)
1888	Heavy snowfall and severe cold
1892	Snowfall and extreme cold (people suffering from flu, fever)
1894	Heavy snow (crops considerably impaired by frost) in Quthing and Mohale's Hoek
1898	Heavy snowfall (severe winter in Quthing)
1899	Very heavy snowfall in the highlands of Lesotho
1902	Heavy snowfall
1909	Heavy snowfall
1913	Heavy snowfall in Eastern Cape and Lesotho (killed livestock)

1921	Heavy snow fell in Natal, Eastern Cape and Lesotho
1922	Heavy snowfall in Free State and Lesotho
1926	Heavy snowfall in eastern Free State and Lesotho
1933	Heavy snowfall over Lesotho and the Eastern Cape (killed livestock)
1936	Heavy snowfall (heavy stock losses and several people froze to death)
1940	Severe snowstorm
1953	Heavy snowfall (several mountain passes closed and immense livestock losses)
1959	Heavy snow fall (Sani pass closed for three months, houses collapsed)
1962	Heavy snowfall in Natal, Free State and Lesotho
1964	Heavy snowfall (several places were isolated)
1965	Heavy snow fell in Lesotho, Eastern Cape and Natal (heavy stock loses).
1967	Heavy snowfall (mountain passes were impassable and roads closed)
1970	Lesotho, eastern Free State and natal saw unprecedented heavy snowfalls
1982	Lesotho and the Eastern Cape had heavy snowfalls (several mountain passes were closed)
1985	Heavy snowfall in Free State and Lesotho
1987	Unseasonal heavy snowfall in October (herd boys and livestock died in the cattle posts).
1988	Heavy snowfall (the border posts to Lesotho were closed and highlands cut off)
1990	Heavy snowfall in the highlands
1991	Heavy snowfall in the highlands
1994	Heavy, widespread snowfall
1996	Heavy snow fall (highland districts remained cut off for several days, killed livestock)
1998	Snow fall (2 head boys died in Tsatsane Quthing)
2001	Severe snow fall in July, killed people and livestock
2002	Heavy, widespread snowfall
2004	Heavy snowfall, killed people and livestock
2006	Heavy snowfall killed livestock and people, caused severe disruptions in the highlands
2007	Widespread heavy snowfall in the highlands, housed collapsed
2008	Heavy snowfall in the highlands
2009	Heavy snowfall killed livestock and left herd boys stranded in the highlands

Sources: Showers, 2005; Ambrose 2009; Grab and Nash, 2010; Nash and Grab 2010; Disaster Management Authority, 2011; Linde, 2011.

Altitude has an effect on the amount of snowfall a location receives, the distribution and duration of cover mainly being influenced by the topography. The maximum area of the snowfall is typically located over the slopes and near the mountain summits. According to Linde (2011), Quthing district has the highest mean duration of snow cover (21-25 days

per annum), which makes it more vulnerable to snow hazards than Mohale's Hoek and the remainder of the country. Highland communities are generally susceptible to the negative impacts associated with heavy and prolonged snowfall, because most are located far from road networks. However, the lowlands and the Senqu River valley have limited snow cover and snow in these areas melts within 1-5 days, as noted by Linde (2011), who carried out a detailed assessment of spatio-temporal trends for long-lasting snow in Lesotho.





Figure 5.31: Stranded motorists in the highlands (Ha Lebelonyane-Quthing, August 2009). Source: Own photo

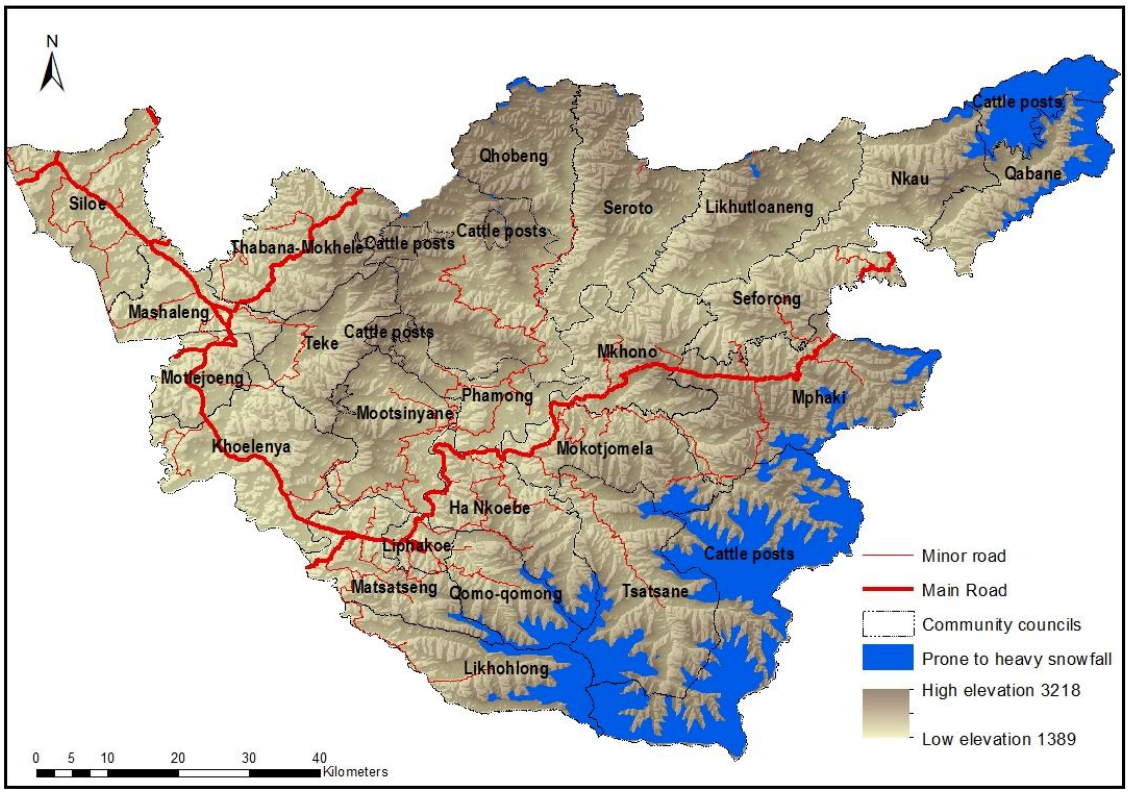

Figure 5.32: Heavy snowfall prone areas
Source: Own data

The lowlands and river valleys exhibit lowest snow risk (Figure 5.32). The location of these high and low risk areas are logical from a geographical meteorological standpoint, as the high elevation areas (above 2000m) are cooler and accumulate large amounts of snow, and because of cold conditions in these areas it lasts longer. Meanwhile the lowlands and river valleys often receive small amounts of snow. As presented in Figure 5.33 cattle posts are situated away from the residential areas and roads, thus during heavy snowfall, herd boys and livestock become trapped and isolated in the mountains. Figure 5.33 also indicated areas with high snow vulnerability, with an index score ranging from 0.8 to 1; these are cattle posts and other mountain areas such as Tsatsane, Mphaki and Qhoali in Quthing, and Hloahloeng and Ketane in Mohale's Hoek. Other areas situated in the foothills, such as Qaqatu, Mpharane and Taung in Mohale's Hoek, have a snow index score of 0.6, and whilst in Quthing, the areas of Mt Moorosi, Qomoqomong and Tele have a medium snow vulnerability index of 0.6. The lowlands in both districts have a low snow

vulnerability score of 0.2; owing to these areas being low-lying and not often receiving heavy snowfall (based on personal observations and household interviews). In addition, the lowlands have a relatively good road network to ease the movement of people and goods, even during times of snowfall, whilst in the highlands people may remain snowbound for several days. This is in agreement with Linde's (2012) findings, that heavy snowfall vulnerability is generally lower in villages located on north-facing slopes, because these areas receive less snow and are mostly snow-free throughout the winter months. On the other hand, some parts of Likhohlong, Qabane and Mokotjomela, all in Quthing, experience prolonged snow cover, mainly on south-facing slopes above 2500m a.s.l.

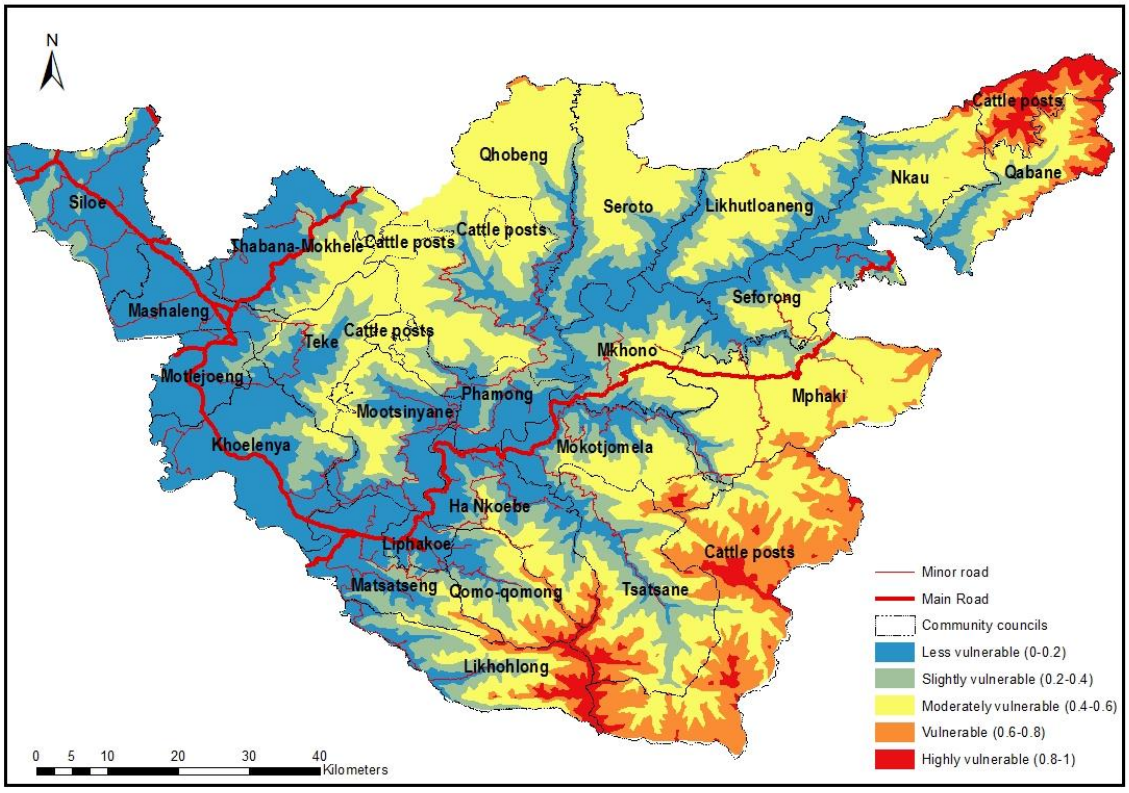

Figure 5.33: Vulnerability to snow hazard
Source: Own data

Due to the effect of snow on people and animals, herders would avoid exposure to heavy snow and extreme cold by obtaining weather forecasts from the Lesotho Meteorological Services through Radio Lesotho, especially in the lowlands and urban areas. Such information allows them to make contingency plans by moving their livestock to lower altitudes, so as to avoid being trapped in heavy snowfall and to stockpile fodder and fuel.

In the highlands of both districts, it was reported that herd boys often fall victim to heavy snowfall and extreme cold weather conditions.

Interviews with key informants confirmed the literature that the snowfall of July 2004 resulted in the loss of livestock and hindered vehicular movement between highlands and lowlands, thus obstructing the movement of people and goods in both districts. Qhoali, Sebapala, Tele and Tsatsane were reported as the most vulnerable to snowfall because of their terrain and inaccessibility in Quthing, whilst Ketane, Hloahloeng and Qaqatu were reported to be the most vulnerable in Mohale's Hoek (Figure 5.34), for similar reasons. According to the Disaster Management Officer in the Quthing district, herders from more than five cattle posts in Mphaki and Tsatsane were reported to be trapped for three days without food and fuel in July 2009. In the majority of cases, herd boys are trapped without communication to the outside world, and with inadequate food, clothing and fuel. Unlike livestock farmers or herders at lower altitudes, herd boys in the mountain areas do not have access to radios, and consequently do not get any early warning about extreme weather conditions. In the absence of adequate shelter for both humans and livestock, and of fuel and warm clothing at the cattle posts, both livestock and herders are exposed to frostbite, extreme cold, hunger and even death.

Snowfall patterns based on the number of heavy snowfalls overlaid on the elevation GIS layer, revealed the mountain areas as places more vulnerable to negative impacts of heavy snowfall because of the altitude and cold weather conditions at higher altitudes. Figure 5.35 illustrates total duration of snow cover, mean duration of snow cover per annum and maximum consecutive days of snow cover in Lesotho (Linde, 2011). This figure depicts a large proportion of Quthing highlands as areas with longer lasting snow cover (for the period 2003-2010). Linde (2011) established that Anone village in the Quthing district had the highest early season snowfall vulnerability ranking in the entire country.

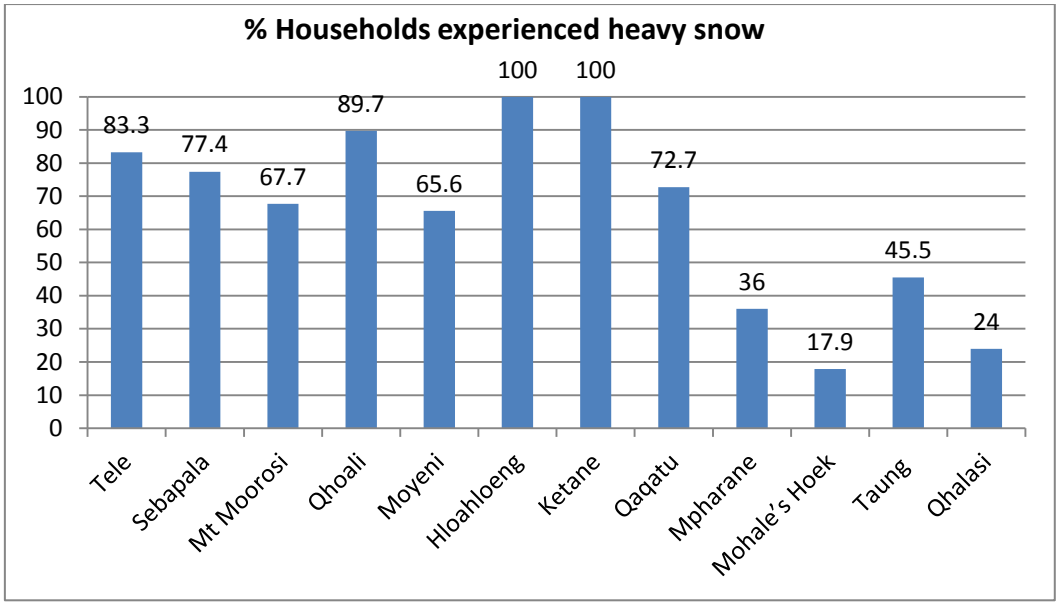

Figure 5.34: Percentage of households that have experienced heavy snowfall during the past two years (2009- 2011).
Source: Own data

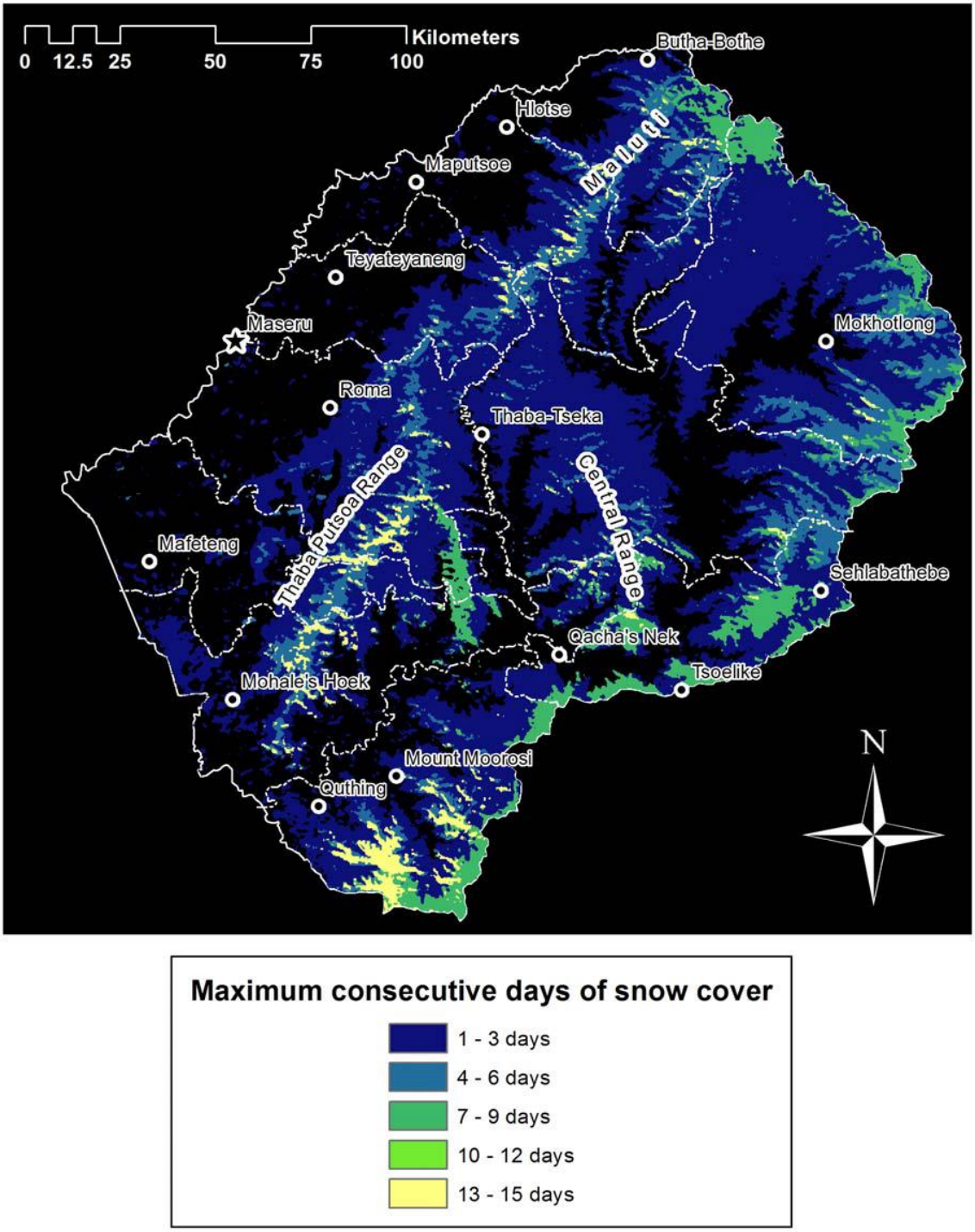

Figure 5.35: Total duration of snow cover (July-August) for the period 2003-2010. Source: After Linde, 2011.

5.6 STRONG WINDS

Strong winds are recognised as exceptionally powerful and destructive meteorological events which result in loss of property, livelihood and life in many parts of the world (Khanduri and Morrow, 2003; Kruger, 2011). For the purpose of this study, and within the local Lesotho context, strong winds are defined as intense, localised and of short duration, accompanied by damaging winds (including tornadoes), hail and lightening. While this definition may be criticised as lacking quantifiable criteria, the researcher believes that it is sufficient for this study, allowing for more flexibility in terms of incorporating a reasonably wide range of intensity and impact of reported storms.

Strong winds and severe local storms cause great losses to agriculture and damage to homes and infrastructure in Lesotho (Mpholo *et al*., 2012a, 2012b). In addition, there have been some reported cases of human deaths and injuries related to strong winds. Table 5.7 shows the historical trend of severe storms from 1834 to 2012. A total of 37 events have been documented within the study period, based on documentary sources and meteorological reports (Nash and Grab, 2010), but this number of cases seems to be small with respect to the examined period, due to limited sources of information. Therefore, this information is assumed to be incomplete and more likely to be biased, as more cases are likely to be found in future.

The table also shows an increase in the number of reported storms and it is assumed that the marked increase since 1989 can be attributed to better reporting and recording of storms in the country, rather than to any absolute increase in their number. Similarly, the low frequency of storms and long intervals between them is probably a result of lack of consistent reporting during the earlier period. Due to the limited spatial extent of these events it is likely that the related extreme magnitude winds affecting small remote areas may not have been recorded. Goliger (2002) also noted a lack of statistics on windstorm disasters on the African continent. Therefore, it is also difficult to assess the magnitude of these strong winds, based on the recorded events in Table 5.7. Until now, no database of wind damage or disaster has been built up in the country, despite several significant devastating events having occurred. The magnitude of wind speed is the most critical characteristic of strong winds that directly affects the extent of damage (Goliger, 2002). Stronger events generally produce greater damage and more frequently result in death, but these events occur less frequently than weaker ones. For less damaging events,

respondents indicated that most households can absorb events that results in relatively limited damage.

This section presents analysis of wind speed data for Moyeni in Quthing from 2000 to 2008 at 25m above ground level (m.a.g.l.). Moyeni is situated at an altitude of 1700m, with the only available wind recording station in the study region, obtained from the Lesotho Meteorological Services. The data was used to highlight extreme wind speed events, indicating damaging strong winds. The analysis used a block maxima technique to analyse extreme values of wind speed using the highest value of the month (Cook, 2013; Anastasiades and McSharry, 2013). This section therefore estimates the frequency and intensity of strong winds associated with severe storms using the extreme value statistics. Severe storms and related destructive wind speeds pose a major threat to communities and their assets (Kunz *et al*., 2010). Figure 5.36 illustrates annual extreme wind gusts and annual maximum mean wind speed (at 25m a.g.l.), with general extreme value distribution. The average annual maximum wind gust and wind speed is 7.19m/s and 5.22m/s respectively. Intra-annual variability of maximum strong winds is witnessed mostly during the months of July, August and September. The frequency and severity of storms were investigated through the calculation of the annual number of days with maximum annual wind speed values. The years with the maximum wind speed values coincide with the documented strong wind events and from the household interviews (2001, 2005, 2006, 2007 and 2008).

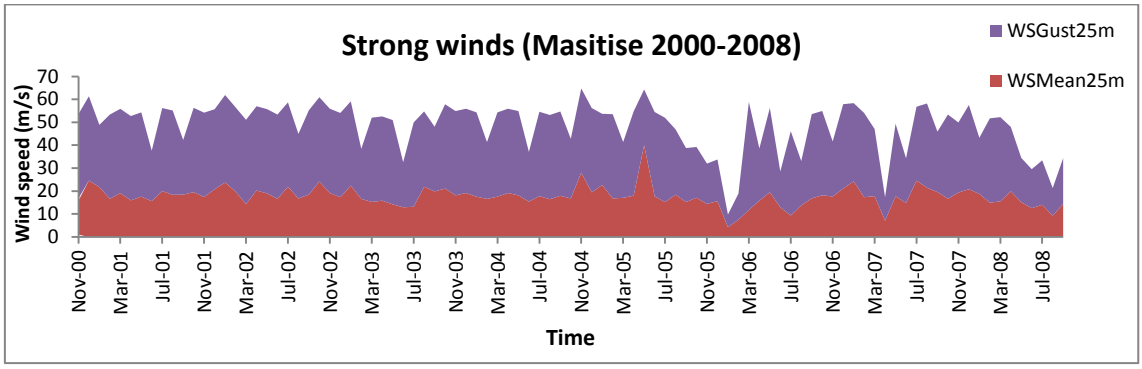

Figure 5.36: Wind speed and gust (Masitise-Quthing 2000-2008).
Source: Own data (Lesotho Meteorological Services data)

Table 5.7: Strong wind events in Lesotho between 1834 and 2012 (documented)

Year	Comment
1834	Terrible storm
1836	Strong winds and thunderstorm
1840	Whirlwinds
1850	Very strong winds
1851	Hurricane
1860	Violent wind storm (hurricane) destroyed fruit trees
1869	Strong winds (carried away roofs)
1881	Frightening wind storm (blew off roofs, destroyed crops)
1885	Violent wind (damaged crops)
1889	Severe gales in Quthing (roofs badly damaged)
1896	Dust storm
1890	Heavy wind storm (devastated standing crops)
1907	Violent storm
1913	Terrible storm
1925	Devastating winds
1949	Severe storm
1954	Wind storm
1956	Storm damage accompanied by cyclonic event
1959	Tornado
1971	Strong winds
1976	Severe storm
1983	Violent storm
1984	Severe wind storm
1986	Severe storm
1989	Strong winds (housed damaged and uprooted trees)
1990	Devastating wind damage
1999	Severe storm (power lines damaged, buildings damaged, people injured and killed)
1993	Strong winds (many houses damaged)
1994	Severe storm
1996	Severe storm
2001	Severe storm
2005	Strong winds (high winds ripped off roofs and 900 houses were affected country-wide).
2006	Severe wind storm
2007	Violent wind storm
2008	Severe storm
2009	Severe winds (destroyed and damaged houses)

2010	Strong winds (uprooted trees and damaged building and power and telephone lines)

Sources: Goliger *et al*., 1997; Ambrose, 1999; www.em-dat.net; Showers, 2005; Nash and Grab 2010.

Single extreme storm events with a low probability of occurrence are very rare, such as the one that occurred in November 2004 (with a wind speed of 36.7m/s) (Figure 5.36, above), which caused economic losses amounting to millions of Maluti (DMA, 2010). Therefore, accurate assessment of the frequency distribution of extreme wind speeds is a prerequisite for risk management and engineering purposes, and detailed place-specific data is required for such an assessment. However, in the current study such data was not available.

In light of climate change and global warming, there is a likelihood of increased severe and frequent wind storms (IPCC, 2007; 2012), but there is no linear trend in terms of the number of reported and observed extreme wind events in the study region. Figure 5.35 did not show any increase in frequency or severity of wind storms, because of lack of long-term instrumental data in the study region, however, household and key informant interviews present a different picture, as they reported an increasing occurrence in the number of severe and damaging wind storms, those being ones that cause damage to property, infrastructure and harm or kill people. However, availability of wind data for more years would have improved the results and resulted in temporal and spatial analysis of strong wind events using place-specific instrumental data. Another challenge for this analysis stems from the limited availability of wind data of sufficient duration for long-term trend analysis. Furthermore, the analysis only uses wind data for one station in Moyeni-Quthing, located at 1700m, which is only representative of the immediate surrounding area.

5.6.1 Strong winds and topography

According to Ngo and Letchford (2008), topographic features such as escarpments, hills, and ridges have strong effects on wind speed profiles because they modify wind flow over them. These topographic features act as barriers to the boundary layer, accelerating the wind near the ground, which leads to increased wind pressure on buildings located in such regions. Terrain or topography has been a significant contributing factor during past hurricane events in different parts of the world (Chock and Cochran, 2005).

Often wind speed increases with altitude (Etienne *et al*., 2010). Generally, wind speed increases when moving up the windward slope of a hill, escarpment or a ridge (field observation). Therefore, wind flows can be very strong at one location but weak in a neighbouring valley, thus showing great discontinuities within small areas. Surface elevation thus has an influence on wind speed and strength (Tennekes, 1973; Miller and Davenport, 1998; Winstral *et al*., 2009, Kruger, 2011). In complex terrain, wind speeds vary considerably even over short distances. Kondo *et al*. (2002) state that wind speed and flow in micro-topographic features such as valleys, cliffs and hills is very complicated. For a specific area or locality, the dominant topography can either increase, as a result of accelerated up-slope flow and over the ridge, or decrease, as a result of shielding and the flow reversal phenomenon, the wind speed magnitude (Goliger, 2002; Ngo and Letchford, 2009). However, where the topography is complex and three-dimensional, such as in the study region, it is difficult to quantify the effects of topography, and this often requires practical and scientifically based methods for predicting such influence on airflow through wind tunnel technology (Cao and Tamura, 2006).

It has generally been observed in Lesotho that west-facing slopes and high mountain areas are windier and hence more susceptible to strong winds, while east-facing slopes and areas in the valley bottoms are less susceptible to strong winds (Linde and Grab, 2011). Extreme wind events have strong spatial characteristics governed by geographical macro-climatic conditions. However, the absence of wind data across the study area limits spatial analysis of strong winds in this region. Nonetheless, DMA reports, key informants and topographic data derived from a DEM were used to map villages that are susceptible to the impacts of strong winds (Figure 5.37) and also to show areas where strong winds have caused great damage in the past. This map only provides an overview of villages with great potential to exposure to severe damaging winds, based on the physical geography of the study area. According to this map, villages in the highlands are more susceptible to strong winds, based on the notion that wind speed and strength increases with elevation. However, a greater part of the exposed mountain tops are uninhabited and have no buildings or infrastructure that can be damaged or destroyed by strong winds. This map can be used to assess terrain effects on building type in the country and can improve wind-hazard mitigation through the identification of severe wind regions based on the topographically and previously affected villages.

In Figure 5.37 it is evident that the topographic exposure of narrow valley bottoms is low, as these areas are sheltered by the surrounding hills and mountains (Phamong, Mkhono, Ha Nkoebe, Thabana Mokhele, Teke, Khoelenya, Motlejoeng, Liphakoe, Siloe and Mootsinyane), while the exposed hilltop sites are more susceptible to strong winds (Tsatsane, Likhohlong, Qabane, Qhobeng, Mphaki and Qomoqomong). High population density, infrastructure, commercial establishments and housing units in urban lowlands heighten their vulnerability and exposure to strong winds, because the potential for damage to property and infrastructure is relatively great in these areas (Liphakoe and Motlejoeng). The urban areas also have a higher probability of sustaining casualties during severe storm events because of high population densities, which contributes to a high exposure to potential wind hazards.

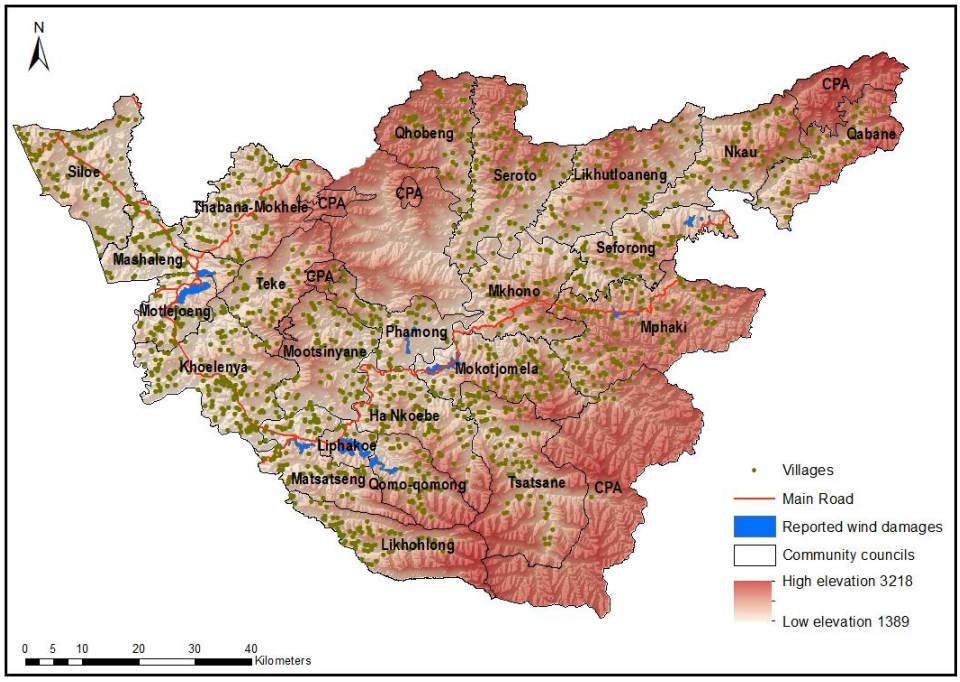

Figure 5.37: Villages highly exposed to strong winds
Source: Own data

Figure 5.38 presents responses from the household interviews, in which respondents were asked if the household had experienced strong winds during the previous two years (2009-2011). All households interviewed in Moyeni reported that they had experienced strong winds and 25% of these said their houses had been destroyed in the process. The district disaster management official reported that Moyeni (Liphakoe), in particular, was

very prone to the effects of strong winds. Most damages to houses and infrastructure were in the urban areas of Motlejoeng, Thabana Mokhele, Khoelenya and Mashaleng in Mohale's Hoek and Liphakoe, Mphaki and Mokotjomela in Quthing. These areas are highly populated, have well developed infrastructure and often suffer great loses in the event of strong winds. However, the rural areas reported fewer cases of houses and infrastructure destruction during strong winds events.

The most wind affected villages were in Liphakoe community council, whose administrative centre is Moyeni (*Moyeni* is a Xhosa word, meaning the place of wind). Survey results (Figure 5.38) also reported that all (100%) households in Moyeni (Liphakoe) in Quthing had experienced strong winds during the study period. Qhoali and Mt Moorosi (83%) were also greatly affected by strong winds, as many households reported damage to houses and crops. In contrast, Mohale's Hoek had slightly fewer households who experienced strong winds, with Taung (89%), Qhalasi (88%), Mohale's Hoek constituency (82%) and Qaqatu (75%) being the communities with the highest number of households affected by strong winds (Figure 5.38). Spatial distribution of strong wind events appear to be relatively consistent in both districts. The survey results did not reveal any particular spatial pattern of vulnerability to strong winds in the study area, as areas in both highlands and lowlands were negatively impacted. The results however, indicate that strong winds are a common weather phenomenon in Lesotho.

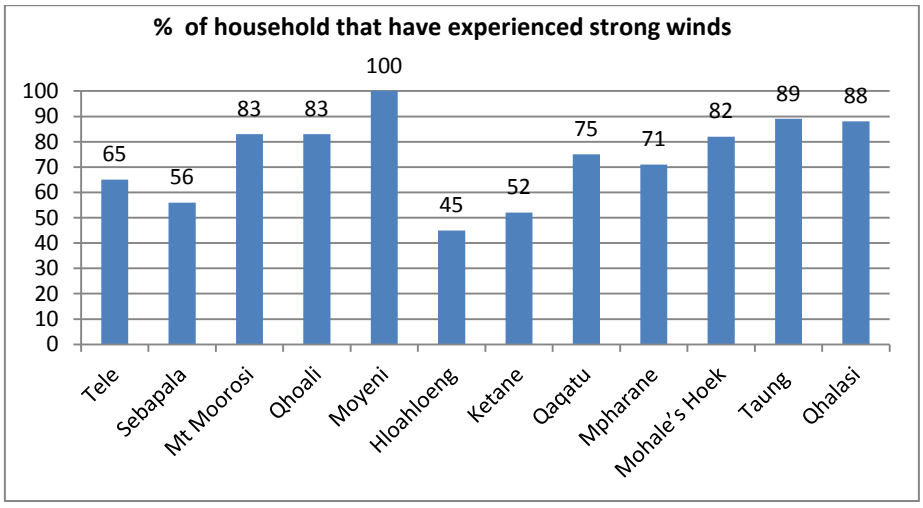

Figure 5.38: Percentage of households who experienced strong winds (2009 to 2011).

Source: Own data

Figures 5.39, 5.40 and 5.41 illustrate the damaged houses caused by strong winds during December 2009 and January 2010 in Quthing and Mohale's Hoek (during the study period). The district disaster management officer in Quthing stated that during this period, about 59 households (29 in Liphakoe, 12 in Mphaki, 8 in Mokotjomela, 6 in Ha Nkoebe and 4 in Matsatseng) were left homeless when their houses were blown away by strong winds. The officer reported that many of these households also lost some contents, such as beds, stoves and utensils. A house is a major physical asset for any family, so when it is lost it leaves occupants homeless and exposed to future threats.

The district disaster management officer (DDMO) in Quthing reported that most of the houses in the district were susceptible to strong winds as they were flat-roofed (Figure 5.41), leaving them prone to damage during strong wind events. In both districts, some residents explained that they buffered their houses against strong winds by planting trees around their homesteads and opting for pitched roofing for newer houses (Figure 5.42). Therefore, this indicates that residents in both districts were aware of the negative effects of strong winds and were taking precautionary measures. During the fieldwork, it was observed that the newly built houses had pitched roofing while old ones had flat roofing. The DDMO in Quthing said they were encouraging households to use wind-resistant (pitched) roofing, as indicated in Figure 5.42. Through the years, and with the advent of modernisation, the majority of houses, most especially in urban and peri-urban settings, have changed in terms of building and roofing materials. The typical stone structure (Figure 5.42) is gradually being replaced by concrete walls, corrugated iron and *Harvey* roof tile (Figure 5.43).



Figure 5.39: A house completely destroyed by wind at Moyeni, Quthing (January, 2010).
Source: Own photo



Figure 5.40: Roof blown off by wind in Mohale's Hoek (January, 2010).

Source: Own photo



Figure 5.41: Wind prone roofing in Phamong, Mohale's Hoek (January, 2010).

Source: Own photo.



Figure 5.42: Grass thatched Mokhoro house (January, 2010).

Source: Own photo

.



Figure 5.43: Newly built houses with wind resistant pitched roofs in Mphaki-Quthing (July 2010).

Source: Own photo



Figure 5.44: Recently built house with *Harvey* tiles and wind resistant roofing in Moyeni, Quthing (February 2010).

Source: Own photo



Figure 5.45: Stone built house with thatch roofs in Qabane, Mohale's Hoek (January 2011)

Source: Own photo



Figure 5.46: Wind resistant house built from sturdy materials in Moyeni, Quthing (July, 2010).

Source: Own photo

Figures 5.45 and 5.46 show two houses built from different building materials of different strength. The first is constructed from stones, mud and has thatch grass roofing. It can be observed that the walls are cracked and the roof damaged, towards the right-hand side, thus in the event of strong winds or heavy snowfall it is likely to be damaged, leaving the owner, a 68 year-old widow, more vulnerable to other shocks. Figure 5.46 depicts another house at Moyeni, Quthing, constructed from sturdy building materials, cement bricks, cement walls and a pitched corrugated roof. This house is more resistant to strong winds than the first, and thus is more resilient to climatic shocks. Structural vulnerability arises when buildings are constructed using designs and materials that are incapable of resisting extreme and strong winds. Thus, structural vulnerability can decrease or increase the effect of hazard exposure, whether to property or residents.

The results presented in Figure 5.46 are based on damage caused by strong winds across the community councils, and also on the overall physical profile of the study region. In densely populated urban settings, the hazard impact intensity is higher, whereby strong winds often destroy structures and accelerate debris that often cause traumatic injuries. Urban areas are also more vulnerable to strong winds because there have greater economic impacts, on property, infrastructure and assets, than in rural areas (DMA, 2010). Even though wind strength increases with elevation, in the rural highlands the population is spread out sparsely over a wide area, thus reducing the probability that a large impact event will occur. The survey results reveal that densely populated urban areas have significantly higher probabilities of occurrence of damaging strong winds than sparsely populated rural highlands. However, much of this disparity is likely due to the absence of settlements in most high elevation areas, where strong winds are more prevalent. Figure 5.47 indicates community councils where the potential for wind damages (large casualties or total damage) is high. The map relates to the reported and observed losses in the study area over the study period. Where the vulnerability index is high, official reports indicate that there have been many casualties from strong winds, with collapsing buildings killing or injuring people, or the total damage has been significant.

Figure 5.47 also shows that community councils with significant losses from strong winds can be found in the urban lowlands, with rural highland areas exhibiting lower vulnerability index scores (0-0.4). These results are contradictory to the expected results, that highlands would have high physical vulnerability scores (0.6-1) because of their

location (high elevation and prone to strong winds). In this case, highlands are less vulnerable as there are very few elements at risk, viz., settlements and population. Strong winds will continue to be a threat in urban areas because of rural urban migration and increases in population densities as these factors increase the spatial extent of hazard exposure. Theoretically, highlands are highly vulnerable to the effects of strong winds because of exposure effects.

The increasing frequency and intensity of reported severe storms translate into potential hazards and increased vulnerability of poor households. Unfortunately, many storms go unnoticed and unreported, or are simply not recorded in remote, sparsely populated rural areas. This study indicates that greater losses and casualties occur when strong winds strike populated urban areas and that when these events strike sparsely populated rural areas they are less likely to result in damage. In open and sparser populated areas, such as cattle posts in the highlands, strong winds may go completely unnoticed and unrecorded in official disaster records.

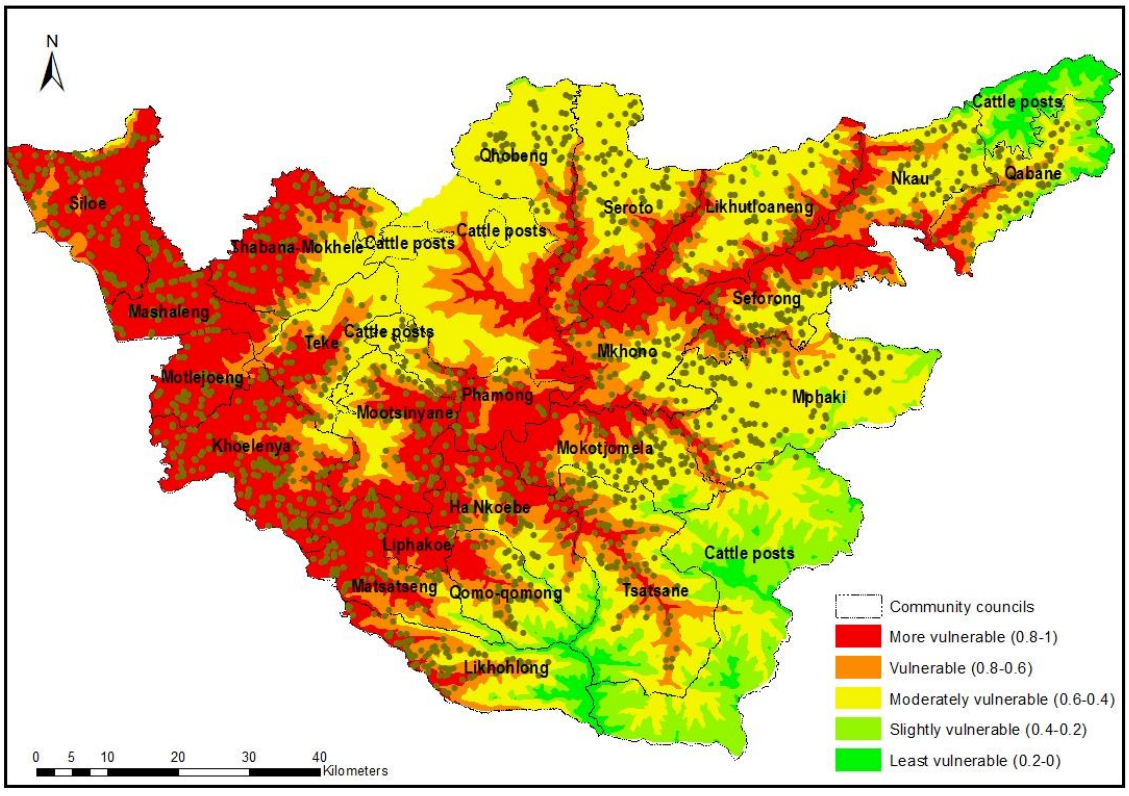

Figure 5.47: Susceptibility to strong winds

Source: Own data

5.7 PHYSICAL VULNERABILITY

This study used various methodologies for the development of a multi-hazard assessment for Quthing and Mohale's Hoek districts. Simple GIS procedures, data bases and spreadsheets were used to develop individual hazard maps and to identify hazard prone or susceptible areas for mapped hazards. Although incomplete records exist, at least 51 droughts, 51 frost events, 54 floods, 37 severe wind storms, and 60 heavy snowfalls affected the study area between 1825 and 2012. The frequency and severity of some of these hazards may have far surpassed those of recent records. The historical datasets indicating the multiple hazards were synthesised to generate a composite map representing the multi-hazards in the study area.

Individual hazard maps were created from the historical datasets for the study area then combined to generate a composite hazard map for the study area. It is necessary to note that the factor elements of each hazard map had to be standardised in to z-scores ranging from 0-1 (least vulnerable to more vulnerable). Therefore, each community council was evaluated in terms of the frequency and severity of hazard occurrences and vulnerability levels were mapped in ArcGIS. Figure 5.48 presents a schematic model followed to create a physical vulnerability map for the study area. Individual hazard maps were cumulatively overlaid to create a physical vulnerability map using a set of graduated vulnerability values (0-1), it being a multi-hazard map whose purpose is to gather together in one map the different hazard-related information for a study to convey a composite picture of the natural hazards of varying magnitude, frequency, affected areas and sectors.

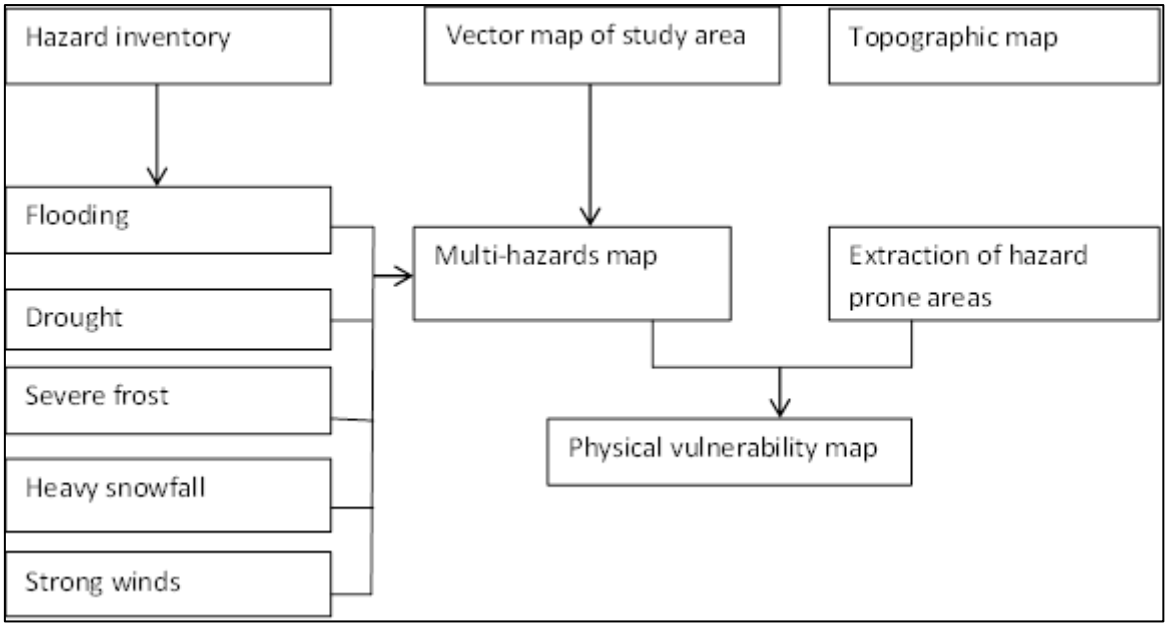

Figure 5.48: Data model for physical vulnerability

Spatial variations in place vulnerability to natural hazards were identified. Overlaying the spatial information of the study region and the natural hazards affecting both districts resulted in a GIS layer of overall physical vulnerability. This illustrates areas in which more than one hazard overlaps. Each area was assigned a score indicating the level of vulnerability, then the physical geography of each area was overlaid and summed to create the overall physical vulnerability map of the study area. The resultant map shows areas of various vulnerability levels considering several hazard types (Figure 5.49). This final outcome illustrates where the most physically vulnerable communities are located and these have the highest calculated vulnerability values (red colour on the map).

The areas with a vulnerability index score between 0.8 to 1 have the greatest physical vulnerability, while the areas with the scores closer to 0 have lowest physical vulnerability. The lowland areas and river valleys have high scores for physical vulnerability to natural hazards. Apart from drought, these areas are affected by a range of natural hazards (flooding, severe frost and strong winds) directly associated with topography or high population densities. The map also identifies localities where hazards occur frequently and where the physical characteristics of the environment makes an area vulnerable to the impacts of hazards (e.g., Siloe, Mashaleng, Thabana-Mokhele, Motlejoeng, Khoelenya, Phamong in Mohale's Hoek and Liphakoe, Matsatseng and some parts of Mkhono, Mokotjomela and Seforong in Quthing). All these areas are situated on relatively lower

elevations and along the rivers, making them most prone to flooding, strong winds and severe frost, but less susceptible to drought. From the map, it is evident that Mohale's Hoek is more vulnerable than Quthing, as most areas within the Mohale's Hoek district are susceptible to and have been affected by the majority of the natural hazards mentioned (flooding, strong winds, heavy snowfall, drought and severe frost). This is particularly due to the fact that Mohale's Hoek has high population densities, a high dependence on rain-fed agriculture, and a relatively large number of lower lying areas.

The physical geography of the study area also played a major role in observed variations in place vulnerability to natural hazards. Differences in elevation, proximity to rivers and slope aspect of each locality all contributed to these variations. High levels of physical vulnerability in Quthing are also found in populated areas, such as Liphakoe and Matsatseng, where flooding, severe frost and drought zones intersect along the Senqu, Tele, Sebapala and Quthing Rivers. Areas exhibiting moderate levels of physical vulnerability occur in the highlands and foothills which suffer from severe frost, heavy snowfall, strong winds and drought. The cattle posts and high elevation areas are relatively less vulnerable because of their topography and distance from the river valleys (i.e., communities of: Mkhono, Seforong, Nkau, Qhobeng and Mphaki). These areas are less susceptible to flooding and damaging strong winds but are likely to suffer from severe frost and heavy snowfall.

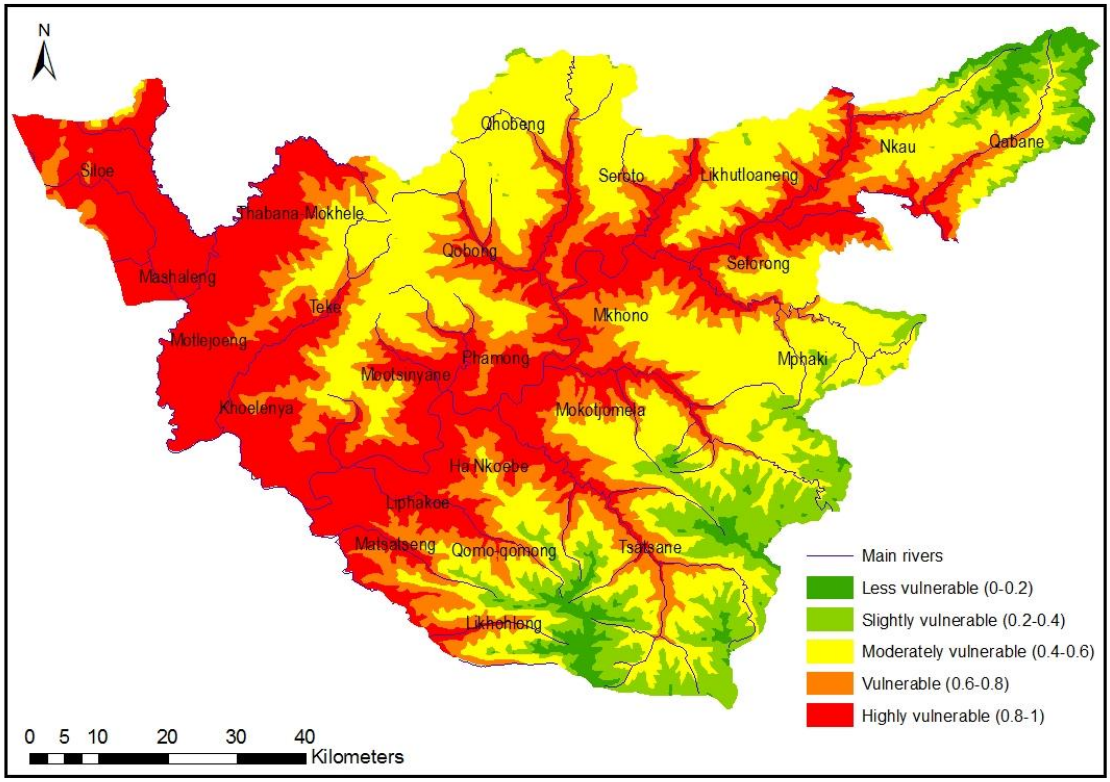

Figure 5.49: Physical vulnerability map

Source: Own data

High physical vulnerability levels can also be seen in some highland areas (Mkhono, Nkau and Seroto) and along the river valleys in Mohale's Hoek. In both districts, a similar pattern of physical vulnerability exists with the regions of highest vulnerability being where severe frost, flooding, strong winds and drought intersect along the Senqu, Mekaling and Makhaleng Rivers. Hazard mitigations in these areas must therefore be a priority to disaster management officials and disaster response organisations. The low-lying landscape of the valley communities and proximity to rivers, combined with the presence of a range of natural hazards (flooding, drought and severe frost), make the river valleys areas physically more vulnerable than other parts of the study area.

As has been argued, topography and the physical geography of a place influence physical vulnerability and the likelihood of hazard occurrence. Therefore, variations in the physical characteristics of a place are important in describing the differential impact of a given hazard across that space. It is worth noting that physical vulnerability factors presented in this chapter are interrelated with hazard severity. For instance, low-lying

river valley localities are more suitable for crop farming, yet these areas are most prone to frost and flooding, and consequently the impact is more severe than in the highlands. Community councils located mainly in the lowlands, with densely built-up environments that are also suitable for agriculture, appeared to be generally more vulnerable than those with smaller population density, which are mostly used as cattle posts. Overall, Mohale's Hoek was found to be the more vulnerable district, while Quthing was found to be the less vulnerable district due in part to its topography (less prone to many natural hazards). Considering the physical characteristics that contribute to high physical vulnerability levels, it has been found that topography of a place influences the frequency and severity of natural hazard events and their impacts on communities. Although highland areas are physically disadvantaged, in terms of topography and accessibility, and highly vulnerable to heavy snowfall and strong winds, the economic losses incurred in the highlands from these hazards are low compared to those incurred in the lowlands from frost, strong winds and flooding.

Table 5.8 presents a summary of hazard occurrences and level of concern in the study area, based on historical climate data and on household interviews. Generally, droughts are a highest concern in both districts, followed by strong winds and severe frost. Heavy snowfall appears to be the least concern in the study area, because severe and heavy snowfalls are a major concern in the highlands where damaging events are often under-reported.

Table 5.8: Hazard frequency and level of concern among community members

Mohale's Hoek			**Quthing**		
Hazard	**Frequency ****	**Concern level***	**Hazard**	**Frequency ****	**Concern level***
Flooding	54	56	Flooding	54	43
Drought	51	100	Drought	51	100
Severe frost	51	65	Severe frost	51	77
Heavy snowfall	37	21	Heavy snowfall	37	43
Strong winds	60	78	Strong winds	60	86

*Based on household interviews (% of total population responding highest concern)

**Derived from historical analysis of hazard events

5.8 SUMMARY

This chapter has provided a historical analysis of natural hazards prevalent in Mohale's Hoek and Quthing districts, and presented a physical vulnerability assessment for the study region. The chapter used several data sources to compute and map physical vulnerability, providing insight into spatial and temporal variations in vulnerability to natural hazards and the factors that contribute to physical vulnerability. The findings revealed that natural hazard effects are influenced by hazard occurrence and magnitude, as well as physical characteristics of a place. Using the frequency of occurrence for each natural hazard type affecting Mohale's Hoek and Quthing, as well as household interviews and focus group discussions, an understanding of the level of threat posed by each hazard was provided and a relative measure of frequency for each hazard determined, dividing the number of occurrences by the number of years in the record. The resulting metric, a surrogate for probability, described how often one might expect each hazard to occur and which may cause the greatest concern to communities and disaster management officials. The physical characteristics of a place determined the likelihood of hazard occurrence. The resultant information provided insight into the types of natural hazards causing negative impacts in the area. Through an assessment of the historic natural hazards events affecting Mohale's Hoek and Quthing, it became apparent that both districts and the entire country have experienced severe droughts, heavy snowfall, strong wind events, floods and frosts of differing magnitudes in the past. Unlike flooding, heavy snowfall and severe frost occurrence, which are place specific, the impacts of drought are more widespread across Lesotho. For strong winds, exposure was higher in urban lowlands and not in highlands, contrary to the expected results, because urban areas have many elements at risk, such as high value assets, infrastructure and buildings.

The spatial analysis of vulnerability to natural hazards at the local and district levels, provided an explanation as to why some areas were more vulnerable to different natural hazards than others. It was expected that the highland communities would be more vulnerable to a number of natural hazards because of their topography and inaccessibility (e.g., strong winds and severe frost). It was discovered that Motlejoeng (lowland urban locality) had the highest physical vulnerability index score in both districts. The major contributing factor to this high vulnerability level in Motlejoeng was its differential exposure as a result of low elevation, crop production, population density, and relatively well developed infrastructure. It was found that Motlejoeng was densely populated and had

a higher percentage of houses with flat roofing, most being built in flood-prone areas and fields are located in flood plains. Thus, all these factors contributed to the high physical vulnerability index score. Community councils with high physical vulnerability scores and recurring hazard events are likely to incur high losses from the impacts of natural hazards. Low physical vulnerability community councils (Tsatsane, Qabane, Mphaki, Qhobeng and the cattle posts in the highlands) are characterised by low and very low population densities.

The areas in the study region with a potential to experience severe frost are spatially similar to those regions prone to flooding, the primary reason for this is elevation. Low lying areas of the study region are more vulnerable to frost than other parts. Conversely, the highlands and cattle posts are less vulnerable due to their high elevation, distance from rivers and are sparsely populated with lower levels of agricultural activity, though highly vulnerable to snow hazards. Although the highlands exhibit low vulnerability levels, the mountainous areas are prone to heavy snowfall, drought and severe frost. These hazards pose serious threat to livelihoods, human lives and livestock and often cause considerable economic losses to farmers in both lowland and highland communities.

CHAPTER SIX

SOCIAL VULNERABILITY

6.0 INTRODUCTION

The primary objective of this chapter is to measure social vulnerability in Lesotho using the social vulnerability index (SoVI), which is a component of the hazards of place vulnerability model (Cutter *et al*., 2003). It further determines the socioeconomic variables that are appropriate for assessing social vulnerability in Lesotho. This chapter also provides a comparative analysis of social vulnerability between community councils and within districts, that is, which district is most vulnerable and why? Which community councils within each district are most vulnerable and why? The focus is to develop an understanding of the underlying social processes that cause certain people and places to be more vulnerable to natural hazards than others.

The SoVI is a quantitative measure of social vulnerability to environmental hazards, originally developed in 2003 and applied to the USA (Cutter *et al*., 2003). Conceptually, it relates well to indices of social well-being and inequality, but its focus is on natural hazards and the capacity of social groups to prepare for, respond to and recover from disasters (Chen *et al*., 2013a). It also takes into account the multidimensional aspects of social vulnerability, especially the dynamic intersection of gender, economic status and access to services. The index synthesises socioeconomic variables known to influence vulnerability (National Research Council, 2006) into multiple dimensions using a principal components analysis. In order to assess social vulnerability to natural hazards, the researcher improvised the SoVI and applied it to the community council level in Quthing and Mohale's Hoek districts of southern Lesotho. The SoVI provides an empirically based comparative measure that facilitates the geographic examination of relative differences in levels of social vulnerability across space (Cutter *et al*., 2003; Cutter and Morath, 2013).

6.1 DETERMINING SOCIAL VULNERABILITY

The study relied mostly on the 2006 population census data and the 2010 district handbooks at the community council level for the construction of a social vulnerability index. The 2006 Census data was the only comprehensive source for socio-economic data at the household level in the study area, thus, the results from this analysis should be treated with caution. However, this shortcoming was addressed by using the 2010 district handbooks. The current study uses 27 variables identified in previous studies (e.g. Cutter *et al*., 2003; Wood *et al*., 2010; Dunno, 2011; Yoon, 2012; Chen *et al*, 2013a; Cutter and Morath, 2013) and by disaster management officials in Lesotho, to account for the local context of social vulnerability (Table 6.1). The selected variables generally correspond to the broader dimensions of social vulnerability: socioeconomic status, gender, education, age, unemployment, rural/urban, special needs population, housing conditions, family structure, occupation, and social dependency (Dunno, 2011; Cutter and Morath, 2013). The selection of these variables was also determined by the availability of socioeconomic data in the study area. However, it should be noted that some of the variables represented here are not traditional socioeconomic variables, but are used to illustrate social vulnerability in the Lesotho context. These variables include: percentage of villages without access by roads, electricity connection, radio and mobile phone ownership, toilets and access to piped water.

Table 6.1: Socioeconomic variables

No	Variable name	Description
1	Total population	Identifying large population densities is an important variable to consider when combining known hazard occurrence areas (Cutter *et al*., 1997). More assistance from local and emergency officials is required to notify these large population groups (Cutter *et al*. 1997).
2	Number of households	The number of households identifies where the greatest number of people live (Cutter *et al*. 1997). This variable is important to show the intersection of hazard zones because it shows how many people are potentially more prone to hazard damages.
3	Percent female population	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities (Blaikie *et al*., 1994; Cutter, 1996; Enarson and Morrow, 1998; Enarson and Scanlon, 1999; Morrow and Ennerson, 1999; Fothergill, 1996; Morrow, 1999; Cutter et al., 2003).

4	Population density	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
5	Average population per village	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
6	Number of households per community council	Areas experiencing rapid population growth often lack available quality housing, and the social services network may be overwhelmed by the increasing populations (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2000).
7	Average household size	Large families, with many dependents often have limited financial resources and this affects their resilience to and recovery from natural hazards (Cutter *et al*., 2003; Chen *et al*., 2013a).
8	Percent of household with toilets	Households that lack basic sanitation facilities such as toilet and piped water are social vulnerable and often live in poor housing conditions (Chen *et al*., 2013a; Sajjad and Jain, 2014).
9	Population with no income	People that have no incomes and live in poverty are less capable of recovering from hazard impacts (Cutter *at al*., 1997, 2003). According to Cutter *et al*. (2003), wealthy populations are able to absorb losses more quickly due to insurance and social safety nets (Cutter *et al*., 2003).
10	Percent of households with over M1000 income per month	People that work tend to have higher incomes, larger social networks, and are better off. Those with formal jobs have relatively better job security in times of crisis (Cutter *et al*., 2003).
11	Percent households with agricultural fields	Agriculture is vulnerable to natural hazards (Cutter *et al*., 2003).
12	Percent households dependent on farming income	Agriculture is vulnerable to natural hazards and households that are dependent on farming are more vulnerable (Cutter *et al*., 2003). For communities dependent on rain-fed subsistence farming, climate variability result in food insecurity and reduction in income for the majority of households.
13	Percent households with trade as source of income	Some occupations, especially those involving resource extractions, may be severely impacted by a hazard event (Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*., 2003).
14	Percent households with formal employment	People with formal employment tend to have regular incomes, educated, and are better off. Those with formal jobs have relatively better job security in - times of crisis (Cutter *et al*., 2003, Thomas *et al*., 2013).
15	Households with no access to radio	Radios serve as a tool for communication. Households without radios are limited to current knowledge and updates on potential disasters (Clark *et al*. 1998).

16	Households with no access to cell phones	Like radios, cell phones serve as a tool for communication. Households without cell phones are limited to current knowledge and updates on potential disasters (Clark *et al*. 1998).
17	Households dependent of social support	Those people who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period (Morrow, 1999; Heinz Center for Science, Economics, and the Environment, 2000; Hewitt, 2000, Cutter and Morath, 2013).
18	Percent dependent on home-based care	Populations on home-based care consist of AIDS and TB patients under supervised care and are on chronic medication. Individuals with chronic illness have unique needs that require more detailed planning in the event of a disaster (Clark *et al*., 1998; Cutter *et al*., 2003; Cutter and Morath, 2013). Clark *et al*. (1998) states that illness can intervene with any actions taken to reduce vulnerability.
19	Percent aged 5 years or below	Children and infants are one of the most stressed demographic groups affected the most by disasters (Cutter *et al*., 2003). For example, parents lose money when caring for the children when day care and school systems are affected (Boruff *et al*., 2005; Finch *et al*., 2010).
20	Percent aged 65 years and above	Elderly populations are the one of most affected demographic groups (Cutter *et al*., 2003). Elderly populations require more attention because they have more mobility constraints than other age groups (Cutter *et al*., 1997, Cutter *et al*., 2003).
21	Percent households with orphans	Child care is a critical activity during a crisis and the resources available to a household are affected by the number of children in that household therefore social vulnerability increases with many child-headed households (Fothergill, 1996; Heinz Center for Science Economics and the Environment 2000; Cutter *et al*., 2003).
22	Percent child-headed households	Child care is a critical activity during a crisis and the resources available to a household are affected by the number of children in that household therefore social vulnerability increases with many child-headed households (Fothergill, 1996; Heinz Center for Science Economics and the Environment 2000; Cutter et al., 2003). Children, especially in the youngest age groups, cannot protect themselves during a disaster because they lack the necessary resources, knowledge, or life experiences to effectively cope with the situation (Martin *et al*., 2006; Flanagan *et al*., 2011).
23	Percent female-headed households	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities (Blaikie *et al*., 1994; Cutter, 1996; Enarson and Morrow, 1998; Enarson and Scanlon, 1999; Morrow and Phillips, 1999; Fothergill, 1996; Morrow, 1999; Cutter *et al*., 2003; Finch *et al*., 2010).
24	Primary education	People with higher levels of education are likelier to have access to and act upon varied hazard information from preparation to recovery (Tierney, 2006; Cutter and Morath, 2013). Education is thus linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings (Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*, 2003; Tierney, 2006).
25	Secondary education	Different occupations require different education levels and skills and produce different levels of income. Lower education constrains the

		ability to find good jobs and understand warning information and access to recovery information (Heinz Center for Science, Economics, and the Environment, 2000; Cutter *et al*, 2003; Tierney, 2006).
26	Access to piped water	Households that lack basic sanitation facilities such as toilet and piped water are social vulnerable and often live in poor housing conditions (Chen *et al*., 2013b; Sajjad and Jain, 2014).
27	Access to roads	Access to roads is important during and after disasters. Effective disaster response needs good infrastructure (Rygel, 2006)

The 27 variables were standardized (Cutter *et al*., 2003; Yoon, 2012) and input into Statistical Package for Social Sciences (*SPSS*) to carry out a principal components analysis (PCA) in order to reduce the number of variables into a smaller set of multi-dimensional components. The PCA procedure reduced the 27 variables into eight components explaining 80.95% of the variance. Only components with *eigenvalues* greater than 1.0 were extracted and named to indicate the latent variable. The components were then summed with equal weights to create a final social vulnerability index (SoVI) score. In the absence of any theoretical justification for the weighting of components, the equal weighting and additive approach seemed the most practical (Cutter *et al*., 2003; Schmidtlein *et al*., 2008). The SoVI scores for each community council were then mapped in ArcGIS, as standard deviations to represent relative social vulnerability levels where higher scores represent higher social vulnerability. The exact procedure for duplicating the SoVI can be found at http://webra.cas.sc.edu/hvri/products/sovi.aspx.

The socioeconomic variables used in the current construction of the SoVI reflect certain social and economic characteristics of communities that influence social vulnerability. However, the intersection of the variables is of paramount importance given the multi-dimensional nature of social vulnerability. Thus, the PCA procedure captures this dimensionality by converting the raw datasets to a new set of independent variables (principal components). Each component explains a proportion of the total variance of the dataset, and the larger variance a component explains the more information it contains (Field, 2012). More importantly, PCA enables a few components to represent the multi-dimensional data, and makes it easier to identify the underlying factors (Jolliffe, 2005; Abdi and Williams, 2010; Chen *et al*., 2013a).

6.1.2 Identifying social vulnerability at the community council level

As a default, the total number of components constructed by PCA is equal to the number of input variables (Table 6.2). However, not all of these components explain a significant portion of the variance. As a result, this research applied the Kaiser Criterion for the extraction of factors. According to Kaiser's (1960) rule, an appropriate threshold for component extraction includes those components having an *eigenvalue* greater than 1.00 (Table 6.2). Such a limit dictates which components significantly contribute most to the overall variance (Kaiser 1960; Joliffe 2002; Bernard 2006; Field, 2012). Upon the completion of the PCA, all components not meeting the Kaiser Criterion were eliminated from further analysis. Additionally, the threshold for the extraction of components was determined by examining a scree plot for major significant drops in *eigenvalues* (Figure 6.1). From the scree plot it can be observed that there is a fall in *eigenvalues* between component eight and nine. Upon further examination, it was found that the *eigenvalue* dropped from 1.2 to 0.99. As a result, the researcher chose to extract only the first eight components (those with *eigenvalues* greater than 1), and this is the number of components that were retained in the final analysis. The factor loadings were then inspected in each individual principal component.

Table 6.2: Variance explained by the components after the Principal Component Analysis and Varimax rotation.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.892	25.525	25.525	4.007	14.842	14.842
2	3.188	11.808	37.333	3.152	11.675	26.517
3	2.900	10.741	48.074	3.070	11.371	37.887
4	2.589	9.588	57.662	2.800	10.369	48.257
5	1.984	7.346	65.008	2.708	10.031	58.287
6	1.668	6.179	71.187	2.351	8.708	66.995
7	1.433	5.308	76.495	2.029	7.513	74.508
8	1.202	4.452	80.948	1.739	6.439	80.948
9	.998	3.697	84.645			
10	.928	3.438	88.083			
11	.805	2.980	91.063			
12	.633	2.345	93.408			
13	.479	1.773	95.181			
14	.303	1.123	96.305			
15	.245	.908	97.212			
16	.197	.731	97.943			
17	.169	.625	98.568			
18	.155	.575	99.143			
19	.098	.361	99.504			
20	.064	.239	99.743			
21	.044	.164	99.907			
22	.014	.051	99.958			
23	.011	.042	100.000			
24	2.463E-16	9.122E-16	100.000			
25	2.335E-17	8.650E-17	100.000			
26	-3.754E-17	-1.390E-16	100.000			
27	-6.027E-16	-2.232E-15	100.000			

Extraction Method: Principal Component Analysis.

Source: Author’s own data

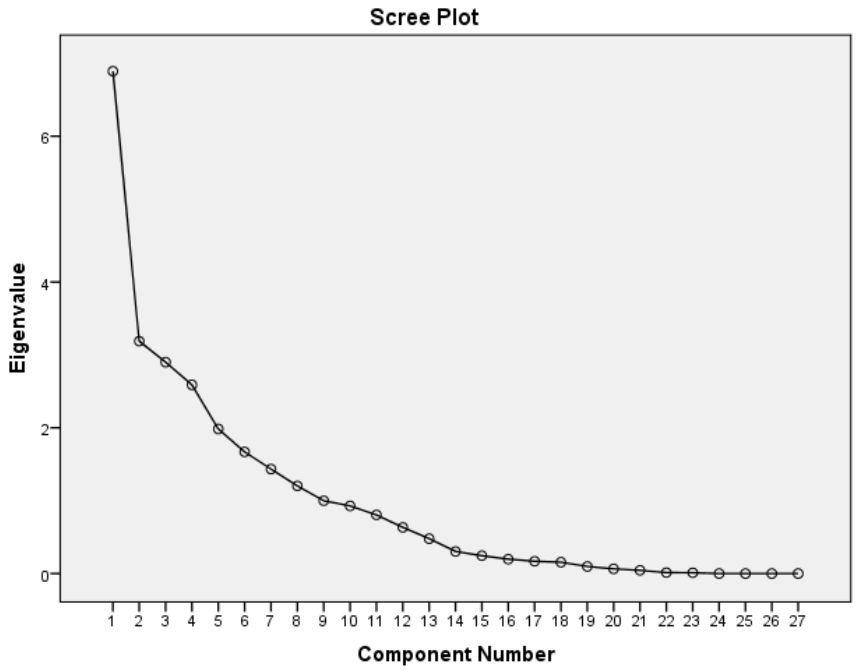

Figure 6.1: Scree plot for Quthing and Mohale's Hoek SoVI factor analysis.
Source: Author's own data

The retained components are significant for the degree of saturation in the variables corresponding to the goal of the study, based on the *Eigenvalue* > 1 criteria. The commonalities output from the PCA in Table 6.2 indicates that SoVI score explains the largest percent of variance in the first component at 25.53% and explains percent of variance in: the second component at 11.81%, third component at 10.74%, fourth component at 9.59% and the fifth component at 7.35%. Among the lowest commonalities are the sixth component at 6.12%, the seventh component at 5.31% and the last component at 4.45% (Table 6.2). The final order of the extracted components indicates the amount of variance explained by each, with the first component contributing the most and the last component contributing the least, comparatively to simplify the underlying structure of the dimensions and to produce more statistical independence between them.

6.2 SoVI results

The extracted components highlight specific characteristics of social groups that might be vulnerable to natural hazards. Each component was assigned a sign denoting the positive or negative effect on social vulnerability based on the dominant variables on each component (Chen *et al*., 2013b). Only those variables with the largest absolute loadings

(greater than or equal to 0.5) were recognised as the main drivers in the corresponding component (Jolliffe, 2005; Holand and Lujala, 2013).

Table 6.3 presents those variables, indicating loadings equal or greater than 0.5, and displays the variables used in the PCA and the resulting extraction value, which measures the communality between an individual variable to all other variables. Numbers range from 0.0 to 1.0. The higher the number the more variance is part of the extracted principal components (Armas and Gavris, 2013; Chen *et al*., 2013a). After calculating the overall vulnerability score for each community council they were standardised then ranked in such a way that positive values indicated high vulnerability scores while negative values indicated lower scores of vulnerability.

Table 6.3: PCA rotated component matrix

	Component							
Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total population			.782					
Average population per village				-.550				
Population density							.687	
Average households size								.550
Number of households			.619					
Percentage of female population			.775					
Percentage of female-headed households				.961				
Percentage of child-headed households		.785						
Percentage of population aged 5 years and below				.961				
Percentage of the population aged 65 years and above		.840						
Percentage of total orphans		.776						
Percentage of households receiving social support					-.659			
Percentage of people dependent on home-based care					-.708			
Percentage of households with agricultural plots								.817
Percentage of households with toilets	.688							
Percentage primary education			.807					
Percentage secondary education						.804		
Percentage of households with access to piped water							.693	
Percentage of villages without road access							-.696	
Percentage of households with electricity connection								
Percentage of households with radios	.791							
Percentage of households with mobile phone					.696			
Percentage of households with no income					.516			
Percentage of households with trade as source of income	.747							
Percentage of households with formal employment income	.903							
Percentage of households with farming income						-.692		
Percentage of households with over M1000 ($100 US) income per month	.718							

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalisation.[a]
a. Rotation converged in 17 iterations.

Subsequent to Booysen's (2002) suggestion, each of the variables was evaluated based on its theoretical effect on the overall construct of social vulnerability for the assignment of cardinality pre-adjustment. After performing the PCA procedure in *SPSS*, the eight components with *eigenvalues* greater than 1.0 were extracted and then named to indicate the latent variable based on the loadings of variables in each component and also based on

expert judgement from disaster management officials (Table 6.4). The eight driving factors affecting social vulnerability in the study region include access to resources, vulnerable population groups, population density, family structure, economic status, employment, access to services and rurality. The individually adjusted variables and their directionality were made to reflect their known influences on social vulnerability as derived from the empirical literature (Twigg, 2001; Cutter *et al*., 2003; Blaikie *et al*., 2005; Wood *et al*., 2010; Yoon, 2012; Armas and Gavris, 2013; Cutter and Morath, 2013). Thus, a positive directionality was allocated to components believed to increase social vulnerability (e.g. orphans, females, elderly), whilst a negative directionality was assigned to components known to decrease vulnerability (e.g. income, employment, education, wealth).

The components were then processed to insure that their contribution to the final social vulnerability index would be in a manner consistent with their theoretical basis. For instance, the economic status component, which had negative loadings for the percentage of households receiving aid and households dependent on home-based care in a community council, and positive loading for the percentage of households without monthly income. Both the presence of people dependent on social protection and support, as well as the households without income, are understood to contribute to social vulnerability; therefore the absolute value of the component was taken.

Table 6.4: List of significant components and their adjusted loadings.

Factor	Cardinality	Name	% variance explained	Dominant variables	Component loading *
1	-	Access to resources	25.525	Households with toilets	-0.688
				Percent households with radios	-0.791
				Percent households with trade income	-0.747
				Percent households with formal employment	-0.903
				Percent households with income over M1000.00 ($100 US)	-0.718
2	+	Vulnerable population groups	11.808	Percent child-headed households	0.785
				Percent population 65 years and above	0.840
				Percent orphans	0.776
3	+	Population density	10.741	Population	0.782
				Number of households	0.619
				Percent female population	0.961
4	+	Family structure	9.588	Population per village	0.550
				Female-headed households	0.961
				Population aged 5 years and below	0.961
5	+	Economic status/social dependency	7.346	Percent households receiving social support	-0.659
				Percent people dependent on home-based care	-0.708
				Percent households with cell phones	0.696
				Percent households with no income	-0.516
6	+	Employment	6.179	Percent primary education	0.804
				Percent households with farming income	0.692
7	+	Access to services	5.308	Population density	0.687
				Percent households without access to piped water	0.693
				Percent villages without access to roads	0.96
8	+	Rurality	4.452	Average household size	0.550
				Percent households with agric. fields	0.817
		Cumulative variance explained	80.948		
Equation for SoVI = -Factor 1+ Factor 2 + Factor 3 + Factor 4 + Factor 5 + Factor 6 + Factor 7 + Factor 8.					

Component 1 (access to resources) is an indication of access to resources. As shown in Table 6.4 the dominant factors in this component are those that theoretically decrease social vulnerability (percentage of households with toilets and radios, those earning income from trade activities, those with formal employment, and those earning M1000.00 ($100 US) and above per month), and have a significant negative factor loading. Thus, the cardinality of this factor remains negative (-) as the sign on the factor loadings for individual variables is consistent with their tendency to reduce social vulnerability. Component 2 is an indicator of vulnerable groups (e.g., the old and the young). As it can be observed, the old and the young, as well as their proxies (orphans) embody the dominant factors. In examining the variables' factor scores, one can see that they all demonstrate positive factor loadings, and all of the variables (child-headed households, population aged 65 years and above and percentage of orphans) have a tendency to increased vulnerability, hence a positive value was maintained in Component 2 and the cardinality of the variables remained with positive loadings.

Likewise, some components may demonstrate significant negative factor loadings on variables that theoretically increase social vulnerability. Components 4 (family structure), 5 (economic status/social dependency) and 6 (employment) are such examples. With negative loadings on total population per village and percentage of population aged five years and below. For Component 5 there are negative loadings on variables such as percent of households receiving social support, percentage of the population dependent on home-based care and percentage of households with no income. To adjust the sign of these components so that these variables appropriately represent their tendency to increase social vulnerability, a positive cardinality was applied and the components multiplied by 1. If a component showed a high positive value for a factor that tends to indicate low social vulnerability, the sign was changed for that factor. For instance, if a community council had a positive value under the factor representing economic status (e.g., households with formal employment (0.903), that value was changed to a negative value (-0.903), thus decreasing the overall social vulnerability score of that community council. All these components have been linked to social vulnerability in past research on natural hazards (Cutter *et al*., 2003; Fekete, 2011; Jankowska *et al*., 2012).

The 8 processed components were then summed with equal weights to create a final social vulnerability index, and mapped by using standard deviation classification so that the relative social vulnerability of each community council could be identified. The component scores can be interpreted as linear combinations of the original variables within each component category. The multidimensional components and the level of explained variance in this present study are consistent with other SoVI studies for different countries (Cutter *et al*., 2003; Boruff *et al*., 2005; Ebert *et al*., 2007; Finnis and Johnston, 2007; Ebert *et al*., 2009; Fekete, 2009; Lowe, 2010; Holand *et al*., 2011; Schmidtlein *et al*., 2012).

6.2.1 Social vulnerability components for Mohale's Hoek and Quthing

The first component accounted for 25.5% of the total variance. This component is a reasonable representation of 'access to resources'. The major factors contributing to access to resources are a combination of employment and income, and are constructed from economic activities engaged by households and communities for their survival. In this component, the summary of the negative value loadings (reduced vulnerability) representing access to resources represents income and employment related characteristics of a place. It reflects community's access to economic resources and is associated with formal income sources and household amenities such as toilets and radios. The dominant variables in this component include: percentage of households with formal employment (-0.903) being the most significant factor, percentage of households with radio sets (-0.791), percentage of households receiving income from trading (-0.747), households with toilets (-0.688) and percentage of households with monthly income of over M1000.00 ($100 US) (-0.718). This component is thus associated with factors that increase resilience and reduced vulnerability levels.

The second component explained 11.8% of the variance and was named 'vulnerable population groups', it includes variables such as: percentage of child-headed households (0.85), population aged 65 years (0.840) and percentage of orphans (0.779). This component consists of variables that are strongly associated with high levels of vulnerability and susceptibility to natural hazards. The number of child-headed households and dependent population in a household were significant variables in this component.

This component consists of vulnerable population groups which are normally economically inactive, dependent on social protection and having fewer financial resources. The dependency is gathered from the number of child-headed households, elderly and orphans, with the assumption that these groups are not physically and economically active and have fewer economic resources and hence more vulnerable as they would require assistance during emergencies. This group also has fewer or no financial and physical assets to buffer against future shocks.

The third component was interpreted as a measure of population density and includes factors such as: total population in a community council, total of number of households in a community council and percentage of female population. This component, accounted for 10.7% of the variance explained. This component was not straightforward; however, it was interpreted as a measure of population density because the two first variables are a proxy of population density. The dominant variables in this component include: percentage of the female population (0.961), total population (0.782) and total number of households (0.619). Population size, density and the extent of urbanisation are essential contexts for viewing vulnerability to hazards. Densely populated urban areas have vast infrastructure developments and large populations at risk. In contrast, Cross (2001) argues that small cities and rural communities, which by definition have a lower population density, are more vulnerable to disasters because small and scattered populations have fewer resources to deal with natural hazards and disasters than large cities and urban localities. While urban areas have a higher probability of experiencing natural hazard events, particularly localised events such as tornadoes, flash floods and landslides, than would smaller communities, those events when they occur in the smaller communities typically affect a much larger share of the community (Huppert and Spark, 2006; Fekete, 2011). Thus, smaller rural communities have far smaller populations at risk, but often far higher proportions of their populations would be victims during disasters, a situation that can be exacerbated in a small country like Lesotho or in small villages in remote areas.

The fourth component, ‘family structure’, explained 9.6% of the variance and the most dominant variables include: percentage of population aged five and below (0.961), percentage of female-headed households (0.961) and population per village (0.550). Females and female-headed households are often associated with poverty and with greater

responsibilities of childcare and caring for the elderly or sick (Pavarini *et al*., 2009). Female-headed households and families with large numbers of dependents (five years and below) often have limited financial resources and this affects their resilience to and recovery from natural hazards. In Lesotho, the percentage of female-headed and child-headed households is increasing (increased by 20% from 1996 to 2006) and female-headed households often live in poverty at twice the rate of male headed households (Mapetla, 2011).

The fifth component, 'economic status', explained 7.3% of the variance and consists of variables such as: percentage of people dependent on home-based care (0.708), percentage of households with mobile phones (0.696), percentage of households with no income (0.692) and percentage of households receiving social support (0.659). In most instances the more prosperous and affluent communities have diverse economic options, such as formal employment and regular income as well as luxury commodities such as mobile phones. This implies more financial resources for mitigation measures, compared to the lack of income and dependence on social support for economically vulnerable households. Dependency on social support does not automatically make an individual or household poor, however, it is a dependable common indicator for average income in any community (Cutter *et al*., 2003; Enarson, 2007). During field visits it was observed that the majority of low- and no-income households were less educated, dependent on social support and home-based care for critically ill household members, and did not own luxury goods such as mobile phones. Lack of financial resources depicted by this component can contribute to social vulnerability because it affects mitigation measures that can be afforded to increase resilience and reduce vulnerability. Where the economic status is high, residents generally have more resources and are more resilient and able to cope with or mitigate natural hazards. In Lesotho, people receiving social support are often the most economically disadvantaged, and depend on food aid from the government or NGOs, and do not have any regular income. Meanwhile, people dependent on home-based care are often critically ill and are mostly TB and HIV/AIDS patients, often unable to take protective actions and requiring outside assistance to do so (Tapsell *et al*., 2010).

The sixth component accounted for 6.2 percent of the variance and was labelled 'employment' because it explains the variations in education level and type of

employment. The dominant variables in this component were: percentage of household heads with primary education (0.804) and percentage of households dependent on farming income. Those households relying mainly on agriculture for their livelihoods are vulnerable in particular to climatic shocks, such as frost, droughts and floods, sometimes with more than one of these calamities taking place in the same year. Educational attainment is closely related to improved skills and formal employment opportunities. According to Leichenko *et al*. (2002), increased overall literacy levels reduce vulnerability by increasing people's capabilities and access to information, thereby enhancing their ability to cope with adversities. In the study area vulnerability of the farming households is the result of their exposure to climate shocks and extreme events as well as the sensitivity of farming to these events in terms of both direct impacts on crop yields and indirect livelihood impacts, and the capacity of households to adapt and adjust to protect themselves from future harm. Therefore, better education typically implies better access to relevant information, such as early warnings of frost or seasonal prediction of drought (Patt *et al*., 2007, Moser and Ekstrom, 2010).

The seventh component accounted for 5.3 percent of the explained variance, and was named 'access to services', explaining the differences in: villages without access to roads (0.96), households without access to piped water (0.93), and population density (0.68). Communities with good infrastructure are more resilient to natural hazards, particularly in terms of access to essential services (Dunno, 2011). Community councils with low levels of access to basic services are thus more vulnerable. Additionally, many rural households in Lesotho and the study area in particular are marginalised by lack of access to piped water supply. During field visits it was observed that many people in the rural areas remain marginalised from access to services such as piped water, electricity, basic sanitation and roads. This not only results in household activities being centred on the collection of water (often a strenuous and timely task for women and children), but also means that they may rely on unsustainable and unclean water resources. Lack of access to essential services such as roads and clean water contributes substantially towards vulnerability to natural hazards (Fekete, 2009). Inaccessibility to roads implies infrastructure deficiencies in community councils, which could lead to inaccessibility after hazardous events and may hamper recovery efforts during and after emergencies. Being able to receive relief services during the recovery period is vital for safety and resilience.

The last component accounted for 4.45 percent of the explained variance and was named 'rurality'. The two dominant variables in this component were percentage of households with agricultural fields (0.817) and average household size (0.55). This component was named thus because most rural areas in Lesotho have larger households, own agricultural fields and depend mainly on subsistence agriculture for their livelihood. The majority of rural households in the study area depend mainly on crop farming, which is very sensitive to natural hazards such as drought, flooding and severe frost. Furthermore, the current rural-urban migration of young adults has a negative impact on agricultural productivity in the rural areas. The absence of physically abled household members reduce the agriculture labour supply and productivity in the rural areas, hence food insecurity and loss of income. Rural areas are also associated with limited economic opportunities, inaccessibility and poor education facilities, as well as disadvantages rooted in social and political inequalities (IFAD, 2011).

6.2.2 Statistical results

Through adding the component scores together and standardising the resulting value, each community council was given a score representative of its social vulnerability in relation to the 24 community councils throughout the study region. The analysis shows that most of the areas with the lowest social vulnerability index scores are the urban and peri-urban areas (Table 6.5). These areas also corresponded almost entirely to access to resources, economic status, access to services, small percentages of people dependent and home-based care, and relatively developed infrastructure (access to roads and existence of water systems). On the one hand, areas with the highest social vulnerability index scores are prevelant in the inaccessible rural highlands and consist of places with large proportions of vulnerable population groups (large percentages of child-headed households, population aged 65 years and above as well as orphans). The variables reveal changes in family structure in Lesotho which is mostly associated with HIV deaths, and this has increased vulnerability and dependency levels of the elderly population and young population in the country.

Table 6.5 presents calculated SoVI scores for the study area from most vulnerable to least vulnerable community councils. The two rural and highland community councils of

Matsatseng and Thabana Mokhele exhibit the highest levels of social vulnerability (1 and 0.84 respectively). High SoVI scores in these areas are a result of low economic status, limited access to services, underdeveloped infrastructure and dependency on subsistence farming. Vulnerability in these areas is influenced largely by inaccessibility and rugged mountainous terrain. In contrast, Mashaleng has a relatively low SoVI score (-0.07) compared to other community councils. Additionally, Mootsinyane (0.04), Teke (0.09), Liphakoe (0.13), Qhobeng (0.14), Khoelenyane (0.19), Qomoqomong (0.23) and Nkuebe (0.24) are other community councils with relatively low SoVI scores. Most of these community councils are situated in the urban and peri-urban lowlands and are geographically accessible. The two urban and lowland community councils of Khoelenya (Mohale's Hoek) and Liphakoe (Quthing) exhibit relatively low SoVI scores (0.19 and 0.09 respectively). Liphakoe and Khoelenya have access to resources and services (developed infrastructure and diverse livelihood options and job opportunities), low unemplomentrates, and a relatively large proportion of literate population with formal employment, and earning regular incomes.

Table 6.5: Social vulnerability index score (SoVI) from most vulnerable to least vulnerable community councils.

Community council	**SoVI scores**	**Rank**
Matsatseng	1.00	1
Thabana Mokhele	0.84	2
Mphaki	0.67	3
Likhutloaneng	0.61	4
Nkau	0.60	5
Likhohlong	0.48	6
Seforong	0.48	6
Seroto	0.45	7
Tsatsane	0.39	8
Qobong	0.39	8
Siloe	0.34	9
Motlejoeng	0.33	10
Mkhono	0.31	11
Mokotjomela	0.31	11
Qabane	0.29	12
Phamong	0.28	13
Nkoebe	0.24	14
Qomoqomong	0.23	15
Khoelenya	0.19	16
Qhobeng	0.14	17
Liphakoe	0.13	18
Teke	0.09	19
Mootsinyane	0.04	20
Mashaleng	-0.07	21

Agriculturally, the urban communities of Khoelenyane and Liphakoe also had fewer households owning agricultural fields and very few households dependent solely on agricultural income. Community councils showing moderate levels of SoVI scores are Seforong, Likhohlong, Mphaki, Qomoqomong and Mokotjmela in Quthing and Qobong, Nkau, Siloe and Seroto in Mohale's Hoek. A few of these (Mokotjomela and Siloe) have reasonable infrastructure developments such as tarred roads, piped water and electricity connection. Although each of these community councils may have a larger proportion of their population exhibiting high levels of social vulnerability, based on one or two variables, for the most part, they tend to exihibit relative homogeneity when comparing variables used to generate the study area's social vulnerability index.

The deduction of the level of social vulnerability in the study area so far has been based on statistical methods, but also semi-structured expert interviews were conducted with disaster management officials to select the most vulnerable community councils in the study area. There were some discrepancies between the computed rankings of the most socially vulnerable community councils and those provided by the disaster management officials (Table 6.6). The expert evaluation of community council vulnerability is based on their perception of vulnerability. The differences between the statistically computed rankings of social vulnerability and those by officials were mainly a result of the rural-urban dichotomy. The interviews with the officials in each district highlighted two discrete points:

1. Normally rural communities are remote, less developed and as result more likely to be negatively impacted by natural hazards, as relief efforts are often delayed. As such, rural communities are more vulnerable.
2. Urban areas offer a range of livelihood options and have better paying formal jobs, facilitating the ability to acquire assets necessary in buffering against natural hazards. Moreover, as is the case in Liphakoe and Motlejoeng, the large urban and administrative centres have good infrastructure (roads and telecommunication networks) through which humanitarian aid can be brought in, thus increasing the residents' chances of receiving aid and early warning information before, during and after emergencies. Hence, urban residents are less vulnerable.

Table 6.6: Social vulnerability ranking per district

District	Community council	Calculated ranking	Expert ranking
Quthing	1. Likhohlong	3	1
	2. Ha Nkoebe	8	6
	3. Liphakoe	10	9
	4. Matsatseng	1	7
	5. Mphaki	2	5
	6. Mokotjomela	7	8
	7. Qomoqomong	9	4
	8. Seforong	4	2
	9. Mkhono	6	3
	10. Tsatsane	5	10
Mohale's Hoek	1. Siloe	6	10
	2. Khoelenya	10	11
	3. Motlejoeng	7	13
	4. Nkau	3	1
	5. Phamong	9	5
	6. Mootsinyane	13	6
	7. Likhutloaneng	2	3
	8. Qabane	8	2
	9. Qhobeng	11	7
	10. Seroto	4	8
	11. Teke	12	4
	12. Qobong	5	9
	13. Mashaleng	14	12
	14. Thabana Mokhele	1	14

(1= greatest and 13= least) by officials and calculated.

According to the government officials, Likhohlong is the most vulnerable community council, followed by Seforong and Mkhono in the Quthing district. The least vulnerable is Tsatsane, followed by Liphakoe and Mokotjomela. In the Mohale's Hoek district, the most vulnerable is Nkau followed by Likhutloaneng and Teke. The least vulnerable is Motlejoeng, followed by Mashaleng and Khoelenya. Although officials may provide helpful insight into the local production of social vulnerability and resilience levels, it

should be noted that their judgement might be biased. Though the expert judgment is not certainly the supreme, it somehow offers one version of reality. Similarly, statistical analysis has some disadvantages, as reliance on numerical data restricts the ability to capture all components of the system. Based on the qualitative expert-based method indicated in Table 6.6, which involves assigning rankings according to expert's opinion, the research deemed that, infrastructure development and economic variables make an equal contribution to raising the general level of social vulnerability in the study area.

6.3 DETERMINING THE SPATIAL DISTRIBUTION OF SOCIAL VULNERABILITY

The SoVI is a spatial measure and does not have a specific unit of measurement, rather its significance is in its comparative value across geographic locations, not its absolute value (Cutter and Finch, 2008). The component scores for each of the eight components were thus mapped to demonstrate the spatial patterns of social vulnerability within each district and community council. Therefore, when interpreting social vulnerability, high SoVI scores define those community councils with high social vulnerability levels, whilst community councils with low social vulnerability levels have lower SoVI scores. The community councils with high levels of social vulnerability were displayed in red, while the community councils with lower levels of social vulnerability were displayed in blue in *ArcGIS 10.1* and *GeoDa*.

To show the geographical patterns of social vulnerability in the study area the SoVI scores were mapped in Figure 6.2 as standard deviations in *ArcMap*, with five categories ranging from less than -1.5 (least vulnerable) to >1.5 (most vulnerable). The standard deviation was chosen as an ideal mapping technique because it demonstrates how much variation in the vulnerability index scores there is from the mean vulnerability index score.

To establish the patterns of similarity and dissimilarity in the clustering of social vulnerability, spatial autocorrelation among community councils were examined (Anselin, 2005a). To assess geographic variability of results, the *Local Moran's I/LISA* (local indicators of spatial association) statistics analyses was conducted in the Open *GeoDa* software (Anselin *et al*., 2006). To present a more defined understanding of the distribution of social vulnerability, the spatial patterns observed at the community council

level were measured for spatial autocorrelation. Potential clusters of social vulnerability were established, one for the least vulnerable and the other for the most vulnerable category. To verify these results, a "hot spot" analysis was also performed (Armas and Gavris, 2013). This statistical spatial technique is used to identify clusters of areas with higher or lower values than expected by random chance alone, by looking at each unit of analysis in the context of neighbouring units (Anselin *et al*., 2006; Cutter *et al*., 2008).

It is important to note that spatial statistics are intrinsically flawed because, as Tobler's First Law of Geography explains, objects near each other are more related than those further from each other (Tobler, 1970). This principle appears in real-world examples and creates inbuilt spatial autocorrelation in spatial statistical analysis, which violates the main basis of independence in statistics (Tiefelsdorf, 2000; Finch *et al*., 2010; Schmidtlein *et al*., 2012). However, *Moran's I* and other measures of autocorrelation used in this study are tools for identifying both spatial homogeneity and heterogeneity (Anselin, 2005b; Ward, 2012). Therefore, results of the *Moran's I* were evaluated with caution and used to pinpoint interesting clusters for exploratory purposes only.

The SoVI scores (Table 6.6) were mapped in *ArcMap* using standard deviation classification (Std. Dev.) to show the spatial variability of social vulnerability across the study area (Figure 6.2). Three potential clusters of social vulnerability emerged in Figure 6.2: the most vulnerable community councils were clustered mostly in Mohale's Hoek, the least vulnerable community councils were also predominantly in the Mohale's Hoek district and clustered in the west and central parts of the study area and moderate levels were largely in the central part of the study area. Generally, Quthing exhibited clusters of moderate and low vulnerability levels. Spatial patterns of high social vulnerability are visible in the rural highlands of Teke and Thabana Mokhele community councils as well in Matsatseng (> 1.5 Std. Dev.). Other areas of high vulnerability (0.5 to 1.5 Std. Dev.) are also found in the rural areas, extending to the highlands in both districts (Likhutloaneng, Nkau and Mphaki). Areas of low social vulnerability (<-1.5 Std. Dev.) are found in Mashaleng in Mohale's Hoek. Areas exhibiting moderately low vulnerability levels are found in both districts, mostly in the urban lowlands and foothills (Mootsinyane, Nkoebe, Liphakoe and Khoelenya). There is a significant and strong cluster of community councils exhibiting moderate levels of social vulnerability (from -0.5 to 0.5 Std. Dev.), mostly in

the central part of the study area (Mkhono, Mokotjomela, Phamong, Qobong, Seforong, Seroto and Tsatsane). There is a moderate spatial clustering of medium-low SoVI (-1.5 to -0.5 Std. Dev.) in Khoelenya, Mootsinyane, Liphakoe and Qomoqomong.

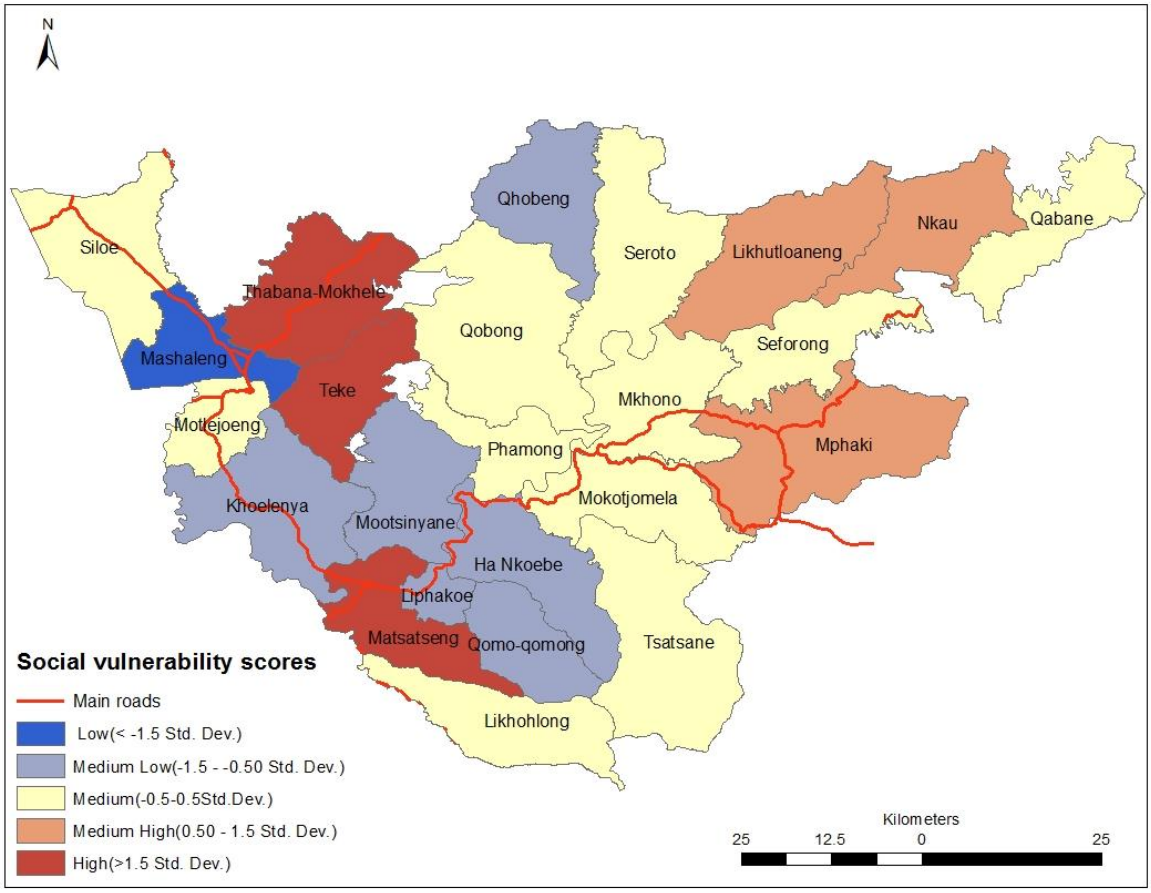

Figure 6.2: Spatial distribution of social vulnerability in Quthing and Mohale's Hoek
Source: Own data

The remaining highlands and some foothills communities of Seforong, Qabane, Likhohlong, Qhobeng and Nkau have medium levels of social vulnerability (-0.5 to 0.5 Std. Dev). Inaccessibility, lack of access to services and resources, dependency on climate sensitive agriculture and mountainous terrain worsen social vulnerability in the remote highland communities. The least vulnerable community councils of Motlejoeng and Liphakoe (< -1.5 Std. Dev.) are urban areas and are relatively well-off.

Concerns of high social vulnerability levels in both districts, mostly the rural highland areas and along the Senqu River valley, has been raised in other poverty related studies in Lesotho (Moeti, 1996; Sechaba, 2002; LVAC, 2010). Predisposition for high social

vulnerability in Matsatseng, Phamong, Mkhono, Seroto, Likhutloaneng, Nkau and Seforong, representing the Senqu River valley is a known problem (food insecurity, poverty and high unemployment rates), which has been worsened by recurrent droughts and severe frosts and a decline in agricultural productivity in this area. Here, the majority of households depend on subsistence farming, with no or low incomes. During field visits, it was observed that in the rural highlands, the population is aging, with large numbers of orphans, female and child headed households, who depend on social support and families living on irregular incomes and villages with poor infrastructure services.

6.4. FACTORS INFLUENCING SOCIAL VULNERABILITY IN LESOTHO

The social vulnerability scores for the study area were then explored in more detail with each of the factors contributing to the eight components examined spatially. A number of spatial patterns emerged in many of the variables; these patterns influenced the overall pattern of social vulnerability in the study area and lead to expectations about where pockets of high social vulnerability may be located. Therefore, it was essential to highlight the individual social vulnerability components that contribute to the overall SoVI score in Figure 6.2. By assessing the individual components, the main causes of social vulnerability in each community council can be clearly understood. The scores for each individual component are mapped separately and followed by an explanation of each of the components (Figures 6.3 and 6.5).

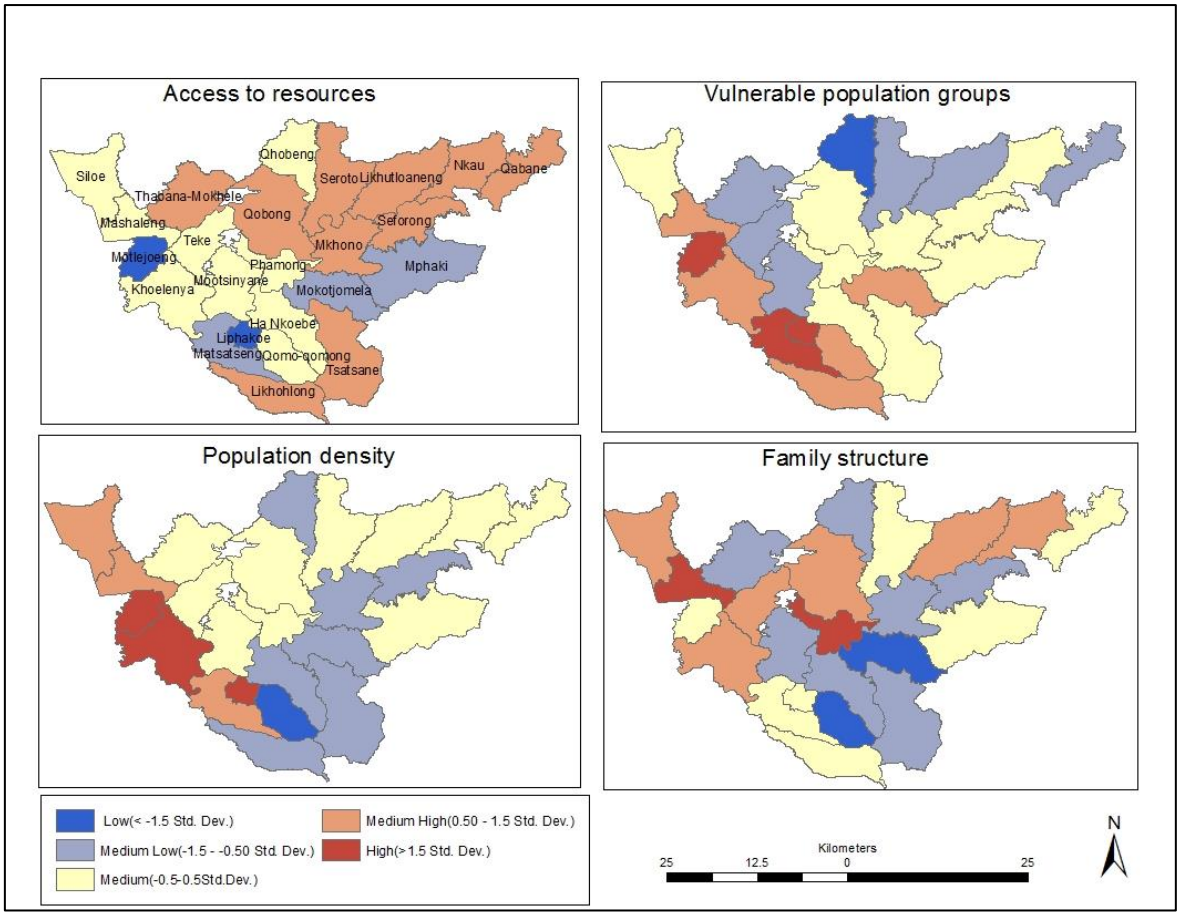

Figure 6.3: SoVI Components 1-4

6.4.1 Access to resources

The major factors contributing to access to resources' component are a combination of employment and income variables. Figure 6.3 demonstrates that the rural communities of Likhohlong, Seforong, Likhutloaneng, Tsatsane, Qabane and Mkhono have limited access to resources. The urban and administrative community councils of Liphakoe and Motlejoeng exhibit low SoVI scores in this component. Household interviews and field observations also confirmed that there were limited formal employment opportunities in areas with limited access to resources, hence high levels of poverty and social vulnerability. The results from the household survey further showed variations in access to resources and economic status in relation to gender, household size, livelihood patterns, access to basic services, infrastructure and geographic location. Previous studies (Turner, 2005; Sechaba Consultants, 2006; LVAC, 2009) carried out in the country have also demonstrated that the rural highlands of Lesotho, which are home to the majority of the

population, are significantly poorer than the more urbanised lowlands. The 2002 Core Welfare Indicator Study, which used an asset-based approach, also showed that extreme poverty is concentrated in the rural areas of Lesotho. During field visits the researcher observed that the majority of rural households were poor and were mainly concerned with how to get through another day. In Lesotho those people with formal employment and those earning over M1000 ($100 US) per month are often employed in secondary and tertiary industries and are generally paid more than those employed in primary industries such as farming, which is the most vulnerable because of its dependency on climatic conditions (Chen *et al*., 2013b).

At the global level, Lall and Deichmann (2009) found that poor people are exposed to natural hazards not only due to the increase in the probability of being hit by one, but also because of greater concentration in risky areas with high poverty levels and higher population densities. Increased disaster risks due to climate change are also expected to exacerbate poverty (Aubrecht *et al*., 2012). Generally, the poor are more susceptible to certain hazards due to lack of resources and their inability to recover quickly (Burton *et al*., 1993; Dasgupta, 1995; Fekete, 2012). Conversely, the wealthiest households may experience greater material losses during a disaster event, but this also enables them to absorb these losses through savings, insurance, social safety nets, and entitlements, and so recover more quickly from the hazard impacts. Lack of access to economic resources is a driving factor of high social vulnerability in the study area. Economic resources are essential for appropriate response to hazards. The extent to which people have sufficient resources to meet their basic needs and to anticipate and respond to inevitable change and disruption is a core factor in resilience, and it varies considerably among households and communities (Aubrecht *et al*., 2012). Poor households are more likely to be located in dangerous locations (e.g. in flood plains or near gullies), with sub-standard housing often in disrepair, and consequently greater vulnerability to natural hazards. Poor communities often do not have the infrastructure or resources to assist residents during crises (Yoon, 2012).

Vulnerability to natural hazards and its associated impacts in developing countries is caused and/or exacerbated by a number of household and community level factors. At the household level, livelihoods are often not diversified and are mostly characterised by a

heavy reliance on natural resources. In such countries, the poorest are more vulnerable because they have low or no security and very few options for income generating activities (Ulstrud *et al*., 2008; Adebimpe, 2011). Events such as hail or rain storms and localised floods often produce overwhelming effects on livelihoods in Lesotho. During such events, field crops and houses are destroyed. In most cases victims incur serious losses and thus become more vulnerable.

6.4.2 Vulnerable population groups component

This component indicated that three of the 27 variables were significant, including percentage of child-headed households, percentage population aged 65 years and older, and total orphans. Figure 6.3 demonstrates a high prevalence of vulnerable population groups in the urban and peri-urban lowlands. A large number of orphans and child headed households were observed in the urban lowlands during field visits, this emanates from the fact that in rural areas of Lesotho there still exists social networks and cohesion; consequently most orphans are taken care of by relatives and neighbours, hence low vulnerability scores for this component in the rural highlands.

However, in Lesotho, both orphans and people aged 70 years and above receive government's old age pension and child grant cash. The old age pension is given monthly, while the child grant is given quarterly to the poor households directly responsible for looking after vulnerable children. The child grant programme is part of a larger one to support orphans and vulnerable children (OVCs) by the government and its objective is to improve the living standards of OVCs (Kardan *et al*., 2014). These social grants only allow households to meet their basic needs but do not totally eliminate poverty. These grants therefore, can only prevent already poor households from falling deeper into poverty, as well as reducing the risk of those households on the brink of poverty from sliding back into it when faced with shocks. Most of the elderly people, more especially in elderly female-headed households, also take care of orphans; therefore, the increased responsibilities put pressure on financial resources. As a consequence, the majority of households have not been able to use their social grants to build assets or to reduce vulnerability. In this way social grants only have limited contribution in reducing household vulnerability.

6.4.3 Population density

This component consists of total population in a community council, percentage of female-headed households and total number of households per community council. For this component, high vulnerability scores are evident in the western part of the study area (Figure 6.3), which consists mainly of the urban and peri-urban lowlands. Medium vulnerability scores are visible in the central and eastern regions of the study area. The south eastern region, mostly in the Quthing district, has low vulnerability scores in this component. The spatial disparities presented in the population density map emanates from the rural-urban dichotomy, whereby low laying urban areas are most favourable for settlements as a result of arable land, economic opportunities and availability of services. Population densities are thus highest in larger urban lowlands whilst low population densities are found mainly in sparsely populated remote highlands. Population distribution and density serve as vulnerability indicators, since higher concentrations of people increase evacuation difficulties (McMaster, 1988; Cova and Church, 1997, Fekete, 2011). High population densities often trigger imbalances between population and resources. In Lesotho, increasing population growth and urbanisation in most urban areas have led to some developments in hazardous areas.

Additionally, the physical size of communities and villages influences both directly and indirectly the development activities and proximity of communities to services and reflect a certain level of importance at the local scale or justifies some investment expenditure (Istrate, 2008). A large settlement requires and develops activities and services that ensure more efficient self-adjustment mechanisms and the capacity to cope with crises (Jankowska, 2011). In contrast, small isolated villages and communities usually have a reduced ability to cope with crises. In the study area, small communities have fewer economic activities, schools or medical services, underdeveloped infrastructure and limited road access to/from small villages, and the economically active population often migrates from such areas to urban settings, leaving the elderly and young behind.

High population densities mean a greater exposure of people and property to natural hazards. Conversely, villages with low population densities often have fewer elements at risk. When disasters occur in densely populated areas the impact is likely to be more severe than it would be in areas with fewer people. More people will be in need of emergency services, such as food rations, water and medical care. Demands on existing

facilities and resources may be quickly overwhelmed, especially if climate change and other shocks force rural populations to migrate to urban areas, making densely populated regions most vulnerable. In addition, hazards and disaster incidents are often better reported in more populated urban areas than in remote rural areas. In urban settings hazard events are likely to be better reported because of the infrastructure and reporting mechanisms existent (Fothergill and Peek, 2004; Oxfam GB, 2011).

6.4.4 Family structure

The fourth component did not depict any particular pattern in terms of rural and urban disparities; however, the majority of community councils in the Mohale's Hoek district scored high in this component (Figure 6.3). Generally, the Quthing district exhibited low and medium scores in this component. Evident from the results, both districts have a large percentage of female and child-headed households and large sized families. On average, there were about seven members per household with an average of four children, about two of whom were below five years of age, yet household members over 65 were fewer (field observation). This shows that every household had about four members who were likely to have special needs during and after emergencies, especially during relief periods.

Currently, female-headed households are an increasing phenomenon in Lesotho and worldwide, and these households are often the poorest (Ray-Bennett, 2009; Mapetla, 2011). According to the World Health Organisation (WHO, 2007), women are more vulnerable than men because they are often underpaid, more likely to be self-employed or unemployed, and more likely to have agricultural based jobs. In most cases natural hazards wipe off much of the agricultural job sector, often for long periods. For instance, in Orissa, India, where 10% of households are female-headed, poverty is very prevalent and profound (Ray-Bennett, 2009). It has been reported that female-headed households in this area are also vulnerable to recurrent multiple disasters (floods, cyclone and drought). All these issues affect the resilience to and recovery from hazards. Households with large numbers of dependents (children aged five and below, as well as pensioners aged 65 years and above) and female-headed households often have limited finances to outsource care for dependents, and thus must manage work responsibilities and care for family members.

6.4.5 Economic status

This component includes variables such as percentage of households receiving aid, households dependent on home-based care, households with no income and households owning mobile phones (Figure 6.5). For this component, negative SoVI scores indicate community councils with low social vulnerability levels. These are generally community councils with the majority of their households earning regular income and fewer people dependent on social support (Liphakoe, Motlejoeng Phamong and Khoelenya). Conversely, the positive SoVI scores in this component represent vulnerable community councils (Thabana Mokhele, Nkau, Seforong and Tsatsane), with the majority of their households dependent on social support and not earning any regular income.

Dependency on social protection has gained substantial importance in many countries because of the rising levels of poverty and income insecurity. According to Barrientos and Hulme (2009), the World Bank conceptualises social protection as social risk management because it recognises vulnerability to natural hazards as a significant constraint on economic and human development, and the efforts to reduce the likelihood of hazards as essential for economic growth and development. However, these initiatives and others are only short-term responses (food aid) to natural hazards (drought), and there is no evidence that they will have a long-term positive effect on household vulnerability (Slater and Mphale, 2008).



Figure 6.4: Old age pension recipients and non-contributory cash transfer recipients.

Figure 6.4 shows recipients of the old age pension and cash transfer vouchers (approximately $50 US) in Teke (Mohale's Hoek). These initiatives to a certain extent

promote the problem of dependency, particularly dependency on government and NGOs. During interviews with government officials, they reported that they were aware of the dependency syndrome in the society and that there was a need to change people's mind-set towards self-reliance instate of dependency. Lesotho is not unique in this situation, the dependency syndrome has been reported in Botswana, Zambia, Ethiopia, Mozambique, Malawi, South Africa, Somalia and Zimbabwe (Nyanda, 1993; Sejanamane, 1993; Fissil *et al*., 2001; Babugura, 2005; Thebe, 2010; Emmanuel, 2011). For instance, in Zimbabwe, dependency syndrome has crept into most rural farmers, stifling their capacity to perform individually. This has disrupted national food security and instead of generating income from their produce, the farmers call for government assistance at the beginning of each farming season (Thebe, 2010, 2011). Although social protection provides relief for many households after a disaster, the disadvantage is that the majority of households that receive social or emergency support become accustomed to free hand-outs and give up on self-reliance. Therefore, there is a need for a sustainable solution to build resilient communities against recurring natural hazards in Lesotho.

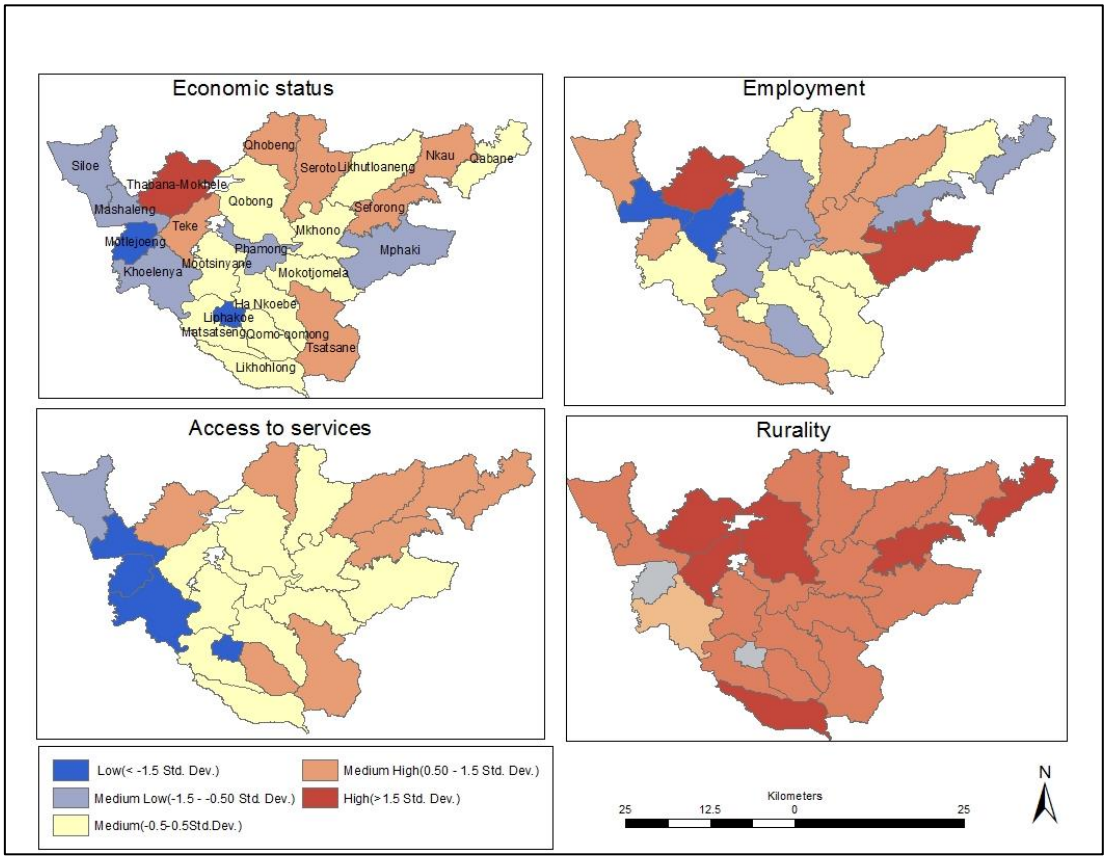

Figure 6.5: SoVI components 5-8
Source: Own data

6.4.6 Employment

The sixth component is made up of two variables: percentage of population with primary education and percentage of households dependent on farming income. The employment component map (Figure 6.5) illustrates that vulnerability is concentrated in the rural highlands (Likhohlong, Mphaki, Teke, Qobong, Qhobeng and Qabane), as well as in few foothill communities (Mootsinyane, Ha Nkoebe and Mokotjomela). Least vulnerable are the urban lowlands of Motlejoeng, Mashaleng and Liphakoe. As observed during field observations, the rural highlands and foothills had a relatively larger share of their households earning income from agriculture. Thus, the rural areas and foothills have a large share of households earning income from agriculture and agricultural workforce, and these variables reveal that these areas are highly vulnerable to natural hazard.

Different occupations require different education levels and skills and result in different levels of income. Less educated people and those with primary education are often employed in extractive industries such as farming. In this study, the least educated were mostly in the rural highlands and employed in the farming sector and these are regarded as the most vulnerable because of this sector's dependence on favourable weather (Cutter *et al*., 2003). Additionally, residents stated that there is often a potential loss of employment following drought, hail storms, severe frost and flooding, and this raises the number of unemployed workers in a community, contributing to a slower recovery from shocks. Reliance of rural households on rain-fed agriculture for a living is very common in rural southern Africa (Ziervogel and Calder, 2003; Thebe, 2010). A single reliance on one economic sector for income generation creates a form of economic vulnerability. Thus, the agricultural sector is no exception and is, perhaps, even more vulnerable given its dependence on climate. Any change in weather conditions or increases in hydro-meteorological hazards, such as flooding, drought, severe frost or hail, can affect annual and decadal incomes and the sustainability of the resource base for many rural communities. Although agriculture is conventionally the main economic activity in the study area it has been declining due in part to the recurring droughts and floods, and these has resulted in declining incomes and livelihoods, especially in rural areas of the country (Gwimbi *et al*., 2012; Matarira *et al*., 2013).

6.4.7 Access to services

Several variables in the seventh component relate to the level of access to basic services and infrastructure development in community councils. These include total population in a community council, access to piped water and access to roads. The community councils showing high levels of social vulnerability in this component were largely rural highlands with no access to roads and without piped water (Figure 6.5). Conversely, the larger urban settlements (Motlejoeng, Mashaleng and Liphakoe) demonstrate low social vulnerability levels, reflected in lower SoVI scores in this component. Community councils with the lowest infrastructure development include those in the remote and inaccessible rural highland areas (Tsatsane, Seforong, Qomoqomong and Thabana Mokhele). Therefore, in terms of access to services, urban areas and their peripheries are less vulnerable than the remote rural highlands.

Access to and availability of infrastructure services can reduce the impacts of natural hazards, because with well-developed infrastructural services, communities can receive early warning messages, take precautions and prepare for hazards even before they occur (Fekete, 2011). Access to services and infrastructure also facilitate good living standards in most communities. Rural highlands are the most vulnerable because rural transportation systems in the remote rural communities in Lesotho are often greatly impacted on by flooding and heavy snowfall. Though most are low-volume roads, these routes are often the only access to rural areas and isolated communities to bring goods and services. Closure or damage to these roads presents a major challenge to rural communities, as it can greatly hinder critical disaster-relief efforts and result in costly road repairs and inaccessibility.

Limited access to roads, low electricity connectivity and lack of communication infrastructure and clean drinking water contribute substantially towards vulnerability to natural hazards (Fekete, 2009). These add to infrastructure deficiencies in community councils, hindering resilience, preparedness efforts and awareness, consequently affecting emergency services during and after a disastrous event such as floods and heavy snowfall. Being able to receive and comprehend awareness or preparedness information, warning messages, and information about emergency services during the recovery period is vital for safety and resilience. During emergencies, people need accurate information about the

danger and behavioural options, and they need it quickly (Norris *et al*., 2008). Information and telecommunication services therefore, become vital in emergencies. Limited access to services restricts delivery of hazard warnings and instruction for safe action in the case of severe local storms and heavy snowfalls, especially in the rural areas of the study area.

Overall, rural areas are frequently presented in the literature as constituting a risk factor for social vulnerability because rural areas often have poor access to services compared to urban areas, and rural residents are often disadvantaged in terms of basic service (Krout and Bull, 2006). In contrast, urban areas offer many advantages, including greater access to essential services and good infrastructure (Moench and Dixik, 2007). Access to services component is closely related to the last component (rurality).

6.3.8 Rurality

The last component has two significant variables, namely, household size and percentage of households dependent on agriculture. In terms of rurality, the community councils that are considered highly vulnerable are Teke, Thabana Mokhele, Qobong, Seforong and Mphaki, all concentrated in rural highlands and the remaining rural community councils have medium-high vulnerability levels (Figure 6.5). High social vulnerability levels in the rural areas and foothills result from many of the inhabitants being dependent on subsistence farming and having large families. The least vulnerable community councils of Motlejoeng and Liphakoe are urban community councils with diverse livelihood options and with the majority of their population engaged in formal employment with relatively smaller families. Reliance of rural households on rain-fed agriculture for a living is very common in rural southern Africa (Bryceson, 1996; Ziervogel and Calder, 2003, Gwimbi *et al*., 2012; Matarira *et al*., 2013). However, Bryceson (2005) explains the process of de-agrarianisation and globalisation in sub-Saharan Africa where urban areas are becoming a loci of livelihood opportunities.

6.5 SPATIAL CLUSTERING OF SOCIAL VULNERABILITY

In order to explore spatial clusters of social vulnerability, the PCA results were further analysed in *ArcMap* and *GeoDa*, using spatial autocorrelations. The local spatial autocorrelations were examined for each component to see where the variations in social vulnerability occur within the study area. The main *GeoDa* output was a map of the significant clusters in Figure 6.6. Significant areas of high and low clustering or "hot/cold spots" were examined using a local *Getis Ord Gi** analysis tool (Klippel *et al*., 2011; Ward, 2012). This spatial statistical method assigned a z-score and a p-value to each cell in the final output raster and identified significant areas of high and low clustering of social vulnerability. Areas with a high z-score and significantly low p-value represent significant "hot spots" (maroon) indicating where high social vulnerability values are clustered, while areas with low negative z-scores and significantly small p-values indicate significant "cold spots" (blue) indicating where low social vulnerability values are clustered (Figure 6.6).

The least vulnerable community councils (less than -1.5 standard deviations from the mean) representing 8.3% of the total, are mostly clustered in the north-western part of the study area, particularly in the Mohale's Hoek district (Siloe and Mashaleng). The medium-low social vulnerability levels are clustered in the western part of the study area, representing 29% of the total. The moderately vulnerable are clustered in the far north and central parts of the study area. Another visible cluster of vulnerable community councils is in the eastern part of the study area mainly in the Mohale's Hoek district, the majority being in the highlands. A patch of high social vulnerability is found in Seroto and Qhobeng constituting 8.3% (in Mohale's Hoek). The clustering of community councils with medium vulnerability levels is mostly found in the Quthing district. The observed clusters do not deviate much from the overall social vulnerability index score presented in Figure 6.2.

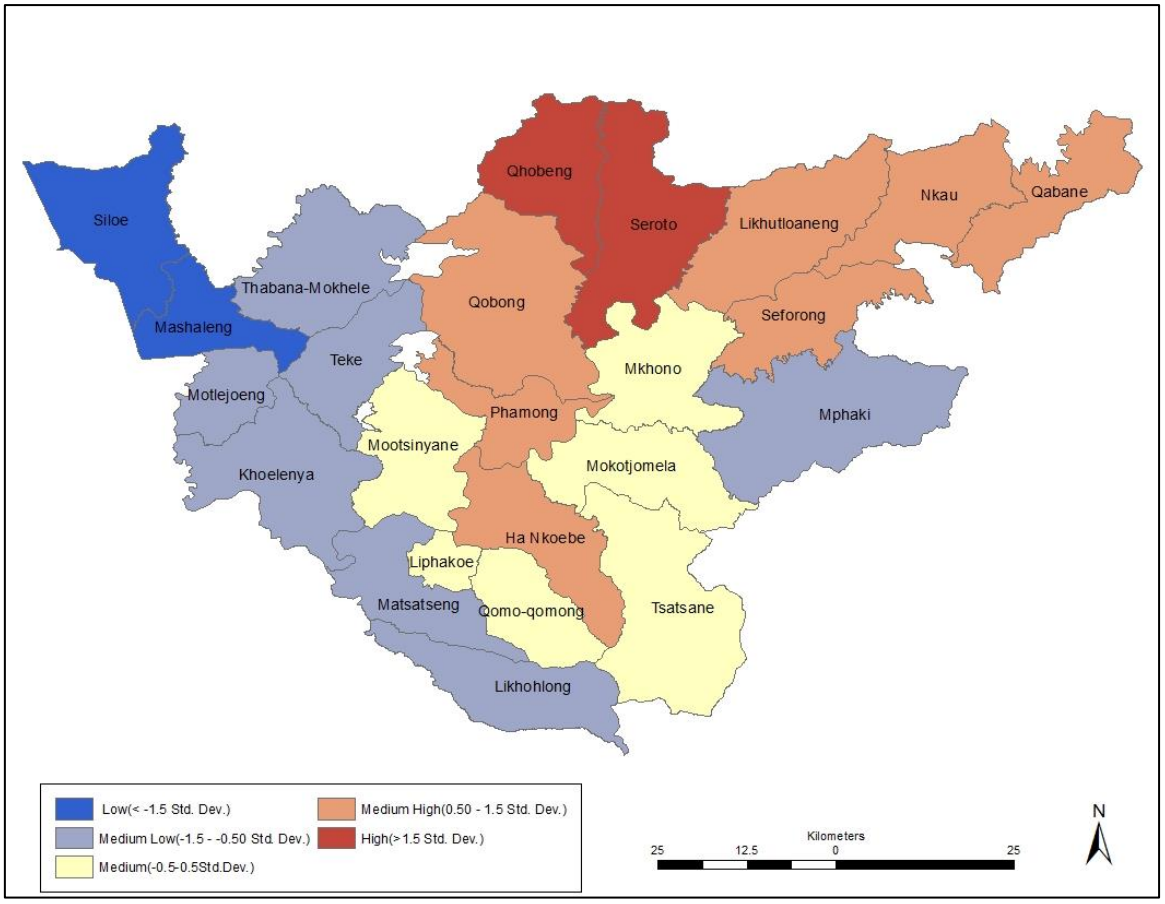

Figure 6.6: Local spatial autocorrelation – Hot spot analysis (*Getis Ord Gi**).
Source: Own data

6.6 OVERALL SOCIAL VULNERABILITY

From the eight individual vulnerability components Matsatseng, Teke and Thabana Mokhele scored high to very high, with lack of access to resources and services being the components in which these community councils had below average social vulnerability index scores. The two urban centres of Liphakoe and Motlejoeng demonstrated low social vulnerability levels because they are relatively wealthier, more developed in terms of infrastructure, and had a small percent of their population dependent on agriculture. The foothills and peri-urban areas had average social vulnerability scores, or below-average in the majority of eight individual components, with a medium score for components such as vulnerable population groups, population density, and employment.

As has been discussed, access to resources and services, as well as varied socio-demographic characteristics, influence overall social vulnerability to all types of hazards. However, variations in social characteristics are also important in explaining the

differential impact of a given hazard across space or social groups (Cutter, 2006). It is important to note that vulnerability factors presented in this chapter seldom occur in isolation. Rather, vulnerabilities are likely to interrelate. Observable examples are that vulnerable population groups, are more likely to be poor, as are women, the elderly, the disabled, orphans, children and the least educated. Rural female-headed households are mostly poor in the study area. Women live longer and thus constitute a large proportion of the elderly population in Lesotho, especially the rural and poor elderly (field observations). Hence, it can be argued that the most vulnerable group in Lesotho are elderly widowed women, and many bear responsibility for raising grandchildren and great grandchildren orphaned by the HIV/AIDS pandemic.

Community councils with high population densities, and a prevalence of low-income minority groups and large concentrations of elderly and/or children, were generally found to be more vulnerable than those with smaller population distributions or the more affluent. Thus, a combination of all indicators of social vulnerability, rather than just one indicator, was necessary to define social vulnerability in Mohale's Hoek and Quthing. Generally, Mohale's Hoek was found to be the most vulnerable district, whereas Quthing was found to be the least vulnerable, due in part to affluence, accessibility to resources and services, smaller proportion of its vulnerable population groups, family structure and diverse livelihoods. The occupational structure in Mohale's Hoek also contributed greatly towards its high SoVI scores. Mohale's Hoek had the highest percentage of its population employed in agriculture, whilst Quthing had a relatively higher percentage of the population employed in formal employment and fewer engaged in agriculture. Thus, the economic status of the population in the Mohale's Hoek district contributed significantly to its high vulnerability index score.

Considering the theory and the characteristics that contribute to increase social vulnerability, it has been discovered that places with high levels of social vulnerability incur greater losses from natural hazard events. Although affluent communities have high economic loss potential, they are not generally considered socially vulnerable. Conversely, natural hazards disproportionally affect places and people with high levels of social vulnerability because of the limited capacity of people in such areas to buffer against natural hazards, leaving them more exposed to shocks. Respondents from household

interviews reported that during the recent and damaging floods of 2011, very few poor households were able to recover from the effects of floods. They further complained that social networks offered them limited relief, as informal safety nets among people were effective when dealing with minor shocks, less so with severe shocks such as the 2011 floods.

This study also found that access to economic resources is extremely important in determining the vulnerability of people, and their poverty is likely to make them even more vulnerable to future hazards due to an inadequate ability to recover. Consequently, the crisis that natural hazards such as severe storms, flooding and drought bring to families and communities, may ultimately lead to poverty in the study area. The entire country is highly vulnerable to natural hazards, and when they occur the impacts cause a deeper entry into poverty for families or entire villages. The least vulnerable community councils consist of households with access to resources, those earning income from trading, formal employment, those earning over M1000.00 ($100 US) per month as well as those with toilets and radios, and these are concentrated in the urban lowlands areas. In contrast the most vulnerable community councils are those with limited access to resources, employed in the agricultural sector and concentrated in the rural highlands of the study area. Additionally, in these areas, communities are predominantly under developed and households are engaged in subsistence farming and do not have regular income. Limited access to resources in these areas is often coupled with low education levels, lack of sanitation facilities and luxury goods such as radios and mobile phones.

This section has examined the characteristics of community councils in the two districts and community councils in terms of their socio-demographic, infrastructure development and economic characteristics. An expectation of this research was that the Senqu River valley and rural highlands would be the most vulnerable region in both districts, while the lowland urban areas would be the least vulnerable in both districts. The research expectation held true in that the Senqu River valley and the rural highlands were found to be the most vulnerable regions and urban lowlands the least vulnerable. Another notable discovery was that Matsatseng had the highest social vulnerability index score in both districts. The component that greatly contributed to the high level of vulnerability in Matsatseng was lack of access to resources, its aging population, high percentage of

orphans, population on home-based care, female-headed households, and social dependence. It was found that the high percentages of the population aged 65 and older, as well as orphans were also receiving social support income and this contributed to the high social vulnerability index score. Thus, community councils with many dependent and economically inactive population groups are more vulnerable. In agreement, Lowe *et al*. (2010) stated that low income and minority population groups have the greatest difficulties securing adequate resources and assistance during and after natural disaster events.

Community councils with low social vulnerability index scores (Mashaleng, Mootsinyane, Liphakoe, Qhobeng and Khoelenya) are characterised by strengths towards natural hazards. These strengths are prevailing capacities for natural hazards mitigation; for instance, employment opportunities, and access to resources and services (developed infrastructure). Susceptibility like dependent population (elderly aged 65 and above and children aged under five) is typically low in these community councils. These variables in the lowlands were consistent with their low social vulnerability index scores in education attainment, access to resources and services, family structure, economic status, and employment components. However, these community councils have indications for potential exposure to natural hazards as a consequence of high population densities and densely built environment.

This study emphasizes that access to economic resources and services, which are strongly place-based are important factors determining spatial dynamics of social vulnerability in Lesotho. The adoption of the SoVI approach in Lesotho was important for two main reasons. Firstly, it created a method for characterising social vulnerability in the Lesotho context which relied on variables that were relatively easy to obtain, indicating that this method is easier to replicate than many other approaches. Secondly, it produced results that were consistent with international theoretical understandings and expert opinion on social vulnerability (Dunno, 2011; Holand *et al*., 2011). Lastly, the results of the study can provide yardsticks with which to assess the changes in the nature and spatial distribution of social vulnerability and natural hazard impacts over time. As such, this study can help researchers and community stakeholders to understand whether these are momentary phenomena or whether they reflect a persistent state, inherent of this poor and hazard prone area of Lesotho. For this research, the SoVI method was determined to be a beneficial method as it utilises secondary data sources. A benefit of creating an index

based on existing secondary data such as a census is that it can be updated as new data become available. This allows for time series analysis of social vulnerability (Simpson and Katirai, 2006). Another advantage of SoVI illustrated here is that it offers a technique with which to include local views into quantitative analyses (household interviews, expert interviews and focus group discussions). The systematic study of social vulnerability helps one to understand the factors that put people and places at risk, and the conditions that reduce their ability to cope and recover from natural hazards (Cutter, 2003). It is important to note that the social vulnerability index is useful as a rough assessment "of the distribution and likely impact of natural hazards and disasters", and that "its utility is exploratory and diagnostic in nature" (Cutter *et al*., 2010:1550), allowing quantification of the relative levels of social vulnerability within a specified area.

6.6 SUMMARY

The main focus of this chapter was to develop an understanding of the underlying socioeconomic factors that cause some people living in particular places to be more vulnerable than others in the study area. The main aim was to understand the underlying socioeconomic processes and factors that cause certain people and places to be more vulnerable than others. In this study, the causal dimensions of social vulnerability in Mohale's Hoek and Quthing were identified using the 2006 Census, district profile data and household and key informants' interviews. A set of 27 socioeconomic variables collected at the community council level was reduced to eight components through principal component analysis. Using this data, basic statistics were computed for each community council, then further analysis was undertaken in *SPSS* and spatial statistics analysis was conducted in *ArcGIS* and *GeoDa*. The next chapter presents the results of the overall place vulnerability assessment and integrates both physical and social vulnerability results.

CHAPTER SEVEN

OVERALL PLACE VULNERABILITY

7.0 INTRODUCTION

A number of conceptual models, frameworks and vulnerability assessment techniques have been developed in order to understand theoretical underpinning and practical applications of vulnerability (Eakin and Luers, 2006; Adger, 2006; Polsky *et al*., 2007; Yoon, 2012). Some of these are place-based. Spatial orientation of vulnerability within a geographical area provides a relatively easy way for planners and decision-makers to identify areas that may require additional resources in order to prepare for disasters and improve overall development (Turner II, 2010). Place-based vulnerability frameworks regard vulnerability as biophysical risk and socioeconomic conditions within a specific geographical domain (Rygel *et al*., 2006; O'Brien *et al*., 2008). According to Turner II *et al*. (2003a:8076), "The strong variation in vulnerability is by location, even to hazards created by global-scale processes and phenomena, elevates the role of place based analysis". In order to build resilient communities that can adapt and respond to natural hazards, both place-specific physical and social vulnerabilities must be understood, planned and mitigated for.

This chapter thus focuses on the socioeconomic and physical factors that heighten place vulnerability to natural hazards in the study region. Communities in Lesotho are affected differently by a range of natural hazards, based on their past experiences with natural hazard and social and physical characteristics. The objective of this chapter is to undertake a comprehensive analysis of place vulnerability and identify factors contributing to vulnerability. The chapter addresses the last research objective, namely to analyse the overall place vulnerability to natural hazards in the study region.

7.1 DETERMINING OVERALL PLACE VULNERABILITY

As indicated in previous chapters, this study attempts to assess place vulnerability to natural hazard using the hazards of place model of vulnerability (Cutter, 1996, 2000, Cutter *et al*., 2003) in Lesotho. In order to answer the third research question, this analysis examines how hazard occurrences, together with the physical and social characteristics of

a place, determine place vulnerability. The overall place vulnerability index and maps identify community councils where natural hazards frequently occur, and where the physical environment and socioeconomic characteristics of the population make the communities most vulnerable to the impacts of natural hazards.

After initial pre-processing, data was standardised for each component of place vulnerability that is social, physical environment and hazard profile by calculating standardised variables as z-scores. When standardized, the values of vulnerability index scores range from 0 to 1 and are not influenced by the number of variables included in the calculation (Borden *et al*., 2007). Though each socioeconomic and physical indicator can be examined separately, the average of all measures gives a general idea of vulnerability for any region within the study area and is more useful for the disaster management and emergency officers and decision-makers than are individual factors. Therefore, the overall place vulnerability index combined socioeconomic and physical factors into a single standardised measure of vulnerability to provide an overall place vulnerability index score. In order to apply the hazards of place model of vulnerability in the study area the vulnerability components were integrated to arrive at the end result (place vulnerability index) (Figure 7.1). To obtain the overall place vulnerability index scores, physical and social vulnerability layers were added together following a simple additive model and mapped in *ArcGIS* to produce a composite place vulnerability map.

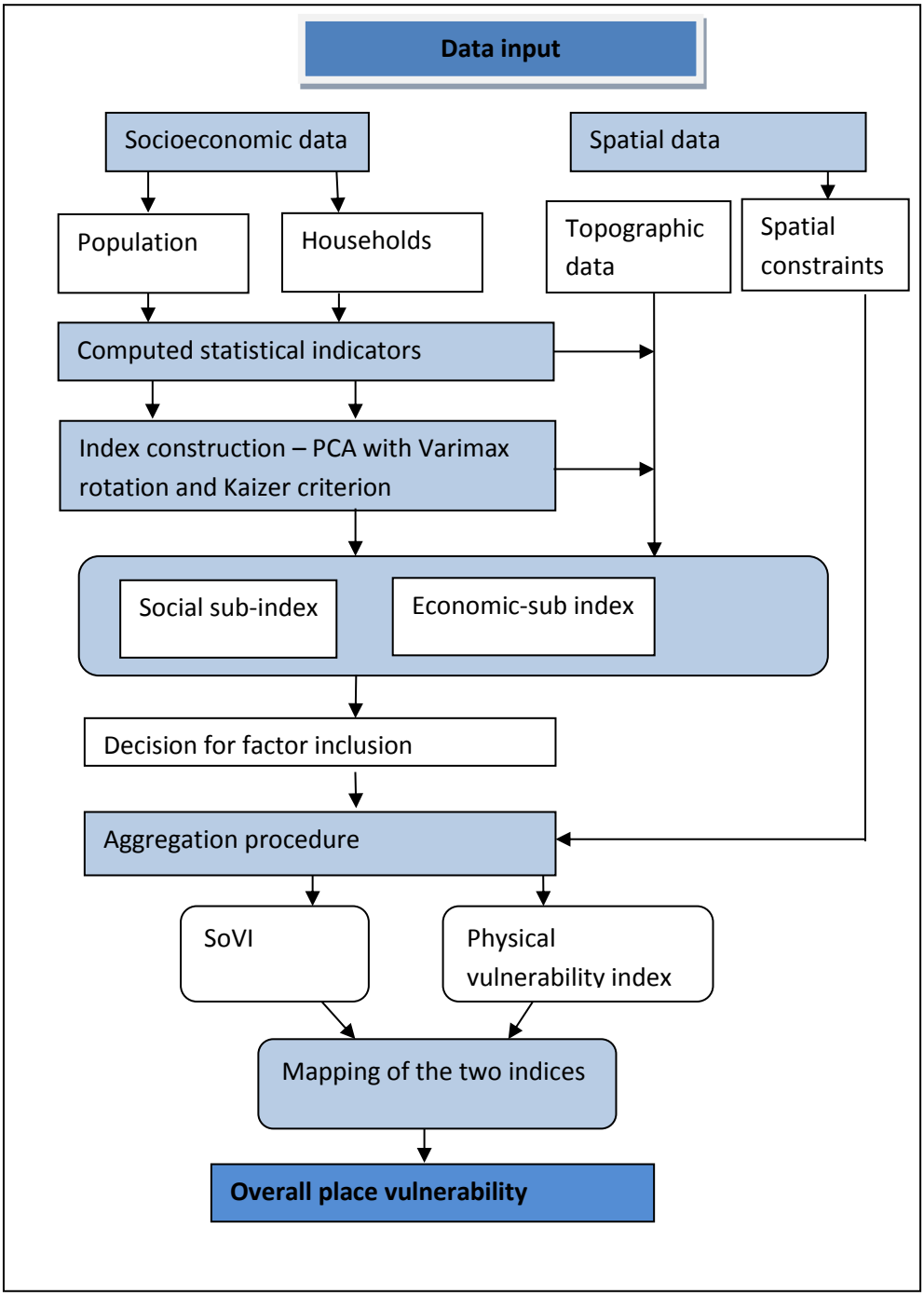

Figure 7.7: A framework used to build the place vulnerability indices for the study area

7.1.1 Place vulnerability assessment results

The statistical results presented in Table 7.1 reveal that overall place vulnerability is highest in the rural highlands in Thabana Mokhele (1), Mphaki (0.99), Matsatseng (0.97) and Teke (0.88). This spatial pattern of place vulnerability is in line with the physical vulnerability distribution discussed in Chapter 5, which demonstrates that relative physical

vulnerability is high in the river valleys and some highland regions. The underlying vulnerability varies across the study region, with high place vulnerability and physical vulnerability levels emerging in the remote rural highlands of the study area in both districts. In Mohale's Hoek district, high levels of place vulnerability occur in the rural highlands and along the Senqu River valley, especially where heavy snowfall, drought, strong winds and flooding intersect severe frost zones (Figure 7.2). Apart from heightened levels of place vulnerability in the highlands and along the river valleys, mapping place vulnerability index scores reveals the influence social vulnerability and physical vulnerability has on the overall place vulnerability. For instance, Qabane and Likhutloaneng in the north-eastern part of the study region have lower physical vulnerability levels. This area comprises some of the highest place vulnerability scores in the entire study region, due to the influence of physical vulnerability and hazard occurrence. Overall, areas showing high levels of place vulnerability are located in Thabana Mokhele, Mphaki, Matsatseng and Teke (Figure 7.2), where heightened levels of social vulnerability overlap with areas susceptible to drought, strong winds, severe frost and heavy snowfall. The study results confirmed reports from government officials and residents, of flooding events of 1988 and 2010/11, the recurrent droughts in 1991-95 and 2007, and severe frost in 1997 and 2007 and heavy snowfall in these communities.

Besides the cattle posts, community councils with low levels of overall place vulnerability in Mohale's Hoek and one in Quthing are mostly found in the foothills [Mashaleng (0.34), Mootsinyane (0.46), Khoelenya (0.48), Liphakoe (0.48) and Qhobeng (0.49)]. These community councils have low physical vulnerability index scores due to their elevation (mainly in the foothills on the foot of slopes and are less exposed to flooding, frost and heavy snowfall) even though they are mainly susceptible to drought and strong winds. Additionally, their dependency on livestock farming, which is relatively resistant to severe frost and drought as compared to crop farming in the lowlands, contributes to their relatively low physical vulnerability levels. Regions demonstrating medium levels of total place vulnerability are found in the foothills and lowlands in Motlejoeng (0.54), Siloe (0.59), Qobong (0.59), Ha Nkoebe (0.60), Mokotjomela (0.62), Qabane (0.63) and Qomoqomong (0.64). These community councils have average levels of social vulnerability and are exposed primarily to drought, strong winds and severe frost. The community councils with the highest and lowest place vulnerability index values are listed and ranked in Table 7.1 and mapped in Figure 7.2.

Table 7.7: Total place vulnerability index

Community council	Place vulnerability index score	Rank
Thabana Mokhele	1	1
Mphaki	0.99	2
Matsatseng	0.97	3
Teke	0.88	4
Seforong	0.85	5
Nkau	0.85	5
Tsatsane	0.79	6
Phamong	0.77	7
Likhutloaneng	0.74	8
Seroto	0.72	9
Likhohlong	0.72	9
Mkhono	0.66	10
Qomoqomong	0.64	11
Qabane	0.63	12
Mokotjomela	0.62	13
Ha Nkoebe	0.60	14
Siloe	0.59	15
Qobong	0.59	15
Motlejoeng	0.54	16
Qhobeng	0.49	17
Liphakoe	0.48	18
Khoelenya	0.48	18
Mootsinyane	0.46	19
Mashaleng	0.34	20
Cattle post	0.21	25
Cattle post	0.21	25
Cattle post	0.21	25
Cattle post	0.21	25

In Figure 7.2, both districts demonstrate high levels of place vulnerability, with each having three of their community councils exhibiting place vulnerability index scores of >1.5 Std. Dev. In general Mohale's Hoek has a larger number of community councils with medium-high place vulnerability index score (0.5-1.5 Std. Dev.), with three of its community councils in this category. However, two community councils in Mohale's Hoek (Mootsinyane and Mashaleng) have the lowest place vulnerability index scores (<-

1.5 Std. Dev.). Additionally, five community councils in Mohale's Hoek have medium-low place vulnerability index scores (-0.5 to 0.5 Std. Dev.), namely, Khoelenya, Qhobeng, Motlejoeng, Qobong and Siloe. Mohale's Hoek generally demonstrates relatively low levels of place vulnerability. In contrast, Quthing largely exhibits moderate levels of place vulnerability. Of all the 24 community councils Thabana Mokhele in Mohale's Hoek has the highest place vulnerability index score (>1.5 Std. Dev.). Liphakoe is the only community council in the Quthing district with medium-low vulnerability index score (-1.5 Std. Dev. to -0.5 Std. Dev.). The community councils with the lowest overall place vulnerability to natural hazards rarely experience damaging events, and/or have low social vulnerability. Moreover, the community council with the highest social vulnerability index score (Thabana Mokhele) also ranks high on overall place vulnerability (>1.5 Std. Dev.). Clearly, the most socially vulnerable also demonstrate significant physical vulnerability, hence resulting in high place vulnerability levels. An analysis of the least vulnerable community councils emphasises the significance of social vulnerability in the overall place vulnerability index score, such as the low social vulnerability index scores in Mashaleng, Mootsinyane and Teke. Spatially, the least vulnerable community councils are situated in the foothills, lowland, uninhabited and inaccessible cattle posts. Similarly, the cattle posts also exhibited low to moderate vulnerability index scores on physical vulnerability. In general, the foothills have moderate place vulnerability levels (-0.5 to 0.5 Std. Dev.), e.g. Siloe, Ha Nkoebe, Mokotjomela and Qomoqomong.

The community councils of Thabana Mokhele, Mphaki, Matsatseng and Teke ranked high for overall place vulnerability to natural hazards. Matsatseng is located in the foothills, while Teke, Mphaki and Thabana Mokhele are located in the rural highlands. The community councils with highest overall place vulnerability index scores often experience frequent and damaging severe frosts, strong winds, heavy snowfalls and recurrent droughts, and additionally have high social vulnerability index scores (Thabana Mokhele and Matsatseng). Mphaki and Thabana Mokhele community councils are the most physically exposed (higher hazard potential and greater physical risk), with added high social vulnerability. Thabana Mokhele, Mphaki and Matsatseng are characterised by high percentages of socially vulnerable populations which often experience significant loses

and casualties due, strong winds, heavy snowfall and drought, suggesting possible cyclic vulnerability due to the reoccurrence of different hazards.

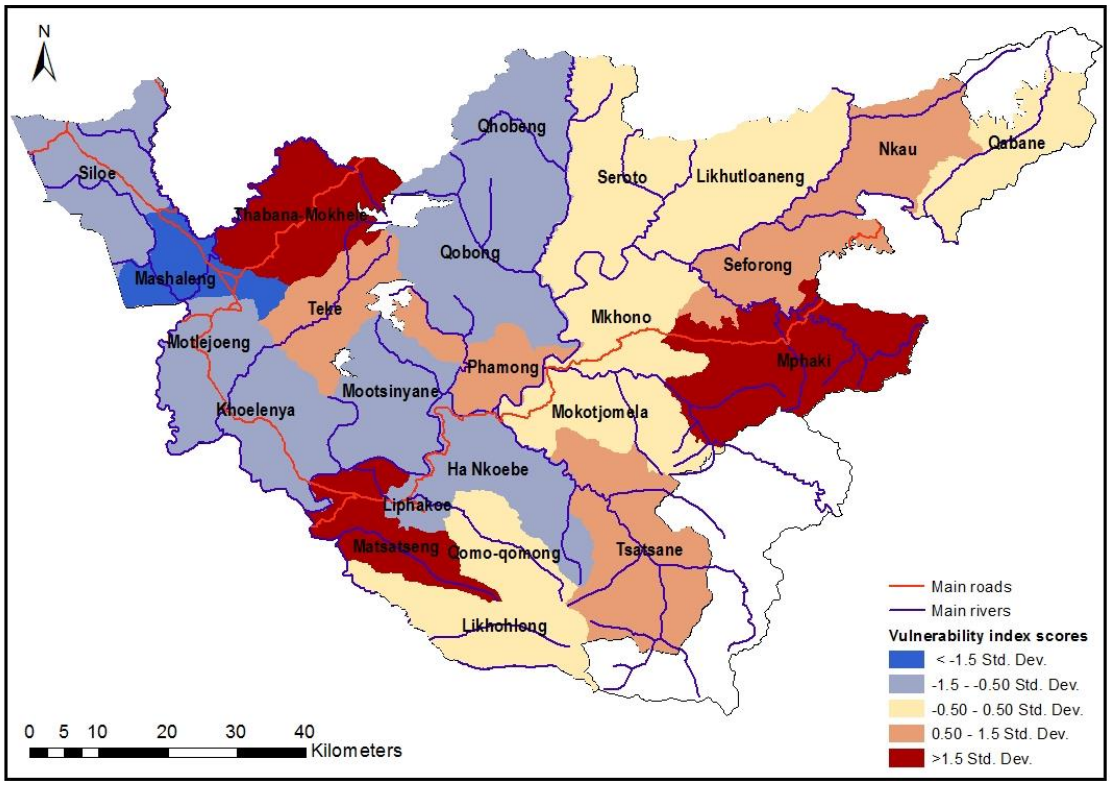

Figure 7.8: Place vulnerability index
Source: Author's own data

The cattle posts, have relatively low overall place vulnerability index scores, even though they are exposed to a range of natural hazards (severe frost, heavy snowfall, lightning and drought). However, it should be noted that cattle posts are uninhabited grazing areas without any human settlements. The majority of the rural highlands exhibit relatively high (0.5 to 1.5 Std. Dev.) place vulnerability levels, for instance, Tsatsane, Mphaki, Likhohlong, Nkau, Likhutloaneng and Seforong. These are the highland areas with sparsely populated areas with a high risk to heavy snowfall, drought and severe frost. In contrast, rural highlands of Qobong and Qhobeng have medium-low place vulnerability levels and comprise of small scattered villages situated in rugged mountains at higher elevations, whilst both their physical vulnerability scores (sparse population, few villages) and social vulnerability scores are relatively low, resulting in lower overall place vulnerability levels. The foothills of Mkhono, Mokotjomela, Qomoqomong and Nkoebe have moderate place vulnerability scores and are less exposed to severe frost, flooding and

heavy snowfall. These foothills communities also have low-medium SoVI scores. Overall, place vulnerability is relatively low in most of the community councils with a low social vulnerability index score such as Mootsinyane, Khoelenya, Motlejoeng, Liphakoe, Mashaleng and Siloe.

The configuration of the overall place vulnerability map (Figure 7.2) reveals a radical spatial pattern with values increasing from the urban lowlands to the marginal highland areas. This corresponds to rurality and lack of access to services components from the social vulnerability index scores (Chapter 6). Rural highlands are characterised by low level of infrastructure development, lack of economic resources and activities, low levels of hazard preparedness and awareness, resulting in moderate to high overall place vulnerability levels in the highlands. Thus the rural highlands have reduced capacity to cope with recurring natural hazards. In addition, the lowlands and their periphery can be distinguished on the map as areas marked by relatively low to moderate levels of overall place vulnerability, based on the low social vulnerability levels (access to resources and services, affluence and good economic status) and moderate physical vulnerability level to natural hazards in these areas. Furthermore, the moderate category includes the community councils in the foothills (Mkhono, Qomoqomong, Nkoebe, Motlejoeng, Siloe, Mokotjomela and Likhohlong), with medium to high scores for social vulnerability but lower scores for physical vulnerability. At the opposite extreme are the cattle posts exhibiting low place vulnerability index scores based on low to moderate physical vulnerability levels. The medium-low community councils are found mainly in Mashaleng, Khoelenya, Mootsinyane and Liphakoe.

7.2 OVERALL PLACE VULNERABILITY

It is interesting to analyse the extent to which the place vulnerability assessment in this study is comparable to existing vulnerability (food insecurity) and poverty mapping studies in Lesotho. A comparison of the LVAC (2010) and Turner (2005) results, together with those of this study, reveals similar patterns of ‘pockets of vulnerability’ concentrated along the Senqu River Valley and in the remote rural highlands. However, the intensity of the highest vulnerable community councils differs. Some of the community councils with the

highest vulnerability classes in the LVAC (2010) and Turner (2005) reports are not displayed as highly vulnerable in this assessment. The previous studies reported Phamong, Mootsinyane, Mkhono and Ha Nkoebe as the most vulnerable areas, while this study highlight Thabana Mokhele, Mphaki and Matsatseng as the most vulnerable community councils in the study area. One the contrary, previous studies highlighted low social vulnerability levels in the lowland community councils of Liphakoe, Mashaleng and Motlejoeng, indicating a similar pattern with the current study. Not surprisingly, the overall place vulnerability map shows that the areas at high risk coincide with community councils with populations with low socioeconomic levels. The inhabitants at greatest risk are the poor female-headed or child-headed households, mainly from the Senqu river valley and rural highlands, who depend on crop farming and social support, given their poverty status.

Apart from physical exposure to natural hazards, social factors and economic characteristics are key factors that affect human vulnerability at a specific place. A well-developed infrastructure and strong social and economic structures can increase community resilience and speed up response and recovery processes, following a disastrous event (Aubrecht *et al*., 2013). In the study area, complex topography, proximity to rivers and dependency on agriculture, coupled with vulnerable population groups (elderly, orphans, child- and female-headed households), lack of economic resources, relatively poor infrastructure and high unemployment rates, characterise highly vulnerable areas and heighten their overall place vulnerability. In the study area, the majority of rural households depend on agriculture, livestock and casual labour and therefore are the direct victims of floods, heavy snowfall, drought and severe frost.

In this study social vulnerability increases with distance from the urban lowland areas, while physical vulnerability decreases away from the lowlands. Areas located in the rural highlands and foothills are the most socially vulnerable, yet the least physically vulnerable. The results generally show that the majority of the community councils with high physical vulnerability scores and lower social vulnerability scores are in a better position to withstand the impacts of natural hazards (Mootsinyane, Qhobeng, Liphakoe, Mashaleng and Khoelenya) than those with high SoVI scores. The community councils with relatively lower social vulnerability levels are Qabane and Qomoqomong, even though they both have high physical vulnerability index scores, these are likely to cope with shocks. The

pattern of place vulnerability thus follows a similar pattern of rural-urban disparities in Lesotho.

The majority of low place vulnerability levels are located mainly in the lowlands and foothills, the lowlands have densely built-up environments and are more prone to flooding, strong winds and drought, with high physical vulnerability levels. Khan *et al*. (2012) also discovered that some biophysical characteristics of a place attract more people for habitation, such as flood plains, gentle hills and moderate climate (which are more suitable for farming and settlements). This consequently increases hazard risk because a greater proportion of the population reside in high risk areas. In Lesotho, flat areas and river valleys are favoured for new settlement developments. Physical exposure to flooding due to proximity to rivers exacerbates place vulnerability in these areas, while population density and infrastructural development exacerbate exposure to strong winds and flooding with consequent damage. Generally, the foothills have medium place vulnerability index scores and have moderate population densities and moderate infrastructure, but are further away from geographically exposed zones, which explain their moderate physical vulnerability levels and overall place vulnerability levels. Although the foothill community councils are not as susceptible to flooding and severe frost, they are still susceptible and vulnerable to drought, strong winds and heavy snowfall. The foothills are predominantly rural areas and the main underlying factors of moderate place vulnerability levels in these areas result from socioeconomic vulnerability are socioeconomic and demographic.

The evaluation of community councils within each district revealed the underlying causes of place vulnerability across the communities. It was expected that the lowland urban community councils situated on gentle to moderate slopes, with relatively well developed infrastructure and diverse livelihoods, would be less vulnerable. Whilst, those located in rural highlands, where there is exposure to heavy snowfall, drought, strong winds and severe frost, were expected to have high place vulnerability index scores. Another notable finding was that Thabana Mokhele had the highest place vulnerability score in both districts. The factors that greatly influenced place vulnerability in Thabana Mokhele were exposure to heavy snowfall, strong winds, severe frost and drought, together with the high percentages of vulnerable population groups, lack of resources, a large number of households dependent on social support, unemployment, and rurality. Clark *et al*. (1998:59) define vulnerability to natural hazards as "people's differential incapacity to

deal with hazards, based on the position of the groups and individuals within both physical and social worlds". To this end, exposure to hazards and coping abilities in Thabana Mokhele determine overall place vulnerability. Disasters are thus caused not only by natural hazards but also by the social systems that make people or places vulnerable (Blaikie *et al*., 1994; Cutter, 2010; Boruff, 2011; Cardona, 2011), as is the case in Thabana Mokhele.

The influence of socioeconomic characteristics, population demographics, proximity to hazard source and other geographical and spatial factors cause vulnerable areas to unfold as clustered patterns or spatial analogues across the study area, instead of randomly distributed patterns, for example, in the highlands, lowlands and river valleys. The results of this study support two findings from the data. Firstly, it is evident that community councils in the foothills, as evident from the physical vulnerability index, are less exposed to flooding, heavy snowfall, severe frost and strong winds. When compared to the social vulnerability map, high vulnerability scores are scattered throughout the highlands and foothills. This indicates that people in the highlands and foothills are relatively less susceptible to hazards, but have medium to high levels of social vulnerability.

Secondly, high risk communities in the highlands, Senqu River valley and some lowland areas are more exposed to flooding, heavy snowfall, drought, strong winds and severe frost and have high social vulnerability levels. This is a consequence of high reliance on crop farming on thin and highly erodible soils in the lowlands, foothills and the river valleys. A connection between dependency on agriculture and natural hazard occurrence reveals the relationship between social vulnerability (lack of livelihood options, poverty and unemployment), and physical vulnerability (susceptibility of agriculture to soil erosion, flooding, severe frost and drought). Recently, with recurring and severe floods, strong winds and drought, the socioeconomic conditions in the study area are expected to deteriorate. During field visits, it was observed that many fields were left fallow, resulting in lower agricultural production food insecurity, high unemployment rates, a significant number of critically ill populations and a large percentage of female and child-headed households was also observed, resulting in increased overall social and consequently place vulnerability. The combination of the prevalence of declining socioeconomic conditions and increased susceptibility to natural hazards affirms high levels of place vulnerability in the study region.

In contrast to previous studies elsewhere, in which place vulnerability emanates mainly from socioeconomic factors (Rygel *et al*., 2006; Fekete, 2009; Dunno, 2011), place vulnerability in the current study is influenced mainly by the physical geography of a place and previous experiences and adaptation to natural hazards. Most of the vulnerability assessments carried out in the USA and the Caribbean identified the most common characteristics that increase place vulnerability to natural hazards as income, gender, age, race and ethnicity, such that in these countries place vulnerability is substantially influenced by social characteristics (Cutter *et al*., 2003; Rygel *et al*., 2006; Turner II, 2010, Dunno 2011). In contrast, place vulnerability in Lesotho is influenced mainly by the physical characteristics. In this study the physical characteristics of a place aggravates the effects of hazard events (e.g., climate variability, slope, elevation, soil, proximity to rivers), and some specific environmental conditions (e.g., river valleys, flood plains and mountain regions) lead to an increase in the level of damage or potential damages. For instance, flood as a hazard is dangerous only when a village or fields are located near a river or situated at low elevations. Thus, a place devoid of human occupation and activities (e.g., cattle posts) is not at as great a risk as an occupied one. However, this then is reinforced by the manifestation of social vulnerabilities. The overall result in this research was a distinct geography of place vulnerability to natural hazards, based on social and physical factors.

7.3 PLACE VULNERABILITY, CLIMATE, ENVIRONMENTAL AND SOCIAL CHANGE

This section presents the dynamics of place vulnerability in both the study area and Lesotho as a country. The 'starting point' approach of vulnerability adopted in this study views vulnerability as a dynamic process, continually transforming with changing biophysical and social processes that shape local conditions and the ability of communities to cope with shocks (O'Brien *et al*., 2004; Abson *et al*., 2012). In the study region, extreme natural hazards such as drought, floods, severe frost, strong winds and heavy snowfalls simply reveal the underlying vulnerabilities in communities and households. Studies have also shown how vulnerability is not caused by natural hazards or climate extremes alone (Sen, 1981; Watts, 1983; O'Brien *et al*., 2004; Gandure, 2005; Gwimbi *et al*., 2012; Matarira *et al*., 2013), but by a configuration of forces that shape the ability to cope with natural hazards.

Emerging from the current study and several others in southern Africa focusing on climate variability and extremes (e.g. Devereux, 2002; Lambrechts and Barry, 2003; FFSSA, 2004; O'Donnell, 2004; Gandure, 2005; LVAC, 2010), is that socioeconomic conditions heighten people's vulnerability to natural hazards. Leichenko and O'Brien (2002) also argue that in the southern African region, vulnerability has to be understood as a dynamic characteristic that is influenced by environmental and global changes. In the Lesotho context, Bharwani and Taylor (2012) examined how changing local conditions in natural and human characteristics are influencing the pattern of social vulnerability taking place within the highland communities and their implications on future climate adaptation and development initiatives.

Climate, environmental and social changes such as urbanisation, HIV/AIDS and unemployment affect the vulnerability of places, hence, trends in environmental change, urbanisation, technologies and demographic processes can make households and places either more or less vulnerable to future or unforeseen impacts (Schneider *et al*., 1998; Cutter, 2003; Adger, 2006). The IPPC (2013) also emphasises that future vulnerability is embedded in contemporary conditions of communities, indicating that new hazards will expose, rather than create, underlying vulnerability factors.

7.3.1 Social change

While this study provides valuable insight into current patterns of physical and social vulnerability, it is not able to incorporate changes in the larger social, demographic, economic and institutional contexts. Place vulnerability in a country is dynamic and can change these dimensions. Within the social context, it is anticipated that HIV/AIDS, through morbidity and mortality in the study region, will continue to increase food insecurity by eroding food security resilience and household assets at different levels within households, villages and community councils. HIV/AIDS is likely to affect household income and livelihood strategies employed by the rural communities, more especially if the breadwinner becomes ill or dies (Ansell *et al*., 2009, Ansell, 2009; Arrehag, 2009; Mambo, 2012). In most households, HIV/AIDS results in loss of labour, reduced agricultural productivity, lower incomes and increased household expenditure on medical care, funerals and weakening of social support systems (evidence on increasing

numbers of orphans and child-headed households in the study area), thus reducing a household's ability to secure household assets. Hence, HIV/AIDS will continue to intensify poverty and vulnerability of households and communities in the country to future hazards and shocks.

7.3.2 Spatial variations

The spatial distribution of various aspects of vulnerability differs across regions. The significance of geography has been emphasised in an analysis of disaster hotspots by Dilley *et al*. (2005). In the case of Lesotho, there are differences between urban and rural areas in terms of accessibility to resources and services, building construction and quality of houses, demographic variations, economic conditions and population density, all of which play a role in determining place vulnerability. Therefore, urbanisation accompanied by high population density is likely to increase exposure to flooding and strong winds in areas not previously subject to them (presence of buildings in flood prone zones). Globally, there is evidence that rapid and unplanned urbanisation in hazardous zones increases vulnerability to natural hazards (Sanchez-Rodriguez *et al*., 2005; UN-HABITAT, 2011). Population growth and rapid urbanisation are likely to be the driving forces behind increased exposure and vulnerability to natural hazards in sub-Saharan Africa (World Bank, 2010).

When hazardous events occur in densely populated areas the impact is likely to be more severe than it would be in areas with fewer people or uninhabited areas, such as the cattle posts. In densely populated areas (mostly urban settings), there will be more people in need of emergency services, and thus demands on existing facilities and resources may be overwhelmed, particularly if natural hazards force rural people to migrate to urban areas (e.g. during severe droughts). With declining agricultural productivity resulting from drought, most people move from rural to urban areas in search of job opportunities. Over the years, declining agricultural employment and income from the agricultural sector have pushed many households into poverty (Gwimbi *et al*., 2012). A noteworthy observation in Lesotho is the historical male rural-to-urban migration to South African mines, which fundamentally changed the gender division of labour in many farming rural households. Men were often not available for ploughing and planting, which are both time- and energy-intensive. For many female-headed households, this translated into a marked increase in

agricultural work, including a wider range of farm tasks, a heavier workload and less time for domestic tasks and childcare. With a diminishing supply of labour from males and shared farm tasks, many women resorted to limiting agricultural operations, with reduced household income and increased food insecurity (Mochebelele, 2000).

Additionally, there are also spatial variations of social vulnerability in the study region and in Lesotho as a whole. The poor tend to be associated with the rural areas, and these communities are characterised by high percentages of poor households, the elderly and female-headed households dependent on farming, while the affluent are more linked to the relatively developed urban areas. This pattern generally reflects the socio-spatial diversification of rural and urban areas present in Lesotho, which is associated with the trend of wealthier populations residing in urban areas, where there are diverse livelihood options and services. This trend is likely to continue in future. Furthermore, exposure of human populations to natural hazards is shaped to some extent by historical patterns of settlements, such as river bank and flood plains being favoured for settlements and farming in Lesotho. The benefits of certain places and environments and their related physical features (e.g., soils, climate) that support livelihoods are in many ways associated with hazard prone regions (Turner II, 2010; Preston, 2013). Flat and fertile floodplains, for instance, have globally been attractive for human activities such as residential developments and agriculture (Merz *et al*., 2010; Brémond *et al*., 2013). The historical development of settlements in Lesotho is by no means an exception.

However, social vulnerability is likely to change over time, depending on socioeconomic and infrastructural development efforts in the study region. For instance, introducing diverse livelihood options in the study area can reduce household vulnerability to natural hazards and poverty by increasing household income, while construction of roads and bridges in the rural highlands can increase accessibility and facilitate economic activities. Thus, vulnerability is manifested in specific places at specific times (Adger, 2006). Even though vulnerability is hazard and place specific, in Lesotho, some factors such as poverty, lack of government support and social networks often affect and exacerbate vulnerability levels regardless of the type of hazard or location.

7.3.3 Vulnerability in mountain environments

Generally, mountain regions are high-risk areas and natural hazards can cause damage, destruction, injury and death at times (Kohler *et al*., 2009). Additionally, mountains are geographically and politically predominantly marginal areas, and the incidences of poverty, vulnerability, and economic and social insecurity are high (ICIMOD, 2011). Notwithstanding their remoteness and low population density, many mountain environments are strongly affected by global change drivers, such as land-use change and climate change (Kohler and Maselli 2009; Macchi 2010; Rodrıguez and Bomhard, 2012). These characteristics of mountain environments make them more susceptible to future hazards.

Lesotho is generally a mountainous country, thus the complex topography coupled with considerable climatic variations has differentially influenced vulnerability to natural hazards, such as snow, droughts, lightening and strong winds. In most cases, such events impact mountain ecosystems and populations negatively. Globally, mountain environments are the most sensitive regions to climate change (Tse-ring *et al*., 2010; Macchi, 2011; Peng *et al*., 2014), a sensitivity also highlighted by the IPCC (2007). But unlike other mountain regions, such as the Himalaya, Rocky Mountains, Andes and the European Alps, Lesotho does not suffer from glacial hazards or avalanches. However, relative size of the country and the comparatively densely populated subsistence farming possibly accounts for greater social and economic vulnerability than in many mountain environments where physical vulnerability may be stronger.

Communities residing in the rural highlands of the study region are particularly vulnerable to natural hazards as a consequence of their high dependence on natural resources for their livelihoods, comparatively increased and higher exposure to extreme events, widespread poverty, unemployment, marginalisation, remoteness and inaccessibility. Over-utilisation of mountain resources in Lesotho has placed resources, such as grazing lands, under stress and made them more vulnerable to climate change. Therefore, any adverse weather events or longer-term climate change and variability are likely to increase sensitivity of the ecosystems due to population pressure, resource overuse and degradation.

7.3.4 Seasonality of vulnerability

In addition to its spatial component, place vulnerability also has a specific time component (Dow, 1992; Kienberger *et al*., 2013). Thus, a strong relationship exists with regard to the seasonal variations and changes associated with natural hazard occurrences and elements at risk. There is a distinct seasonality to risk and exposure posed by droughts, floods, strong winds, severe frost and heavy snowfall in Lesotho. For instance, the highlands are at great risk from heavy snowfall and extreme cold/severe frost in winter, while the lowlands and river valleys are at great risk in summer as a result of flooding, and from severe frost in autumn.

The highlands are also characterised by lightning occurrences in summer, but this natural hazard was excluded from this analysis because of insufficient data. Knight and Grab (2013) have emphasised the impacts of lightning and thunderstorms in the Drakensberg, which includes the Lesotho highlands, especially on mountain summits in summer. Thus, highland and lowland communities are exposed to different types of natural hazards at different times of the year, indicating a continued pattern of hazard exposure throughout the year. Attention is thus warranted, not only on "hot spots" but also on "hot-seasons." Information on seasonal risk for different hazards is useful for disaster risk management, therefore it is acknowledged that the temporal characteristics of natural hazards shape the temporal scale at which vulnerability could be understood, and account for the role of the hazard in revealing, triggering or causing place vulnerability (Kienberger *et al*., 2013). A compounding issue impacting seasonal place vulnerability in mountain regions is 'wrong' hazard events that occur during the 'wrong' season, for instance severe snow blizzards in mid-summer, as was the case in Lesotho in 2000 when several livestock were killed, or floods in mid-winter, the middle of dry season. In such cases there is an element of societal unpreparedness, which consequently exacerbates the vulnerability of those impacted.

7.3.5 Potential vulnerability

Climate change research indicates that climatic extremes will become more frequent and in some instances more severe (Karl *et al*., 2008), thus inducing changes to local climate. If these projections hold true, time between extreme weather occurrences may shorten, thereby increasing the likelihood of maladaptation. Some coping mechanisms may reduce

vulnerability in the short term, but worsen them in the long run, or even create new and unintended negative effects (Moser, 2010, Simatele 2012). For instance, selling of livestock or household items for cash during drought leaves households poorer, eroding asset protection and accumulation, and thus reducing their capacity to withstand future shocks. Frayne *et al*. (2012) found that household assets enable adaptation and resilience to the impacts of natural hazards. Thus, any differences in the extent to which households use their assets across geographic space, may influence future levels of place vulnerability.

Other likely future vulnerabilities identified by the respondents relate to the erosion of social cohesion. Generally, communities in Lesotho are undergoing notable social and economic transformations. The principles of humanity (intra-community solidarity and collective support) which have been the norm in the social fabric of the Basotho nation are now being challenged through modernity and democracy. This promotes individualism and gradually erodes the collective nature of the traditional support system in the country. For instance, family members or villagers used to take care of orphans after the death of parents, but this is no longer the case, as evident from a large number of child-headed households in the study area (discussed in Chapter 6). Eroding social cohesion is not a unique situation in Lesotho but has been reported among the fishing communities in the Solomon Islands (Schwarz *et al*., 2011), and should thus be factored into future potential vulnerability across spatial divides.

7.4 ENDOGENOUS AND EXOGENOUS FACTORS INFLUENCING PLACE VULNERABILITY IN LESOTHO

The negative socioeconomic consequences of the physical environment and natural hazards are numerous and often occur simultaneously, for instance, flooding, drought, erratic rains, strong winds, severe frost and heavy snowfall result in land degradation, soil erosion, lower crop yields, loss of assets, physical injury, deaths, and damage to houses. They exacerbate poverty, hence exposure to one or more, in turn weakens the adaptive capacity of communities and households to withstand any hazard that may follow. Figure 7.3 illustrates endogenous and exogenous factors influencing place vulnerability in the study region, which combines hazard occurrence, physical and social conditions to analyse the cause-effect relationship and interactive processes between these dimensions of place vulnerability. This integrated approach developed for the study region assumes that when a

hazardous event occurs it triggers physical vulnerabilities and exposes social conditions and processes, causing households and communities to become more vulnerable to future natural hazards. Losses due to natural hazards potentially aggravate existing vulnerabilities in societies and can ultimately have greater impacts from future and current natural hazard losses. For instance, the loss of agricultural production due to drought and severe frost in an area adversely impacts on food security, casual labour employment and livelihood options. On the other hand, food insecurity and lower incomes can lead to a cycle of problems, which indirectly magnify the impact of natural hazards.

The external drivers are those factors originating from outside the control of local communities, including distant events and processes (Figure 7.3). For instance, during the early 1990s, national policies in South Africa resulted in the retrenchment of thousands of Basotho men from the mines and this had a direct impact on the national economy and on household income. Therefore, the root causes of place vulnerability are embedded in economic, social and institutional processes on a broader scale vulnerability at the local level is indistinguishably linked to processes happening at other geographic scales. This shows that the interconnectedness of processes taking place at local and other scales influences dynamism and complexity of place vulnerability (Eriksen *et al*., 2005). Similarly, social vulnerability described in this study is related to differential place vulnerability resulting from social inequalities and lack of access to resources. In particular, social vulnerability parameters that impact a community's ability to recover from future hazards can be related to the inherent factors such as household structure, economic situation and demographic characteristics.

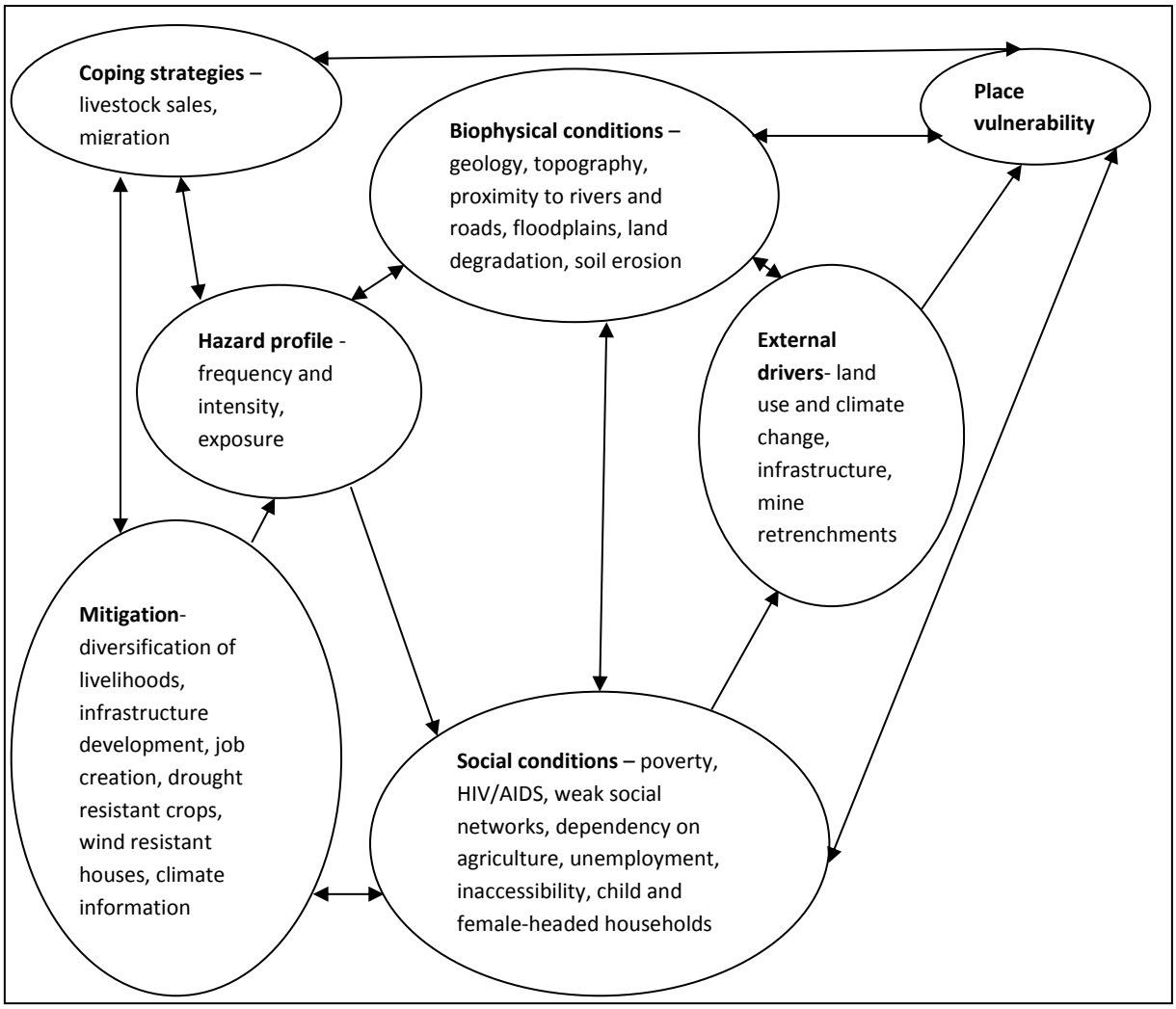

Figure 7.3: Endogenous and exogenous factors influencing place vulnerability in Lesotho

Generally, exposure to natural hazards is driven by manifestations of socioeconomic factors, including poverty and underdevelopment, whereby dependency of households and communities on agriculture in marginal environments, such as farming on steep slopes and along the river banks, magnifies adverse consequences. Reliance on gradually lower-yielding subsistence agricultural, deteriorating pastures and declining livestock result in a multi-facet deterioration of household income, asset accumulation, lower social status and weakens social support and ties. Families no longer share food during drought periods and orphans are left on their own after their parents' deaths.

Respondents consistently indicated linkage between climate variability and their worsening dilemma by recognising that numerous and compounded hazard occurrences

are worsening pre-existing adverse social and livelihood consequences. For instance, during drought incidences, households sold livestock in order to buy food and to pay school fees. However, respondents indicated that selling livestock was a short-term solution, which in the long run pushes them further into poverty, as it reduces their physical assets and household wealth, thus endangering their long-term response capacity. Figure 7.3 also suggests that communities and households are seen as active agents rather than passive victims of hazardous events. In these instances people have their own coping strategies and do not depend on external interventions such as food aid. However, these coping strategies are not adequate to reduce the negative impacts of predicted/projected climate change and variability, neither are such strategies sufficiently supported by policy processes (Eriksen *et al*., 2008).

Additionally, current rural-urban migration from the highlands to the lowlands in search of employment opportunities is a main factor that has led to greater concentration of population in urban areas, overwhelming urban services and facilities (overcrowding of schools, hospitals and caused water shortages). Often, this kind of migration is associated with poverty, which by itself exposes people to higher risk, especially where access to services is not considered (ISDR, 2002). Moser *et al*. (2010) also view urban areas of most underdeveloped and developing countries as being at greater risk from extreme weather events because a larger proportion of their population lives in hazard prone areas (informal urban settlements) where their assets, lives and livelihoods are threatened. Thus rural to urban migration has a great impact on small holder farming households in rural areas. The negative impacts include loss of labour (farming), reduced production and economic status, gender and age dynamics.

7.5 COPING AND ADAPTATION STRATEGIES

Analysing vulnerability involves identifying both the threat and resilience or the ability of communities to exploit opportunities and resist or recover from associated negative impacts (Rose, 2004; Gbetibouo and Ringler, 2009; Khazai, 2013). Adaptive capacity is an important factor in characterising vulnerability. The capacity to adapt to natural hazards is context-specific and differs from place to place and among social groups and individuals. The communities across the study region are already reacting to the perceived/potential

vulnerability. Table 7.2 outlines some of the different coping and adaptation strategies that are being implemented by the communities in response to climate, environmental and global changes. In particular, people living in the highland areas are used to climate varying considerably from year to year and season to season at different altitudes, and even on slopes of different exposure.

Table 7.8: Coping and adaptation strategies to natural hazards in south-western Lesotho

Communities' perception of change	**Experienced impacts on livelihood**	**Coping and adaptation**	**Potential vulnerability**
Decrease in rainfall and increase in extreme rainfall events	Overall decline in agricultural production, pastures and livestock	Replacement of maize with sorghum; delayed sowing, selling livestock	Increasing food and livelihood insecurity, erosion of productive assets
Longer dry spells	Drying up of springs, poor pastures	Planting drought resistant crops	Scarcity of water for drinking, agriculture and livestock; increased health problems; increased workload for women and children; (women walk long distances to fetch water and fuel wood, children staying away from school) Crop failure,
Higher temperatures	Poor pastures, lack of water for animals, land becoming less productive	Sell off livestock, less land under cultivation, buying food	Livestock deaths. Risk of malnutrition, dependency on cash income, increased food insecurity
Severe snowfalls	Increased incidences of human and livestock deaths in highlands	Bring animals to the lowlands, store food and fuel in cattle posts	Increased number of deaths due to heavy snowfall
Strong winds	Damaged and destroyed houses and infrastructure	Build wind resistant houses, schools and churches	Loss of property

Traditional land-use systems in Lesotho have adapted to this variability, such as establishing settlements on north-facing slopes, which are warmer and snow melts faster than on south-facing slopes, and moving livestock to graze on high summer pastures (cattle posts) after the snow season. However, in future, climate change may increase vulnerability to climate variability beyond the limits of such past experiences (Kohler *et al*., 2009). Equally, the capacity to withstand the negative effects of natural hazards in a given geographical location can also be related to the coping capacities in a community (e.g., employment opportunities, infrastructure, essential services, physical assets, and resources for recovery of livelihoods). Coping with successive negative impacts of natural hazards has locked households and communities into a poverty trap, as fewer resources remain with which to accrue assets and put in place safety nets.

7.6 OVERALL PLACE VULNERABILITY

Incorporating both social and physical vulnerability reveals a slightly similar spatial pattern of exposure to natural hazards in the study region. Overall, the geography of vulnerability changes considerably when different elements are mapped, although there are some similarities. Several research expectations were confirmed, although there were a few exceptions that were not met. The highlands and the Senqu River valley were expected to be the most vulnerable, for both regions (Senqu River valley and highlands) the expectation was proven true. Additionally, the foothills were expected to be moderately vulnerable and this expectation held true. It was anticipated that the relatively developed lowlands would be among the least vulnerable, however, this expectation held true in few places as the majority of the lowlands exhibited moderate to low place vulnerability levels.

In view of the theory and characteristics that influence place vulnerability, it has been established that places with high levels of physical vulnerability sustain greater losses and damages, from natural hazard (Papathoma-Kohle *et al*., 2011; Wang *et al*., 2013). Although the urban lowlands have high economic potential and a relatively well developed infrastructure, they are generally considered more physically vulnerable than the rural highlands. Equally, natural hazards disproportionally affect communities and populations with high levels of physical and social vulnerability because of increased exposure (elements at risk) and the limited capability of populations in such areas to buffer

themselves against the effects of natural hazards, leaving them exposed to future shocks. Consequently, the predicament that natural hazards such as flooding, drought and severe frost bring to households and communities may ultimately result in poverty (reduced crop production impacting on income and livelihoods) in the study area. Additionally, topography, dependency on social support, lack of access to resources and services, urbanisation, population density, economic status and household demographics play a significant role in defining overall place vulnerability in the study area. Amongst these factors, physical geography (topography and climate) is the core component as it drives much of all factors discussed in this thesis.

Identification of vulnerable community councils is essential for developing targeted and proactive disaster planning and emergency management practices. Economically deprived population groups in disadvantaged locations require special assistance before and after the occurrence of a natural disaster. Hence, identification of highly vulnerable community councils is crucial for disaster management and planning. Consequently, suitable policies must take into account the local context of a given place, instead of following a broad approach to hazard vulnerability reduction (Boruff *et al*., 2005; Papathoma-Kohle *et al*., 2011). For instance, introducing drought-resistant maize seedlings in the study area (shallow soils, steep slopes, and low amounts of rainfall) may not be a viable option in the study region. However, introducing drought resistant maize seedlings may be a solution in the arable north-western lowlands of the country, because these lowlands have relatively fertile soils with relatively good rainfall.

7.7 SUMMARY

This chapter explored various aspects of place vulnerability. The results presented in this chapter attempt to address the research question guiding this study, namely, what are the socioeconomic and physical characteristics of communities and households that make them vulnerable to natural hazards? Synthesising these variables on a local scale provides a detailed overview of place vulnerability to natural hazards in Lesotho and provides an in-depth analysis of place vulnerability on a small scale. Furthermore, this chapter has presented the dynamics of place vulnerability in Lesotho, where such work has not

previously been undertaken. Place vulnerability was examined for the study region as a whole and at community council level. The research conclusions, contributions and recommendations for future research are presented in the next chapter.

CHAPTER EIGHT

CONCLUSIONS, CONTRIBUTIONS AND RECOMMENDATIONS

8.0 INTRODUCTION

In its seventh session, the conference of the Parties (COP7) considered special circumstances of least developed and landlocked countries to adopt measures to address specific needs and concerns of these countries and to prepare and submit national adaptation action programmes (NAPAs). The key objectives of the NAPAs involve the identification of communities and livelihoods most vulnerable to climate change. The issue of specific need for these countries is also covered in Article 4 of the UNFCCC (UNFCCC, 2011) under clause 8 which provides for parties to:

> …give full consideration to meet specific needs and concerns of developing country parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures, especially on [countries that are highly vulnerable to climate change including those] with fragile and mountainous eco-systems" as well as "land-locked and transit countries.

Following this, the current assessment attempted to examine Lesotho's situation in relation to the above and attempted to identify vulnerable places and populations in Mohale's Hoek and Quthing. Lesotho is one of the least developed, mountainous, landlocked countries and is vulnerable to a range of natural hazards, yet no multi-hazards assessment has previously been conducted there. Furthermore, there has not been any prior research on community level place vulnerability in the country. This study employed the hazards of place vulnerability model which looks at the characteristics of a place that makes it more or less vulnerable to the impacts of natural hazards.

The preceding chapters analysed the dynamics, relationships and linkage between physical, social and overall place vulnerability to natural hazards. An understanding of these dynamics, especially in Lesotho, could hardly be more relevant, given the prevalence and recurrence of extreme weather events, including droughts, severe frost, snowfall, strong winds and floods, in combination with high poverty levels among the majority of Lesotho's citizens described above in this thesis and elsewhere (Obiaha, 2010). In this

regard, the study highlights valuable lessons in vulnerability assessment research and contributes to the understanding of place vulnerability to natural hazards. The study was guided by evidence that shows that in sub-Saharan Africa in general, natural hazards and disasters (both climatological and hydrological) have increased in frequency, magnitude and impact during the recent past (FANRPAN, 2010; Gwimbi *et al*., 2012). For a country that is prone to recurring hazards, experiencing declines in agricultural production, increasing poverty levels, food insecurity and a rising the number of vulnerable households (e.g., Mwakabolo, 2007; FANRPAN, 2010; LVAC, 2011), an understanding of place vulnerability, especially in Lesotho, should be most relevant.

While there has been awareness and interventions from the government and NGOs, with initiatives such as LVAC and RVAC established to identify populations that are most food insecure and those that are vulnerable to hunger, the role of the geography of a place, hazard profile and physical variables in vulnerability assessments has lagged behind. Given the role of both the physical and social characteristics on vulnerability to natural hazards, especially in the face of climate change, poverty and economic losses, attention now needs to focus more on the influence of 'place' in terms of research, mitigation and climate adaptation.

The south-western region of Lesotho was understudied from the natural hazards vulnerability perspective. Using a modification of the hazards of place model of vulnerability as a fundamental framework, overall place vulnerability was thus conceptualised as a combination of social and physical vulnerabilities. Social vulnerability was developed from indicators of demographic, social and economic variables of households and communities. Physical vulnerability was computed as a function of the physical environment, hazard frequency, intensity and impact by each hazard. Place vulnerability was thus investigated through examining vulnerability distribution and by identifying the underlying causes of vulnerability in the study area. To empirically assess the influence of social and physical characteristics on place vulnerability, a hazard occurrence database was created for the study area.

The research was guided by three specific questions which the researcher argues need to be answered for a better understanding of place vulnerability to natural hazards in Lesotho. These questions are: 1) What are the physical characteristics of communities that make them more vulnerable to natural hazards? 2) What are the socioeconomic characteristics of

communities that make them more vulnerable to natural hazards? 3) What factors, including social and physical, are responsible for spatial variation in overall place vulnerability? This chapter therefore provides an analysis of how the information presented in this research answers the research questions. Concluding statements are offered and then the overall contributions of this research to hazard and vulnerability science are discussed. Finally, areas for future research and recommendations are presented.

8.1 RESEARCH QUESTIONS

1. *What are the physical characteristics of communities that make them vulnerable to natural hazards?*

As highlighted in Section 5.7, topography has been a key determining factor contributing to susceptibility to a range of natural hazards, thus influencing physical vulnerability of communities to natural hazards. This study treats vulnerability as a pre-existing condition (topography, relief and climate) and focuses on exposure to natural hazards (Cutter, 1996). Researchers following this approach often evaluate the distribution of hazardous conditions, the extent of loss of property and life resulting from a particular event, and human occupancy of the hazard zones (Rygel *et al*., 2006).

The research results indicate areas of concern as the low lying river valleys and the highlands in the study area. These areas are susceptible to flooding, drought, severe frost and heavy snowfall. Because of their location, the low lying areas are prone to flooding and severe frost, and remarkably to drought, with direct impact on agricultural production, income, household food security and livelihoods. Because of their topography, highland communities are more prone to heavy snowfall, severe frost and strong winds, and less susceptible to flooding due to their elevation; furthermore, these communities are isolated and remote. The remoteness and inaccessibility of the highlands reduces their livelihood options in terms of alternative economic options other than livestock farming. As evidenced from previous vulnerability assessments (Gares *et al*., 1994; Papathoma-Kohle *et al*., 2011; Silva and Pereira, 2014), physical characteristics, including topography,

contribute to the hazardousness of a place. The extent of hazardousness measures the degree to which a given place is susceptible to particular natural hazards. In the study area, it was found that the physical landscape influences human activities and hazard occurrence and impact. The factors identified in this analysis are consistent with the broader literature on hazards and demonstrate both the geographical variability and a range of the underlying causes of place vulnerability (physical environment, previous hazards, and impacts).

Generally, it was discovered that steep slopes with sparse vegetation cover were most predominant in mountain areas, rather than surrounding foothills and lowlands, and these characteristics influenced the frequency and intensity of snowfall, frost and strong wind hazards. Topography and the physical geography of a place influences physical vulnerability and the likelihood of hazard occurrence at a particular place. Topography has been identified as a key parameter influencing vulnerability to natural hazards in mountain environments (Bertrand *et al*., 2010; Papathoma-Köhle *et al*., 2011). Apart from topography, susceptibility to natural hazards was further increased by human activities on marginal lands (e.g., agricultural activities on mountain slopes). These results confirm what has been established by Yanda (2011) and Maro (2011) who argued that human activities increase susceptibility to natural hazards, particularly hydrological and geo-hazards. This study also established that it is important to consider topography when conducting physical vulnerability assessments in mountain environments such as Lesotho, because there are substantial differences in hydrological and geomorphological processes across such areas. This study therefore concludes that disasters result from a combination of physical exposure and human vulnerability to the geophysical processes associated with natural hazards (Abhijeet, 2011; Dang *et al*., 2011; Ho *et al*., 2013). Hence, in mountain environments, elevation can be regarded as a reliable indicator for geo-hazards and hydrological hazards.

Variations in the physical characteristics of a place are therefore, important in describing the differential impact of a given hazard across space. It is worth noting that physical vulnerability factors presented in this chapter are interrelated with hazard severity. For instance, low-lying river valley localities are more suitable for crop farming, yet these areas are most prone to frost and flooding, and consequently the impact is more severe than in the highlands (mostly livestock farming). Considering the physical characteristics that contribute to high physical vulnerability levels it has been found that topography of a

place influences the frequency and severity of natural hazard events and their impacts on communities.

However, applying the hazard of place model to assess place vulnerability in the Lesotho context (an underdeveloped country) presents a challenge because of a lack of relevant place specific data (e.g., climate data). Detailed and complete hazard data is crucial for place vulnerability assessments at the local or community council level. For instance, historical and documented records (extreme climatic events) are not place-specific but generalise hazard occurrences for the entire country, therefore, the spatial distribution of documentary records have implications for the wider applicability of a place-based vulnerability assessment. Grab and Nash (2010) affirm that Lesotho's complex topography allows for significant altitudinal, latitudinal and longitudinal climatic differences over short distances, and thus highly variable hazard distributions are likely. Therefore, hazard occurrence and severity in a given area may not likely reflect hazard occurrence and severity across the entire country. Nevertheless, the vulnerability assessment results based on this approach are promising. It is evident that the hazards of place model can be improvised to effectively assess vulnerability to natural hazards in other developing countries. Furthermore, this research differs from previous studies (e.g., Cardinali *et al*., 2002; Santos 2003; Macquarie *et al*., 2004; Sterlacchini *et al*., 2007; Fuchs *et al*., 2007; Cappabianca *et al*., 2008; Papathoma-Köhle, 2011, 2012) in that it is a multi-hazard assessment and places emphasis on the influence of topography in place vulnerability assessment.

2. *What are the socioeconomic characteristics of communities that make them vulnerable to natural hazards?*

Social vulnerability results illustrate that vulnerability is relatively high in Thabana Mokhele, Mphaki and Matsatseng, followed by the community councils the rural highlands and the Senqu River valley, the majority of which are located in the Mohale's Hoek district. A remarkable reliance on rain-fed agriculture for income, which creates a form of economic vulnerability, is preeminent in the rural areas, which means that any change in weather conditions or increases in hydro-meteorological hazards, such as flooding, severe frost, drought, or hail, is likely to affect annual to decadal incomes and the sustainability of livelihoods in rural areas. In contrast, Mashaleng, which is a peri-urban

community council with few of its households entirely dependent on agriculture, with relatively good infrastructure and access to employment opportunities has the lowest vulnerability index score in the entire study area. Additionally, Liphakoe and Khoelenya (the two urban centres in the study area) have relatively low social vulnerability index scores, because these two have a larger proportion of affluent citizens, as well as developed infrastructure and diverse livelihoods options. Low social vulnerability in most urban areas indicates communities with an increased capacity to recover from natural hazard events; therefore socioeconomic factors play an important role in determining impacts from natural hazards. Other areas demonstrating medium-low social vulnerability index scores are Mootsinyane, Liphakoe, Ha Nkoebe, Qomoqomong and Qhobeng. These areas are situated in foothills, have access to services and resources, and have lower population densities, with the exception of Liphakoe which is a densely populated urban area.

It was found that access to basic services and economic resources, such as employment and diverse livelihoods, are vital in determining the social vulnerability of communities. Generally, poverty is likely to make communities more vulnerable to natural hazards as a result of inadequate capacity to recover from continuing shocks. The presence of vulnerable population groups (orphans, elderly, child- and female-headed households) was another significant factor influencing social vulnerability. Collectively, urbanisation, access to resources and services, population densities, infrastructure development, household demographics and economic status jointly influenced social vulnerability in the study area. The importance and the role of socio-demographic and economic factors in determining social vulnerability is also echoed by others (e.g. Cutter *et al*., 2003; Cutter and Finch, 2008; Lowe, 2010; Wood *et al*., 2010; Martins *et al*., 2012). Most of these studies used census data to construct social vulnerability index scores, however this research used an improvised methodology for constructing the social vulnerability index and included local views into quantitative analyses, by employing data from household interviews, expert interviews and focus group discussions. This supplementary data were used to suit the Lesotho context and included variables of social vulnerability specific to the country, such as access to roads, electricity connectivity, mobile phone ownership, villages with existing water systems, and populations receiving social support. These variables would have been excluded had standard vulnerability variables from the original

model and its variants (Cutter, 1996; Cutter *et al*., 2003; Cutter and Morath, 2013) been available.

3. *What factors, including social and physical, are responsible for spatial variation in overall place vulnerability?*

Place vulnerability in this research was mainly a product of physical and environmental factors, and dependency of communities, on rain-fed agriculture. Thus, exposure to natural hazards as a result of the physical environment was a prominent factor for overall place vulnerability, suggesting that overall place vulnerability did not necessarily emanate only from the socioeconomic characteristics of communities. The physical and environmental factors in the study area and in Lesotho as a whole determine and influence livelihood activities because physical factors enhance exposure and susceptibility, and therefore increase overall place vulnerability.

The Thabana Mokhele community council was found to be the most vulnerable and susceptible to a range of natural hazards because of its location (remote highland with low rainfall, cold temperatures and with the majority of its population dependent on crop farming on steep slopes with shallow soils) and topography, as well as the presence of vulnerable population groups (female-headed households, orphans and people dependent on social support), and limited access to resources and services, and thus was the most vulnerable community council. As evidenced in the studies by Dunno (2011), Hung *et al*. (2013), and this research, place vulnerability is a combination of socioeconomic characteristics and the physical characteristics of a place, as well as the region's past experience with natural hazard. Therefore, factors highlighted in this study are consistent with the broader hazards and vulnerability literature and prove that both the geographical variability and a range of the underlying factors are causes of place vulnerability (socioeconomic characteristics, physical environment, previous hazard occurrences and impacts). In contrast to previous studies undertaken elsewhere (Cutter *et al*., 2003; Wisner *et al*., 2004; Fuchs *et al*., 2011; Dunno, 2011; Hung *et al*., 2013; Hung and Chen, 2013), where place vulnerability is mainly socially constructed, for this research it is mostly physically constructed.

Furthermore, the research results revealed that the potential for loss is higher in places with intersecting high social vulnerability and high physical exposure or high social vulnerability and high natural hazard occurrence (which indicates frequent hazard occurrences in areas that are naturally exposed). Identification of such community councils is essential to developing targeted and proactive disaster planning and emergency management practices. Deprived population groups in disadvantaged locations require special assistance before and after natural hazard occurrences. Lastly, this study discovered that place vulnerability in Lesotho is a dynamic process, continually changing with physical and social processes that are shaped by local and external factors.

8.2 KEY FINDINGS

The key findings were the following:

- Generally, rural highland community councils have high place vulnerability index scores. Thus, the rural highlands exhibited high social and place vulnerability levels. For these areas, lack of access to resources and services, poverty, unemployment, presence of vulnerable groups (orphans, elderly, female and child-headed households) were the most influential factors to social vulnerability. Access to economic resources was a key factor determining social vulnerability of populations and communities because poverty is likely to make people more vulnerable to future hazards, as it reduces their inability to recover from future shocks.
- In the study area, the most vulnerable group are child-headed households and elderly widowed females who also bear the responsibility for raising orphaned grandchildren because of the HIV/AIDS pandemic.
- For many areas, the physical geography, exposure to natural hazards and past experience with natural hazards were the most important factors influencing physical and the overall place vulnerability. Hazard exposure was the main indicator, most especially for the river valley communities, where settlements and fields are located in hazard prone areas, with a direct impact on agriculture and household food security, income and livelihoods.

- Overall, Thabana Mokhele in Mohale's Hoek district was the most vulnerable community council in the two districts. Vulnerability in Thabana Mokhele was a result of inaccessibility, limited access to resources services and high levels of economically vulnerable groups.
- Identifying the importance of the key physical vulnerability indicators (topography, climate and soils) can signal to decision-makers where and how to develop communities that are more resilient to natural hazards over the longer term.
- Vulnerability in the study area is dynamic both seasonally and temporally and is influenced by environmental and global changes. There is a distinct seasonality to risk and exposure posed by natural hazards (e.g., snowfall and frost hazards in winter and floods in summer).

8.3 CONTRIBUTIONS TO INTERNATIONAL AND LOCAL VULNERABILITY ASSESSMENT RESEARCH

A place vulnerability assessment to natural hazards presented in this study addresses some of the aims outlined by the global and regional bodies such as the International Strategy for Disaster Reduction in Africa, which among others (ISDR, 2004; 2010), called for improving the assessment and identification of natural hazards. Furthermore, this research is in agreement with the Southern African Vulnerability (SAVI) framework, which seeks to examine local vulnerabilities to shocks (O'Brien *et al*., 2010). By using local knowledge gathered from household interviews, focus groups and key informants interviews, this research is therefore compliant with the framework of the IPCC (2012), which calls for the integration of local knowledge with scientific and technical knowledge to improve disaster risk reduction.

Additionally, this research also expanded upon Cutter's (1996) hazards of place vulnerability model by incorporating qualitative and quantitative data to assess place vulnerability to natural hazards. Thus, the research identified theoretical and practical linkage between different bodies of literature. The contribution of this research, both theoretically and practically, to the literature on natural hazards and vulnerability research, is that it advances both theory and knowledge about place vulnerability within a developing country's context, in which lack of accurate and reliable data is a major limitation. This research, therefore, incorporated instrumental climate data, documentary

climate data sources, focus group discussions, and household and key informant interviews into the original hazards of place vulnerability model, to create a natural hazards database for the study area and to come up with the overall place vulnerability index. Thus, this research demonstrates that through a combination of both quantitative and qualitative methods, a comprehensive vulnerability assessment can be accomplished. It further extended the applicability of this model in Lesotho by using a set of indicators especially applicable to Lesotho and applied them at the sub-district level. The adjustments in the selection of the data and input variables were required to fully capture the geography of Lesotho and the study region in particular. These particular variables included percentage of orphans and child-headed households, percentage of the population dependent on social protection (thought to increase vulnerability in the study area), percentage of households owning mobile phone, percentage of villages with no access to roads, and percentage of villages with existing water system, as economic and socio-demographic indicators. These variables are not normally used by social scientists for social vulnerability assessments, yet they are significant from a preparedness point of view in the Lesotho context. Vulnerability indicators normally used to represent race and culture in the original social vulnerability index methodology were not applicable to Lesotho (Lesotho is a homogeneous country), therefore they were excluded.

Regardless of these limitations, this study has laid the groundwork for future vulnerability assessments in Lesotho. This assessment is the first to apply this modified model in Africa and it assesses multiple hazards at local level. The model proved to be applicable to Lesotho's context and is an effective framework for comprehensively analysing place vulnerability.

Practically, the results from this study present policymakers, NGOs and disaster management officials with a suitable method of identifying vulnerable populations and communities affected by different natural hazards, and can assist in identifying appropriate place specific mitigation measures. Vulnerability and associated natural hazard mapping can offer decision makers with rich data which incorporate both socioeconomic and physical characteristics in emergency efforts. Thus, without analysing and mapping different aspects of vulnerability, one would not know what makes a particular place vulnerable, and consequently not know how to target that particular place to reduce hazard

risk and vulnerability. In this sense, the presented work will play a vital role in determining the main direction of efforts made by the Lesotho government to reduce the economic losses and threats to the population, caused by natural disasters.

Until now, there were no hazard databases or maps available throughout the country, or the study area in particular. Hence, the identification of natural hazards and their frequency and impacts was one of the main contributions of this research. Another key outcome of this study was the production of an overall place vulnerability map which can be used in locating previously overlooked areas, or previously unknown pockets of vulnerability. This map revealed some unrecognised and unknown community councils with high vulnerability levels.

8.4 CONCLUSION

This research demonstrated that an improvised methodology for place vulnerability assessment, which incorporated new indicators specific to Lesotho's context, could be implemented in the Lesotho's context, may be implemented in other developing countries where data availability is a challenge. Vulnerability analysis in relation to natural hazards is of paramount importance if one is to analyse the potential impacts of future hazard occurrences. This study showed that a single method cannot capture all aspects of vulnerability.

The place vulnerability approach employed in this study elucidates why community councils experiencing similar natural events can be more or less vulnerable. Therefore, the extent to which communities and populations are vulnerable to natural hazards is determined not only by a population's proximity to the source of risk, but also by its social vulnerability status and the hazard profile (frequency and severity). Understanding the differential impact of natural hazard is critical to reducing the negative impacts of disasters.

The results of this empirically based place vulnerability assessment in Lesotho can be a valuable tool for the government, local and international NGOs and disaster management officials, because the study delineates vulnerability hot spots for maximising efforts before and after hazard events. Reducing vulnerability in Lesotho has been a documented concern

for the government and NGOs, and the initial step in addressing this concern is to identify the most vulnerable populations and where they live. This study therefore provides a spatially based method for identifying vulnerable populations and communities, and compares their levels of vulnerability at district and community council levels. As a comparative study, it demonstrates who and what areas are most vulnerable. The results, therefore, provide input for decision makers in producing more localised and hazard specific mitigation strategies.

8.5 RECOMMENDATIONS

Based on the research findings, the following recommendations are made:

- For future natural hazard prevention planning, the government should increase the prevention and mitigation efforts in the rural highlands and the Senqu River valley region, in order to improve resilience and reduce vulnerability. This would especially enhance the disaster prevention capacity of these regions. Because natural hazards tend to impact differentially across various spatial scales, the typical vulnerable population groups in any village should also be taken as the focal point of the mitigation initiatives.

- There is a need to provide information on seasonal risk for different hazards especially in the rural highland communities for effective disaster risk management.

- Additionally, considering that the majority of the population in Lesotho depends on agriculture, which is highly sensitive to the impacts of natural hazards and climate variability, the agricultural sector thus possesses weak and poorly resilient agricultural infrastructure, for example, irrigation, therefore, sustained efforts should be made to increase the ability of the agricultural sector to withstand the effects of natural hazards.

- Additionally, to test the method presented here, similar research could be undertaken in other parts of the country, or for the entire country, and also focus on other natural hazards, for example, hailstorms, locusts, lightning and diseases, prevalent in the country.

8.6 FUTURE RESEARCH

The main objective of this study was to assess place vulnerability to natural hazards in Mohale's Hoek and Quthing districts. Although the research findings answered some essential questions that can inform policy and planning, there is a need to build on this research and improve it. The following are recommendations for future research:

- There is a need to incorporate resilience when examining place vulnerability to natural hazards. Future research has to focus more on resilience and this has to be incorporated in natural hazard research. Therefore, the place vulnerability assessment model in this study can be improved by incorporating some resilience indicators.

- This study is the initial step in place vulnerability assessment to multi-hazards in Lesotho. It therefore lays the foundation for undertaking more refined place vulnerability assessments to natural hazards in the country in future.

- Future research could determine the percentage of the population residing in different hazard zones by using data on land use, land cover and population at the enumeration level. These datasets are currently not available. This information could be used to identify the number or percentage of the population living in susceptible areas for each hazard type.

- There is a need to create a natural disasters database with the inclusion of economic losses in the entire country and include monetary information on the impact of past events on the built environment, livelihoods and the physical environment.
- Future research should focus on seasonal place vulnerability "hot seasons"especially in the rural and inaccessible highlands.

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