VULNERABILITY ASSESSMENT OF SETTLEMENTS TO FLOODS: A CASE STUDY OF WARD 7 AND 9, IN LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

by

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DISSERTATION

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DEDICATION

I would like to dedicate this dissertation to my mother Suzan, my two younger sisters, Valencia and Nerissa, my grandmother Rebecca and my late friend, Atlas Hakelo Maluleke

DECLARATION

I declare that ‘vulnerability assessment of settlements to floods: A case study of Ward 7 and 9, in Lephalale Local Municipality, Limpopo Province, South Africa’ is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

....

Full names **Date**

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ABSTRACT

Floods are one of the major natural hazards that occur with devastating effects globally. South Africa is one of the countries that is affected as flooding frequently occurs at different sub-national scales and with devastating impacts on human settlements. The variability of the nature, impact and frequency of flood occurrence in the country has heightened interest in the assessment and determination of flooding vulnerability, particularly in areas that have been affected or are likely to be affected in the near future. Given the uncertainties surrounding flood occurrence and the enormous damages resulting from the events, this study sought to assess the vulnerability of settlements to floods in Ward 7 and 9 of Lephalale Local Municipality. To accomplish this, both primary and secondary sources of data were used in this study. A mixture of closed-ended and open-ended household questionnaire, which was administered to 133 and 227 randomly selected households in Ward 7 and 9 respectively was used. In addition, a vulnerability index was developed using an indicator approach in order to determine levels of flood vulnerability in the study areas. Indicators were identified, grouped and normalised using the standardization method, then weighted using pairwise comparison method. The various indicators were then aggregated through a linear summation method into a vulnerability index. This index was subsequently used to produce a vulnerability map showing the spatial pattern of the different flood vulnerability levels in the studied areas. The results reveal that socio-economic as well as physical factors influence settlements' vulnerability to flooding disasters. Furthermore, the vulnerability index map showed that Ward 7 was more vulnerable to flooding, with an average index of about 0.16 while Ward 9 was less vulnerable, with an average flood vulnerability index of 0,07. The vulnerability map also indicated that out of the total land area of 13.54km^2 occupied by settlements in Ward 7, 9.38 km^2 was very vulnerable, 2.27km^2 highly vulnerable and 1.89km^2 had low vulnerability. In Ward 9, about 4.44km^2 of settlements land was experiencing low vulnerability while 29.96km^2 experienced very low levels of vulnerability. The study concludes that the high vulnerability of Ward 7 was a result of an interplay of factors that include its nearness to the stream, a high proportion of low-lying land, land use type and high population densities. The results of this study can serve as a basis for targeting prioritization efforts, emergency response measures, and policy interventions at the ward level for minimizing flood disaster vulnerability in municipal areas. The study recommends that flood vulnerability assessments should integrate socio-economic characteristics with physical factors in order to adequately assess vulnerability and therefore enable municipalities to anticipate floods and plan for them.

Key concepts: Floods, vulnerability, settlement, indices, Lephalale, South Africa

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LIST OF ACRONYMS

AHP	Analytical Hierarchy Process
BBC	British Broadcasting Corporation
IFRC	The International Federation of Red Cross
IDW	Inverse Distance Weighted
CI	Consistency Index
CNN	Cable News Network
CR	Consistency Ratio
CRED-MDAT	Centre for Research on the Epidemiology of Disasters Emergency Event Database
EPoA	Emergency Plan of Action
DEA	Department of Environmental affairs
DEM	Digital Elevation Model
DPCD	Department of Planning and Community Development
FEMA	Federal Emergency Management Agency
GDP	Gross Domestic Products
GIS	Geographical Information System
GIS-MCDA	GIS based Multiple Criteria Decision Analysis
GPS	Geographical Positioning System
IFRCRC	The International Federation of Red Cross and Red Crescent Societies
HDI	Human Development Index
HIV/AIDS	Human immunodeficiency virus and acquired
immunodeficiency	Syndrome
IHP	International Hydrological Programme
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change
LPI	Lived Poverty Index
MCA	Multiple Criteria Analysis
MCE	Multi Criteria Evaluation
MCDA	Multi Criteria Decision Analysis
NDMC	National Disaster Management Centre

OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PCM	Pairwise Comparison Method
PRW	PreventionWeb
RDP	Reconstruction Development Plan
RI	Random Index
SAWS	South African Weather Services
SANSA	South African National Space Agency
SPSS	Statistical Package for Social Sciences
Stats SA	Statistics South Africa
UN	United Nations
US$	United States Dollar
UNISDR	United Nations International Strategy for Disaster Reduction
UNDP	United Nations Development Programme
VLIR	Flemish Interuniversity Council
WRI	World Resource Institute

CHAPTER 1: INTRODUCTION

1.1 Introduction

This introductory chapter outlines the background to the study, details of the research problem and gives the study aim and objectives. The chapter also discusses the significance of conducting a study which assesses the vulnerability of settlements to floods.

1.2 Background to the study

Floods are the most common recurring natural disasters in the world, affecting the livelihoods of about 520 million people globally every year and claiming the lives of approximately 25 000 lives annually (IHP, 2004). The destructive nature of floods also renders approximately 3.2 million people homeless throughout the world every year (IHP, 2004). The annual cost to the world economy due to flood destruction amounts to over US$60 billion (Simonovic, 2009), whilst the damage to cultural assets and natural resources is immeasurable (IHP, 2004). Records from 1970 to 2005 indicate that over 30% of all natural global disasters during that period were caused by floods (UNISDR, 2006). According to IPCC (2001), floods incidences are most likely to get worse, as scientific evidence indicates that the magnitude and frequency of floods will increase due to climate change. The risk and vulnerability associated with floods can therefore not be ignored.

The problems brought about by floods are not just global, but are also found at a local scale. South Africa, for example, is one of the countries that is affected by floods. Frequent floods occur in the country at least once every two years with more extensive floods occurring at least once every 10-15 years (PRW, 2011). Some of the most extensive floods occurred in the country in 1974, 1988 and 2000 (Viljoen and Booysen, 2006). The flood of 1988 caused widespread damage to Lower Orange River, Free State, Northern Cape and the Karoo whilst the 2000 floods affected areas along the Limpopo basin.

Floods occur as a consequence of meteorological, hydrological and/or human factors/processes (Niekerk and Nemakonde, 2017). These processes may either act individually or together to create a flood hazard. Meanwhile, meteorological and hydrological processes can be fast or slow, producing unpredictable flash floods or more predictable river floods (Parker, 2000). Meteorological factors include prolonged seasonal rainfall which may be due to storm surges, typhoons and cyclones. In Africa, for example, the greatest flood hazards are caused by tropical cyclones and severe storms (Mohammed and Rahman, 1998, Chikoore *et al*., 2015). In South Africa, the most common cause of floods is climatic extremes, especially excessive rainfall (Van Zyl, 2008). Hydrological factors such as overflowing of large rivers and its tributaries and localised runoff following intense local rain over a short or long period of time can also lead to flooding.

Globally, it has been estimated that the mean annual population being affected by riverine floods alone is around 21 million people and this figure is projected to increase to approximately 54 million by 2030 (WRI, 2016). The number of people vulnerable to devastating floods is, therefore, also expected to increase**.** In South Africa, the problem of flooding is expected to continue. Although rainfall averages may change over time in South Africa, it is projected that heavy rainfall events may increase in some parts of the country in the near future (Ziervogel *et al*., 2006). The increase in heavy rainfall events is likely to pose the most significant risk to people and their settlements.

The vulnerability of human settlements to floods is an outcome of the settlements' exposure and sensitivity to flood risks as well as the extent to which the settlement can resist, cope and recover from flooding events (DEA, 2014b.). The vulnerability of settlements to floods, therefore, includes not only exposure to heavy rainfall, but more importantly the impact such heavy rainfalls may have on social, economic and physical setup of human settlements as well as measures in place to resist, recover or adapt (Van Huyssteen *et al*., 2013). As Van Huyssteen *et al*., (2013: p6) observe, "areas that are socially vulnerable are typically communities with high disparities in income, high levels of poverty, high illiteracy rates, age dependencies, political instability, high population concentrations, single-headed households, population growth, migration and limited access to livelihoods and services". Developing communities tend to be more vulnerable due to increasing exposure of many people, especially those who are sensitive and have low adaptive capacity to floods (Ziervogel *et al.*, 2006).

Flood vulnerability assessment is a crucial factor in determining how vulnerable an area is to floods and why is it vulnerable. Flood vulnerability has been assessed by developing vulnerability indices through the use of indicators (Ologunorisa, 2004, Connor and Hiroki, 2005, Rygel *et al.*, 2006, Balica *et al.*, 2009, Fekete, 2009, Müller *et al.*, 2011, Son *et al.*, 2011, Balica *et al.*, 2012, Park *et al.*, 2012, Antwi *et al.*, 2015, Oulahen *et al.*, 2015). One such index, the Flood Vulnerability Index (FVI), is a quantitative representation of all the characteristics of a settlement that are related to flooding (Balica *et al.*, 2012). The characteristics are factored as indicators that can be combined into the FVI and visualized with a map in a GIS (Geographical Information System) environment. The indicator approach has been widely used in the areas of vulnerability assessment (Adger *et al.*, 2004, O'brien *et al.*, 2004, Brooks *et al.*, 2005). This indicator approach, in which both physical and socio-economic factors are systemically combined to form a FVI was regarded as being suitable and hence it was adopted in this study. This approach adequately quantifies different levels of vulnerability whilst allowing for the assessment of vulnerability of human settlement to floods using socio-economic and physical indicators of the study area regarding exposure, sensitivity and adaptive capacity (Akukwe and Ogbodo, 2015)

Geographical Information System (GIS) is a useful spatial tool in the development of flood vulnerability index. This tool has the ability to capture, store, manage, analyse and visualize geographically referenced data (Coppock and Rhind, 1991, Maguire, 1991, Chrisman, 1999, Tomlinson, 2007, Kavita and Patil, 2011, Singh and Fiorentino, 2013). Indicators for floods vulnerability are spatially referenced and could therefore be handled and manipulated using GIS (Cutter *et al.*, 2000, Wu *et al.*, 2002). GIS is integrated with Multiple Criteria Decision Analysis (MCDA) to systematically analyse indicators and develop the flood vulnerability index. GIS allows the decision maker to identify a predefined set of indicators, pre-process and analyse data with the overlay process (Aurora, 2003). The MCDA in GIS helps decision makers to make effective decisions mainly in terms of choosing, ranking and weighing the indicators. GIS-MCDA (GIS based Multiple Criteria Decision Analysis) is a process whereby geographical data is transformed and combined and weighted, according to the decision-maker's preferences, as to subsequently obtain information to inform decision making processes (Greene *et al.*, 2011). The Analytical Hierarchy Process (AHP), developed by (Saaty, 1980) is an analytical tool in MCDA, designed specifically to calculate the weights that express the relative importance of the selected criteria/factors (Alfares and Duffuaa, 2008). These appear to be flexible decision-making tools for multiple criterion problems such as identifying areas vulnerable to floods because they have the ability to evaluate and dissect a problem into hierarchies while ensuring that both qualitative and quantitative aspects of a problem are incorporated in the evaluation process (Carreño *et al.*, 2007). Identifying areas vulnerable to floods is related to decision support and could, therefore, be achieved through the use of GIS and MCDA (Malczewski, 2006).

While flooding incidents in the country are on the increase, and the number of communities and households being affected are also rising substantially, very little has been done to explore ways of assessing the magnitude of vulnerability as a step towards planning and responding effectively in municipal areas of South Africa. Against this background, it becomes imperative to propose, develop or adopt scientific methodologies that allow assessment of human settlements vulnerability to floods with a fair level of accuracy, using collected and available data (Spaliviero *et al.*, 2014).

Understanding vulnerability of settlements to the impacts of floods requires localized assessments that can help policy makers to find answers to questions about who are vulnerable, why are they vulnerable, how are they vulnerable, what are the causes of their vulnerability, and what can be done as a response to reduce their vulnerability to floods? (Hill and Cutter, 2001, Birkmann, 2006). Thus, vulnerability assessments are critical to enable a speedy and effective response to flooding impact and to inform adaptation procedures.

1.3 Statement of the problem

Floods are one of the major natural hazards occurring in South Africa. There have been 77 reported flood disaster events in the country between 1980 and 2010 with annual flooding risk being estimated at 83.3% (PRW, 2011). This previous floods events have resulted in unprecedented disruption of economic activities, damage to roads and building infrastructure, loss of livelihoods, displacement of people, and even worse, loss of lives (Els, 2011).

While South Africa as a country is vulnerable to floods, the probability of risk to flooding is not uniform at the sub-national level. In 2000, for example, a flood event devastated the Limpopo Province (Donohue *et al.*, 2000, Dyson and Van Heerden, 2001, McCusker, 2004, Mekiso, 2011, Malherbe *et al.*, 2012, Maponya and Mpandeli, 2012). These floods caused extensive damage to public and private infrastructure costing billions of rands (Nethengwe, 2007). In March 2014, Limpopo Province was again affected by floods with the municipalities of Lephalale, Mogalakwena, Modimolle, Bela-Bela, Thabazimbi, and Mookgopong in Waterberg District being the hardest hit (EPoA, 2014). The cost of damage to infrastructure such as main roads, houses, farmland and tourist centres, was estimated to run into millions of rands. In 2014, the rivers around the villages and farms (particularly Phalala and Mokolo) in Lephalale Local Municipality, burst their banks and flooded adjacent low-lying areas (EPoA, 2014). Given Alexander (2000b)'s estimates that there are between 50 000 - 100 000 people living along rivers and streams in South Africa below levels reached by previous floods, the impact of any flood events is likely to be devastating to people in close proximity of river banks and flood plains.

After the past flooding events in Limpopo, the extent of devastation in areas such as Lephalale Local Municipality was catastrophic (EPoA, 2014). This heightened interest in understanding the vulnerability of settlements to flooding (Adger, 2003, Adger *et al.*, 2005). This, therefore, warrants a study in

Lephalale Local Municipality, which identifies areas that are vulnerable to floods as well as the extent of their vulnerability to flooding, paying a closer look at the drivers of the exposure, sensitivity and the adaptive capacity of people in these settlements. Understanding the underlying processes that cause certain places to be more vulnerable than others as well as the extent of their vulnerability will facilitate the generation of a vulnerability map for the area. Such a vulnerability map will help in identifying the spatial variations to flooding vulnerabilities within the area. The information generated could then be used to support spatial policy and planning and disaster risk management processes in the local municipality.

1.4 Rationale

Lephalale Local Municipality in the Waterberg District is prone to flooding (IDP, 2009). A huge information gap however, still exists in understanding the vulnerability of settlements to flooding in these areas (Van Huyssteen *et al.*, 2013). Furthermore, few studies have also been conducted in South Africa using the indicator approach to understand vulnerability of settlements to flooding. The indicator approach uses a combination of social, economic and physical indices to measure the vulnerability to flooding. Much of the literature on vulnerability, particularly in the developing countries, pays more attention to causes, impacts, and community perceptions on flooding (Musyoki *et al.*, 2016). According to Mudau (2001) and Sengani (2008), comprehensive assessments of vulnerability to flooding, which combine physical, social and economic variables are few and spaced. It has, however, been argued that useful vulnerability studies on flooding should include not only an understanding of the causes and impacts, but also an appreciation of the key variables that increase vulnerability as well as the computation of indices to use for predictive purposes (DPCD, 2008). In the developed world, studies on vulnerability now generally follow an integrated vulnerability assessment approach, where indicators accounting for both physical and socio-economic variables are systemically combined to determine vulnerability (Wisner *et al.*, 2004). This study will adopt the indicator approach to assess floods vulnerability.

1.4.1 Aim

The aim of this research was to assess the vulnerability of settlements to floods in Ward 7 and 9 of Lephalale Local Municipality in Limpopo Province.

1.4.2 Objectives of the research

The study sets the following objectives:

i. to determine and profile the drivers of settlements' vulnerability to floods;
ii. to develop a flood vulnerability index of the settlement; and
iii. to map and identify settlements that are vulnerable to floods in the municipality.

1.5 Significance of the study

This study will contribute towards the understanding and advancement of relevant knowledge of vulnerability of settlements to flooding. The research will provide insights into integrating social, economic and physical characteristics of human settlements in floods disaster management in the municipality. In a country and context where knowledge and information on flood vulnerability is limited, and where municipalities lack capacity to respond timeously to flooding incidents, this study will contribute to policy development as well as intervention strategies and the derivation of new physical and non-physical measures to improve planning processes in the study area. Furthermore, the study findings may also be useful in supporting decision makers to effectively plan for vulnerable settlements. Thus, better flood management strategies may be introduced in Lephalale Local Municipality.

1.6 Organization of chapters

This study is organized into five chapters. Chapter One is an introductory chapter. It outlines the background of the vulnerability assessment of settlements to flood hazard, the problem statement, the rationale as well as the significance of conducting a study of this nature. Chapter Two reviews literature on the status of the flood vulnerability assessment with special focus on: spatial distribution of floods, key drivers of vulnerability to flood hazards, the use of GIS in assessing and monitoring floods, the combination of vulnerability index and GIS techniques and the direction for future studies. The chapter also discusses how vulnerability is conceptualized in the context of this research. Chapter Three presents and discusses the methods and materials used to assess settlement vulnerability in Lephalale Local Municipality. Chapter Three begins with a brief description of the study and followed by the discussion of research design, sampling procedure, data collection methods as well as the processing and analysis of research data. The limitations of the research are also presented in this chapter. Finally, the chapter elaborates on issues of ethical consideration and ends with concluding remarks. In chapter Four, the study results are presented, analyzed and discussed to meet the objectives of the study as set out in the first chapter. Chapter Five presents a summary of the research findings, a conclusion and suggests measures that can be adopted to reduce the vulnerability of settlements to floods and increase susceptibility and ends with recommendations for improvements as well as further assessment of settlement vulnerability to flooding.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents a review of literature related to flooding and vulnerability. It seeks to review the status of the flood vulnerability assessment with a special focus on: (i) floods and human settlement; (ii) spatial distribution of floods; (iii) key drivers of vulnerability to flood hazards; (iv) vulnerability index (v) the use of GIS in assessing and monitoring floods (vi) the combination of physical and socio-economic data on vulnerability assessment (vii) direction for future floods vulnerability studies and finally (viii) presents the conclusion where major literature findings are summarized.

2.2 Floods settlement nexus

Floods are renowned as one of the principal causes of catastrophic economic damages and loss of human lives globally. Between the period of 1980 and 2013, floods resulted in loses that exceeded (US) $1 trillion and approximately 220 000 fatalities globally (Dottori *et al.*, 2016). Flooding impacts and effects have been noted to range from damage to societal, cultural and natural resources, disruption of economic activities and livelihoods, obstruction of day to day activities (e.g. traffic flow) displacement of people, loss of property, and even worse, loss of lives (Akukwe and Ogbodo, 2015). The frequency and severity of the effects of flooding events in the forthcoming decades is estimated to dramatically increase in some regions because of the current and ongoing shift in climatic variations (IPCC, 2013). Therefore, the number of people exposed to possible flooding is also expected to increase. Meanwhile, the world's population has also dramatically increased from 1.1 billion over the last 12 years to about 7.6 billion currently. The world's population is projected to further increase to 9.8 billion in 2050 with more than half of the anticipated population growth between now and 2050 expected to occur in Africa (UN, 2017). An increase in population will put more pressure on land as a resource. This will lead to a development of settlements in areas prone to floods, such as river banks. The shift in the global climatic pattern together with increasing population render settlements a very critical sector for flood disaster and risk management.

Floods refer to an extreme water accumulation and a flow which then cannot be contained in a channel resulting in an overflow onto its banks, adjacent floodplains and/or surrounding areas that are normally dry (Kundzewicz *et al.*, 2014). Floods are caused primarily by climatic system, most notably precipitation. The natural characteristics of an area such as drainage basin conditions, soil characteristics, slope, altitude also determine the potential for flooding (Mulugeta *et al.*, 2007). Anthropogenic activities such as land degradation; deforestation, high population density, improper land-use planning, zoning, and control of floodplain development, exacerbate flood events (Niekerk and Nemakonde, 2017). Floods in Africa mainly occur along the larger river basins, with flash floods causing damage mainly in urban areas (World Bank, 2010). An example of the most severe and disastrous flood event in history occurred in the Yellow river in China in 1887 killing approximately one million people. This disastrous flood occurred because the Yellow river was over flowing its banks by a magnitude above 1500 times (Kozlowski, 1984, Jonkman, 2005). Floods could occur in an area over a period of time varying from several times a year to once in a few hundred years (Kozlowski, 1984). Considering the severity and a rapid increase in the frequency of natural flood hazard events, much effort still needs to be exerted into developing accurate and efficient mechanisms to assess vulnerability of settlement to floods.

Human settlements are places – large and small, urban and rural, formal and informal -where people live (Chen and Ye, 2014). Globally, many people still reside in the rural areas especially in the developing countries (World Bank, 2010). Rural settlements are strongly influenced by access to resources such as land and primarily water resources. This explains the high magnitude of human settlement concentrations along the rivers and flood plains which are particularly threatened by the risk of flooding (Di Baldassarre *et al.*, 2013). Subsequently, the nature and extent of flood impacts is determined by the physical characteristic of the settlement setup and socio-economic traits of the settlers. In that regard, vulnerability to flooding events does not only vary in the extent and nature amongst areas, but also within settlements at the individual or household level. These individual factors also cumulatively affect the vulnerability of settlements (Tewari and Bhowmick, 2014).

2.3 Spatial distribution of flood events

Figure 2.1 illustrates the spatial distribution of flood occurrence globally. It can be observed that the floods events are concentrated mostly in the coastal regions. Figure 2.1 illustrates that in North and South America, reported flood events frequently occurred along the coastal regions. In inland North America, flood events reported between 1998 and 2010 were more concentrated between latitudes 35 and 45. A similar trend is observed along the coast of Asia, Australia and Southern Europe. In Northern Africa there seems to be less flood events occurrences. However, the eastern and western coastal areas of Africa seem to be incurring a high frequency of flood events. In southern Africa, specifically, the Atlantic and Indian coastal areas are also encountering a high frequency of floods events. Furthermore, the Southern region of Zimbabwe and the northern region of South Africa have a high frequency of flood events (Figure 2.1).

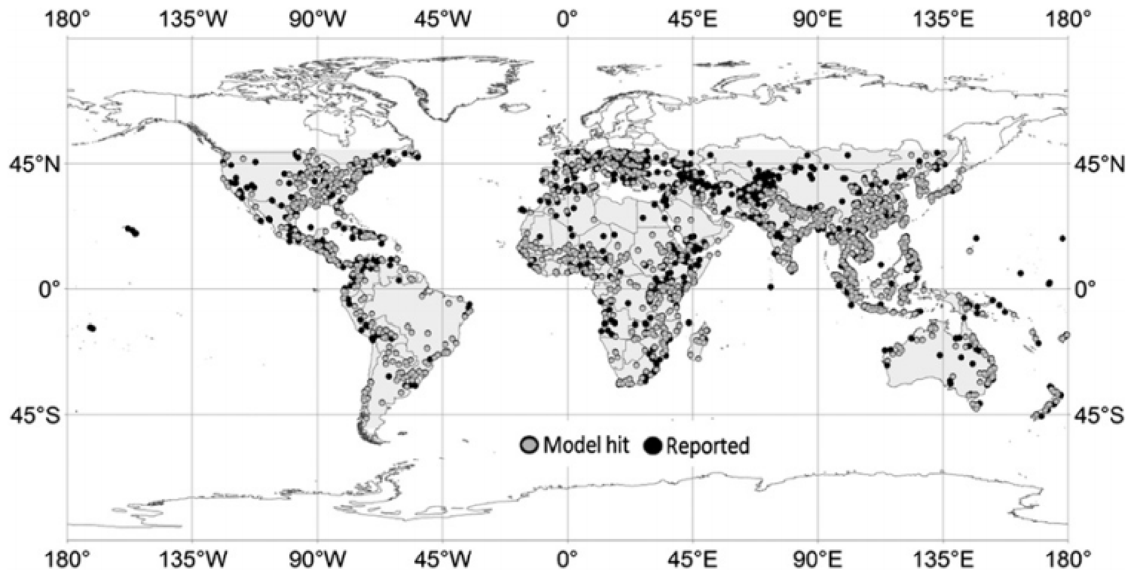

Figure 2.1: Global spatial distribution of floods events detected based on the global flood monitoring system as well as reported between the period of 1998–2010 (Wu et al., 2012).

2.3.1 Spatial distribution of flood events in Africa

Floods are among the most devastating natural hazards in Africa, with greatest hazards arising from tropical cyclones and severe storms (Mohammed and Rahman, 1998). Periods of extreme rainfall, storms and cyclones floods in Africa appear to correlate with El Niño events (Field *et al.*, 2012). (Parker, 2000) observed that in many African countries, floods had created great natural threats to life, health and population. Flood-related fatalities in Africa, as well as associated economic losses, have increased dramatically over the past half-century (Di Baldassarre *et al.*, 2010). From 1900 to 2006, a total of 937 recorded flood events (CRED-EMDAT, 2016) affected over 72 million people, killed nearly 20 000 and caused damage estimated at about US$8 billion (Hounkpè *et al.*, 2016). Table 1 illustrates flood events that occurred in the various regions of Africa. in Northern Africa, specifically, the most devastating floods occurred in northern Algeria during the year 2001 where 800 people were reported dead (Lukamba, 2010).

In East Africa, the most devastating floods were recorded in Kenya during the year 1987 and in Somalia during in the year 1997. In West Africa, Ghana experienced the worst floods in the year 2001, where 100000 homes were consequently destroyed, displacing millions of people (Table 2.1). Southern Africa witnessed its most devastating floods; associated with tropical cyclone Eline, during the year 2000, where Mozambique, South Africa, Zimbabwe and Botswana were drastically affected. About 300 000 Mozambicans were affected whilst the economic growth rate was drastically reduced from 10% to 4%. Meanwhile, in Botswana, 4000 people were displaced. In South Africa, severe damage to housing and infrastructure were recorded. The rapid increases in flooding events, degradation and catastrophic economic damages in most countries of Africa requires affordable and accurate methods for rapid, accurate and efficient flood hazard evaluation at local to regional scales.

Table 2.1: Past flood events in Africa

Region	Year	Affected area	Type of floods	Extent of devastation	Sources
North Africa	2001	Northern Algeria		800 people were reported dead. Economic loss of approximately (U$$400 million) were encountered.	Lukamba (2010)
	2013	Sudan Sudan	Nile River floods	About 48 people lost their lives Thousands were adversely affected.	BBC (2013)
	2010	Egypt	flash floods.	12 people in Sinai Peninsula lost their lives. A great number of houses in four regions of Egypt (North Sinai, South Sinai, Red Sea and Aswan) were severely hit. About 3,500 persons (500 households) were evacuated.	IFRC (2010)
	2008	Algeria	flash floods	About 29 people lost their lives. 50 people were injured. About 1 000 were homeless around Ghardaia.	IFRC (2008)
	2011	Algiers Algeria		13 people were declared dead Hundreds of houses were destroyed.	The Guardian (2001)
	2007	Northern Algeria,	flash floods	severe damage to local. infrastructure and livelihoods.	IFRC (2007c)
		North Eastern Morocco	flash floods	3 people lost their lives.	
		Southern Tunisia	flash floods	18 people lost their lives.	
	2013	Libyan capital	Heavy rain floods	Disruption from Tripoli to Tunis and beyond.	Aljazeera (2013)
		Tunisia	flash floods	Severe damage to local. infrastructure and livelihoods.	
		Morocco	flash floods	Severe damage to local infrastructure and livelihoods.	
East Africa	1997 /8	Kenya	El Niño related floods	Infrastructure and property worth about U$$1.8 billion were destroyed.	Gadain *et al.* (2006)
	1988	Sudan	River (White and Nile) floods	Severe damage to irrigation canals, sewage system, electricity, roads and water system. Food production fell by at least 60% in Khartoum Province Severe losses were reported in agriculture, the main economic activity of	Sutcliffe *et al.* (1989)

				the population.	
	1997	Somalia	Juba River floods	At least 448 people have died more than 150,000 have been displaced.	CNN (1997)
	1999	Sudan		affected 1.8 million people	Williams and Nottage (2006)
	2002	Tanzania, Uganda, Kenya, Burundi and Rwanda	Floods	Landslides led to evacuations of homes.	Huq *et al.* (2007).
	2004 /2006	southern Ethiopia	River(Detachu) flooding	300 people in Dire Dawa lost their lives. Thousands of people were displaced. extensive damage to homes and markets were encountered.	IFRC (2006),
		Somalia	River(Juba)flooding	Floods killed and displaced hundreds of people.	
		Kenya	River (Dechatu, Shabelle and Juba) flooding	Floods killed and displace hundreds of people.	
West Africa	2001	Ghana(Accra)	torrential rain	More than 100,000 homes were destroyed. Roads infrastructure in the city were completely submerged.	BBC News (2001).
	2007	Nigeria Lagos, Ogun, Plateau, Sokoto, Nasarrawa, Bauchi, Yobe, Borno and Kebi.	overflow of water from a dam due to poor drainage systems	Housing and transport other infrastructure were destroyed.	IFRC (2007b)
	2007	Burkina Faso	heaviest rainfalls	Over 40,000 people were severely affected.	Lukamba (2010)
Central Africa	2001	Cameroon (Limbe Municipality)	extensive and prolonged rainfall	Destroyed, agricultural land, urban property and homes.	Ayanji (2004) in Lukamba, 2010
	2007	Congo(Brazaville)	torrential rain and river(Congo) flooding, Poor drainage	3,000 families were affected. 700 have been left homeless.	(IFRC, 2007a)
		Sudan	torrential rain and river(Nile) flooding	Atleast 30 people were killed 100 and more people were injured. At least 25 000 houses were destroyed. Villages were submerged under water. Extensive damage to infrastructure, including roads and bridges.	(IFRC, 2007d)

Southern Africa	2000	Mozambique	Rainfall accompanying tropical cyclone Eline	300 000 people were adversely affected. Annual economic growth rate was reduced from 10% to 4%. 800 people lost their lives. 329,000 were displaced.	Christie and Hanlon (2001) (Brouwer and Nhassengo, 2006)
		South Africa		Housing infrastructure were severely damaged.	Nethengwe (2007)
		Botswana		4000 people were left homeless.	(Tsheko, 2003)
	2007	Zimbabwe		600 households in the flood prone areas of Tsholotsho and Masvingo were affected. People ran in shortage of food and clean water. Malaria outbreak.	(IFRC, 2018)
		Malawi		Property and crops were mostly damage. 60,995 people were affected.	
		Mozambique		94,760 people were affected.	
		Zambia		More than 16,680 people were affected.	
		Lesotho		An estimated additional 4,000 people were affected.	
		Swaziland		2,500 persons were affected.	

2.3.2 Floods in South Africa

The occurrence of floods in South Africa is not a recent phenomenon (Table 2.1). Literature shows that flooding is one of the major catastrophic natural hazards that occurs in South Africa. Climatic extremes, especially excessive rainfall have been noted to be the most common cause of floods in South Africa (Van Zyl, 2006) with greatest hazards arising from tropical cyclones and severe storms. For example, the most catastrophic flooding event in South Africa occurred in 1999 to 2000 due to the extreme cyclone Eline. During that catastrophic flooding event, more than a million people in the Limpopo province were left with no access to portable water, hundreds of people lost their lives, and many hundreds were evacuated into the camps. Roads infrastructures were severely damaged. To date, numerous events have been reported with various magnitudes of devastations. Despite the numerous reports on the flood occurrences, little has been done to understand the key factors contribution to the peoples' level of exposure and sensitivity to flood hazards as well as their adaptive capacity. In this regard, there is need to review literature and identify the key drivers of vulnerability to flood hazards.

Table 2.2: Historical Flood events in South Africa

Year	Affected area	Cause and/or type of floods	Extent of devastation
1958	Musina	River floods (Sand and Selati) flooding Tropical Cyclone Astrid	Houses and bridges along these rivers were washed away.
1966	The former Transvaal Lowveldt	Cyclone Claude	
1968	Port Elizabeth		Communication links were severely damaged. About 11 people drowned. Damage cause by floods was estimated at R400 million.
1974	The interior of South Africa	River (Modder and Riet) flooding	Damage to infrastructure were estimated at millions of rands. 200 homes in Cradock were inundated. Orange River flooded 80% of the houses along the river.
1977	North- Eastern South Africa	Cyclone Emilie	Ten people drowned at Tshipise near the Kruger National Park.
1981	Western Cape		The flood waters washed away a considerable part of the town including bridges and irrigation schemes. 100 people lost their lives. 104 people drowned. 185 homes, old-age home.
1984	North-Eastern Regions	Cyclone Domoina and Imboa	more than 200 people in Mozambique, Swaziland, Eastern Transvaal and North-Eastern Natal died.
1987	Kwa-Zulu Natal		Houses collapsed, and some were washed away. 14 bridges were washed away. Damage was estimated at R3 300 million. 68 000 people were displaced. 388 people lost their lives.

Year	Affected area	Cause and/or type of floods	Extent of devastation
1994	Ladysmith		Damage was estimated at R60 million. More than thousands of families were left homeless.
1996	Limpopo province; Giyani, Mapayeni and, Kruger Park, Kwa Zulu Natal Province	Heavy rains	200 people died (Kwa-Zulu Natal Province) Homes were evacuated.
1999 to 2000	Limpopo Province	Cyclone Elina	More than a million people in the northern provinces of South Africa had no access to portable water. Hundreds of lives were lost. Hundreds were taken to the camps. Severe damage was accounted on more than 200 bridges and several thousand kilometers of roads.
2006	Southern Cape	Intense cold front	Loss of almost a dozen lives. Severe damage to housing, roads and other infrastructure along 'Garden Route.
2014	Northern South Africa	Heavy rainfall river flooding	8 people were killed. Thousands of people were stranded in Mpumalanga and Northern Provinces 19 people reported missing. Many dams overflowed, and roads were closed. 13 people were reported dead in Limpopo Province. Residents living near Mokolo Dam and Vaalwater areas near Ellisras were warned to evacuate their properties. More than 600,000 were without portable water in Nkomazi and Kizikazi near Nelsrpuit.

Sources: Grobler (2003) and EPoA (2014)

2.4 Identifying key indicators and drivers of vulnerability to flood hazards

Prior to identifying key drivers, it is essential to define vulnerability as well as other terms associated with it. Vulnerability is a term that has been used and conceptualized differently in various fields by various scholars (Kein and Nichols, 1999, IPCC, 2001, Downing and Patwardhan, 2004, UNISDR, 2004, Downing *et al.*, 2005, Adger, 2006, Fussel and Klein, 2006, IPCC, 2007). In this study vulnerability is defined as the ability of a settlement to be adversely affected by floods due to its exposure and sensitivity to the risk of floods as well as its ability to cope with, resist or adapt to the effects of floods. Vulnerability is the most complex and multidimensional concept that is not readily measurable or observable (Birkmann, 2011). Its complexity and inability to be measured requires a reduction of potentially gatherable data, particularly those drivers that make a specific human settlement to be vulnerable to floods, into a set of indicators. Kienberger *et al.* (2009) indicates that appropriate vulnerability indicators can play a critical role in vulnerability assessment. Cutter *et al.* (2008). Defined an indicator as a factor that quantitatively estimates the condition of a studied system. Research has demonstrated that regardless of the type of vulnerability assessment, there are some key terms that determine the vulnerability that must be considered and adequately defined (Ciurean *et al.*, 2013). These terms are exposure, sensitivity and adaptive capacity. Figure 2.2 gives a link of these components.

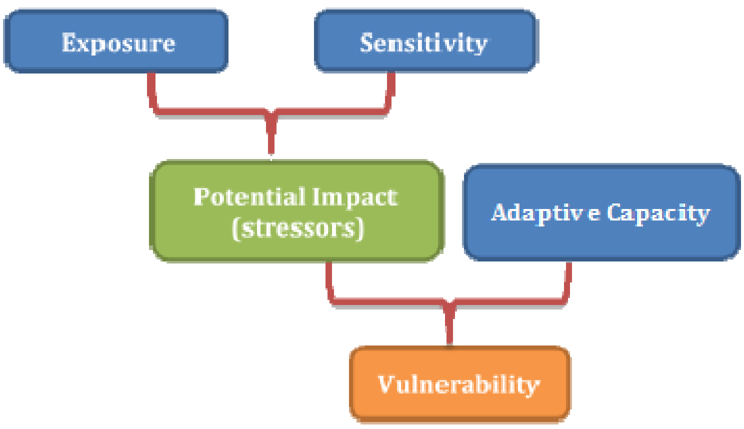

Figure 2.2: The components of vulnerability (Source: NPS 2017)

According to the International Panel on Climate Change (IPCC, 2007), exposure is defined as the extent of climate stress upon a unit or system. It may be represented as either long-term changes in climate conditions, or changes in climate variability, including the magnitude, duration and frequency of climate change related extreme events. In the context of floods vulnerability, exposure is defined as the ability of a system to be affected by a flooding event due to its locational characteristics (Balica, 2007). Therefore, the working definition of exposure in this research refers to the physical characteristic of the location (either structural or environmental) that makes an area to be vulnerable. Meanwhile, sensitivity is the degree to which a system is either adversely or positively influenced by climate variability or climate changes based on the definition provided by the (IPCC, 2007). (Snover *et al.*, 2007) emphasized that the system is considered sensitive to climate change if it is likely to be affected by the projected climate scenarios. For this research sensitivity refers to the elements of a settlement's location which influences the probabilities of it being harmed in times of flood hazards. Finally, adaptive capacity includes undertaking effective adaptation measures for reducing potential damages and to cope with the consequences. In the context of flooding events, adaptive capacity is defined as the capacity of a system to endure floods, maintaining significant levels of efficiency in its social, economic, and physical components (Tewari and Bhowmick, 2014, Valdivia, 2015). The working definition of adaptive capacity in this research is defined as measures put in place to resist, cope with or adapt from flood hazards.

Integrated vulnerability assessment should acknowledge these three concepts associated with vulnerability. Integrated vulnerability assessment could aid scholars and decision makers in adequately addressing levels of vulnerability. Literature illustrates that the main reasons to use indicators in floods vulnerability are (i) to reduce the complexity of vulnerability into adaptive capacity', 'sensitivity' and 'exposure' (Leary, 2013), and (ii) to integrate physical and socio-economic setup of an area into adequate vulnerability assessments. The initial investigation into floods vulnerability mainly focused on the bio-physical processes (Rashetnia *et al.*, 2015). However, this has changed to integrate the socio-economic issues such as how different socio-economic groups have different degrees of vulnerability typically based on societies; illiteracy rates, proportions of age, female headed households, household size, age, unemployment rates, percentage of people below poverty line, disabled people and percentage of population without basic necessities such as electricity, water and food. (Lahsen *et al.*, 2010).

2.4.1 Physical drivers of vulnerability

Physical vulnerability drivers are mainly associated with the location (Smithers and Smit, 1997) as well as the environmental characteristics of the site where a settlement is located. Physical drivers of vulnerability include aspects of geography, location, and place (Wilbanks, 2003); settlement patterns; and physical and occupancy structures infrastructure located in flood hazard-prone areas (Shah, 1995).

The physical drivers that are related to the type of settlements can be categorised into two. This is structural elements and occupancy indicators. Structural elements is comprised of building type and material used (Giovinazzi and Lagomarsino, 2004, Kircher *et al.*, 2006, Porter *et al.*, 2008, Duzgun *et al.*, 2011). Meanwhile, building occupancy refers to the usage of the building, for example, commercial, industry or residential. These occupancy types determine the potential values of the losses from a hazard (Kircher *et al.*, 2006, FEMA, 2013a, FEMA, 2013b). The type of construction influences the extent of flood damage (Pradhan *et al.*, 2007).

Literature also indicates that the vulnerability of both infrastructure and buildings are influenced by their environmental characteristics and conditions of where they are located. For example, the proximity of a building to a river may affect its vulnerability to flood hazards. Since ancient times, people tended to settle in flood prone areas given that these areas are associated with highly fertile soils which are good for agricultural production as well as transport accessibility which in turn facilitates economic growth. Areas which are located near the stream and river have a high risk of flooding. Furthermore, areas which are characterised by a low elevation tend to be extremely affected by floods when compared with those that have a higher altitude. In addition, the suspension and retention of water is relatively higher in low lying areas (Fernández and Lutz, 2010, Kia *et al.*, 2012, Saini and Kaushik, 2012). Literature also shows that flood incidents varies amongst various types of land use and land cover (Tollan, 2002, Panahi *et al.*, 2010). Infiltration capacity is different for each land use category. Built up and bare areas tend to facilitate flooding conditions, whereas forested and vegetated areas increase infiltration and percolation of rain water while decreasing the water runoff. Literature points out that vegetation cover acts as a protective layer and controls the runoff and water overflow (Kia *et al.*, 2012, Saini and Kaushik, 2012, Stefanidis and Stathis, 2013). Change in the land use type increases susceptibility of flooding for example change from vegetated areas to bare lands affects the amount of runoff, infiltration rate and total discharge and therefore, increases the risk of flooding (Konrad, 2003, Fernández and Lutz, 2010, Paquette and Lowry, 2012).

The other physical indicator that is critical in vulnerability assessment is population density. Population density offers information about areas with higher concentration of the people per unit area. In an area with higher population density, more people and infrastructure are likely to be affected by the floods (Chang and Franczyk, 2008, Paquette and Lowry, 2012, Saini and Kaushik, 2012).

2.4.2 The socio-economic drivers of vulnerabilities

Scholars suggested that vulnerability factors are not limited to the physical characteristics of a settlement, but also the impact on the social traits of the affected households in different settlements (Morrow and Phillips, 1999, UNISDR, 2004). For example, Khandlhela and May (2006) established that the varying impact of floods at a households level and the community at large was not only due to its locational characteristics or setup but rather an outcome of the interaction between socio, economic and political process. These factors include the economic status, structure of households, gender, age of individuals in a household.

Literature illustrates that economic status of a household plays a critical role in determining the level of its vulnerability to flood hazards. The poor tend to be the most vulnerable due to their lack of options in adapting and coping with flood hazards and impacts. They are also made more vulnerable from a web of circumstances(i.e poor housing infrastructure, lack of access to land) that make them prone to the effects of disasters (Khandlhela and May, 2006).

Close analysis of disaster impact also shows that the vulnerability of men and women to natural disasters, their capacities, and the options available to them differs in character and scale (Wickramasinghe and Ariyabandu, 2005). Wickramasinghe and Ariyabandu (2005) noted that although women are often more vulnerable to disasters than men, it is owing to conventional gender responsibilities and relations, they are not just helpless victims as often represented. Women have valuable knowledge and experience in coping with disasters. However, these strengths and capabilities of women are often ignored in policy decisions and in mitigation. Thus, ignorance of gender differences has led to insensitive and ineffective relief operations that largely bypass women's needs and their potential to assist in mitigation and relief work. According to Rashid (2000), women are the most vulnerable during the disasters. During the 1998 floods, women admitted to walking long distances with female relatives or planned trips together by boat to other less flooded areas to use the latrines (Rashid, 2000).

Literature illustrates that age also plays a significant role in determining level of social vulnerability (Comfort *et al.*, 1999, McEntire *et al.*, 2002, Vincent, 2004, Rygel *et al.*, 2006, Adikari *et al.*, 2013). (Clark *et al.*, 1998, Comfort *et al.*, 1999, McEntire *et al.*, 2002, Vincent, 2004, Rygel *et al.*, 2006, Adikari *et al.*, 2013). Vincent (2004) identified the population that is < 15 or > 65 years old as being the most vulnerable. Both young and old people may be unable to respond to disasters on their own (Peek, 2008). Although not all elderly and young people are poorly or physically weak in general, it is their lack of necessary physical and economic resources that hinders them to respond effectively to a disaster. Older people also tend to be more reluctant to evacuate due to special attachment to the environment they spent almost all their lives and/or fear of living in groups.(Gladwin *et al.*, 1997).

Another socio-economic aspect that significantly influences the level of vulnerability to flood hazards is the level of education. Higher educational attainment results in greater lifetime earnings as well as an informed decision-making process with regards to mitigating the impacts of extreme natural hazard such as floods. Limited education constrains the ability of individuals per households to access and understand warning information related to catastrophic floods (Cutter, 2003). People with higher levels of education are more capable of performing emergency measures effectively whereas people with lower levels of education appear to have less recovery capacity (Fekete, 2009).

Financial access is an important indicator which relates to the potential capacity of people to prepare for natural hazards. For example, research shows that households with relatively high-income have a better hazard insurance facility (Botzen and van den Bergh, 2012, Bubeck *et al.*, 2012) when compared to households with lower income. However, level of vulnerability for those earning high income can be lower due to high compensation for their losses (Davidson and Shah, 1997, Peduzzi *et al.*, 2009)

2.4.3 Adaptive Capacity drivers of vulnerability

Adaptive capacity is the ability, potential or capability of a household to adapt to flood hazards or the impacts of flood hazards. The households differ regarding absorptive capacity to resist or buffer the distress caused by a disaster and how they adjust and maintain their livelihood (Cardona and Barbat, 2000). Vulnerability of settlements/ households to flood hazards and their impacts or effects is influenced by their adaptive capacity. Consequently, this study also reviewed literature to identify factors that characterise the adaptive capacity of households to flood hazards.

Risk perception or awareness is one of the critical factors which is associated with adaptive capacity of households to natural disasters illustrated in literature. Research has shown that risk perception is an important factor for households as it determines their level of preparation for natural hazard such as floods (e.g. Balica *et al*., 2012, Bubeck *et al*., 2012). Furthermore, past flood experience can also determine the level of households or community's vulnerability. For example, the experience with previous events has a positive effect on the awareness level (Balica *et al*., 2009). In addition, access to information sources, such as newspapers, television and radio sets, determines the knowledge and awareness of individuals in a household to the occurrence and preparedness for flood hazards (Balica *et al*., 2009, Brink and Davidson, 2015).

Literature also underscored the institutional and political characteristics as significant indicators of adaptive capacity to natural hazards. Institutional and political factors are statutory instruments and frameworks that are put in place to reduce the impact of natural hazards on the citizens or dwellers of a specific area. These statutory instruments and frameworks are put in place by both public sector as well as the private sector specifically for natural hazards. These factors are often related to a certain level of planning and preparing for natural hazards. For example, strong spatial planning regulations may be an indicator that building codes and zoning protocols have been developed and enforced to reduce the impact of natural hazards such as floods (Cutter, 2003, Blaikie *et al*., 2014).

Social capital can also be used to strengthen coping capacity and to better withstand climatic hazards and extreme events (Lee, 2014). Individuals and households can make use of social networks to connect to the emotional, social, and economic resources of others Social capital can emerge in a variety of ways and contexts but its main aim is to capture element of social organisation such as, norms, values, mutual trust, and social networks to link ties and improve the efficiency of society (Adger, 2001). families, neighbours, close friends, and work colleagues can benefit from social capital. For example, in lower-income wards of Paramaribo, Suriname, about ten percent of households moved in with family and friends during a flood (Linnekamp *et al.*, 2011). Collective action was also significantly higher in lower-income areas, where more bonding social capital was evident from households that had regular contact with other households, friends and family who provide information, advice, financial resources, and labour (Linnekamp *et al.*, 2011).

Although the use of indicators and indices to measure vulnerability continues to attract more attention in literature, there are a few setbacks associated with the development of and use of indicators. First, there is the challenge to reduce the complexity of an interaction within a system to a factor or set of factors. This has major implications for how and what is measured (Bogardi and Birkmann, 2004, Barnett *et al.*, 2008). Secondly, not all factors contributing to vulnerability can be captured in quantitative indicators (e.g., institutional factors, policies) and some concepts or interactions are very difficult to quantify. Lastly, data availability poses problems for both hazard and population parameters and this may hinder the selection of input variables. Despite the above mentioned caveats of using indicators, literature indicates that it is critical to assess the exposure, sensitivity and adaptive capacity of households for effectively identifying different levels of vulnerability to flood hazards for prevention and timely mitigation purposes (Cutter *et al.*, 2008, Tewari and Bhowmick, 2014). Table 2.3. summarises some of the key indicators that could be used to assess vulnerability to flooding hazards and/or to construct floods vulnerability indices.

Table 2.3: Key indicators used to assess vulnerability to flood hazards

Elements of vulnerability	**Driver of vulnerability**	**Indicator**	**Sources**
Exposure	Physical	Rainfall	(Korah and López, Yalcin and Akyurek, 2004, Yahaya *et al*., 2010, Lawal *et al*., 2012, Damavandi and Panahi, 2013, Matori *et al*., 2014, Ouma and Tateishi, 2014, Zeleňáková *et al*., 2015, Blistanova *et al*., 2016, Danumah *et al*., 2016, Gelleh I. D, 2016, Al-Abadi *et al*., 2017, Rimba *et al*., 2017, Roslee *et al*., 2017)
		Flood frequency (year)	(Akukwe and Ogbodo, 2015, Kissi *et al*., 2015, Komi *et al*., 2016)
		Flood duration (day)	(Kissi *et al*., 2015)
		Flood probability	(Karagiorgos *et al*., 2016, Komi *et al*., 2016)
		Flood severity	(Akukwe and Ogbodo, 2015)
		Flood water level (m)	(Akukwe and Ogbodo, 2015, Kissi *et al*., 2015)
		size of watershed	(Yalcin and Akyurek, 2004, Lawal *et al*., 2012, Damavandi and Panahi, 2013, Blistanova *et al*., 2016)
		Population Density	(Siddayao *et al*., 2014, Yeganeh and Sabri, 2014, Behanzin *et al*., 2016, Danumah *et al*., 2016, Komi *et al*., 2016, Kablan *et al*., 2017, Ntajal *et al*., 2017, Sadeghi-Pouya *et al*., 2017)
		Distance from drainage network	(Yalcin and Akyurek, 2004, Yahaya *et al*., 2010, Ouma and Tateishi, 2014, Siddayao *et al*., 2014, Yeganeh and Sabri, 2014, Akukwe and Ogbodo, 2015, Kissi *et al*., 2015, Rahmati *et al*., 2016, Al-Abadi *et al*., 2017, Gigović *et al*., 2017, Ntajal *et al*., 2017)
		drainage density/analysis	(Korah and López, Yalcin and Akyurek, 2004, Lawal *et al*., 2012, Damavandi and Panahi, 2013, Ouma and Tateishi, 2014, Zeleňáková *et al*., 2015, Danumah *et al*., 2016, Rimba *et al*., 2017, Roslee *et al*., 2017)
		Elevation	(Ituen *et al*., 2014, Ouma and Tateishi, 2014, Siddayao *et al*., 2014, Yeganeh and Sabri, 2014, Kissi *et al*., 2015, Gelleh I. D, 2016, Rahmati *et al*., 2016, Gigović *et al*., 2017, Kablan *et al*., 2017, Ntajal *et al*., 2017, Roslee *et al*., 2017)

		basin slope	(Korah and López, Yalcin and Akyurek, 2004, Yahaya *et al.*, 2010, Lawal *et al.*, 2012, Damavandi and Panahi, 2013, Ituen *et al.*, 2014, Matori *et al.*, 2014, Ouma and Tateishi, 2014, Yeganeh and Sabri, 2014, Zeleňáková *et al.*, 2015, Blistanova *et al.*, 2016, Danumah *et al.*, 2016, Gelleh I. D, 2016, Rahmati *et al.*, 2016, Al-Abadi *et al.*, 2017, Gigović *et al.*, 2017, Ntajal *et al.*, 2017, Rimba *et al.*, 2017, Roslee *et al.*, 2017)
		land use/cover	(Yalcin and Akyurek, 2004, Yahaya *et al.*, 2010, Lawal *et al.*, 2012, Ituen *et al.*, 2014, Matori *et al.*, 2014, Ouma and Tateishi, 2014, Yeganeh and Sabri, 2014, Zeleňáková *et al.*, 2015, Behanzin *et al.*, 2016, Blistanova *et al.*, 2016, Danumah *et al.*, 2016, Gelleh I. D, 2016, Karagiorgos *et al.*, 2016, Rahmati *et al.*, 2016, Al-Abadi *et al.*, 2017, Gigović *et al.*, 2017, Kablan *et al.*, 2017, Ntajal *et al.*, 2017, Rimba *et al.*, 2017, Roslee *et al.*, 2017, Sadeghi-Pouya *et al.*, 2017)
		Soil type	(Yalcin and Akyurek, 2004, Yahaya *et al.*, 2010, Lawal *et al.*, 2012, Damavandi and Panahi, 2013, Ituen *et al.*, 2014, Matori *et al.*, 2014, Ouma and Tateishi, 2014, Zeleňáková *et al.*, 2015, Blistanova *et al.*, 2016, Danumah *et al.*, 2016, Gelleh I. D, 2016, Al-Abadi *et al.*, 2017, Ntajal *et al.*, 2017, Rimba *et al.*, 2017, Roslee *et al.*, 2017)
		Geology	(Matori *et al.*, 2014, Gelleh I. D, 2016)
		building material(type, age and quality)	(Akukwe and Ogbodo, 2015, Kissi *et al.*, 2015, Behanzin *et al.*, 2016, Sadeghi-Pouya *et al.*, 2017)
Sensitivity	Socio-economic	Gender	(Behanzin *et al.*, 2016, Kablan *et al.*, 2017)
		Disability	(Karagiorgos *et al.*, 2016)
		Poverty level	(Behanzin *et al.*, 2016)
		Education status(literacy)	(Akukwe and Ogbodo, 2015, Kissi *et al.*, 2015, Behanzin *et al.*, 2016, Karagiorgos *et al.*, 2016, Kablan *et al.*, 2017)
		Employment stattus/rate	(Behanzin *et al.*, 2016, Karagiorgos *et al.*, 2016, Kablan *et al.*, 2017)
		Income level	(Akukwe and Ogbodo, 2015, Behanzin *et al.*, 2016)
		Household size	(Kissi *et al.*, 2015)
		Family headship	(Kissi *et al.*, 2015)
		Length of residency	(Kissi *et al.*, 2015)

Adaptive capacity	**Adaptive measures**	Insurance	(Kablan *et al.*, 2017)
		Community Awareness	(Kissi *et al.*, 2015)
		Household Coping mechanisms	(Kissi *et al.*, 2015)
		Emergency service	(Kissi *et al.*, 2015, Sadeghi-Pouya *et al.*, 2017)
		Household Past experience	(Akukwe and Ogbodo, 2015, Kissi *et al.*, 2015, Karagiorgos *et al.*, 2016)
		Household Preparedness	(Kissi *et al.*, 2015)
		Warning system	(Akukwe and Ogbodo, 2015, Kissi *et al.*, 2015)
		Household perception on flood risk	(Kissi *et al.*, 2015)
		Household Evacuation capability	(Kissi *et al.*, 2015, Sadeghi-Pouya *et al.*, 2017)
		Household flood Training awareness	(Akukwe and Ogbodo, 2015, Kissi *et al.*, 2015, Sadeghi-Pouya *et al.*, 2017)
		Recovery capacity	(Kissi *et al.*, 2015)
		Recovery Time	(Kissi *et al.*, 2015)
		Long term resident (10 years +)	(Kissi *et al.*, 2015)
		Environmental recovery	(Kissi *et al.*, 2015)

2.5 Vulnerability index

Vulnerability indices have been used for a long time in a wide variety of disciplines to measure complex, multi- dimensional concepts such as vulnerability that cannot be observed or measured directly (Chakraborty *et al.*, 2005, Rygel *et al.*, 2006, Balica *et al.*, 2012, Felsenstein and Lichter, 2014). Vulnerability index is based on several sets of indicators that result in vulnerability of a system. It produces a single number, which can be used to assess and compare different regions. Literature shows that several indices have been proposed and used to measure flood vulnerability and profile the risk. These include Coastal city flood vulnerability index (Balica *et al.*, 2012) geophysical risk index (Chakraborty *et al.*, 2005) and flood risk index (Komi *et al.*, 2016). Other indices such as Social vulnerability index (Rashetnia *et al.*, 2015) were solely constructed based on the socio-economic factors of the communities. Meanwhile, Urban Flood risk index (Ouma and Tateishi, 2014) and Flood hazard index (Stefanidis and Stathis, 2013) were constructed based on physical characteristics of an area. Despite the plausible performance of these indices, it is important to note that their applications were either limited to a specific context or they only utilized either socio-economic or bio physical data without integrating these two types of datasets. This is contrary to how vulnerability assessment is conceptualized in this study. The Flood Vulnerability Index (FVI) proposed by Balica *et al.* (2009), illustrated a holistic indicator approach integrating the physical and the socio-economic indicators. However, this study by Balica *et al.* (2009) was conducted in the context of a developed world hence there is need to evaluate its performance in the context of third world countries. Furthermore, Balica *et al.* (2009) did not use GIS to assess the spatially explicit variability of their vulnerability index.

2.6 The use of GIS in assessing and monitoring floods

GIS is considered as a key technique and a powerful visual tool for assessing and mapping vulnerability. It allows ease of data editing, analysis, management, storage, and visualization (DeMers, 2005) as well as exploration of statistical output that would otherwise be difficult to interpret.

GIS software packages are commonly used in flood vulnerability analysis and modelling to display ranks of different regions developed through the vulnerability index (Cutter *et al.*, 2000, Chakraborty *et al.*, 2005, Rygel *et al.*, 2006, Ebert *et al.*, 2009). However, the most important contribution that GIS technology has brought to spatial analysis is the establishment of a link between map-based analysis of spatial patterns and well-developed, quantitative analytical methods.

Literature indicates that GIS has been a very useful and reliable tool in assessing and monitoring flood hazards, risk and/or vulnerability globally (Fernández and Lutz, 2010, Yahaya *et al.*, 2010, Kourgialas and Karatzas, 2011, Zeleňáková *et al.*, 2012, Ituen *et al.*, 2014, Ouma and Tateishi, 2014, Yeganeh and Sabri, 2014, Papaioannou *et al.*, 2015, Al-Abadi *et al.*, 2016, Blistanova *et al.*, 2016, Danumah *et al.*, 2016, Rahmati *et al.*, 2016, Samanta *et al.*, 2016, Gigović *et al.*, 2017, Rimba *et al.*, 2017, Roslee *et al.*, 2017, Trail *et al.*, 2017). Mapping of flood risk using GIS follows a multi-parametric approach and integrates crucial variables which contribute to the risk of flooding based on the physical characteristics of the region. The multiple parametric approach used in the aforementioned studies is based on only the physical variables. It does not take into consideration the socio-economic variables. The identification of flood vulnerability is comprised of two basic phases. Firstly, the effective factors causing floods are identified. Secondly, several approaches to multiple criteria analysis (MCA) in a GIS environment are applied. These approaches are further evaluated to prepare flood vulnerability map. Literature indicates that vector data sets such rivers, soil type, geology as well as raster data sets such as rainfall, Euclidean distance from rivers, land use, Digital Elevation Model (DEM) and its derivatives (e.g. slope, Aspect, flow accumulation, flow direction, stream order and topographic wetness index) have been widely used as causative factors, in modelling the spatial distribution of flood hazards. Integration and analysis of these variables produce a map which shows the ranks or categorization of possible flood risk zones or levels.

The above literature has demonstrated a great deal of capabilities of GIS in handling physical factors associated with floods vulnerability. This could be attributed to the fact that information on physical variables is readily available whereas there are relatively higher costs associated with the acquirement of socio-economic status data. Furthermore, available data on socio-economic is characterised by high generalisation since the information is not context specific. Therefore, this data does not offer information required for flood assessment. However, based on how vulnerability is conceptualised in this research, the use of only bio-physical data in a GIS as a stand-alone tool is limited as it does not take into consideration some of the critical factors, such as socio-economic backgrounds of people, that are essential in understanding the vulnerability to flood hazards. To circumvent this challenge, the majority of related studies integrated physical data with other socio-economic factors so as to adequately determine the level and extent of vulnerability of a specific population to flood hazards in a spatially explicit manner.

2.7 Integration of physical and socio-economic factors in assessing vulnerability

Much literature has demonstrated the integration of bio-physical and socio-economic data in constructing vulnerability assessment models/indices. GIS technology is integrated with MCDA, particularly AHP to analyse the integrated vulnerability assessment. The integrated vulnerability assessment approach normally adopts indicators that can be grouped either into exposure, sensitivity and (Akukwe and Ogbodo, 2015). For example, Meyer *et al.* (2009) developed a GIS-based multicriteria flood risk assessment and mapping approach. Kubal *et al.* (2009) applied the approach developed by Meyer *et al.* (2009) to the city of Leipzig (Germany) to estimate the damage potential on economic, social, and environmental aspects after a flood event. Scheuer *et al.* (2011) presented an approach to modelling and mapping multicriteria flood vulnerability which integrates the economic, social and ecological dimension of risk and coping capacity in the city of Leipzig, Germany following the vulnerability index approach demonstrated by Kienberger *et al.* (2009). (Behanzin *et al.*, 2016) applied GIS and physical, social, economic and environmental indicators to address flood vulnerability and risk in the Bénin

Niger River Valley. Brouwer *et al.* (2007) conducted a comprehensive vulnerability assessment alongside the Meghna River in Bangladesh using indicator approach to assess the environmental risk and socio-economic vulnerability. Kablan *et al.* (2017) used physical and socio-economic indicators to evaluate the social vulnerability of urban Abidjan District, Côte d'Ivoire to flooding. Yankson *et al.* (2017) constructed an integrated vulnerability index based on socio-economic and physical data.

Although these studies have demonstrated the utility of integrating physical and the socio-economic data with the aid of multicriteria decision analysis, little research has been done in South Africa. For example, Gbetibouo *et al.* (2010) analysed the vulnerability of South African agriculture sector to climate change and variability by developing a vulnerability index and comparing vulnerability indicators across all provinces of the country. The environmental and socio-economic indicators were identified to reflect exposure, sensitivity, and adaptive capacity. The results of the study showed that the regions most exposed to climate variability do not always overlap with those experiencing high sensitivity or low adaptive capacity. Although this authors demonstrated a good understanding of vulnerability and use of indicator approach, they focussed on a different sector that this research focusses on. Nethengwe (2007) used a participatory GIS approach to examine flood vulnerability in Milaboni and Dzingahe villages, in the Thulamela municipality of the Limpopo Province. The study employed integrated quantitative spatial analysis using household survey and traditional GIS data with qualitative methods such as mental mapping, interviews, GPS-based transect walks, oral narratives and focus group discussions. Using a case study of an informal settlement in Cape Town, Musungu *et al.* (2012) also demonstrated the use of a participatory multicriteria evaluation (MCE) for risk assessment using Geographic Information System (GIS) for flood risk assessment. Chari *et al.* (2018) used geostatistical approach to assess and evaluate adaptive capacities of resource-poor communities in the Nkonkobe Local Municipality, Eastern Cape using GIS. However this authors used demographic indicators only, to assess capacities of different communities and produce maps that shows varying levels of adaptive capacities on a scale ranging from low, medium to high Le

Roux *et al.* (2017) identified and profiled settlements at risk of sea level rise, storm surges and flooding by using socio-economic, projected rainfall events and proximity to coastal areas. Le Roux *et al.* (2017) further indicated that integrated analyses are crucial to timeously support governance and inform integrated management and planning processes

Vulnerability as a comparative component means little without a method of visualization. According to Eakin *et al.* (2007), integration and analysis of physical and socio-economic data produces a map which shows ranks or categorization of possible flood risk zones or levels. However, literature has subsequently indicated that there is no global standard or national agreements on the number of flood zones. This is evident in some of the reviewed literature (Musungu *et al*., 2012, Suleiman, 2014, Akukwe and Ogbodo, 2015, Sar *et al*., 2015). For example, Suleiman *et al*., (2014) identified three zones (low, medium and high) showing different levels of flood vulnerability in Lokoja town, Nigeria. Sar *et al.* (2015) classified flood hazards susceptibility into four zones (very low, low, medium, high), whilst Akukwe and Ogbodo (2015) classified floods vulnerability into 5 levels (Very high, High, Moderate, Low, Very low). Although different authors used different classes of vulnerability, floods zonation remains the best alternative in communicating flood hazards. GIS based zonation maps has been widely used in communicating different levels of vulnerability. Meanwhile using vulnerability maps as planning tool, can address the root causes of vulnerability which in turn will reduce the risks associated with floods. At a local scale, planners and managers can look beyond geographical exposure to understand how unique physical, social and economic factors facilitate vulnerability to floods (Yarnal, 2007, Frazier *et al*., 2008). Furthermore, GIS can aid with real time decision making and strategic planning for effective flood risk management and hazard preparedness.

The above studies have demonstrated that integration of both physical and socio-economic factors creates a strong basis for determining the level and extent of vulnerability. Meanwhile effective adaptation strategies are influenced not only by geographical condition of an area but by social characteristics and economic background of households and individuals.

2.8 Conceptual framework

A wide variety of conceptual frameworks have been developed to address the vulnerability of human and environmental systems to perturbations, shocks, and stresses (Ciurean *et al.*, 2013). The study adopted, modified and used a conceptual framework developed by Birkmann (2006). The framework illustrates how human settlements are vulnerable to flooding and seeks to illustrate how vulnerability is conceptualised in this study. The proposed framework views floods vulnerability as a state determined by the internal natural and human characteristics of a system that exist within a settlement before the occurrence of a flood hazard event. It incorporates combinations of both indicator-based and participatory approaches in order to capture the physical and socio-natural aspects of the human settlements' vulnerability to flood risk. The framework further recognises the diversity and representations of vulnerability profiles at varying scales ranging from individual, household, village, and at ward level.

The framework (see Figure 2.2) shows that vulnerability of a settlement to flooding is built upon three major dimensions namely; exposure, sensitivity, and adaptive. Based on the reviews of a variety of literature, this study is built upon a growing evidence on settlement's' flood vulnerability which indicates that most flood-related disasters are not mainly caused by natural disasters, but an interplay of both bio-physical and socio-economic characteristics of a settlement. Each of the three dimensions of flood vulnerability provides different vulnerability drivers with varieties of selected indicators that captures the multidimensional (physical, social and economic) aspect of the human settlement.

Exposure can be interpreted as the physical as well as the environmental characteristics of the site where a settlement is located. Drivers of settlement's exposure include aspects of geography, area of location, settlement patterns; and physical occupancy structures(Shah, 1995). Figure

2.2 shows that exposure of a household to floods has a direct impact on vulnerability. For instance, a settlement that is located in an area which has relatively high rainfall, coupled with, clayey bare soils or built up in an impermeable surface can turn a heavy rainfall into a catastrophic flood. This may lead to increased exposure, which consequently increases level of vulnerability to flood risks.

Sensitivity describes the elements of a settlement's location which influence the probabilities of it being harmed in times of flood hazards. It is important in assessing the social vulnerability of societies or communities to floods. Social vulnerability refers to "the state of individuals, groups, or communities defined in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being" (Adger 1999). Social and economic aspects of the settlement thus influence the coping or adaptive capacity of households and communities in settlements (van Huyssteen et al. 2013). Figure 2.2 indicates that social vulnerability can typically be identified in communities where there are high illiteracy rates, low educational level, high levels of poverty, low levels of economic activity, high dependency rates high proportions of age dependent populations and pressures associated with female headed households as well as a high population density, (van Huyssteen *et al.*, 2013). A single variable may not render individuals or households vulnerable, but a combination of the above-mentioned variables (or a relationship between these variables) may render a person or household vulnerable Such increase in sensitivity in the household increases the degree of floods impacts (Le Roux *et al.*,2017)

The conceptual framework further illustrates that vulnerability is not only determined by exposure and sensitivity to flood hazards, but it also depends on the adaptive capacity of the human settlement system. Meanwhile, adaptive capacity of a settlement decreases vulnerability. In this study, adaptive capacity represents efforts in place to resist, cope with or adapt from flood hazards. This includes alerts for possible flooding especially in the event of heavy rains occurring for several hours, ability to handle floods, community early warning systems, evacuation capability and access to weather forecasts. In most cases the households that fall within such categories have high adaptive capacity. Hence their vulnerability to flood risks decreases. However, households that lack such adaptive capacity measures will be considered as vulnerable to flood risks.

Exposure and sensitivity are intrinsically linked to mutually influence the potential flood impacts while adaptive capacity is the potential of a system to cope with these impacts. The levels of exposure, sensitivity and adaptive capacity are very crucial in assessing the level of vulnerability (IPCC, 2001). Thus, vulnerability can be expressed with the Following mathematical equation:

$$FV = (E + S - AC)$$

Where FV is Floods Vulnerability, E is Exposure, S is Sensitivity, and AC is Adaptive Capacity.

The conceptual framework shows that households and decision makers can adopt a variety of strategies to mitigate risks associated with floods. These strategies are aimed at reducing household floods risk whilst building resilience of these communities and strengthening sustainable flood risk governance. Some of these strategies may entail landuse spatial planning, which may result in the decline of residential developments in areas declared as vulnerable. Whilst flood forecast, and early warnings assist households in preparing for floods, government and non-government associations might use the information in preparing for floods and responding with immediate effect. The adoption and use of some of these strategies may however require policy development and enforcement such as building codes, stakeholder participation and capacity building. These strategies will assist policy makers to design well-structured and sustainable adaptation and mitigation measures.

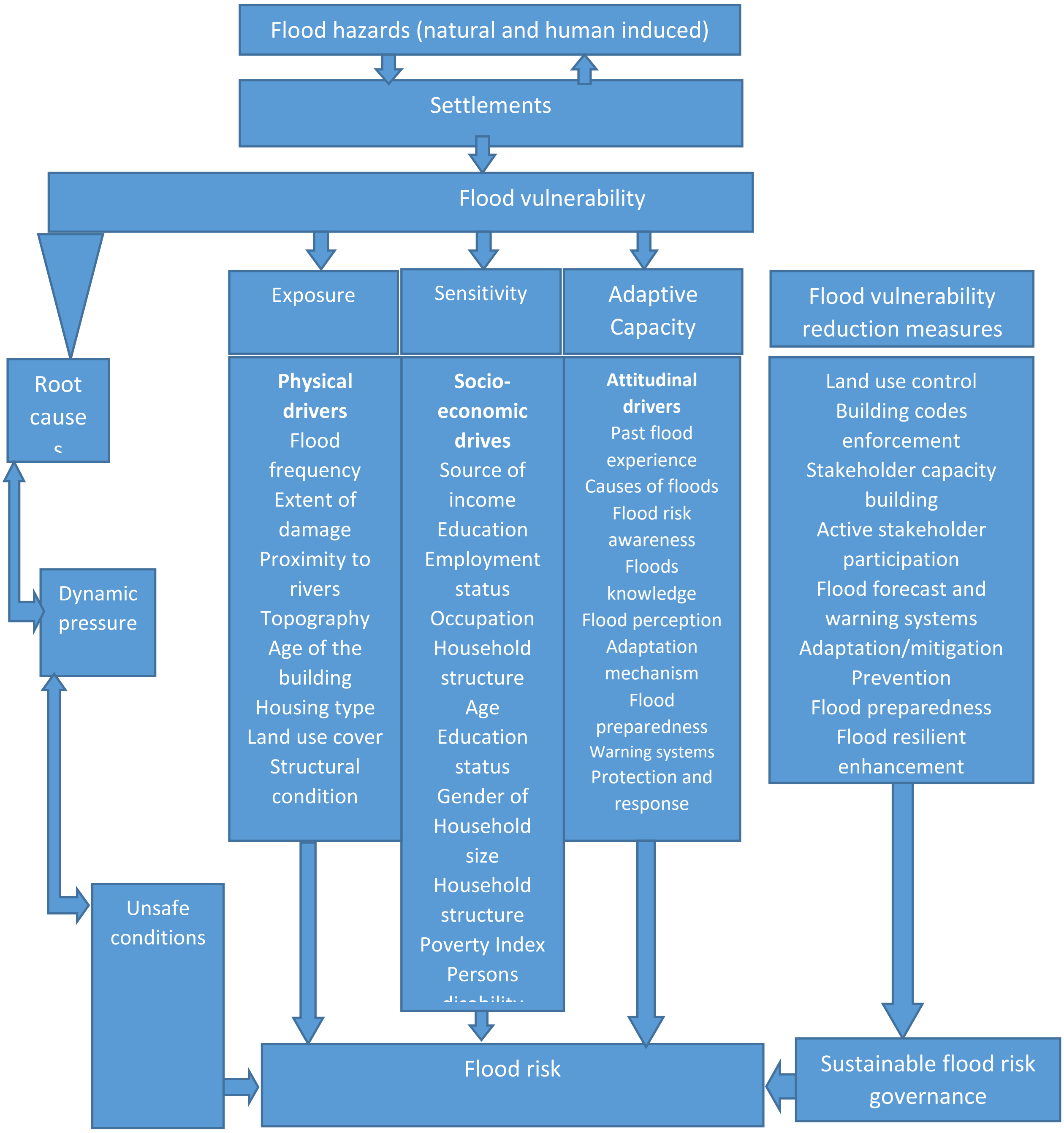

Figure 2.3: Conceptual framework (Adopted from Birkmann, 2006)

2.9 Conclusion

The chapter sought to review literature on flood hazards and human settlement, with a special focus on the use of indicator approach to assess vulnerability. It has reviewed the historical records of floods events, in the world, Africa and South Africa and subsequently found that floods occur mainly along the coastal areas across all continents. In northern Africa there seems to be less flood events occurrences. However, the eastern and western coastal areas of Africa seemed to be incurring a high frequency of flood events. In southern Africa, specifically, the Atlantic and Indian coastal areas are also encountering a high frequency of floods events. In South Africa, floods also frequently occur along the coastal areas as well as the north-eastern section of the country. Physical characteristics such as, building materials, elevation, proximity to rivers and social factors such as age, gender, employment status, among others are critical in assessing vulnerability. These indicators can be further grouped into exposure, sensitivity and adaptive capacity to construct vulnerability index. With an aid of GIS, socio-economic and physical factors can be analysed and visualised. FVI and GIS-MCDA to assess floods vulnerability has been clearly explored and it can be concluded that to acquire a holistic approach in assessing household's vulnerability to flood hazards there is need to combine bio-physical and socio-economic variables based on MCDA in a GIS environment. Although information on integrated vulnerability assessment approach is still sparse, a number of literature indicates that significant efforts have been channelled towards the integrated approach in understanding floods vulnerability globally. In South Africa, a lot of research still needs to be done if the sectoral and area specific vulnerability of floods on human settlement is to be fully understood. Moreover, the few studies that have been done have tended to dwell mostly on the bio-physical vulnerability and ignored methodological issues of integrating both the bio-physical and socio-economic elements of the settlement. This lack of information on methodological issues and about the vulnerability of human settlement to flooding thus creates a strong case for an academic enquiry into the subject. The next chapter discusses the methodology used in the study.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter outlines the methods and materials used for the study. It describes the study sites, provides a rationale for the research design adopted, discusses the sampling methods, data collection techniques and analytical procedure used and elaborates on the reliability and validity of the research, ethical consideration and data analysis procedures.

3.2 The study site

3.2.1 Location

Lephalale Local Municipality is situated between 23°30' and 24°00' latitude and 27°30' and 28°00' longitude, in the Limpopo Province of South Africa (Figure 3.1). The municipality is located within the north-western regions of the Waterberg District, with its borders forming part of the international border between South Africa and its neighbouring country, Botswana. It is one of the five local municipalities in the Waterberg District and the biggest local municipality in the Limpopo Province in terms of its geographical size as it covers 14 000 km^2.

This local municipality is demarcated into 12 wards (IDP, 2009). Two wards out of 12 have been selected for this study, namely, Ward 7 and 9. The selection of the municipality as a study area was motivated by the occurrence of persistent flooding events in the municipality in the past few years (Grobler, 2003), the latest being the 2014 flood events (EPoA, 2014). It was predicted that such flooding occurrences would provide the study with adequate and relevant data on vulnerability of settlements to flooding.

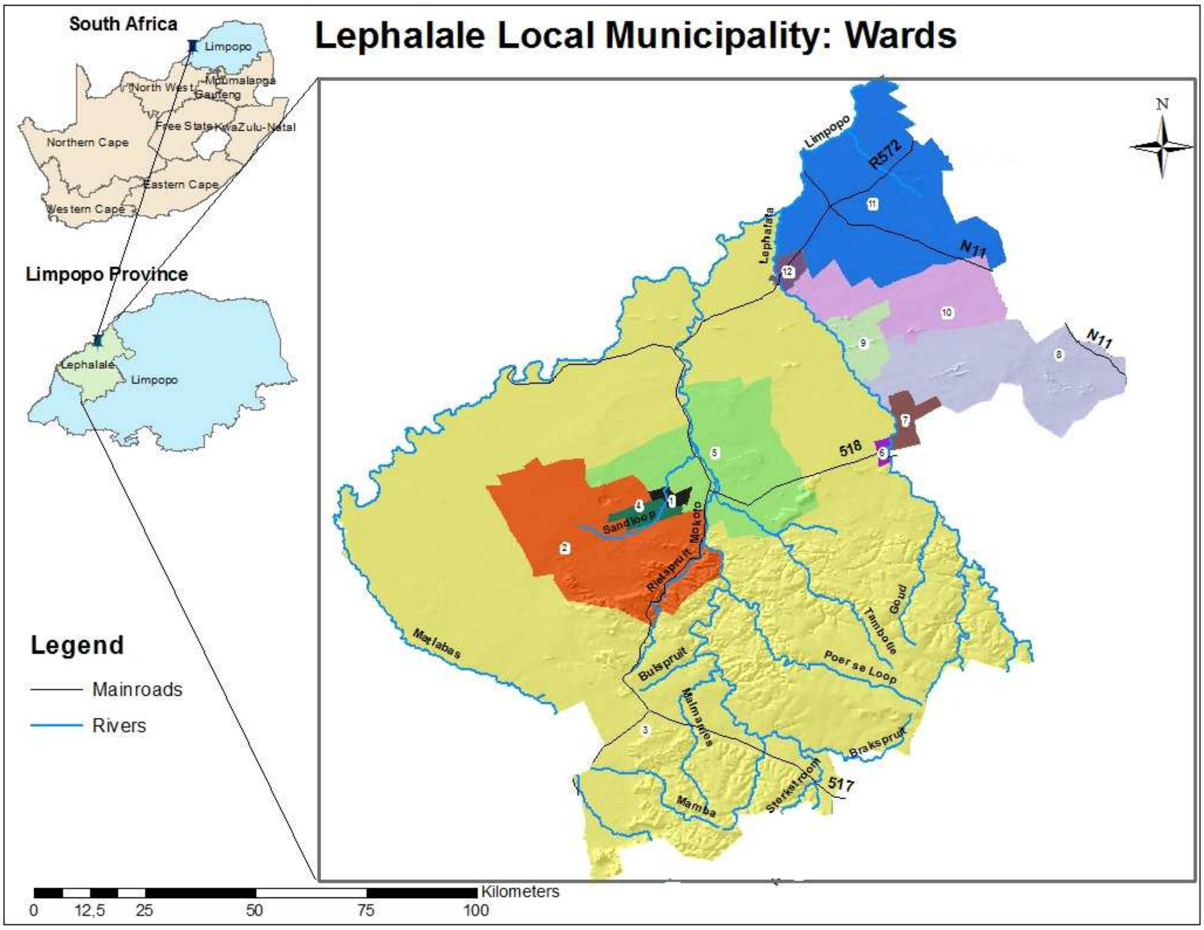

Figure 3.1: The study area

3.2.2 Climatic conditions

Lephalale Local Municipality falls in the summer rainfall. The average annual rainfall is around 400-600 mm, while average daily temperatures vary between 17°C and 32°C in summer and between 4°C and 20°C in winter. The climate varies spatially, becoming warmer and drier from the south to the north of the municipality (IDP, 2009).

3.2.3 Vegetation type

Lephalale area is in the bushveld region. It is situated in the lowveld physiographic region where vegetation varies from a dense, short bushveld to rather open tree savanna vegetation consisting mainly of dry woodlands, thorny bush and grassland. Thicket, bushveld, bush clumps and high fynbos cover about 55% of land area in the municipality (IDP, 2009).

3.2.4 River systems

There are four main rivers in Lephalale Local Municipality which drain northwards into the Limpopo River. The Phalala River originates in the higher southern portion of the Phalala plateau and flows through it northwards into the Limpopo River. The Mokolo River also originates in the higher southern portion of the Waterberg and flows northwards through the Phalala plateau into Limpopo River. The source of the Matlaba River is in the western portion on the farm Mamiaanshoek through Marakele National Park with Mogalakwena River flowing along the eastern boundary of the municipality. These rivers together with numerous lesser rivers and streams constitute a major water catchment area for the lower Limpopo basin (IDP, 2009). It can be observed that Ward 9 is located along the Phalala River, whilst in Ward 7, the river traverses through the ward. Most of the areas along these rivers are prone to flooding (EPoA, 2014). This is mostly due to water that exceedingly fills up the rivers (i.e. Mokolo and Phalala) and eventually overflow its river banks. For example, in 2014, the rivers around the villages and farms in Lephalale Local Municipality burst their banks and flooded the surrounding areas.

3.2.5 Topography

Lephalale Local Municipality consists of varied topography. The municipality is steeper on the south-east and generally flattening out towards the north, with altitude above sea level of between 700 m and 1 900 m. Ward 7 and 9 are located at a relatively low area.

3.2.6 Socio-economic base

Lephalale's socio-economic status is often a factor in the ability to mitigate flood hazards. Lephalale Local Municipality has a relatively unevenly distributed contribution by sectors, both in GDP and formal employment numbers. Most formally employed people work in the agriculture (39%) and mining (28%) sectors. Most of the GDP comes from mining (59%) while other sectors are very small in comparison to the mining sector. The remaining percentage of population are employed in tourism, retail and service delivery about 14% of the adults are unemployed while 13% is informally employed (IDP, 2015-2016).

The following are the main economic sectors in the municipality: mining and quarrying (71.4%), finance, insurance, real estate and business services (5.2%), wholesale and retail trade, catering and accommodation (4.4%), transport, storage and communication (4.4%), general government (4.3%), agriculture, forestry and fishing (3.9%), electricity, gas and water (2.8%) (IDP, 2015-2016).

3.2.7 Human settlement

There are several towns, townships, villages, informal settlements and farm houses in the Lephalale Local Municipality. The majority of houses in the municipal area are good quality brick structures. They are uniformly distributed across municipal settlement areas. There is no specific pattern regarding settlement. Ward 7 and 9 are characterized by a number of smaller villages in a linear pattern on the eastern part without any economic activity. In Lephalale Local Municipality, the land is mainly used for conservation, crop farming, game farming, mining, energy and a small portion is used for settlement.

Land tenure and ownership is currently very difficult to access. In rural areas the land is tribal and household have usufruct rights. Rented housing occurs only in Onverwacht, Marapong and Lephalale towns. Hostel accommodation type exists for Exxaro and contractors for Medupi project (IDP, 2015-2016)

3.2.8 Population dynamics

According to StatsSA (2011) the population of Lephalale Local Municipality is approximately 11576 with 7346 people in Ward 7 and 860 people in Ward 9 respectively. The municipality consists of 33 599 households with 1337 in Ward 7 and 2270 in Ward 9.

3.2.10 Land use/land cover in Lephalale local municipality

The geographical size of the municipal area of jurisdiction is estimated at 1 378 429 hectares. The municipality has large tracks of cultivated commercial rain fed land and cultivated commercial irrigated land located along the Mokolo, Phalala and Limpopo River. The rural villages are mainly characterised by cultivated subsistence rain fed land which is located 65km away in the eastern part of Lephalale town. The larger portion of the municipal area is characterised by degraded forest, woodland, bush clumps and thicket. The provincial growth point includes areas such as Ellisras town, Onverwacht, Marapong and light industrial area. The mining area and quarries also form part of land use in the municipality.

3.3 Research design

A research design is 'a plan of how a researcher intends to conduct the research' (Fouche and Delport, 2005). It is about the methods, materials and sources which the researcher will use to select a representative sample, and to collect and analyse data. Fouche and Delpot, (2005), further point out that the research design used is influenced by the purpose of the study, the nature of the research objectives as well as the resources available to the researcher.

Vulnerability assessment to flooding is an integrative process in which bio-physical and socio-economic factors interact to determine exposure, sensitivity and adaptive capacity (UNISDR, 2004, Birkmann, 2006). It should, therefore, be assessed through a variety of methods. This study adopted a quantitative approach to explore differential flood vulnerability among wards in the study area.

The quantitative method provided research with indicators (e.g. age household size, disability, income level gender, household headship, and building materials) that were used to assess floods vulnerability and develop the vulnerability index. After a review of literature, data collection and analysis, a methodological framework for vulnerability assessment was conceptualized and outlined in Figure 3.2.

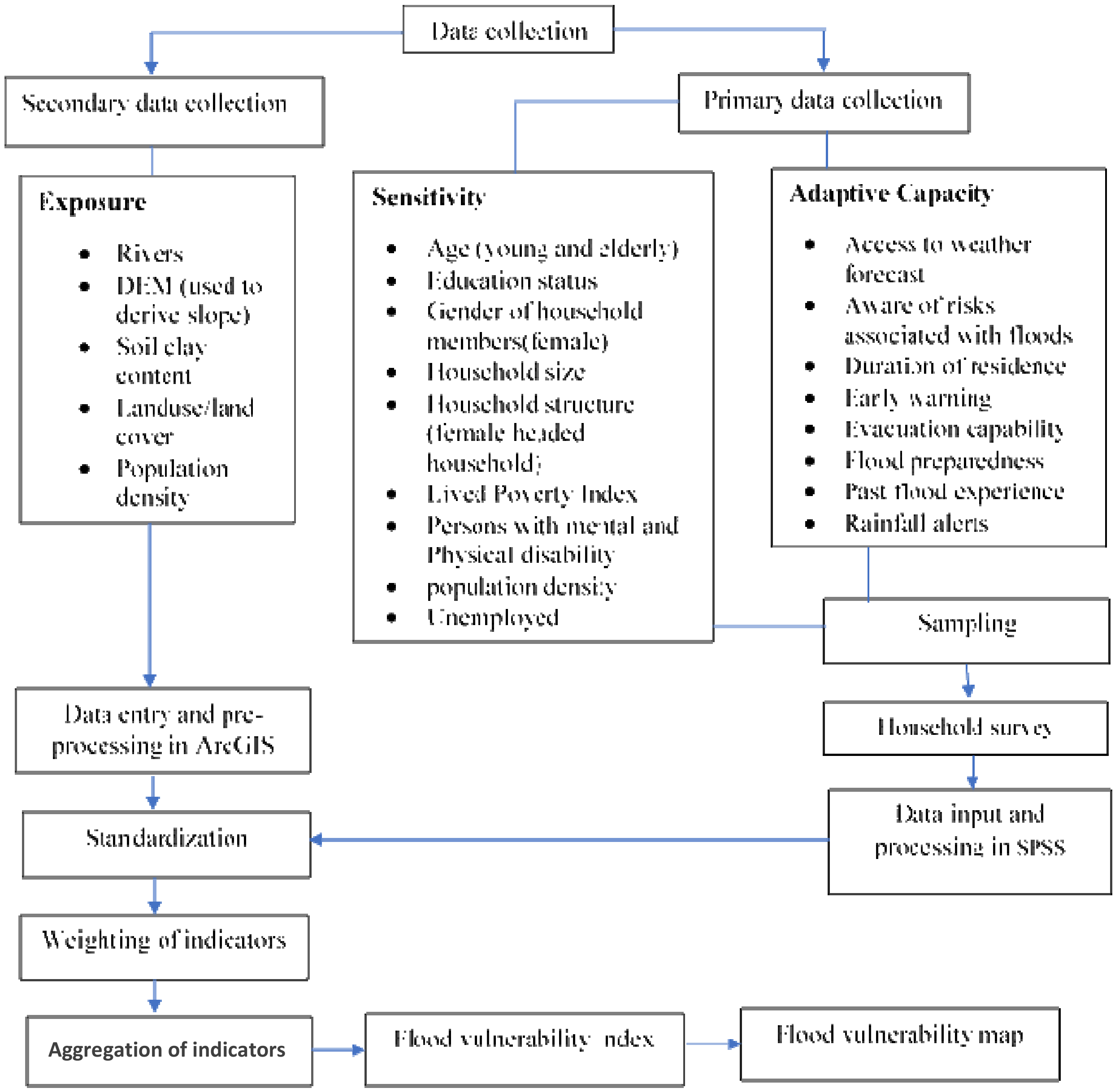

Figure 3.2: Methodological framework

3.4 Data collection

To assess the vulnerability of settlements to floods in Ward 7 and 9 of Lephalale Local Municipality, Limpopo Province, both primary and secondary sources of data were used.

3.4.1 Secondary data collection

Grey literature from media and government reports was accessed to gain knowledge of reported flood incidences, their nature as well as the extent of the damage they caused. Information regarding the actual flood events was obtained from local and regional newspaper reports, local and district municipal as well as National Disaster Management Centre.

The South African National Space Agency (SANSA) provided spatial data that was required in analysing and displaying data on floods vulnerability in a GIS environment. These layers/shapefiles included rivers, DEM (Digital Elevation Model), Land cover/landuse, soils, Limpopo Local Municipalities' boundaries of wards and villages. Soil clay content data was downloaded from SOTER website: (http://85.214.241.121:8080/geoserver/sotwis/wms?). whilst rivers were extracted from Department of Water Affairs Online Database:

http://www.dwa.gov.za/iwqs/wms/data/000key2data.asp.

Historical rainfall data for 8 rainfall weather stations obtained from the South African Weather Services (SAWS). The source datasets were received in the form of an excel spreadsheet. The data was converted into point map and later resampled into 30 x 30 cm resolution rainfall map using GIS resampling techniques. The dataset was clipped and re-projected to match the Ward 7 and 9 data layers. Census data for Ward 7 and 9, were obtained from Statistics South Africa (Stats SA). The data was used during sampling procedure.

3.4.2 Primary data collection

The quantitative approach for primary data collection involved the use of a household questionnaire (Appendix A) to obtain data on the socio-economic characteristics of households and their adaptive measures.

3.5 Sampling Procedures

Sampling is a process of taking any portion of a population as representative of that population (Fouché and Delport, 2005). A multi-stage sampling was adopted in the study as to sequentially select samples across various levels; ward, village, household and within the household. First, the 2 study wards were stratified into existing villages. All existing households in the villages could not be surveyed due to time and financial resource constraints, therefore sampled households within villages of Ward 7 and 9 rural were selected for the survey. Finally, households' heads were subsequently selected to participate in the survey.

3.5.1 The sampling frame and size

A sampling frame is a total population from which sample size is to be selected and it is usually denoted by the letter *N*. Two sampling frames were selected for use in this study , one was Ward 7 and the other was Ward 9. The sampling frame for Ward 9 consisted of all 2270 households, while that of Ward 7 consisted of all 1337 households.

A sample size refers to a portion of a population from which the required data is collected and is usually denoted by the letter '*n*'. The selected sample size directly affects the accuracy of findings. The basic objective of any sampling design is to minimize, within the limitation of cost, the gap between the values obtained from a sample and those prevalent in the study population while not jeopardizing the accuracy, reliability and validity of the collected data (Biemer and Lyberg, 2003).

It was not possible to study all households in the study areas because of limited time and financial resources, hence the need for sampling, which was conducted in the study areas. Using Yamane's statistical procedures (Equation 1), 133 households in Ward 7 and 227 households in Ward 9 were selected for the study, giving a combined total of 360 households. These sample sizes were considered adequate for this study because as (Payne, 1983) points out, a survey that involves 5-10% of the target population is fairly representative of the whole especially where the total units from which the sample is selected are less than 10 000. With a larger research budget, however, a much larger number of households might have been sampled.

Yamane's (1967:886) formula was used to calculate the sample sizes illustrated in Table 3.1at 95% confidence level.

$$n = \frac{N}{1 + N(e)^2}$$

Where *n* is the sample size; *N* is the population size; and e is the level of precision.

$$n = \frac{3601}{1 + 3601(.05)^2}$$

$$n = \frac{3601}{1 + 9}$$

$$n = 360{,}1$$

Therefore *n*=360 (Equation 1)

3.5.2 Sampling methods

Three sampling methods were used at different stages to select respondents who took part in this study. These are stratified random, systematic random, and purposive as detailed in Table 3.1.

Table 3.1: Summary of sampling procedures for household survey in Ward 7 and 9.

Ward 7					**Ward 9**				
Target group	Sampling method	Total Popu-lation	*n*	*n* as % of target group	Target group	Sampling method	Total Popu-lation	*n*	*n* as a % of target popu-lation
Households	Systematic random	1331	133	10%	Households	Systematic random	2270	227	10%
Household heads or an elder family member	Purposive	1331	133	10%	Household heads or an elder family member	Purposive	2270	227	10%

3.5.2.1 Stratified sampling

With this type of sampling, the target population is divided into subgroups called strata. The method is used when different sections of the target population are expected to respond differently to questions, or when different sections of the target population are expected to vary in sizes. For this study, Wards 7 and 9 were stratified based on villages so that respondents could be selected from all the villages in the wards in order to capture varied experiences and perceptions.

3.5.2.2 Systematic random sampling

Systematic sampling was independently carried out within each village. Systematic sampling involves selecting every n^{th} member from a surveyed population (Equation 2). The households in the settlements were arranged in a linear pattern and surveyed households were chosen using systematic sampling method where researcher walked through the community and surveyed every 10^{th} household. This was derived by dividing the population size by the sample size.

$$nth = \frac{N}{n}$$

$$nth = \frac{3600}{360}$$

$$nth = 10 \qquad \text{(Equation 2)}$$

Where n^{th} is systematic sample; N is population size; and n is sample size.

3.5.2.3 Purposive sampling

According to Fouché and Delport (2005), purposive sampling involves selecting sample that is composed of elements that contain the most characteristics, representative or typical attributes of the population. This type of sampling is entirely based on the judgment of the researcher. Purposive sampling was employed to select household heads on whom questionnaires were administered. From each sampled household, the household head was targeted for interview on the premise that they will provide sufficient data on household income, and on past flood experience as well as impacts posed by floods. In the absence of the household head, the questionnaire was administered to the most senior member of the household (any member above 18 years) who was also expected to be knowledgeable about households' information such as age, and income of households' members and information related to floods; impacts, experience and perception.

3.6 Data collection methods

For this study two methods were used to collect primary data, at different stages. These are household survey and field observations.

3.6.1 The household surveys

A household survey was conducted in Ward 7 and 9 over a period of three weeks between October and December 2015. During this survey, a standard questionnaire (Appendix A) was administered to 133 and 227 household heads in selected households in Wards 7 and 9 respectively, bringing the total number of questionnaires administered in the study to 360. The questionnaire was explained in Setswana and Sepedi (their mother tongue) and the responses were recorded. Data on demographic characteristics, past flood experience, and flood resilience was collected using questionnaire**.** A mixture of closed-ended (quantity, category, list or multiple choice, scale, ranking, table) and open-ended questions were used in the questionnaire. Close-ended questions dominated the questionnaire for ease of data capture and analysis, but open-ended questions were used where explanations were necessary. Narratives from the open-ended questions were used to record and analyse people's experiences and perceptions of the flood disaster.

Five research assistants were employed to administer the questionnaires to the household heads or any household member above 18 years. These research assistants were trained to ensure consistency in questionnaire administration as to minimise interviewer bias. The administration of each questionnaire lasted about 30-40 minutes.

3.6.2 Field Observation

In the two study areas, during the household survey, on-site observations were conducted. An observation guide was made and it detailed the main things to be observed. These included the building materials, roofing materials and type of a houses where the questionnaires were administered. Every detail of what was observed was recorded. The data gathered from observations further enhanced the reliability of study's findings.

3.7 Data Analysis

Data collected in a research study through various data collection methods had to be analysed for the purpose of generating conclusions and recommendations. According to Terre-Blanche and Kelly 1999, in Durrheim (1999), data analysis is a process that involves reading through data repeatedly, and engaging in activities of breaking the data down and building it up again in a novel way (elaborating and interpreting) that will offer insights on floods and vulnerability of settlements. For this research, descriptive, statistical and GIS methods of analysis were used to analyse collected data.

3.7.1 Data pre-processing

Pre-processing refers to the data preparation that is done before any analysis can commence. Both the primary and secondary data were pre-processed prior data analysis.

3.7.1.1 Pre-processing primary data

After the standardized household questionnaire survey, a data cleaning process was carried out, which involved checking the 360 questionnaires from the survey for omissions, inconsistencies and verifying the accuracy of outliers. Data was captured and organised in a Statistical Package for Social Sciences (SPSS), version 22.0, for computer-aided analysis.

3.7.1.2 Pre-processing

GIS was used to pre-process the spatial data before any analysis could commence. Rainfall was generated from SAWS data and interpolated by the Inverse Distance Weighted (IDW) Method from 8 weather stations in Lephalale Local Municipality. Spatial data pre-processing included the vector layers; soil clay content and river, which were converted into a raster format. Euclidean distance was performed to convert rivers into proximity to river and subsequently a multiple buffer zone of 500m was used. The slope map was derived from the Digital Elevation Model (DEM) and slope generation tools in ArcGIS software. Surface analysis was also used to generate Streams from DEM. This was done to validate river layers extracted from Department of Water Affairs Online Database. Layers were finally re-projected to the same coordinate system and their spatial extent was resampled to a 30m pixel size.

The data collected from the field was also subjected to pre-processing. This include generating Lived Poverty index from the questions based on answers to questions about how often a household has gone without certain basic household items in the previous year, including food, medical attention, electricity, clean water, cooking fuel and a cash income.

3.8 Data storage and analysis

The analysis of household survey data involved labelling and coding data using Statistical Package for Social Sciences (SPSS). The quantitative data was used in the analysis to select and extract indicator values. For spatial data, a database was developed in a GIS environment and layers were manipulated. Subsequently, the survey and secondary spatial data was used to generate Flood Vulnerability Index (FVI) as a measure of settlement's vulnerability to floods.

3.9 Developing the Flood Vulnerability Index (FVI)

GIS and MCDA (Multiple Criteria Decision Analysis) were used to develop flood vulnerability index and to identify areas vulnerable to floods. The study adopted methodological process used by Fernandez *et al.* (2016). This step by step methodological process involve: (i) defining aim and objectives, (ii) determining, selecting and processing data and transform it into indicators using IBM SPSS 22 and ArcGIS 10.4; (iii) Normalizing indicators using standardization methods (iv) weighting indicators using analytical hierarchy process (AHP) (v) aggregation of weighted indicators using linear summation and (vi) mapping of vulnerability in a GIS environment.

3.9.1 Aim of the vulnerability model

For this research, the main goal was to assess the vulnerability of human settlements in Lephalale Local Municipality using indicators. To achieve this main goal, study acknowledges three components of vulnerability, namely exposure sensitivity and adaptive capacity. Physical and socio-economic data are categorised in those three components.

3.9.2 Data determination, selection and processing of indicators

Indicators that are representative of vulnerability were selected (Kienberger *et al.*, 2009, Kienberger *et al.*, 2013). Indicators for this study were collected from secondary sources and through questionnaire-based interviews at household levels, and personal field observation. Indicators were selected, grouped into exposure, sensitivity and adaptive capacity and abbreviated accordingly (Table 3.1). Two functional relationships between the indicator values and vulnerability were identified and associated with each indicator. This is positive and negative relationship. The indicator is considered to have a positive relationship when they tend to increase vulnerability of a settlement to flood, while indicator with negative relationship lead to a decrease in the vulnerability to flood (Ntajal *et al.*, 2017).

Table 3.2: Selected indicators to assess settlement floods vulnerability

Component	Indicator	Abbreviation	Functional relationship
Exposure	Annual rainfall	E1	+
	Building materials	E2	+
	Elevation	E3	+
	Landuse/Landcover	E4	+
	Proximity to rivers	E5	+
	Slope	E6	+
	Soil clay content	E7	+
Sensitivity	Age (young and elderly)	S1	+
	Education status	S2	+
	Gender of household members(female)	S3	+
	Household size	S4	+
	Household structure (female headed household)	S5	+
	Lived Poverty Index	S6	+
	Persons with mental and Physical disability	S7	+
	population density	S8	+
	Unemployed	S9	+
Adaptive capacity	Access to weather forecast	AC1	-
	Aware of risks associated with floods	AC2	-
	Duration of residence	AC3	-

	Early warning	AC4	-
	Evacuation capability	AC5	-
	Flood preparedness	AC6	-
	Past flood experience	AC7	-
	Rainfall alerts	AC8	-

Adopted from (Kissi *et al.*, 2015)

3.9.3 Normalization of the indicators

Each indicator gathered was normalised using the standardization method. Since each indicator was measured on different scales, dimension for each of the indicators values must be standardized to obtain figures which are free from the measuring units. Two methods of standardization were used. This are fuzzification and UNDP's Human Development Index (HDI) method. For all continuous (i.e rainfall, slope, altitude, proximity to rivers, soil clay content) secondary spatial data, fuzzification, using linear increasing or decreasing function, in was used to standardize exposure indicators in a GIS environment. Fuzzy evaluates the possibility that each pixel belongs to a fuzzy set by evaluating any of a series of fuzzy set membership functions. In fuzzy set membership, '0' is assigned to those locations that are definitely not a member of the specified set, '1' is assigned to those values that are definitely a member of the specified set. All the in-between values receive some membership values based on the function.. Eastman (2009) suggested the standardization of indicators should be done using fuzzy set membership functions. For categorical\qualitative spatial data (landuse/landcover), normalization was done by reclassifying and assigning new values to each category where zero is the least vulnerable and one is the most vulnerable.

Each indicator gathered through a questionnaire was normalised using the standardization method of the UNDP's Human Development Index (HDI). This method was chosen because it takes into consideration, a functional relationship of each indicator of vulnerability. Indicators with positive functional relationship (i.e. exposure and sensitivity on Table 3.3) to vulnerability were normalised using this formula:

$$Y_{ij} = \frac{X_{ij} - \text{Min}\,(X_{ij})}{\text{Max}\,(X_{ij}) - \text{Min}\,(X_{ij})}$$

(Equation 3)

In case that the indicator has a decrease functional relationship with vulnerability (negative indicators, i.e. adaptive capacity on Table 3.3), the normalized score was computed using the formula:

$$y_{ij} = \frac{\underset{i}{Max}\{X_{ij}\} - X_{ij}}{\underset{i}{Max}\{X_{ij}\} - Min\{X_{ij}\}}$$

(Equation 4)

Where y_{ij} stands for the standardized vulnerability score with regard to vulnerability component (i), for village (j); X_{ij} stands for the observed value of the same component for the same village; *MaxXi* and $MinX_i$ stand for the maximum and minimum value of the observed range; of value of the same component, for all villages.

3.9.4 Evaluation of the indicator weights

Flood vulnerability assessment involves indicators of varying importance, therefore, information about the relative importance of each indicators is necessary. Such information is typically obtained by assigning a weight to each indicator. The analytical hierarchy process (AHP) was used to assign weights. This method was considered the best weighing techniques method for this study because of its flexibility, ability to check inconsistencies (Ramanathan, 2001; Saaty, 1980) as well as to avoid the uncertainty of equal weighting given the diversity of indicators used (Deressa *et al*., 2008). A questionnaire on comparisons ratings (referred to as pairwise comparison method (PCM)) based on Saaty's 1-9-point continuous scale (Saaty, 1980) (Table 3.4) was prepared to judge and assign an appropriate weight of each indicator,. This method allows the comparison of two indicators at a time whilst converting subjective assessments of relative importance into a linear set of weights. Every possible pairing was compared, and the ratings were entered into a pairwise comparison matrix. The pairwise comparison matrix takes the pairwise comparisons as an input and produces the relative weights as output while AHP provides a mathematical method of translating this matrix into a vector of relative weights for the indicators. Moreover, the final weightings for the indicators are the normalized values of the eigenvectors that is associated with the maximum eigen values of the ratio (reciprocal) matrix (Razandi *et al*., 2015).

Table 3.3: Saaty's scale for weight assignment (Saaty 1980)

Extremely	Very strongly	Strongly	Moderately		Moderately	Strongly	Very strongly	Extremely
Less important				Equally important	More important			
1/9	1/7	1/5	1/3	1	3	5	7	9

In the AHP process, the consistency of judgments was adequately checked by calculating the consistency ratio (CR). The CR defines the probability that the matrix weights are randomly generated, or the level of the judgements given by the experts/user in pairwise comparisons is consistent. The formula below was used to calculate CR:

$$CR = \frac{CI}{RI} \qquad \text{(Equation 5)}$$

Where RI is Random Index and CI is Consistency index. Random Index(RI) is the consistency of a randomly generated pairwise comparison matrix. It depends on the number of indicators being compared and takes the following values:

Table 3.4: Random Index

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty (1977)

The random index (RI) is a tabulated value for the number of criteria/indicators (*n*), and CI is the consistency index, which provides a measure of departure from consistency.

$$CI = \frac{\lambda max - n}{n-1} \qquad \text{(Equation 6)}$$

Where λmax is average value of the consistency vector and *n* is number of indicators. Consistency index (CI) and random index (RI) table were used to compute the consistency ratio (CR). The pairwise comparisons in a judgement matrix are considered to be adequately consistent if the corresponding consistency (CR) ratio is at most 10% or the CR is at most 0.10 (Saaty, 1980). Saaty (1980) further suggests that matrices with CR ratings greater than 0.10 should be re-evaluated.

3.9.5 Estimation of the flood vulnerability index (FVI)

3.9.5.1 Aggregation of Indicators

After the normalization and weighing of indicators representing each component of vulnerability, the linear summation aggregation method was used to generate the three sub-indices of exposure, sensitivity, and adaptive capacity. Firstly Index (I) of the indicator *y* for village (i) was calculated by multiplying its weight (Wy), by its normalized value (Nyi). Therefore,

$$Iyi = Wy * Nyi. \qquad \text{(Equation 7)}$$

Secondly, Index (I) of each component of vulnerability (Exposure, Sensitivity and Adaptive Capacity) was computed as the arithmetic mean of the values of all indices of the component for each village. Given a component of vulnerability with indicators Y, measured for a village (i), then the Index (I) of the component of vulnerability in that particular village (i) is given by:

$$I\ (E;\ S;\ AC) = \Sigma Iyi/n = \Sigma\ (Wy * Nyi)/n \qquad \text{(Equation 8)}$$

Where *n* = number of indicators of the component of vulnerability. The exposure index was obtained through an overlay analysis of the location of settlements, total annual rainfall, altitude, slope, proximity to rivers, soil clay content, landuse/landcover and building materials (mud house) using the raster calculator in ArcGIS environment. In a raster calculator, all normalized indicators were multiplied by their weightings, and subsequently added together and divided by the total number of exposure indicators (7) to develop exposure index.

3.9.5.2 Flood Vulnerability index

Since vulnerability increases with exposure and sensitivity but reduces with adaptive capacities, the composited Flood Vulnerability Index (FVI) of a particular village is given by:

$$Vulnerability = Exposure + Sensitivity - Adaptive\ capacity$$

Therefore,

$$FVI = (We*IE + Ws*IS - Wac * IAC) /n \qquad \text{(Equation 9)}$$

Where *FVI* = flood vulnerability index of the village/town/area, *We* = weight of exposure, *Ws* = weight of sensitivity, *Wac* = weight of capacity, *IE* = exposure index, IS = sensitivity index, *IC* = adaptive capacity Iindex. *N* = number of components.

3.9.6 Mapping flood vulnerability indices

Flood Vulnerability Index (FVI) was measured as a composite of exposure, sensitivity, and adaptive capacity indices and subsequently mapped in an ArcGIS environment. Flood vulnerability index was classified into 5 classes (very low, low, medium, high and very high), using the natural breaks method and displayed as graduated symbols map. The area occupied by each of these vulnerability classes was quantified in GIS environment for each of the wards for comparison purposes.

3.10 Ethical considerations related to data collection

The research study involved human subjects and therefore it was important that the research be conducted in a professional and ethical manner. This study was therefore completed using professional ethics and moral principles not just to protect the researcher’s interest, but also the interests of the respondents.

3.10.1 Ethical clearance and consent

Research involving human subjects requires ethical clearance. After application, approval was granted by the University of Limpopo ethics committee. This ensured that all national, international laws and regulations as well as university policies governing research are were adhered to. The clearance certificate obtained from the University is attached (Appendix B).

Gaining permission from the authority (Appendix D) is also an integral part of the research process. A written permission (Appendix C) was sought from Lephalale Local Municipality, to whom the intention of the study was explained. From there, local chiefs from the selected villages were also consulted and asked for further permission into their villages to conduct the study.

The research involved the collection of primary data from sampled households and therefore informed consent was considered in the process. Informed consent refers to the on-going agreement by a person to participate in research after purpose, risks and benefits of the research have been fully explained (Christians, 2005). Thus, the selected respondents were informed about the purpose of the study and their consent to conduct the interviews was sought. Explaining the purpose of the research ensured that respondents made informed and voluntary decisions on whether or not to participate without feeling as if they were being forced to do so, physically or psychologically. Those who agreed to take part in the survey were asked to sign consent forms.

3.10.2. Maintaining confidentiality and anonymity

Sharing information about a respondent with others for purposes other than research is unethical. It is unethical to also identify an individual respondent and the information provided by him/her. Therefore, it was important to ensure that after the information has collected, its source could not be identified. To ensure confidentiality and anonymity, respondents were not asked their names, nor was information collected that could lead to the personal identification of the respondents.

It was re-emphasized to the respondents that their agreement to participate in the survey would in no way be linked to the information that they provided and that their agreement should not make them feel compelled to continue participating if, at any point during the interview they did not feel so. The respondents were also advised that they could terminate the interview any time they wanted to. During standardized household questionnaire administration, all communication was in the local *Pedi/Tswana* language so that the respondents fully understood the purpose of the interviews as well as the information being sought.

3.11 Limitations of the research

The first challenge that the study faced was on how to reduce the complexity of an interaction within a system to an indicator or set of indicators. For example, not all factors contributing to floods vulnerability can be captured as quantitative indicators while some concepts or interactions are very difficult to quantify. Some of the socio-economic indicators such as age and income had missing values as some respondents were not comfortable to give such information. Therefore, some of the costs had to be estimated. To capture poverty more accurately, the study thus used the Lived Poverty Index (LPI) in quantifying sensitivity. The fact that some estimates were used may therefore have decreased the accuracy of the data. In addition, the weighing of indicators involves a certain degree of subjectivity and therefore an in-built margin of error. However, the AHP helps to capture both subjective and objective evaluation measures by providing a useful mechanism for checking the consistency of the evaluation measures and thus reducing biasness in decision-making (Saaty, 1980). Despite these limitations, the findings of this study are argued to be generally reflective of vulnerability of human settlements to floods in the study area.

3.12 Conclusion

This chapter has discussed the methodological and analytical framework within which this study operated. It showed the advantage of using indicators in order to understand the flood vulnerability phenomena. Quantitative survey with secondary data played a significant role in practically measuring vulnerability in a settlement. An attempted integrative assessment approach where both physical and socio-economic vulnerability pursued an effective means of combining these together as an overall vulnerability index system. This methodology proved useful in capturing the complexity and dimensionality of settlement flood vulnerability, particularly in a flood prone area such as that in Lephalale Local Municipality. The following chapter presents and discusses results obtained from the collected data.

CHAPTER 4: VULNERABILITY OF SETTLEMENTS IN WARDS 7 AND 9 TO FLOODS

4.1 Introduction

This chapter presents and discusses research findings on the vulnerability assessment of settlements to floods in Ward 7 and 9 of Lephalale Local Municipality in order to meet research objectives. The chapter also reflects on the practical and theoretical implications of the findings thereof. Finally, a conclusion and summary of the results is provided.

4.2 Drivers of settlement's vulnerability to floods

4.2.1 Sample characteristics

This section presents the demographic and socio-economic characteristics of the respondents in the surveyed areas. These demographic and socio-economic characteristics are important, given that they constitute source of vulnerability during times of flood disaster (Wisner *et al.*, 2004).

4.2.1.1 Gender of household members

The sample population in Ward 7 was made up of 710 people of whom 46.9% were male and 53.1% female, while in Ward 9 there were 1212 households consisting of 46.6% male and 53.4% female. In the combined sample, males made up about 47% in comparison to 53% females (Table 4.1). The dominance of females over males was expected, given the national sex-ratio of 95 males per 100 females (StatsSA, 2011a). In social floods vulnerability studies, gender is important. In many societies, women's access to resources and power is limited as compared to that of men, hence they are more vulnerable to flood hazards than men. Previous studies indicate that Women can further have more challenges during a floods recovery period, often due to their lower wages and higher family care responsibilities (Hewitt, 1999, Cutter, 2003, Fekete, 2009). Therefore, the lower the number of females, the lower the sensitivity to floods and vice versa. Nevertheless, this does not mean that men are spared from vulnerability to floods.

Table 4.1: Gender profile of household members

Sex	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Male	333	46.9	565	46.6	898	46.72
Female	377	53.1	647	53.4	1024	53.28
Total	710	100	1212	100	1922	100

4.2.1.2 Household structure

Four main types of households were identified in the study, based on the gender of the head and the structure of the household: (a) female-centred households (headed by a woman without a male spouse or partner); (b) male-centred households (headed by a man without a female spouse or partner); (c) nuclear households (usually male headed with a female spouse or partner and immediate relatives) and (d) extended households (made of immediate and distant relatives and non-relatives, usually male headed with a female spouse or partner) (Table 4.2). Over one-third of all surveyed households were headed by females: 35.3% in Ward 7 and 37.9% in Ward 9. Female headed households are not automatically more vulnerable to the effects of floods disasters in every society, but the gendered division of labour often puts women at increased risk than men. Women often have less access to key assets that are considered to be essential for survival and flood recovery. This include diverse income, health and safety, time, information, transportation, language skills and social support (Enarson, 2006). In Ward 7, 64.7% of households were headed by men, 9.8% made up of the household headed by males without a female partner, 36.8% of them headed nucleated and 18% headed extended households (Table 4.2).

In Ward 9, 62.1% represented households headed by males, 7.5 % constitute household without a partner, 48.0% represented males heading nucleated and 6.6% extended household structure. The dominating household structure was that of the nucleated and the extended household structure. This is explained by the patriarchal system in South Africa, which is male dominated, where men are normally considered the *de facto* heads of household. As StatsSA (2014) showed, male-headed households account for the highest proportion of households in South Africa's rural settlements. Although households headed by man, (including household headed by a man without a female spouse or partner and male headed with a female spouse or partner) are not spared from flood disaster, it is women headed households that are at a higher risk of being affected by floods.

Table 4.2: Household structure and gender of household head

Structure	Gender of household head	Ward Number				Total	
		7		9			
		(n)	(%)	(n)	(%)	(n)	(%)
Female centred	Female	47	35.3	86	37.9	133	36.9
Male centred	Male	13	9.8	17	7.5	30	8.3
Nuclear	Male	49	36.8	109	48.0	158	43.9
Extended	Male	24	18.0	15	6.6	39	10.8
	Total	133	100	227	100	360	100

4.2.1.3 Age

The population of Ward 7 and 9 consisted of generally young people, close to two-thirds (60%) of the sample population being under the age of 30 (Table 4.3). Those below the age of 19 constituted 39.7% of the sample. The dominance of children as a proportion of the overall population in the surveyed area is a cause for concern with regards to flooding, particularly because it makes it difficult for a quick and efficient evacuation to be organised in the event of flooding. This is because children and the elderly are more vulnerable to flood events as they slow down the evacuation process and are difficult to organize (Hewitt, 1999, Cutter, 2003, Fekete, 2009, Kuhlicke *et al.*, 2011). The population aged 60 years and above accounted for 9% of the sample population, hence increasing the population at risk during flood incidences.

Table 4.3: Age profile of household members

Age group	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
0-9	133	18.7	231	19.1	364	18.9
10-19	120	16.9	280	23.1	400	20.8
20-29	152	21.4	239	19.7	391	20.3
30-39	77	10.8	172	14.2	249	13.0
40-49	74	10.4	116	9.6	190	9.9
50-59	64	9.0	91	7.5	155	8.1
60+	90	12.7	83	6.8	173	9.0
Total	710	100	1212	100	1922	100

4.2.1.4 Household size

Table 4.4 shows the household size in Ward 7 and 9. Household size ranged from a minimum of 1 member to a maximum of 16 members. The largest proportion of households in the surveyed areas was made up of those households composed of 1–5 members (62.8%) (Table 4.4). This was followed by households with between 6 and 10 members (32.5%). Only a few households (4.7%) had 11 or more members. The average household size in both wards was 5.3 persons per household. This average household size in the study area was above the national average household size of 3.3 persons per household reported in the national census of 2011 (StatsSA, 2011b). The larger households tended to be extended family units while most of the smaller households were female or male-centred households.

Household size matters in flood vulnerability studies. This is because larger families often have more dependents to evacuate, such as children and the elderly and may also need more resources and time to recover after the event (Fekete 2009). After a flood event, members from larger households generally have to share the meagre resources available. In addition, larger households may also find it difficult to outsource the care of their many dependents as well as encountering difficulty in harmonizing work responsibilities with the care duties (Hewitt 1999, Cutter *et al.* 2003, Fekete, 2009). Thus, household size ultimately affects the resilience and recovery of the household from flood hazards by aggravate flood vulnerability as more mouths rely on the inadequate income to survive. While the addition of a member in a household during normal economic times may increase household income by increasing income sources, the effect is not necessarily the same with regards to disaster as any additional member may actually be a burden that aggravates the household situation and slows recovery.

Table 4.4: Household size

Range	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
1-5	78	58.6	148	65.2	226	62.8
6-10	52	39.1	65	28.6	117	32.5
11+	3	2.3	14	6.2	17	4.7
Total	133	100	227	100	360	100

4.2.1.5 Health status of household members

The health status of household members is important as it directly impacts on the physical labour available during crisis time as well as the number of members that may need to be assisted because of their immobility. Survey results indicated that almost nine-tenths (89.4%) of the sampled population were in good health (Table 4.5). Those household members who were listed as having some health problems constituted 10.9% of the sample, covering diseases such as HIV and AIDS, tuberculosis, heart diseases, hypertension, stroke, arthritis, asthma, diabetes, and pneumonia. People with disabilities, whether mental or physical constituted 0.9% of the sample. While this proportion was low, and may therefore not be a cause for concern, it is prudent to highlight that such people are more likely to be killed or injured in the event of natural disasters than the general population and also have a greater difficulty in coping during recovery from natural disasters. Evidence from previous disasters suggests that disabled people are at greater risk of injury, diseases, displacement and even worse, loss of lives, when compared with the general population (Lathrop, 1994, WHO, 2005). Considering that the majority of the surveyed household members were in a healthy status, these findings suggest that the surveyed household members are less susceptible to hazards associated with flooding events.

Table 4.5: Health Status

	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Accident	0	0.0	4	0.3	4	0.2
Pneumonia	1	0.1	1	0.1	2	0.1
Mental disability	2	0.3	3	0.2	5	0.3
Other	27	3.8	22	1.8	49	2.5
none of the above (good health)	602	84.8	1117	92.2	1719	89.4
Diabetes	12	1.7	13	1.1	25	1.3
Asthma	9	1.3	5	0.4	14	0,.7
Hypertension and stroke	30	4.2	20	1.7	50	2.6
Heart problems	2	0.3	1	0.1	3	0.2
Arthritis	6	0.8	8	0.7	14	0.7
Physical disability	7	1.0	4	0.3	11	0.6
HIV/AIDS	5	0.7	2	0.2	7	0.4
Tuberculosis	7	1.0	12	1.0	19	1.0
Total	710	100	1212	100	1922	100

4.2.1.6 Highest level of education

The educational levels of the sampled population in the study areas were generally low (Table 4.6). The results indicate that about 1.1% had no formal education, 12.3% only had some primary education, 2.7% completed primary school and 50.1% had some high school education (Table 4.6). A smaller number (6.9%) had post-secondary qualifications. Levels of formal education were generally low with only an average of 24.7% of the sampled adults having completed high school and about 2.0% university. The social survey generally revealed that most of the respondents in these two sections of the study area had low education levels (some secondary school education). Adults with no formal education or having only primary school as the highest level of formal education are regarded as 'functionally illiterate' (Olorunfemi, 2009). The level of education of the household members has an important bearing on the socio-economic status and income security of households, and thus also on their vulnerability to floods. This is because lower education entails that the members will be engaged in low paying jobs or be unemployed, get lower incomes and will generally be marginalised. Thus, households constituted by people with low levels of education tend to have minimal recovery capacity when compared to those with high levels of education (Fekete 2009a).

Table 4.6: Highest level of education

Educational level	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
No formal schooling	6	1.5	6	0.9	12	1.1
Some primary	52	13.3	78	11.7	130	12.3
Primary completed	6	1.5	23	3.4	29	2.7
Some High school	218	55.8	312	46.7	530	50.1
High school completed	72	18.4	189	28.3	261	24.7
Post-secondary qualifications (Diploma, or degree from Technikon or college)	27	6.9	46	6.9	73	6.9
Some university	8	2.0	13	1.9	21	2.0
University completed	2	0.5	0	0.0	2	0.2
ABET	0	0.0	1	0.1	1	0.1
Total	391	100	668	100	1059	1.1

4.2.1.7 Employment status

There was a high number of household members that were not working-and looking for employment in this study (Table 4.7). The proportion of household members that was unemployed in the survey area was 46.0%. Unemployment is related to an individual's vulnerability to flooding events in that lack of employment results in a lower or limited income, making an individual highly vulnerable to the impacts of flooding. Generally, unemployed people face more challenges in recovering from flood damages than those that are employed and therefore have access to resources necessary for the recovery process. Unemployed people have limited financial means to enable them to cope as they cannot access better building materials, food and other items. Thus, lack of socio-economic capacity decreases the possibility of an individual to be able to cope with the consequences and recover from adverse flood event (Tapsell *et al.*, 2002). In that regard, most people in the study will therefore be moderately susceptible to floods impacts because of their unemployment status.

Table 4.7: Work status

Status	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Working full time	107	27.4	232	34.7	339	32.0
Working part time/casual	31	7.9	79	11.8	110	10.4
Not working-looking	203	51.9	284	42.5	487	46.0
Not working-not looking	50	12.8	73	10.9	123	11.6
Total	391	100	668	100	1059	100

The vast majority of households receiving income from wages or casual income in the study areas had members who were employed in the unskilled manual labour market, with an average of 19.3% (Table 4.8). Apart from the unskilled manual labour, the other major sources of employment in the study areas were skilled manual labour with an average of 25.2%. Only a very small proportion of those with jobs were employed in more skilled occupations such as office work, health work and teaching (all less than 20%) (Table 4.8). Over one-third of household members worked as unskilled manual labourers. Just under 5% worked in the informal economy as hawkers, vendors and traders and around 10.5.% ran their own businesses. Other low-skilled jobs included domestic work (18.9%), mine work and service work (40.8%).

Table 4.8: Sources of employment

Source	7		9		Total	
	(n)	(%)	(n)	(%)	(n)	(%)
Farmer	4	2.8	7	2.2	11	5
Skilled manual labour	20	13.9	36	11.3	56	25.2
Unskilled manual worker	29	20.1	59	18.5	88	38.6
Trader/hawker/vendor	2	1.4	7	2.2	9	3.6
Security personnel	3	2.1	15	4.7	18	6.8
Police/military	3	2.1	7	2.2	10	4.3
Businessman/woman(self-employed)	2	1.4	29	9.1	31	10.5
Employer/manager	1	0.7	2	0.6	3	1.3
Professional worker	8	5.6	10	3.1	18	8.7
Teacher	8	5.6	6	1.9	14	7.5
Agricultural worker	1	0.7	8	2.5	9	3.2
Health worker	4	2.8	10	3.1	14	5.9
Civil servant	0	0.0	2	0.6	2	0.6
Truck driver	3	2.1	5	1.6	8	3.7
Agricultural worker	2	1.4	3	0.9	5	2.3
Taxi Driver	0	0.0	2	0.6	2	0.6
Service worker	12	8.3	54	16.9	66	25.2
Domestic worker	16	11.1	25	7.8	41	18.9
Managerial office worker	0	0.0	6	1.9	6	1.9
Office worker	5	3.5	5	1.6	10	5.1
Foreman	3	2.1	3	0.9	6	3
Mine worker	17	11.8	12	3.8	29	15.6
Dont know	1	0.7	6	1.9	7	2.6
Total	144	100	319	100	463	100

4.2.1.8 Household poverty level

Afrobarometer's Lived Poverty Index (LPI) was used to measure poverty levels among surveyed households. The LPI is a subjective measure based on answers to questions about how often a household has gone without certain basic household items in the previous year, including food, medical attention, electricity, clean water, cooking fuel and a cash income (Afrobarometer, 2003). Figure 4.1 shows the responses of household members in assessing how often they go without basic necessities based on a five-point scale (never; just once or twice; several times; many times; always (Figure 4.1).

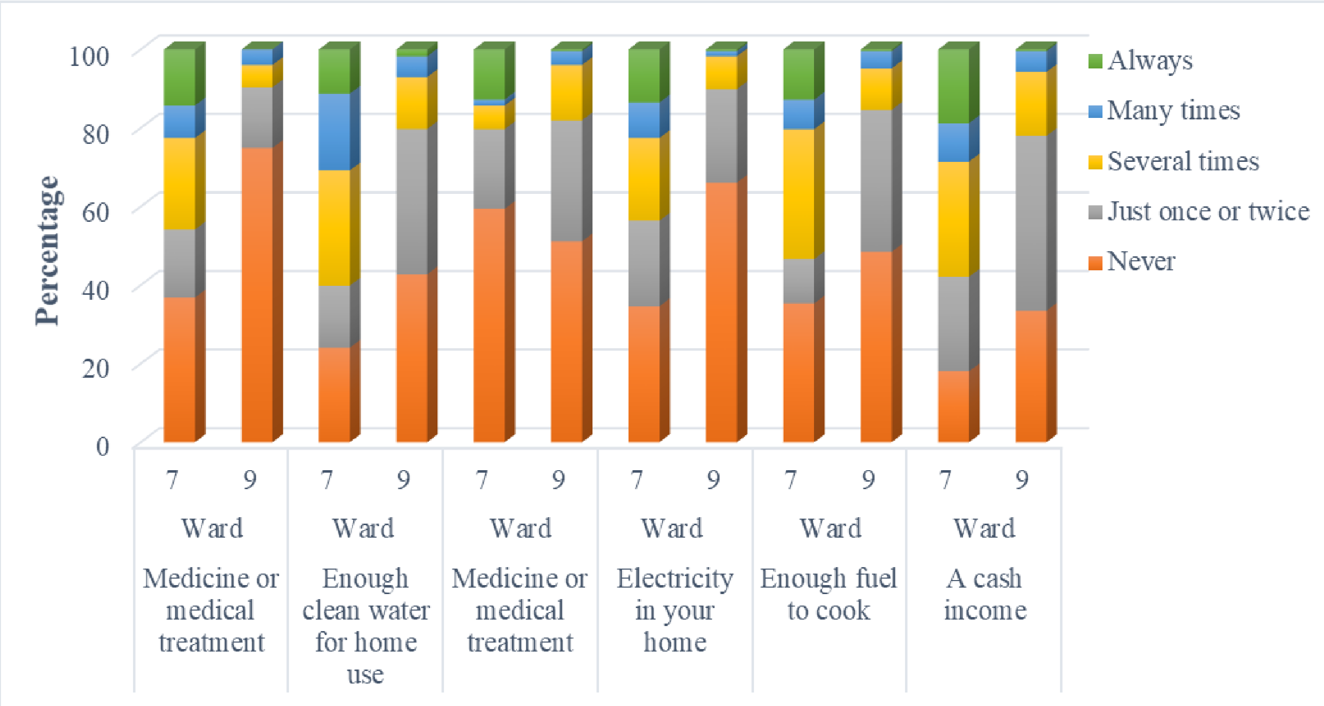

Figure 4.1: Frequency of going without basic necessities

A mean LPI score was computed for all the households. The LPI score is calculated on a scale of 0.0 to 4.0, where the lowest possible score of 0.0 represents the extreme of never going without basic needs and the highest possible score, which is 4.00 represents the extreme of always going without basic needs (Afrobarometer, 2003). (Table 4.9). The average LPI for the sample households in Ward 7 was 1.5, with a minimum of 0.00 and a maximum of 4.00. In Ward 9 the average LPI was 0.69, with a minimum of 0.00 and maximum of 2.50. As table 4.9 shows, 21.1 % of the households in Ward 7 and 2.2% in Ward 9 had higher LPI indices of above 2.00. Ward 9 is better than Ward 7, and therefore it is less vulnerable because of its low poverty levels. It can be observed from Table 4.9 that Ward 7 had the highest number of people (11.3%) with the scale of often to always doing without basic necessities when compared with Ward 9 which has no household in that category. In contrast, Ward 9 had a higher number of households (81.5%) that never or seldom do without basic necessities in relation to Ward 7 (40.6%). In that regard based on the LPI, Ward 7 is more vulnerable to the impacts of flooding events in relation to Ward 9. Poverty reduces access to basic necessities such as housing, water and energy required for maintaining a household. While poverty encompasses many dimensions, the one that dominates in reducing household access to basic necessities is income. For any household, access to an adequate and stable income is vital for household preparedness and recovery from disasters such as floods.

Table 4.9: Lived Poverty Index score

LPI categories	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
0.00-1.00 (never to seldom without)	54	40.6	185	81.5	239	66.4
1.01-2.00 (seldom to sometimes without)	51	38.3	37	16.3	88	24.4
2.01-3.00 (sometimes to often without)	13	9.8	5	2.2	18	5.0
3.01-4.00 (often to always without)	15	11.3	0	0.0	15	4.2
Total	133	100	227	100	360	100

4.2.1.9 Population density

Population density is a key variable in the flood-vulnerability matrix. Generally, the higher the population density of an area, the higher the vulnerability is likely to be (Chang and Franczyk, 2008, Paquette and Lowry, 2012, Saini and Kaushik, 2012). Ward 7 had a population density of 98.3 per Km^2 whereas the population density for Ward 9 was 63.0 per Km^2. These results indicate that, all other things constant, Ward 7 would be more susceptible to the impacts of flooding events when compared to Ward 9. Thus, more people and infrastructure in Ward 7 are likely to be affected by the flooding events in relation to Ward 9 which has a relatively lower population density.

4.2.1.10 Duration of residence

Survey results show that close to nine-tenths (89.5%) of the surveyed households in Ward 7 and about four-fifths (79.3%) in Ward 9 have been resident in the study area for more than 10 years (Table 4.10). Meanwhile, less than one-sixths of the surveyed households have been residing in the study area for the past 9 years. Considering that literature shows that the longer people reside in a particular area the more they learn to cope with the effects of the natural disasters occurring incurring in that area.

Table 4.10: Residence duration

Years	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
0-4	2	1.5	16	7.0	18	5.0
5-9	9	6.8	22	9.7	31	8.6
10+	119	89.5	180	79.3	299	83.1
Don't know	3	2.3	9	4.0	12	3.3
Total	133	100	227	100	360	100

4.2.2 Adaptive capacity factors

4.2.2.1 Past flood experience

With regards to the past flooding experiences, survey results indicate that most of the respondents had never experienced floods before. In Ward 7, over four-fifths (84.2%) of surveyed households reported that they have never experienced floods and the comparative figure for Ward 9 was 83.7% (Table 4.11). Those whose houses were never affected indicated that the reason why they have never been affected before it's because the stay farther away from rivers. This was justified by a respondent from Ward 9 who stated that:

> *"My house is far away from Phalala River, that is why our house has never affected by floods before." (Respondent no 150, 17th of December 2015, Ward 9)*

Thus, only 15.8% and 16.3% of the households in Ward 7 and 9, respectively, confirmed having experienced floods. The majority of the people in the study area, therefore, have a limited understanding of the nature, occurrence and even destructiveness of flooding. When asked to describe what happed, this is what one of the respondents said:

> *"It happened in 2014 when it rained for over 4 hours without ceasing. The Phalala river burst its river banks and overflows into Shongoane and Mmatladi. Water ran all over the place and eventually gets into a house and destroy wooden properties such as wardrobe and cupboards."* (Respondent no 30, 16th of December 2017, Ward 7)

Balica *et al.* (2009), argues that a household's experience with previous flooding events has a positive effect on awareness levels and makes the households more prepared in case another flooding event happens. In that regard, most people in the study will therefore be more susceptible to floods impacts because they do not know what to expect and even how to react in the event that a flood occurs in future.

Table 4.11: Past flood experience

Experience of a past flood event	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	21	15.8	37	16.3	58	16.1
No	112	84.2	190	83.7	302	83.9
Total	133	100	227	100	360	100

4.2.2.2 Rainfall alerts

Despite the fact that people in the study area had little experience of flooding events, a total of 62.8% of the households in the study sites reported that they are always alert to possible flooding. The proportion of alert households was higher in Ward 9 (72.7%) than in Ward 7 (45.9%) (Table 4.12). This could be explained by that Ward 9 respondents' level of access to weather forecast is higher when compared to Ward 7. In addition, level of awareness of risks associated with floods in Ward 7 is slightly higher than that in Ward 7. Rainfall alertness is important in floods scenarios as it acts as a trigger to the implementation of action plans against the flooding event. Survey results, thus, suggest that residents of Ward 7 are more vulnerable to flooding since more than half of the households are generally not alert to possible flooding events, even in times when it rains heavily for several hours.

Table 4.12: Rainfall alerts

Alertness to possible flooding	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	61	45.9	165	72.7	226	62.8
No	72	54.1	62	27.3	134	37.22
Total	133		227		360	100

4.2.2.3 Awareness of risks associated with floods

Risk perception or awareness is one of the critical factors associated with adaptive capacity of households to natural disasters. Risk perception is therefore a crucial factor for households to determine their level of preparedness against flood events (e.g. Balica *et al.*, 2012, Bubeck *et al.*, 2012. In this study, 77.2% of the households indicated that they were aware of the risks associated with floods. Conversely, about one-fifth (20.3%) of households in Ward 9 and slightly above a quarter (27.1%) in Ward 7 were not aware of flood risks (Table 4.13). Because early warning systems are related to the level of risk knowledge among the population at risk, the significant numbers of households who were not aware of the risks in the study area pose a challenge to the effectiveness of the early warning systems. Effective early warning systems require that almost all the households in the area be aware that they are at a risk of flooding. That way, they may be able to assimilate faster the information targeted to them and act promptly when required to do so.

Table 4.13: Awareness of risks associated with floods

Awareness of risks associated with flooding	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	97	72.9	181	79.7	278	77.2
No	36	27.1	46	20.3	82	22.8
Total	133		227		360	100

4.2.2.4 Flood preparedness

Despite the higher levels of flood risk awareness among residents, study findings reveal that awareness and preparedness may not be closely related. This is because while 77.2% of the households were aware of the risks, about two-thirds (65.8%) of the total households in all the areas reported not being able to handle floods (Table 4.14). The separate figures for the two wards were 69.9% and 63.4% for Wards 7 and 9, respectively. Only 2.3% of the households in Ward 7 and 1.8% in Ward 9 indicated that they were able to handle floods. Less than a quarter (16.7%) of the households did not know on whether they are able to handle floods or not. These findings on the ability of households to handle flooding events suggest worrying levels of uncertainty regarding preparedness, which may increase the population’s vulnerability in the case of a flood event. People that are uncertain of their ability to handle a situation are unlikely to act faster in the event that they are faced with the flood.

Table 4.14: Preparedness to flooding

Ability to handle floods	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Able	3	2.3	4	1.8	7	1.9
Not able	93	69.9	144	63.4	237	65.8
Less able	4	3.0	52	22.9	56	15.6
Don't know	33	24.8	27	11.9	60	16.7
Total	133	100	227	100	360	100

4.2.2.5 Early warning

Results for the assessment of the early warning system showed that over two-thirds (70.3%) of the study respondents were not aware of any existing early warning system in their communities. A total of 82% in Ward 7 and 63.4% in Ward 9 had never received any early warning information on floods before. Only less than a quarter (23.3%) of the respondents were thus affirmative that there was a community early warning system in their area: 3.8% in Ward 7 and 34.8% in Ward 9 (Figure 4.15). A respondent in ward 7 stated that:

> *"we do receive flood warnings from the police. The message on possible flood events is conveyed by police car, roaming around the village with a voice behind the loud speaker to inform people about floods events. This is normally done before the floods could occur".* (Respondent no 12, 10th of October 2015)

Early warning systems play a crucial role in flood disaster risk reduction and management. Messages and warnings are disseminated in order to prevents loss of life, minimize the impact of disasters and facilitate preparation for evacuation. one the respondents in Ward 9 said:

> *"With the information we received about floods events, my family and I were able to evacuate before the flooding, to our relatives who stay in Lerupurupung'* (Respondent no 187, 17th of December 2017)

For early warning systems to be effective, both the stakeholders and the communities at risk need to be actively involved, as to facilitate public education and awareness. In this regard, results from the study area indicate that the communities, especially those in Ward 7 are highly susceptible to the impacts of flooding since few are aware of any early warning system.

Table 4.15: Community early warning systems

Does your community have an early warning system?	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	5	3.8	79	34.8	84	23.3
No	109	82.0	144	63.4	253	70.3
Don't know	19	14.3	4	1.8	23	6.4
Total	133	100	227	100	360	100

4.2.2.6 Access to weather forecast

Contrary to the high percentage of the households that were not aware of community early warning systems, the majority of the respondents (81.1%) reported having access to weather information in the study area. Only 19.9% indicated having no access to weather information (Table 4.16). Information from newspapers, television and radio raises awareness of individuals and households regarding flood occurrences and preparedness to respond to natural hazards (Balica *et al.*, 2009, Brink and Davidson, 2015). Thus, the findings of this study indicate that the majority of the people in the study were aware of the weather patterns and hence, could be well prepared to deal with the flood hazards.

Table 4.16: Access to Weather information

Do you have access to Weather information?	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	112	84.2	205	90.3	317	81.1
No	21	15.8	22	9.7	43	19.9
Total	133	100	227	100	360	100

4.2.2.7 Evacuation capability

Regarding evacuation capability in the study area, 34.6% of the households in Ward 7 and 52.9% in Ward 9 reported being able to evacuate in case of a flood event (Table 4.17). However, the fact that close to half of the total households (46.1%) indicated that they were unable to evacuate in the event that a flood occurs, is a cause for concern. The ease and possibility of evacuation in the event of a natural hazards is one critical element that determines the susceptibility of people dwelling in the area in the event of natural hazards. Ward 7 households are most likely to be susceptible to flooding events when compared to Ward 9 since the majority of the respondents indicated that they were not in a position to evacuate in the event of floods.

Table 4.17: Evacuation capability

Are and your family able to evacuate, in case of a flood?	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)
Yes	46	34.6	120	52.9	166	46.1
No	67	50.4	99	43.6	166	46.1
Don’t know	20	15.0	8	3.5	28	7.78
Total	100	133	100	227	360	100

4.2.3 The physical setup of the study area

This section analyses the physical characteristics of the study sites. The type of construction and locational characteristics of settlements are significant indicators of exposure and will ultimately affect the vulnerability of the settlements to floods.

4.2.3.1 Building status

The assessment of the quality of construction materials in the surveyed areas showed that the majority of the houses were built using strong materials such as cement bricks. Over 95% household utilised cement bricks which are regarded as one of the best construction materials (Salami *et al.*, 2017) (Table 4.18). A total of 80.5% houses in Ward 7 and 100% in Ward 9 were built using cement. Very few houses in the two study areas were built using mud (1.39%) respectively) and corrugated iron (0.3%). The main construction material for walls determines how resistant a building is towards damage cause by floods. It also indicates the social status of the inhabitants (Schneiderbauer, 2007, Müller *et al.*, 2011). Construction material serves as a variable in assessing housing quality and determining inhabitant’s level exposure to flood hazards (Rumbach and Shirgaokar, 2017). Results of this assessment imply that most of the residents utilised strong building materials in constructing their homes, therefore, their level of exposure and vulnerability to flood is minimal.

Table 4.18: Main material used for the wall

	Ward Number				Total	
	7		9			
	(n)	(%)	(n)	(%)	(n)	(%)

Mud	5	3.8	0	0.0	5	1.4
Cement bricks	127	80.5	794	100	354	98.3
Corrugated iron	1	0.8	0	0.0	1	0.3
Total	133	100	227	100	360	100

4.2.3.2 Rainfall variability in the study areas

Floods are related to extremes in precipitation. Figure 4.2 illustrates the spatial distribution of precipitation in Wards 7 and 9. This data was generated from South African Weather Service (SAWS) data using Inverse Distance Weighted (IDW) Method. The data was from 8 weather stations in Lephalale Local Municipality. In Ward 7 high rainfall of about 429mm occurs in the central section of ward and decreases towards the south and the north of the ward to a minimum of about 420. Meanwhile, in Ward 9, slightly higher rainfall of about 436mm incurs mostly in the southern section of the ward and decrease northwards to a minimum of 427 mm per annum (Figure 4.2). In this regard, households that are located in the central section of Ward 7 and in the southern section of Ward 9 are more susceptible to flooding events due to the high annual precipitation received there.

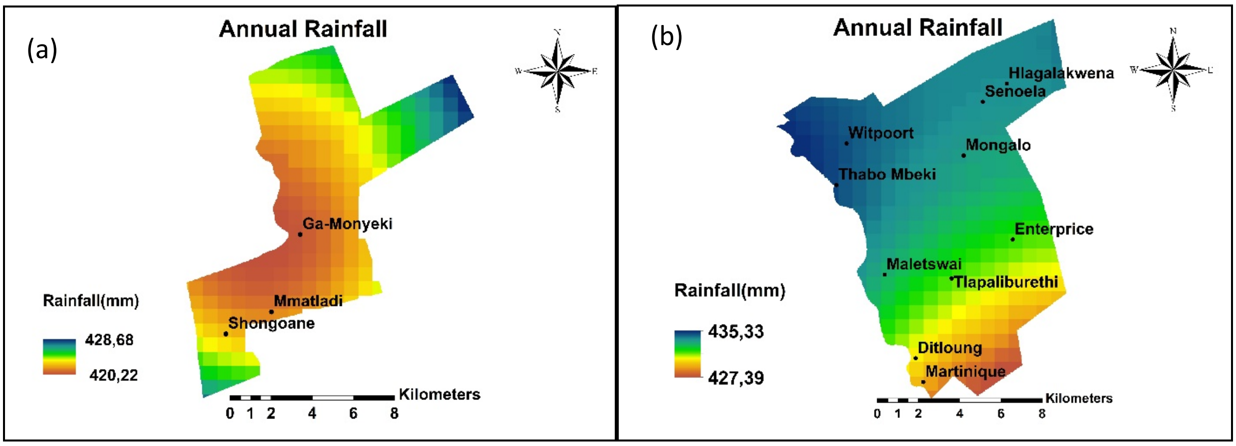

Figure 4.2: The spatial distribution of rainfall in Ward (a) 7 and (b) 9

4.2.3.3 Topography of the study area

4.2.3.3.1 Altitude

The altitude of these two study areas is relatively low (i.e. between 815 and 996 above sea level). Figure 4.3 shows the variation of altitude within Wards 7 and 9. It shows that the Ward 7 is at a higher risk of floods due to its lower elevation of between 845 and 926. Low elevation locations are generally at higher risk because water flows into these areas (Paquette and Lowry, 2012). In Ward 9, Thabo Mbeki is situated at the lowest elevation, compared to other villages in the ward. Mongalo, Senoela and Hlagalakwena are located at a higher elevation and are therefore less susceptible. elevation is a significant flood factor because it determines the severity, flow size and direction of floods (Kia *et al.*, 2012, Saini and Kaushik, 2012). Lower elevated areas are at a higher risk of floods than areas with higher elevation. Furthermore, water tend to remain in the lower area for a longer period than in higher elevated areas (Fernández and Lutz, 2010, Kia *et al.*, 2012, Saini and Kaushik, 2012). Areas such as Thabo Mbeki, Maletswai, Ditloung and Martinique in Ward 9 are therefore at a higher risk of flooding due to their lower elevation.

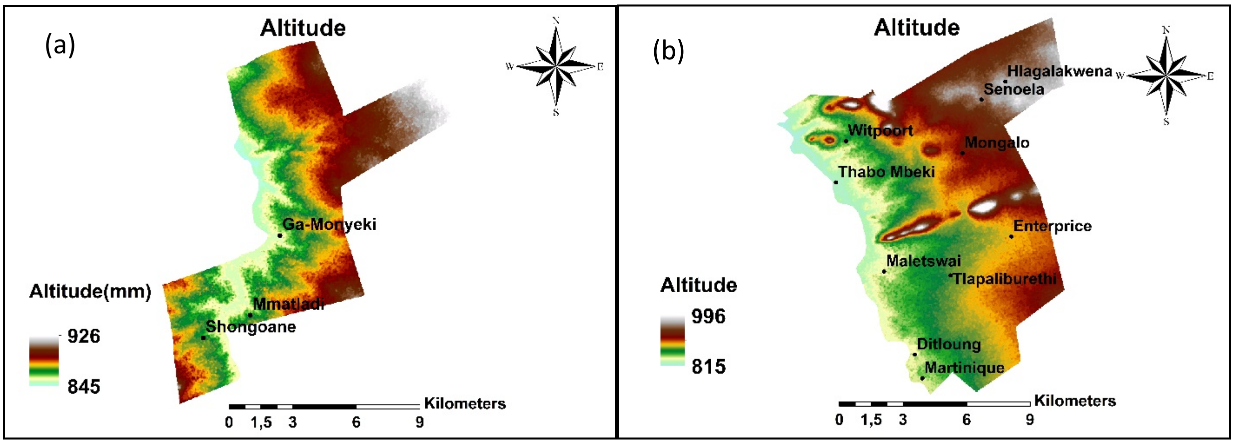

Figure 4.3: Variation of altitude of (a)Ward 7 and (b) 9

4.2.3.3.2 Slope

Figure 4.4 shows the spatial variation of the slope generated from DEM data in Wards 7 and 9. The slopes in Ward 7 range between 0 – 90.0 degrees whereas in Ward 9 the slope is relatively low ranging between 0 and 25.6 degrees. Exposure of Ward 7 villages to flood hazards is relatively low due to high mean slope which facilitates the flow of water following the slope whereas that of Ward 9 is high due to low slope which facilitates accumulation of water. All villages in Ward 9 are situated below 5 degrees slope, therefore their chances of being flooded are high.

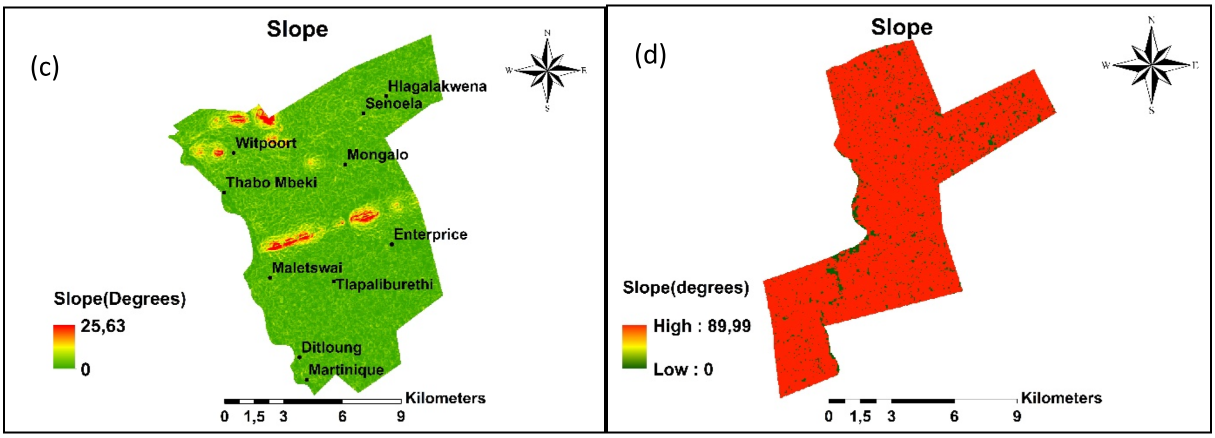

Figure 4.4: Spatial variability of Slopes in Ward (a) 7 and of (b) 9.

4.2.3.4 River networks

Figure 4.5(a) shows drainage characteristics of the study sites. It can be observed that Ward 9 is located along the Phalala River, whilst in Ward 7, the river traverses through the ward. The western section of Ward 9 and the central section of Ward 7 are at a closer range to the river and therefore they are more susceptible to flooding than any other sites in the wards. Experience obtained through field observation confirmed that the three villages in Ward 7 are located closer to Phalala river. The 'distance from rivers' factor plays a significant role in determining the flooding of an area. According to a previous study conducted by Fernández and Lutz (2010), the most affected areas during floods are those near these rivers, as a consequence of channel overflow. Figure 4.5(b) shows that Thabo Mbeki, Ditloung and Martinique in Ward 9 are within 500m from the river, while Witpoort, Mongalo, Enterprise, Senoela, Tlapaliburethi and Hlagalakwena are more than 1.5km away from the river channel (Figure 4.5(b)). Those villages within a 500m distance from the river are therefore considered highly exposed as compared to those that are further away. In Ward 7, both Mmatladi and Ga-Monyeki were located within 501 to 1000m from the river whilst Shongoane is located over a kilometre away. This makes all the villages in Ward 7 to be exposed to floods due to their close proximity to the river channel. In a related study, Tran *et al.* (2009) also noted that the settlements that were closer to the river channels were often affected by flooding events in their conducted in the Thua Thien Hue Province, Central Vietnam.

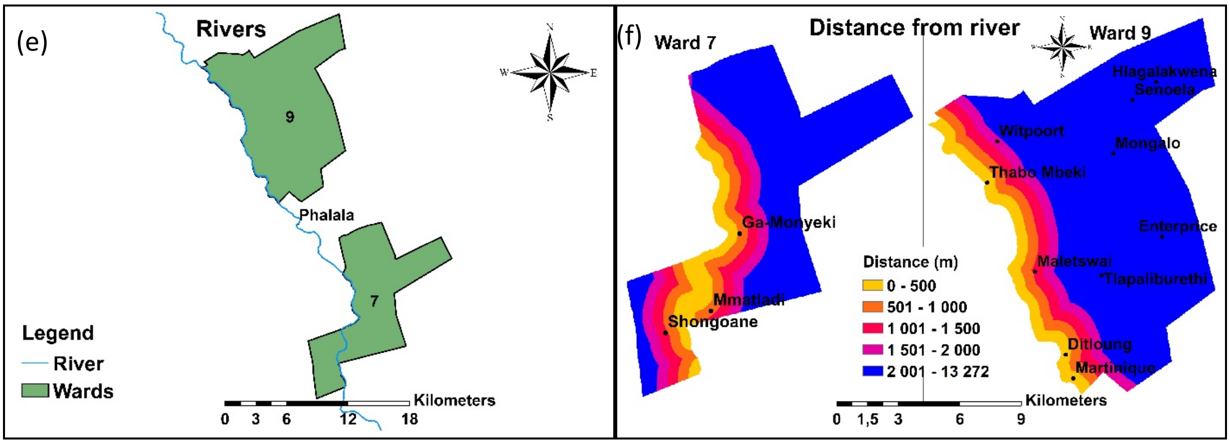

Figure 4.5: Drainage characteristics of rivers traversing through the study sites(a) and proximity to rivers(b)

4.2.3.5 Soil clay content of the study sites

In Ward 9, soils that were characterised by high clay content (maximum of 14%) were located in the northern and southern sections of the ward. These soils were of medium permeability (Figure 4.6). All of Ward 7 was generally characterised by soils with relatively low clay content of less than 8%. Clay soil tends to restrict rapid water flow, which causes "puddling" of water (Mao *et al*., 2016). The permeability of the soil is an important aspect in this study because it influences the susceptibility of an area to floods. Soils with high permeability rates allow more water to pass through, while those with low permeability are likely to lead to high run-off, hence increasing the likelihood of flooding. Thus the results of clay content analysis indicate that Ward 9 is most likely to be susceptible to flooding because of the high clay content of its soils. Roslee *et al.* (2017) also noted that areas that were characterised by high clay content were the most susceptible to flooding events in their study in the Penampang District of Sabah, East Malaysia.

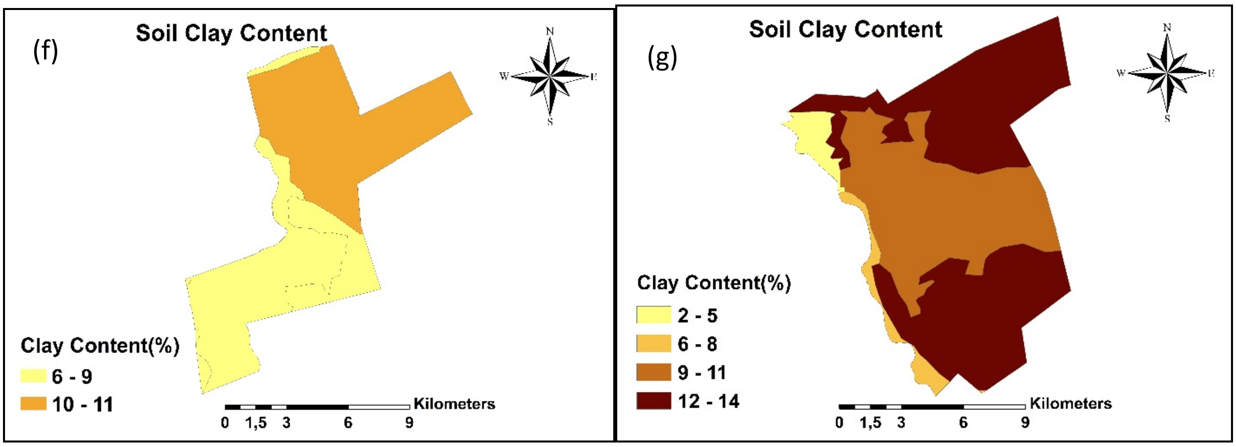

Figure 4.6: Spatial variability of clay content in Wards (a) 7 and (b) 9

4.2.3.6 Landcover of the study sites

Land cover has a direct influence on a number of parameters in the hydrologic cycle .This include interception, ground infiltration and surface runoff (Ntajal *et al*., 2017). Removal of vegetation increase surface runoff of water which is more likely to lead to flooding, especially in flat and low-lying areas and on impermeable soils and surface. Figure 4.7 and 4.8 shows the distribution of a landcover map provided by SANSA (South African Space Agency). Bare soils and built-up areas tend to increase surface runoff, especially on steep slopes, where the rate of infiltration is simultaneously reduced (Ntajal *et al*., 2017). High run-off therefore increases the susceptibility to flood risk. These two study sites have similar landcover classes, they are both characterised by a number of built up areas, cultivated commercial and subsistence farms, grasslands, thicket dense bush, low shrubland, narrow river that runs along the boundary of Ward 9 and cut across Ward 7 as well as patches of eroded land. Most villages that incurred damages from floods were those found along the rivers, located in areas characterised by bare soils and contain a low amount of green spaces as was the case in the study by Roslee *et al.* (2017). To support that, experience gained through field observation confirmed that the three villages in Ward 7 were located closer to Phalala river hence their susceptibility to flooding. Furthermore, experience gained through field observation confirmed that most yards in both Ward 7 and 9 had no to few vegetation, hence their chances of flooding incidences are higher. Closer proximity to rivers, lack of vegetation cover and clearance of land for farming result in an increase in the rate of runoff and a decrease in infiltration, and consequently cause flooding (Roslee *et al.*, 2017).

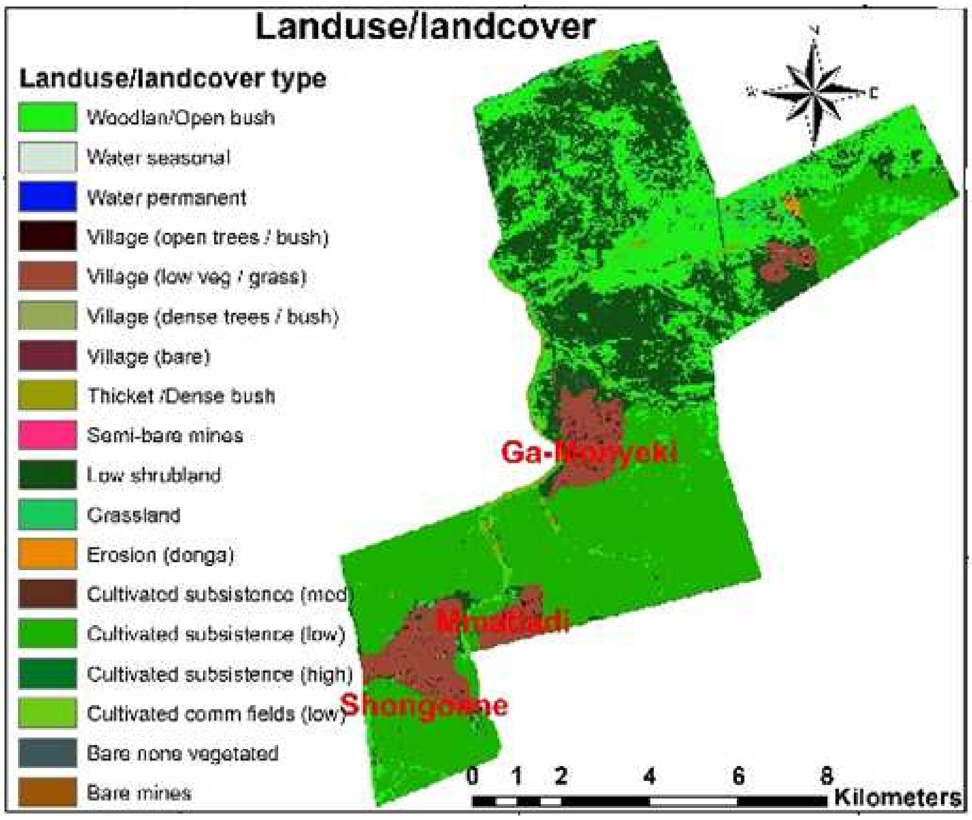

Figure 4.7: The spatial distribution of various landuse/landcover types in Ward 7

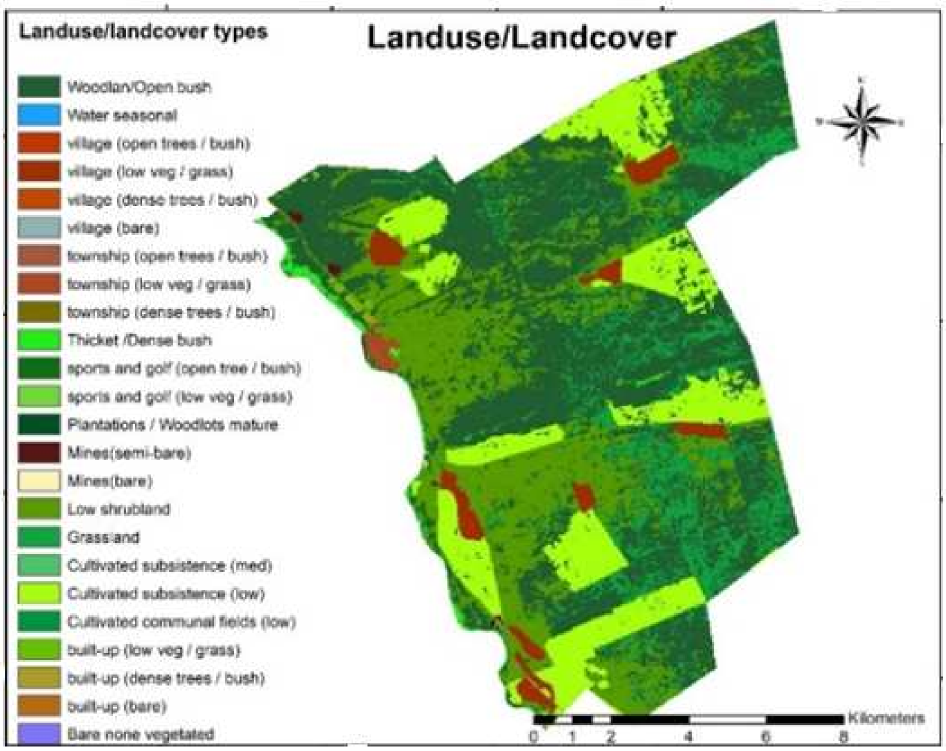

Figure 4.8: The spatial distribution of various landuse/landcover types in Ward 9

4.5 Flood vulnerability index of settlements in study areas

4.5.1 Normalization of indicators values for exposure components

Exposure indicators were measured in different units and therefore, required transformation into a common unit of measurement. Exposure indicators have a positive relationship to vulnerability as they tend to increase vulnerability of a settlement to floods. Taking into consideration the relationship of exposure to vulnerability, spatial (Figure 4.2 to 4.8) and questionnaire data (Table 4.18) were normalised using standardisation method and subsequently, thematic maps illustrated on Figure 4.8 (a) to (f) and Table 4.19 were derived. The normalised values of exposure indicators ranged between 0 and 1 with the red shading indicating a high level of exposure, orange indicates a moderate level of exposure while the green one indicates a low level of exposure to flooding. Therefore, the higher the normalised values the higher the level of exposure. For example, Figure 4.9 (a) indicate that the northern, north eastern and south western portion (shaded in red-orange colour) of Ward 7 had higher values associated with exposure indicators. Figure 4.9 (b) shows that the north western sections of both Ward 7 and 9 also had high exposure levels with regards to distance. It can be concluded that the lower the normalised values of altitude the lower the exposure.

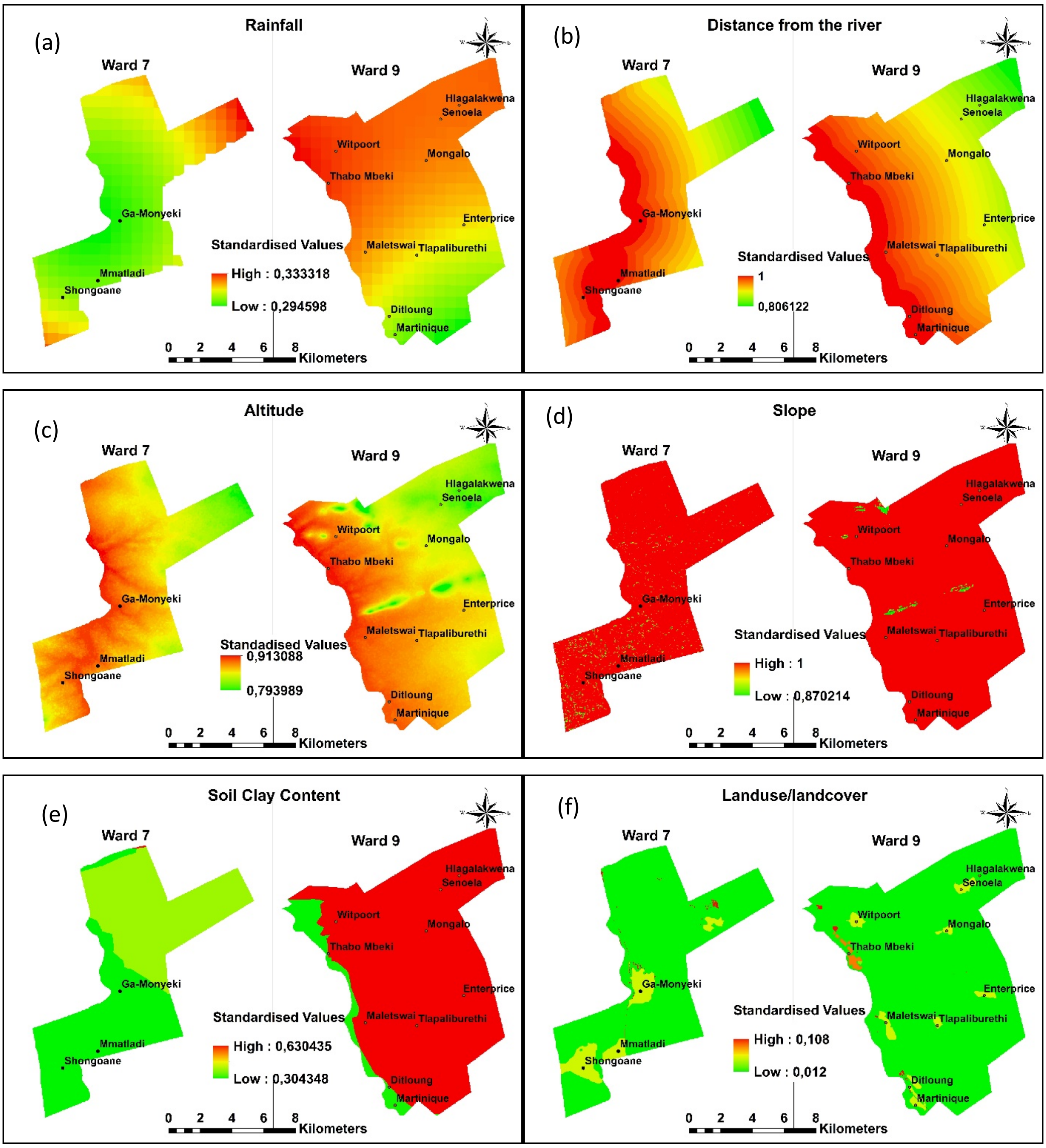

Figure 4.9: (a) – (e) standardised exposure indicators

Table 4.19: The normalised values of the building material (mud house) indicator

Ward number	**Village name**	Building materials(mud)
7	Shongoane	0
	Mmatladi	0,7
	Ga-Monyeki	1
9	Ditloung	0
	Enterprise	0
	Tlapaliburethi	0
	Mongalo	0
	Maletswai	0
	Hlagalakwena	0
	Martinique	0
	Senoela	0
	Thabo Mbeki	0
	Witpoort	0

4.5.2 Normalized values for sensitivity indicators

Table 4.20 illustrates the normalized values for sensitivity indicators ranging between 0 and 1 in Wards 7 and 9. The colour coding was used to present different levels of sensitivity; red shading indicates a high level of sensitivity, orange indicates a moderate level of sensitivity while the green shade indicates a low level of sensitivity to flooding (Table 4.20). Therefore, the higher the normalised values the higher the level of sensitivity. It can be observed that villages in Ward 7 generally have a high sensitivity values compared to villages in Ward 9. Shongoane village in Ward 7, for example, has relatively high sensitivity values of 1. Meanwhile, Hlagalakwena village in Ward 9 exhibited relatively low sensitivity values close to 0. These results suggest that Ward 7 villages are generally more sensitive to flood hazards.

Table 4.20: Normalized values for sensitivity indicators

Ward	Village	S1	S2	S3	S4	S5	S6	S7	S8	S9
7	Shongoane	1.000	1.000	1.000	0.250	1.000	0.333	0.750	0.217	1.000
	Mmatladi	0.783	0.667	0.500	0.000	0.407	1.000	0.500	0.039	0.317
	Ga-Monyeki	0.434	0.667	0.273	0.500	0.111	1.000	1.000	0.211	0.317
	Ditloung	0.024	0.524	0.007	0.250	0.259	0.000	0.000	1.000	0.020
9	Enterprise	0.229	0.190	0.227	1.000	0.407	0.083	0.000	0.183	0.238
	Tlapaliburethi	0.036	0.429	0.000	0.250	0.074	0.000	0.500	0.232	0.000
	Mongalo	0.337	0.333	0.227	1.000	0.148	0.083	0.250	0.314	0.257
	Maletswai	0.337	0.667	0.333	0.750	0.296	0.000	0.250	0.000	0.238
	Hlagalakwena	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.043	0.040
	Martinique	0.398	0.476	0.307	0.000	0.444	0.083	0.000	0.955	0.178
	Senoela	0.096	0.095	0.080	0.000	0.148	0.083	0.250	0.122	0.069
	Thabo Mbeki	0.446	0.429	0.400	0.000	0.296	0.083	0.500	0.458	0.267
	Witpoort	0.313	0.238	0.260	0.250	0.370	0.000	0.000	0.311	0.129

4.5.3 Normalized values for adaptive capacity indicators

Table 4.21 illustrates normalized values of adaptive capacity indicators also ranging between 0 and 1, with red shade indicating a high level of adaptive capacity, orange indicates a moderate level of adaptive capacity while the green indicates low adaptive capacity to flooding (Table 4.21). Therefore, the normalised value of an indicator is directly proportional to the level of adaptive capacity component. After normalising the adaptive capacity indicators, it was observed that majority of the villages in Ward 7 exhibited relatively low adaptive capacity indicator values whereas in Ward 9 the majority of the villages exhibited relatively higher adaptive indicator values. It can be observed that Tlapaliburethi village in Ward 9 had adaptive indicator values that were 1.0. On the other hand, Shongoane village in Ward 7 exhibited adaptive capacity indicators that were zero. This finding indicates that villages in Ward 7 have limited adaptive capacities to flood hazard events in relation to Ward 9.

Table 4.21: Normalized values for adaptive capacity indicators

Ward	Village name	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8
7	Shongoane	0.000	0.000	0.000	0.862	0.000	0.000	0.765	0.586
	Mmatladi	0.477	0.490	0.429	0.966	0.760	0.500	0.118	0.345
	Ga-Monyeki	0.727	0.531	0.694	1.000	0.880	0.667	0.353	0.483
9	Ditloung	0.955	0.816	0.939	0.655	1.000	1.000	0.059	1.000
	Enterprise	0.795	0.673	0.776	0.793	0.640	0.813	0.235	0.655
	Tlapaliburethi	1.000	0.816	1.000	0.931	0.960	1.000	0.059	0.931
	Mongalo	0.864	0.673	0.837	0.862	0.760	0.875	0.000	0.793
	Maletswai	0.773	0.551	0.673	0.690	0.560	0.729	0.353	0.414
	Hlagalakwena	0.932	0.796	0.959	0.828	0.880	1.000	0.176	0.759
	Martinique	0.545	0.449	0.592	0.931	0.600	0.667	0.059	0.207
	Senoela	0.909	0.735	0.959	0.828	0.840	0.979	0.176	0.828
	Thabo Mbeki	0.500	0.265	0.653	0.000	0.200	0.542	1.000	0.000
	Witpoort	0.568	0.531	0.776	0.759	0.360	0.667	0.059	0.448

4.6 Indicator weights

4.6.1 Exposure indicator weightings

Flood vulnerability assessment involves indicators of varying importance and should therefore be assigned weights. The exposure component in the study comprised of 7 indicators which were compared in pairs to develop a matrix (Table 4.22). Table 4.23 shows the normalised matrix and the calculated weight score of the exposure indicators. The priority vector was subsequently used to weight indicators as illustrated on Table 4.23. The exposure's consistency ratio computed based on the pair-wise comparisons was CR= 0.021. Considering that the CR value was less than 0.10, the exposure weights were accepted.

It can be observed that annual average rainfall (E1) had a relatively high value of 0.314, followed by the slope (E6) with a priority vector of 0.205, elevation (E3) with a priority vector of 0.198, proximity to rivers (E5) with a priority vector of 0.120, landuse/landcover (E4) with a priority vector of 0.081, soil clay content (E7) with a priority vector of 0.053 and lastly building materials (E2) with a priority vector of 0.030 (Table 4.23 and Figure 4.10). In that regard, average annual rainfall has a higher degree of importance in relation to the others whilst building materials had the least degree of importance. For this study, rainfall was considered the most important indicator as it determines the amount of water running in the rivers, low altitude and slopes.

Elevations and slope were ranked second and third respectively, with the degree of importance that are more or less the same. In this study, elevation and slope are important but not as important as rainfall. It is the frequency, magnitude and duration of rainfall that determines on whether water will overflow the river banks, settle in areas that have a low altitude and slope or not. Proximity to rivers were placed at fifth rank. This is also important although its less important in relation to rainfall, slope and altitude because water in the rivers is influenced by the amount of rainfall whereas how the velocity of a river is determined by the slope . Landcover was placed at fourth rank mainly because it indirectly influences interception, infiltration and runoff in flat slopes, low elevation areas and impermeable soils. Finally building materials of a house are influenced by location characteristics (i.e. slope, altitude, proximity to rivers, soil clay content) that is why it has a low degree of importance.

Table 4.22: Square pairwise comparison matrix for exposure indicators

	E1	E2	E3	E4	E5	E6	E7
E1	1	7	2	4	3	2	5
E2	1/7	1	1/6	¼	¼	1/6	1/3
E3	½	6	1	3	2	1	4
E4	¼	4	1/3	1	½	1/3	2
E5	1/3	4	1/2	2	1	½	3
E6	½	6	1	3	2	1	5
E7	1/5	3	1/4	½	1/3	1/5	1

Table 4.23: Normalized matrix and the calculated weight score of the exposure indicators.

	E1	E2	E3	E4	E5	E6	E7	Priority vector	Weight (%)
E1	0.342	0.226	0.381	0.291	0.330	0.385	0.246	0.314	31.430
E2	0.049	0.032	0.032	0.018	0.028	0.032	0.016	0.030	2.960
E3	0.171	0.194	0.191	0.218	0.220	0.192	0.197	0.198	19.750
E4	0.085	0.129	0.064	0.073	0.055	0.064	0.098	0.081	8.120
E5	0.114	0.129	0.095	0.146	0.110	0.096	0.148	0.120	11.960
E6	0.171	0.194	0.191	0.218	0.220	0.192	0.246	0.205	20.450
E7	0.068	0.097	0.048	0.036	0.037	0.039	0.049	0.053	5.330
Total	1	1	1	1	1	1	1	1	100
CR= 0.022									

Note the column average must sum up to 1 approximately.

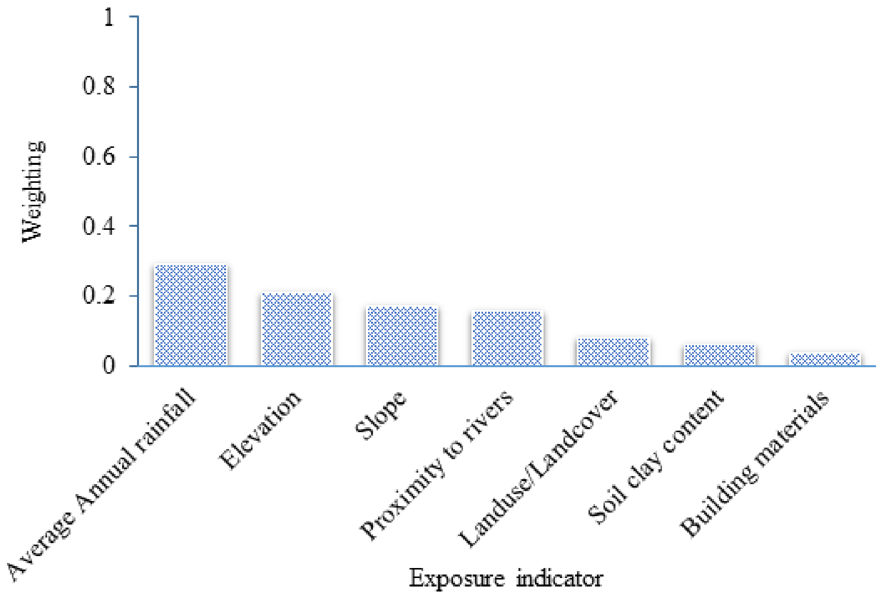

Figure 4.10: Ranking (ranging from highest to lowest) of the exposure indicators in terms of the assigned weights.

4.6.2 Sensitivity indicators weightings

The sensitivity component had 9 indicators which were compared in pairs as illustrated on Table 4.24. An AHP (Analytical Hierarchy Process) computation of results (Table 4.25) showed that the education status (S2) was the largest contributing factor for floods sensitivity with a priority vector of 0.28 followed by unemployed (S9) with a priority vector of 0.23 and Lived Poverty Index (S6) with a priority vector of 0.15 (Table 2.25 and Figure 4.11). Female headed households (S1) had the least sensitivity indicator score with a priority vector of 0.04 (Table 2.25 and Figure 4.11). The sensitivity component consistency ratio computed based on the pair-wise comparisons was CR= 0.047. Considering that the CR value was less than 0.10, the sensitivity weights were accepted. Results of this assessment imply that education status of individuals in a household is the most important factor, as it influences greater lifetime earnings as well as an informed decision-making process with regards to the mitigating the impacts of extreme natural hazards such as floods. Female headed households had lower sensitivity indicator scores meaning that they are least important in contributing towards floods sensitivity.

Table 4.24: Square pairwise comparison matrix for sensitivity indicators.

	S1	S2	S3	S4	S5	S6	S7	S8	S8
S1	1	1/6	½	½	2	¼	1/2	1/3	¼
S2	6	1	4	5	6	2	5	4	2
S3	2	¼	1	½	3	1/3	3	½	¼
S4	2	1/5	2	1	4	1/3	2	½	1/5
S5	½	1/6	1/3	¼	1	1/5	1/3	½	1/5
S6	4	½	3	3	5	1	3	2	½
S7	2	1/5	1/3	½	3	1/3	1	½	¼
S8	3	¼	2	2	2	½	2	1	1/5
S9	4	½	4	5	5	2	4	5	1

Table 4.25: Normalized Matrixes and the calculated weight score of the exposure indicators.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	Priority vector	Weight %
S1	0.041	0.052	0.029	0.028	0.065	0.036	0.024	0.023	0.052	0.04	3.88
S2	0.245	0.309	0.233	0.282	0.194	0.288	0.240	0.279	0.412	0.28	27.57
S3	0.082	0.077	0.058	0.028	0.097	0.048	0.144	0.035	0.052	0.07	6.89
S4	0.082	0.062	0.116	0.056	0.129	0.048	0.096	0.035	0.041	0.07	7.39
S5	0.020	0.052	0.019	0.014	0.032	0.029	0.016	0.035	0.041	0.03	2.87
S6	0.163	0.155	0.175	0.167	0.161	0.144	0.144	0.140	0.103	0.15	15.04
S7	0.082	0.062	0.019	0.028	0.097	0.048	0.048	0.035	0.052	0.05	5.22
S8	0.122	0.077	0.117	0.113	0.065	0.072	0.096	0.070	0.041	0.09	8.58
S9	0.163	0.155	0.233	0.282	0.161	0.288	0.192	0.349	0.206	0.23	22.54
Total	1	1	1	1	1	1	1	1	1	1	100
CR= 0.047											

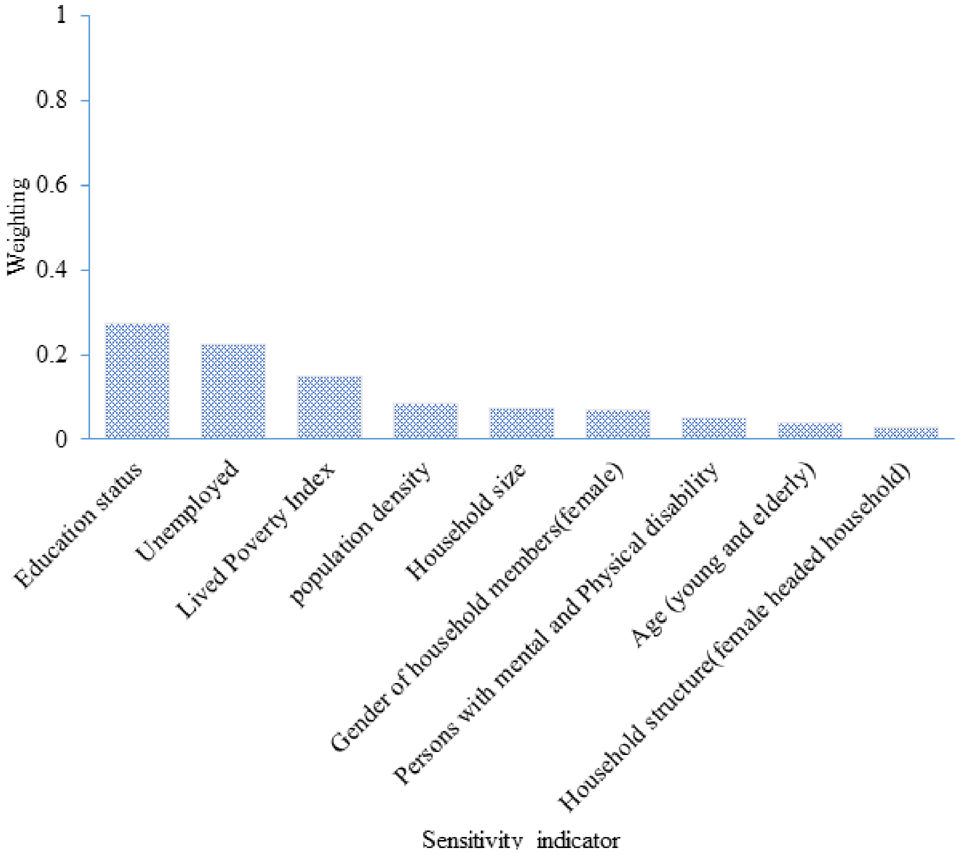

Figure 4.11: Ranking (ranging from highest to lowest) of the sensitivity indicators in terms of the assigned weights

4.6.3 Adaptive capacity indicator weightings

Seven indicators representing adaptive capacity were used in this study. Indicators were paired, compared (Table 4.26) and "priority weights" were produced (Table 4.27). The normalized indicator weights were calculated as 0.21, 0.20, 0.19, 0.11, 0.10, 0.09, 0.05, and 0.04 for awareness of risk associated with floods, early warning systems, flood preparedness, evacuation capability, access to weather forecast, rainfall alerts, past flood experience and duration of stay, respectively (Figure 4.12). Awareness of risk associated with floods has a higher degree of importance in relation to the others whilst duration of stay has the least degree of importance. Results of this assessment indicate that awareness of risks associated with floods has a relative high importance whilst duration of stay has less influence on level of vulnerability. Based on the pairwise comparison and weights calculated, a consistency ratio (CR) of 0.013 was derived. The CR of adaptive capacity was below the threshold value of 0.10 (Table 4.27). This indicated a reasonable level of consistency in the pairwise comparison of the factors, hence, weights were accepted.

Table 4.26: Square pairwise comparison matrix for adaptive capacity indicators

	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8
AC1	1	½	2	½	1	½	3	1
AC2	2	1	5	1	2	1	5	3
AC3	½	1/5	1	1/6	1/3	1/5	½	1/3
AC4	2	1	6	1	2	1	4	2
AC5	1	½	3	½	1	½	2	2
AC6	2	1	5	1	2	1	3	2
AC7	1/3	1/5	2	¼	½	1/3	1	½
AC8	1	1/3	3	½	½	½	2	1

Table 4.27: Normalized matrices and the calculated weight score of the adaptive capacity indicators.

	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8	Priority vector	Weight (%)
A1	0.102	0.106	0.074	0.102	0.107	0.099	0.146	0.085	0.100	10.000
A2	0.203	0.211	0.185	0.203	0.214	0.199	0.244	0.254	0.210	21.000
A3	0.051	0.042	0.037	0.034	0.036	0.040	0.024	0.028	0.040	4.000
A4	0.203	0.211	0.222	0.203	0.214	0.199	0.195	0.169	0.200	20.000
A5	0.102	0.106	0.111	0.102	0.107	0.099	0.098	0.169	0.110	11.000
A6	0.203	0.211	0.185	0.203	0.214	0.199	0.146	0.169	0.190	19.000
A7	0.034	0.042	0.074	0.051	0.054	0.066	0.049	0.042	0.050	5.000
A8	0.102	0.070	0.111	0.102	0.054	0.099	0.098	0.085	0.090	9.000
Total	1	1	1	1	1	1	1	1	1	100
CR= 0.013										

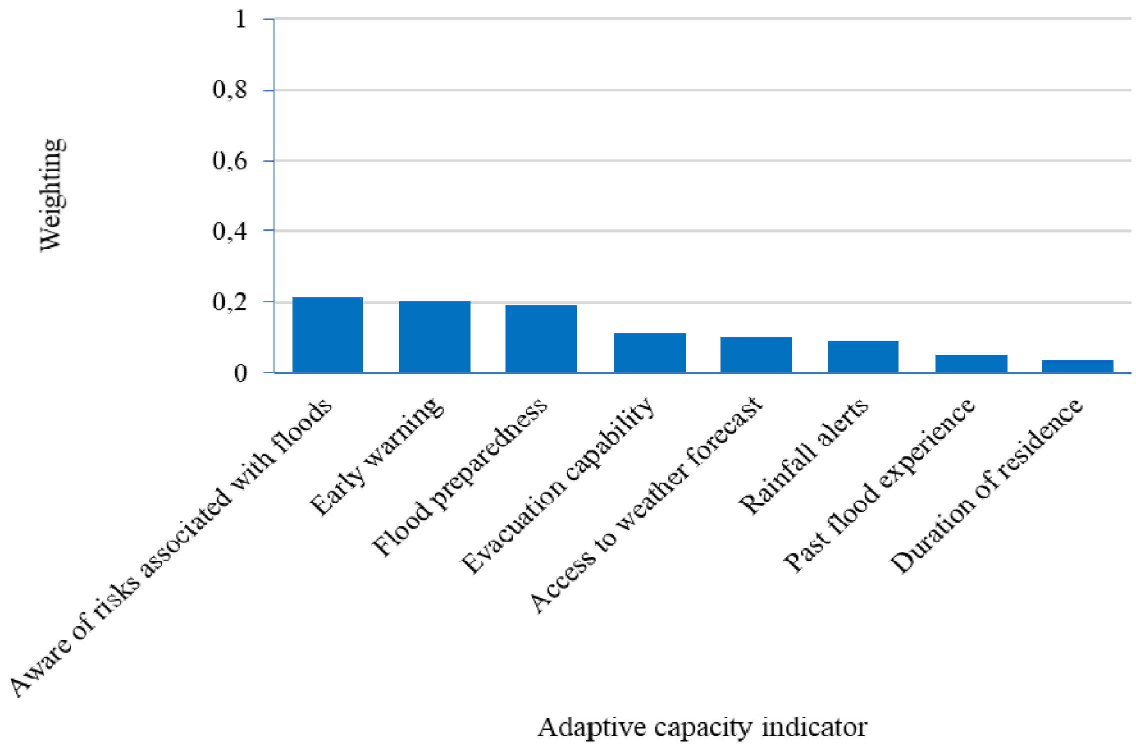

Figure 4.12: Ranking (ranging from highest to lowest) of the adaptive capacity indicators in terms of the assigned weights

4.7 Aggregation of Indicators

4.7.1 Exposure index

Figure 4.13 shows the aggregated exposure indicators that were spatially represented to show degrees of exposure in the study sites. In Ward 7, high levels of exposure were observed in the north-eastern part of the ward. Villages such as Shongoane and Ga-Monyeki exhibited a high level of exposure to flood events. The higher exposure in these villages could be attributed to the frequent occurrence of floods in these regions due to high frequency of precipitation associated with the Limpopo river basin. Villages like Thabo Mbeki have been reported to have incurred momentous losses over the last decades due to frequent flooding occurrences. These vulnerable regions are clearly highlighted in the exposure map (Figure 4.13). Thabo Mbeki and Maletswai have higher probabilities of areas that can be inundated as a result of floods. The analysis does not show much difference in the exposure index of the villages in Ward 7 and 9, possibly because of their similar physical settings.

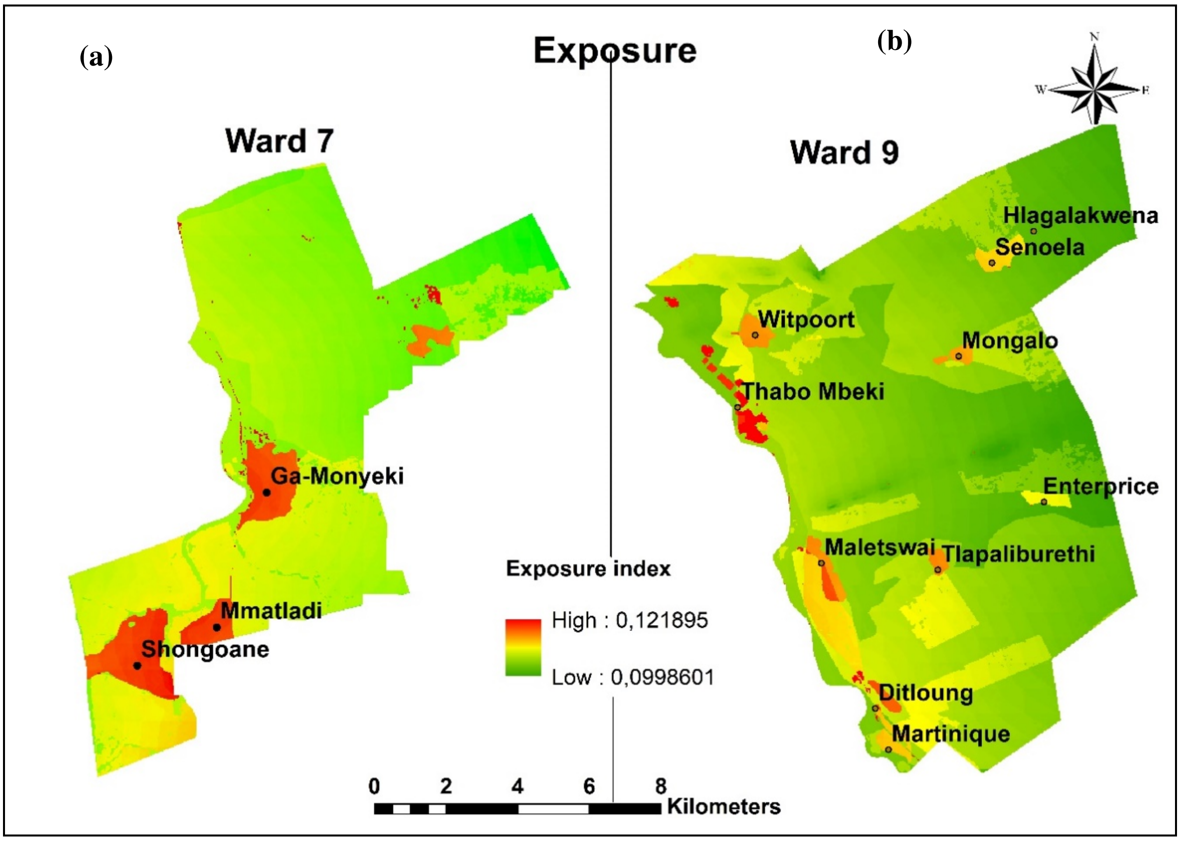

Figure 4.13: Composite Exposure Index

4.7.2 Sensitivity index

Table 4.28 column 4 shows the sensitivity of the villages in Ward 7 and 9 to floods. The colour shadings of the villages in each ward indicate their levels of exposure to flood. The red shading indicates a high level of exposure, orange indicates a moderate level of exposure while the green one indicates a low level of sensitivity to flooding (Table 4.28). Table 4.28 shows that in Ward 7, the most sensitive area is Shongoane which has a score of 0.757 (highest score), followed by Ga-Monyeki (0.536) and finally Mmatladi with a low score of 0.057. In Ward 9, the, most vulnerable villages are Maletswai, Mongalo, Thabo Mbeki, Martinique, Enterprise, Ditloung, Tlapaliburethi, Witpoort, Senoela and finally Hlagalakwena (0.572) (Table 4.28). The high sensitivity to flooding in Ward 7 is not only explained by pupation density but also high number of females young and elderly and low number of educated people. High level of sensitivity of settlement to floods increases the level of flood risk of the people.

Table 4.28: Indices of each component of vulnerability to flooding

Ward	Name of the village	Exposure	Sensitivity	Adaptive Capacity
7	Shongoane	0.108	0.757	0.033
	Mmatladi	0.108	0.057	0.073
	Ga-Monyeki	0.108	0.536	0.088
9	Ditloung	0.111	0.188	0.104
	Enterprise	0.109	0.230	0.089
	Tlapaliburethi	0.112	0.168	0.112
	Mongalo	0.112	0.284	0.095
	Maletswai	0.113	0.352	0.077
	Hlagalakwena	0.113	0.010	0.104
	Martinique	0.110	0.247	0.072
	Senoela	0.110	0.083	0.102
	Thabo Mbeki	0.113	0.278	0.039
	Witpoort	0.112	0.159	0.071

4.7.3 Adaptive capacity index

Based on the indicators that explain the ability to resist, adapt and cope with floods disasters, Table 4.28 column 5 depicts the adaptive capacity across the villages in Ward 7 and 9. The red shading indicates a high level of adaptive capacity, orange indicates a moderate level of capacity while the green ones indicate a low level of adaptive capacity to flooding. The overall performance of adaptive capacity was moderate to low. It can be observed from Table 4.28 that Shongoane in Ward 7 and Thabo Mbeki in Ward 9 have a relatively low level of capacity to face flood disaster, while Tlapaliburethi had relatively moderate level of capacity to anticipate, cope and recover from flood disaster. The low to moderate index of adaptive capacity in this study is associated with insufficient strategies and capacity to mitigate flood risk. For instance, the people interviewed pointed out the lack of community based early warning systems and lack of evacuation capabilities as contributing factors to low adaptive measures. A lower level of adaptive capacity measures of households to flooding increases the level of sensitivity and physical exposure of households to floods.

4.7.4 Integrating the Exposure, sensitivity and adaptive capacity indices

It can be observed from Table 4.28 and Figure 4.14 that Ward 7 and 9 villages have generally low values of the exposure index ranging between 0.108 to 0.113. Ward 7 villages exhibited very high sensitivity index values in this study ranging between 0.536 to 0.757 for Ga-Monyeki and Shongoane, respectively. Meanwhile, Ward 9 villages showed relatively low sensitivity index values ranging between 0.010 in Hlagalakwena to 0.352 in Maletswai. With regards to adaptive capacity index values, both wards had relative low values (Table 4.28 and Figure 4.14). The results of the study showed that the areas most vulnerable to floods do not always overlap with those experiencing high exposure.

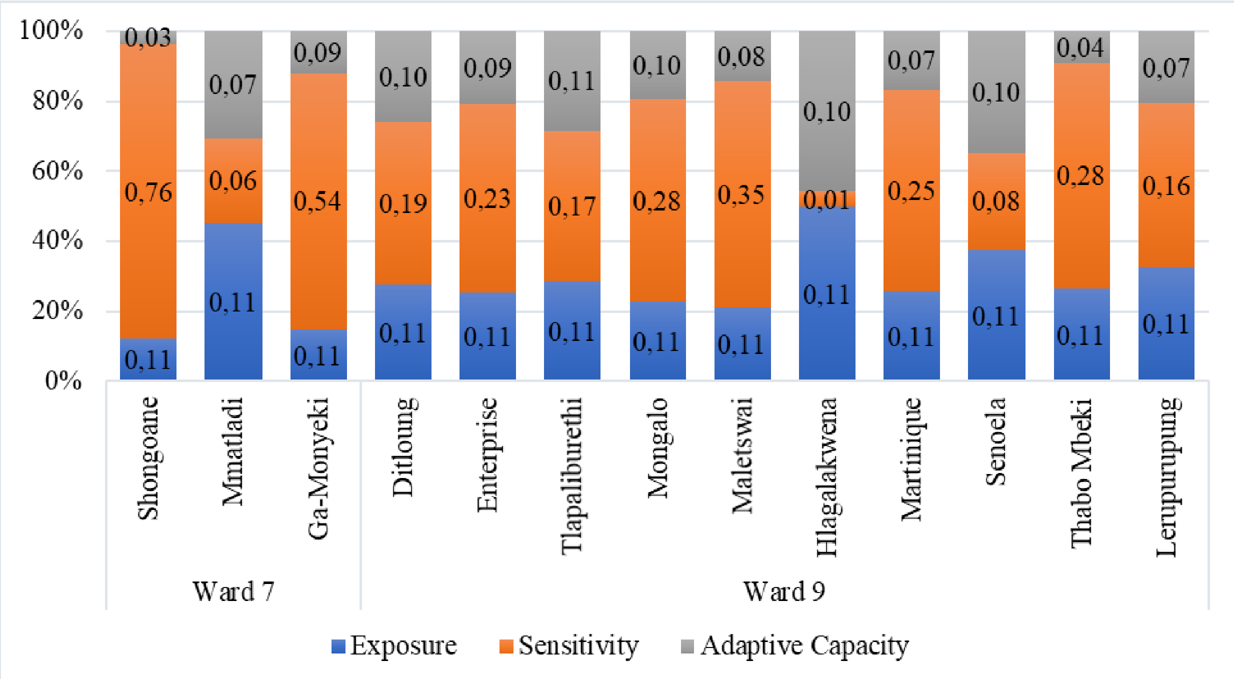

Figure 4.14: Contribution of Exposure, Sensitivity and Adaptive Capacity towards floods vulnerability

4.8 Flood vulnerability index

The presented flood vulnerability indices summarize complex information about flood vulnerability in a simple way that is easy for both experts and non-experts to understand and use in flood risk management and planning. Table 4.28 was used in developing the index for measuring the adaptive capacity at the village level. Exposure and sensitivity increase vulnerability, while adaptive capacity reduces vulnerability to floods. Figure 4.15 shows flood vulnerability index of Ward 7 and 9. It can be seen from the figure and from Table 4.29 that Ward 7 villages are more vulnerable to floods than those in Ward 9. Shongoane and Ga-Monyeki villages had very high vulnerability index ranging between 0.28 and 0.19 respectively whilst Mmatladi had a very low flood vulnerability index of 0.03. In Ward 9, Maletswai had the highest flood vulnerability index of 0.13 followed by Thabo Mbeki with index value of 0.12 and Mongalo with an index value of 0.10. In all the surveyed wards, Hlagalakwena village had the least flood vulnerability index value of 0.01. The higher vulnerability of Ward 7 could be attributed to high sensitivity and limited adaptive capacity measures.

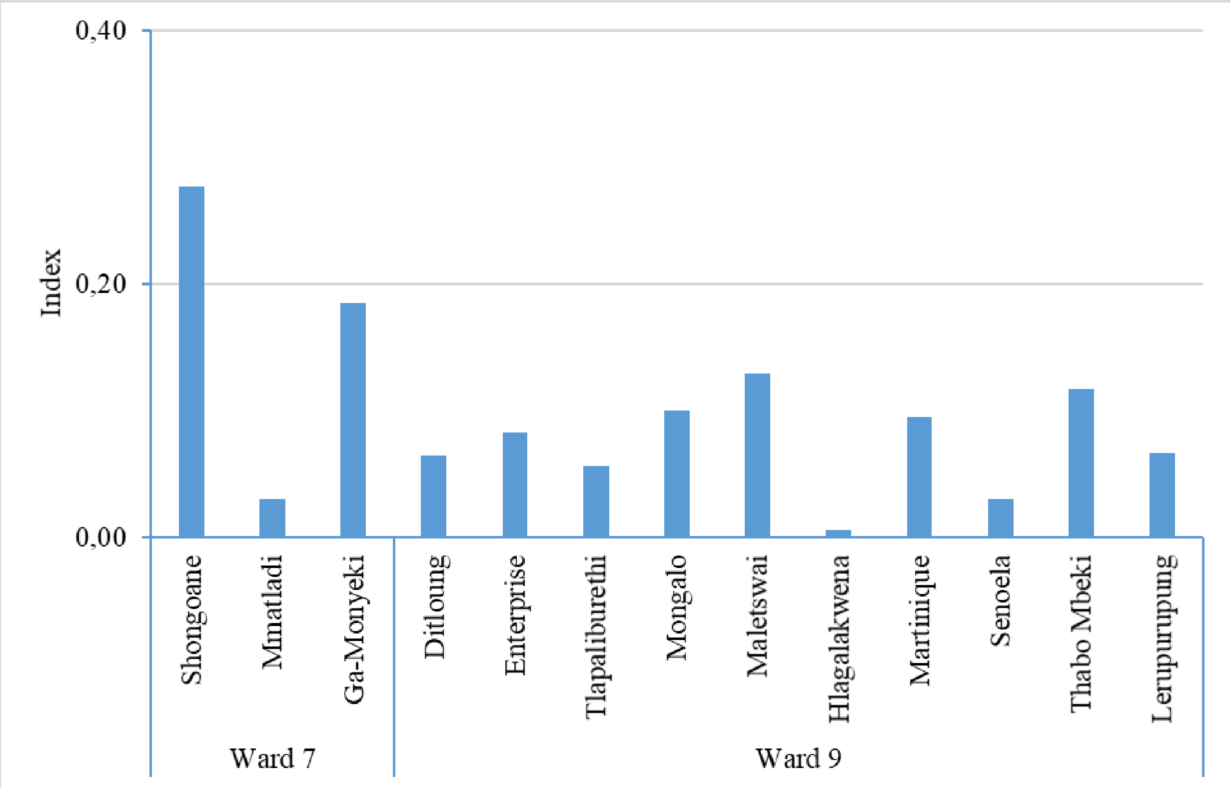

Figure 4.15: Composite Flood Vulnerability Index

Table 4.29: Flood vulnerability index score

Categories	Level of vulnerability	Villages	
		Ward 7	Ward 9
0.24- 0.28	Very high	Shongoane	None
0.19 – 0.23	High	Ga Monyeki	None
0.14 – 0.18	Moderate	None	None
0.09 – 0.13	Low	None	Martinique, Maletswai, Enterprise, Thabo Mbeki, Mongalo
0.03 – 0.08	Very low	Mmatladi	Ditloung, Tlapaliburethi, Senoela Hlagalakwena, Witpoort

4.9 Flood vulnerability map of study areas

The vulnerability map was produced as a means of visualizing the different levels of flood vulnerability within Ward 7 and 9 and to aid in the planning and preparing for flood disaster. Flood vulnerability mapping as conducted here, included both physical characteristics and socio-economic factors of the two study areas in the Lephalale Local Municipality. The various levels of flood vulnerability in Ward 7 and 9 are presented (see Figure 4.16). The vulnerability map shows 5 classes of vulnerability and uses different colours to show spatial variations in vulnerability. The derived vulnerability map (Figure 4.16) indicate that Ward 7 is more vulnerable to floods than Ward 9.

In Ward 7, about 9.38 km^2 (69.27%) of the total land covered by settlement is characterised by very high level of flood vulnerability and approximately 2.27 km^2 (16.78%) has a high floods vulnerability while the remaining 1.89 km^2 (13.95%) is characterised by low level of floods. Shongoane village was located in the category of high vulnerability whilst Ga Monyeki was found to have high vulnerability level. Mmatladi was located in the area categorised as having a very low level of flooding vulnerability. Ward 7's high vulnerability level is due to high sensitivity (relative to Ward 9) values and as well as limited adaptive capacity.

In Ward 9, approximately 4.44 km^2 (60.02%) and about 2.96 km^2 (39.98 %) of the total area covered by settlement, were categorised as an area with low and very low level of floods respectively. This implies that the entire settlements in Ward 9 exhibited a low-level of flood vulnerability. Villages categorised as having low level of vulnerability were Ditloung, Tlapaliburethi, Senoela Hlagalakwena and Witpoort. Meanwhile, Martinique, Maletswai, Enterprise, Thabo Mbeki, and Mongalo were classified as having very low levels of vulnerability. Though in Ward 9 households appeared to have a slight high level of exposure to flood disaster when compared to ward 7, the source of its low flood risk is due to pre-existing factors of sensitivity and adaptive capacity.

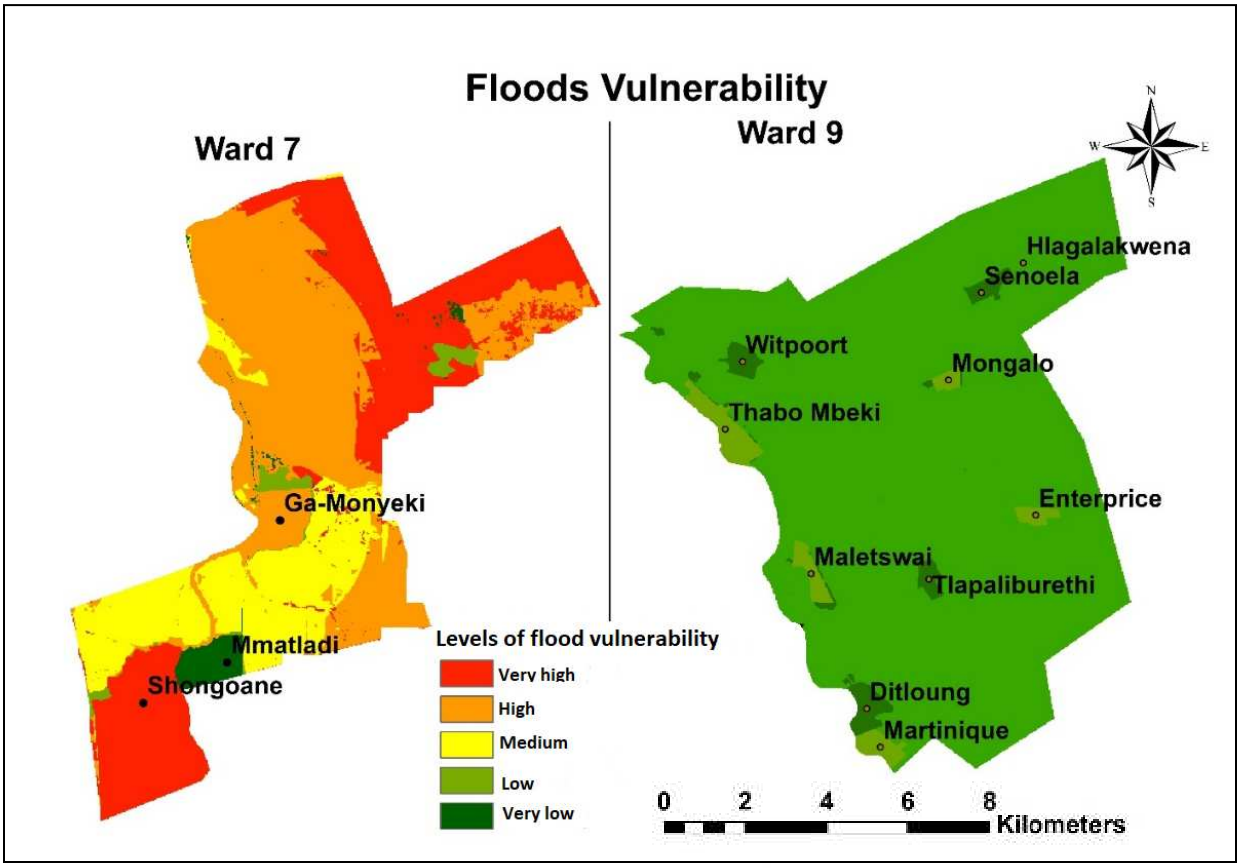

Figure 4.16: Flood vulnerability in Ward 7 and 9

4.10 Conclusion

This study presented and discussed a comprehensive flood vulnerability assessment of settlements in Wards 7 and 9 of Lephalale Local Municipality. The chapter identified and assessed physical and socio-economic characteristics of the study are in the form of exposure, sensitivity and adaptive capacity, with an attempt to integrate the results of the analysis into the broader vulnerability context. While exposure and sensitivity increase the level of vulnerability, adaptive capacity tends to decrease it. On the basis of these findings, it is therefore concluded that Ward 7 has a higher level of vulnerability while Ward 9 has a relatively low level of vulnerability. Though flood vulnerability for all villages in Ward 9 is relatively low, there were moderate levels of exposure and sensitivity. Consequently, decreasing exposure and sensitivity and increasing capacity of the villages will assist in effective flood disaster management and planning in the study area. The next chapter provides a summary of the major findings, gives recommendations and suggests areas for further research.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The study assessed vulnerability of settlements to flooding in Wards 7 and 9 of Lephalale Local Municipality. The objectives of the study were: a) to determine and profile the drivers of settlements' vulnerability to floods, b) to develop a flood vulnerability index of the settlement, and, c) to map settlements that are vulnerable to floods in Ward 7 and 9. Having discussed the study findings in the previous chapter, this chapter presents a summary of the research's substantive findings, and also provides a conclusion, recommendations and areas for further studies.

5.2 Summary of major findings

There is much literature available discussing vulnerability of settlements to floods. This literature is disproportionately tilted in favour of physical vulnerability and/or mapping and impacts of floods. However, flood vulnerability is not only naturally constructed, but is also a socially-oriented phenomenon. Both natural and socio-economic factors, therefore, play a significant role in the assessment of flood vulnerability. In South Africa, little is known, at the municipal level, regarding the vulnerability of settlements to floods. Furthermore, there are no frameworks for gaining insights on how vulnerable these sub-national areas are, owing to the lack of flood vulnerability maps that show spatially explicit levels of vulnerability. Given that flooding events are predicted to increase in the country in future, the findings of this study will make a modest contribution towards understanding vulnerability of human settlement to flooding events much better as well as increasing the capacity of the municipal area to react quicker and better.

Findings from household characteristics indicated that nucleated and the extended household structures were dominating with household size ranging from a minimum of 1 member to a maximum of 16 members. Both wards had more male than female with the largest proportion of households headed by men. The population of the study area were generally young and in good health. Educational and employment levels in both wards were generally low. The Lived Poverty index indicated that Ward 9 was better off than Ward 7. Although most respondents that resided in the study area for more than a decade reported that they never experienced floods before, over quarter of the households in the study sites reported that they were always alert to possible flooding. The proportion of alert households was however higher in Ward 9 than in Ward 7. Despite the higher levels of flood risk awareness among residents, study findings reveal that, floods awareness preparedness and evacuation capabilities may not be that closely related. Results for the assessment of the early warning system showed that over two-thirds of the study respondents were not aware of any existing early warning system in their communities. Contrary to the high percentage of the households that were not aware of community early warning systems, the majority of the respondents (81.1%) reported that they had access to weather information in the study area.

Overall, twenty-four sets of physical, social and economic indicators of vulnerability were gathered using questionnaires in the study area. In addition, secondary data was accessed and used in combination with the primary data for use in the study. Physical, demographic and socio-economic characteristics of the settlements that influenced exposure, sensitivity and adaptive capacity were profiled. These indicators were then normalized using the UNDP's Human Development Index (HDI)'s method and fuzzification. Saaty's (1980) analytical hierarchy process (AHP) method was applied to estimate the weights of the indicators. Subsequently, all indicators were aggregated together using linear summation to compute flood vulnerability index (FVI) and finally mapped in a Geographical Information Systems(GIS) environment.

The findings of this study indicate that Ward 7 is more vulnerable to flood hazards while Ward 9 is less vulnerable. Although exposure indices for the two wards had differences of less than 0.01, the overall findings related to the exposure component indicate that Ward 9 was most exposed to flood impacts compared to Ward 7. In relation to sensitivity, Ward 7 was more sensitive to flooding events than Ward 9. High level of sensitivity of settlement to floods increases the level of flood risk of the people. With reference to the adaptive capacity component, the results indicate that Ward 7 had limited adaptive capacities to flood hazards than Ward 9. The derived FVI results show that in Ward 7, Shongoane was the most vulnerable village followed by Ga-Monyeki.

Mmatladi village was the least vulnerable. In Ward 9, the FVI results show that all villages had low vulnerability to flooding hazards. Although Maletswai and Thabo Mbeki villages had the highest vulnerability in Ward 9, their vulnerability was lower in comparison to Ward 7 villages.

The flood vulnerability map indicates that Shongoane and Ga-Monyeki, in Ward 7 were located in the areas of very high and high vulnerability, occupying an area of 9,38km^2 (69.27%) and 2.27 km^2 (16.78%), respectively. Meanwhile, all settlements in Ward 9 were located in low-level category of flood vulnerability. The area of Ward 9 categorised as having low vulnerability covered 4.44 km^2 (60.02%) while 2.96 km^2 (39.98 %) was classified as having very low vulnerability to flooding.

The findings of this study suggest that low educational level, low employment, lack of access to necessities, lack of coping mechanisms and high population density were the most influential sensitivity indicators of flood hazard vulnerability in the study sites. Meanwhile, low adaptive capacity indicators that were more influential in these study sites were lack of alerts for possible flooding especially in the event of heavy rains occurring for several hours, less ability to handle floods, lack of community early warning systems, less evacuation capability and lack of access to weather forecasts. Poor building materials, low slope and altitude, closeness of households and settlements to the river confluences, high annual rainfall, and moderate to high soil clay content were the most influential exposure indicators.

5.3 Conclusion

Frequent flood occurrences are already a reality in South Africa. Various human settlements around the country are vulnerable to such catastrophic events. Studying vulnerability of human settlements to flooding should therefore be a priority in the country. This will enable the government, municipalities and other policy-makers to predict which human settlements are vulnerability and which ones are not, as well as to prepare for evacuation or measures to lessen the impacts. As has been shown by the study results, a major source of flood vulnerability in Ward 7 and 9 derived from a combination of extreme high rainfall amounts as well as the interaction of existing socio-economic and physical factors in the study areas. Flood vulnerability index and mapping therefore provides an optimal way of integrating GIS data and socio-economic data in assessing the vulnerability of an area to flood hazards. Furthermore, while the flood risk index gives a quantitative measure of vulnerability, mapping provides a spatial variation of levels of flood vulnerability in an area which is useful for spatial planning and disaster management. Although the computation of flood vulnerability is complex and dynamic due to its integration of exposure, sensitivity and adaptive indices as well as the incorporation of physical and socio-economic data, it is nevertheless a worthy process. This is because it enables responsible authorities to plan for high vulnerability of settlements as well as devise strategies aimed at decreasing vulnerability and increasing resilience of human settlements.

5.4 Recommendations

Based on the key findings of the study, it is recommended that various structural and non-structural measures be implemented in order to reduce flood vulnerability and minimize adverse effects of floods in the study area. The recommended measures will help the community leaders, municipal managers, disaster management sections, households and other stakeholders to reduce and mitigate vulnerability and effects of floods.

5.4.1 Public awareness and education

This study showed that most of the surveyed households were not aware of risks associated with flooding. It is recommended that awareness and disaster management campaigns be initiated in the study area to raise awareness and educate household members. Such awareness campaigns should involve the collaboration of all stakeholders who include households, municipal leaders and traditional leaders. This collaboration will not only equip interested and affected parties with relevant flood disaster, risk and vulnerability information, but will also increase the sharing of responsibilities while improving information flow. Increased understanding of flood vulnerability and risks will increase preparedness and thus reduce damage.

5.4.2 Improvement on the socio-economy

The socio-economic characteristics of households play a key role in reducing flood vulnerability. Households that were more at risk in the study areas were those with high unemployment, low education levels, and disability. Government and the local municipality should, thus, prioritize increasing employment opportunities and offering better opportunities and facilities for improved education in the area. This increase resilience in all members of these communities. Community leaders and municipalities should develop programmes to insure resilience in these communities by the incorporation of flood management in Integrated Development Planning.

5.4.3. Flood early warning system

The findings of this study indicated that there were little or no early warning systems in some of the studied communities. Thus, there should be initiatives to launch a robust early warning system in the area. In addition, better risk prediction and flood forecasting should be introduced at the municipal level. This will improve the preparation of both the municipality and households against floods. An improved early warning system will also improve disaster management by detecting hazardous flood events in advance and communities can prepare in advance.

5.4.4 Relocation

It was found in this study that some households were located in close proximity to rivers, and experienced previous floods incidences. These households were the most vulnerable to flooding hazards in the study area. Municipal and community leaders should therefore relocate these households from these areas to safer RDP-built areas. Priority for relocation in studied areas should be given to Shongoane and Ga Monyeki village in Ward 7 and Thabo Mbeki in Ward 9 which are the most exposed villages.

5.4.5 Adequate and operational regulation/policies

It is recommended that adequate and effective regulation or policies be enacted and enforced to manage and mitigate against activities that increase flooding such as deforestation. In addition, measures should be taken to engage in programmes such as afforestation in areas prone to floods. The government should set and enforce river buffer zones for settlement development in the municipality.

5.4.6 Approaches towards reducing vulnerability

When a natural disaster such as floods occurs, government and non-governmental organisation focus primarily on responding with immediate effort. They also tend to pay much attention on preparing for disasters than actively seeking to minimize risks of further flood disasters. However, as study findings show, a longer term and more sustainable approach is required to build up the resilience of people and the environment to cope with as well as to manage the risks of future flood hazards., It is therefore not only necessary but crucial to develop a good understanding of vulnerability, the underlying causes of vulnerability and the interactions among components of vulnerability.

5.5 Further Research

This study has triggered a number of issues concerning the vulnerability of human settlement to floods that need further attention and analysis. First, flood vulnerability changes over time. There is thus need for continuous flood vulnerability assessment to manage flood risks. Secondly, the results depend on the selected indicators, their classification as well as level of application. Therefore, the selected indicators only simplify key elements of flood vulnerabilities that the scope of this study considered. Future studies can extend or modify the vulnerability indicators based on the characteristics of measurements as well as their scale of measurements. This study thus makes a modest contribution to the discourse on flood vulnerability in South Africa.

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Appendices

Appendix A: Standard questionnaire

QUESTIONNAIRE NUMBER

FOR OFFICE USE

Vulnerability assessment of human settlements to floods survey

IDENTIFICATION OF HOUSEHOLD

COUNTRY (1) South Africa

LOCAL MUNICIPALITY ________________________________

WARD NUMBER ________________________________

NAME OF VILLAGE ________________________________

INTERVIEW LOCATION ________________________________

GPS COORDINATES --

INERVIEW STATUS [1 = Completed; 2 = Refused; 3 = Not at home; 4 = Premises empty]

NUMBER OF CALLS [to household where interview actually took place]

TO BE COMPLETED BY INTERVIEWER	DATE OF INTERVIEW
TIME INTERVIEW: STARTED ____________ COMPLETED ____________	MONTH
NAME OF INTERVIEWER ________________________	
SIGNATURE ________________________	YEAR
COMMENTS:	

TO BE COMPLETED BY SUPERVISOR	HOUSEHOLD BACK-CHECKED? [Yes=1; No=2]
NAME OF SUPERVISOR ________________________	
SIGNATURE ________________________	QUESTIONNAIRE CHECKED? [Yes=1; No=2]
COMMENTS:	

INFORMED CONSENT

READ OUT ALOUD

I am a researcher for the University of Limpopo. We are talking to household's heads in this ward. Your household has been randomly selected and we would like to discuss these issues with yourself, or an adult member of your household. There are no right or wrong answers, but your opinions will help us understand vulnerability of human settlement to floods better. The interview will take about 30 minutes and your answers will be confidential.

Are you willing to participate? (TICK THE ANSWER GIVEN)

Yes…1 **No… 2**

IF NO: READ OUT: Thank you for your time. Goodbye.

IF YES: IF WILLING TO PARTICIPATE, READ OUT THE FOLLOWING:

Thank you for agreeing to participate in this study. Just to emphasize, any answers you provide will be kept absolutely confidential, and there is no way anyone will be able to identify you by what you have said in this interview. We are not recording either your address or your name, so you will remain anonymous. You have the right to terminate this interview at any time, and you have the right to refuse to answer any questions you might not want to respond to. Are there any questions you wish to ask before we begin?

Specify: ……..

Please tick appropriate box or fill in the appropriate responses in the spaces provided.

SECTION A: HOUSEHOLD COMPOSITION										
PNO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
a Relation to HHD										
b Sex										
c Age										
d Marital status										
e Highest level of education										
f1. Occupation										
(most important first accept up to two)										
f2. Income last month for main occupation										
g. Lives away from this household?										
h. Work status										
I. Where born?										
J1. Where living now?										
J2. When did you come to live here?										
J3. Why moved to present location?										
(Enter up to three reasons for moving)										
k. Health Status										
(Enter up to three health issues)										

Codes for Q1 (One code for each)

1a Relation to head
1 Head
2 Spouse/partner
3 Son/ daughter
4 Adopted/ foster child/ orphan
5 Father/ mother
6 Brother/sister
7 Grandchild
8 Grandparent
9 Son/ daughter-in-law
10 Other relative
11 Non-relative
97 Refused
98 Don't know
99 Missing

1b Sex
1 Male
2 Female
99 Missing

1c Age at last birthday
0 under 1 year
Whole numbers only
97 Refused
98 Don't know
99 Missing
(If respondent is older than 96, record 96)

1d Marital status
1 Unmarried
2 Married
3 Living together/ cohabiting
4 Divorced
5 Separated
6 Abandoned
7 Widowed
97 Refused
98 Don't know
99 Missing

1e Highest education
1 No formal schooling
2 Some Primary
3 Primary completed (Junior or Senior)
4 Some high school
5 High school completed
6 Post secondary qualifications not university (diploma, or degree from technikon or college)
6 Some university
7 University completed
8 Post-graduate
97 Refused
98 Don't know
99 Missing

1f Occupation
01 Farmer
02 Agricultural worker (paid)
03 Agricultural worker (unpaid)
04 Service worker
05 Domestic worker
06 Managerial office worker
07 Office worker
08 Foreman
09 Mine worker
10 Skilled manual worker
11 Unskilled manual worker
12 Informal sector producer
13 Trader/ hawker/ vendor
14 Security personnel
15 Police/ Military
16 Businessman/ woman (self-employed)
17 Employer/ Manager
18 Professional worker
19 Teacher
20 Health worker
21 Civil servant
22 Fisherman
23 Truck driver
24 Pensioner
25 Scholar/ Student
26 House work (unpaid)
27 Unemployed/ Job seeker
28 Other (specify)
97 Refused
98 Don't know
99 Missing

1g Lives/works away from this household but still a member of the household
1 No
2 Yes, migrant-working
3 Yes, migrant-looking for work
5 Yes, attending school
5 Other (specify)
99 Missing

1h Work status (wage employment)
1 Working full-time
2 Working part-time/ casual
3 Not working – looking
4 Not working – not looking
7 Refused
8 Don't know
9 Missing

1j Where born
1 Rural area
2 Urban area
3 Foreign country rural area
4 Foreign country urban area
7 Refused
8 Don't know
9 Missing

1k Where living now?
1 Same rural area
2 Different rural area
3 Same urban area
4 Different urban area
5 Foreign country rural area
6 Foreign country urban area
7 Urban area
8 Rural area
97 Refused
98 Don't know
99 Missing

1l Why to present location
1 Housing
2 Land for livestock/grazing
3 Land for crop production
4 Formal sector job
5 Informal sector job
6 Food/hunger
7 Military Service
8 Drought
9 Overall living conditions
10 Safety of myself/family
11 Availability of water
12 Political exile
13 Asylum
14 Education/schools
15 Crime
16 Attractions of the city: urban life/modern life
17 Illness related (HIV/AIDS)
18 Illness related (not HIV/AIDS)
19 Moved with family
20 Sent to live with family
21 Marriage
22 Divorce
23 Abandoned
24 Widowed
25 Freedom/democracy/peace
26 Retirement
27 Retrenchment
28 Eviction
29 Deaths
30 Floods
31 Religious reasons
32 Returned to former home
33 Other (specify)
96 Not moved
97 Refused
98 Don't know
99 Missing

1m Health Status
1 Accident
2 Diabetes
3 Asthma
4 Hypertension and stroke
5 Heart problems
6 Arthritis
7 Physical disability
8 HIV/ AIDS
9 Tuberculosis (TB)
10 Malaria
11 Chronic diarrhoea
12 Weight loss (severe)
13 Pneumonia
14 Cancer
15 Mental illness
16 Other (specify)
17 None of the above (good health)
99 Missing

1o Where was main meal eaten yesterday?
01 Home (this household)
02 Small shop
03 Informal market/street food
04 Shared meal with neighbours/or other households
05 Work place
06 School
07 Community food kitchen
08 Food provided by neighbours/ or other households
09 Did not eat a meal
10 Other (specify)
99 Missing

SECTION B: HOUSEHOLD DATA				
B1. Household structure				
a. Female Centered *(No husband/ male partner in household, may include relatives, children, friends)*	1		d. Extended (Husband/ male partner and wife/ female partner and children and relatives)	5
b. Male Centered (No wife/ female partner in household, may include relatives, children, friends)	2		e. Under 18-headed households female centered (head is 17 years old or less)	6
c. Nuclear (Husband/ male partner and wife/ female partner with or without children)	3		f. Under 18-headed households male centered (head is 17 years old or less) Telephone/cellphone	7
			g. Other (specify):	8
B2. How long have your family been settled in this area? …………………………„,…….. (Years)				
B3. Housing type				
a. House			h. Room in backyard	
b. Town house			i.Room in house	
c. Flat			j. Room in flat	
d. Traditional dwelling/ homestead			k. Squatter hut/ shack	
e. Traditional dwelling with built-on rooms			l. Mobile home (caravan/ tent)	
f. Hostel/ Compound			m. Other (specify):	
g. Hotel/ Boarding house				
B4. Main material used for the wall				
a. Mud	1		e. Corrugated iron	5
b. un baked bricks	2		f. Planks	6
c. baked bricks	3		g. Other(specify) ………………………… ……………..	7
d. grass	4			
B5. Household income from all sources (in the last one (1) month):				
(a) Read list aloud, circle the code that applies (column (b)) and complete the information for that row; leave rows blank for categories that do not apply. (c) Enter amount over the past one (1) month to nearest currency unit in column (c). For income in kind i.e. 'Remittances – goods/ food', 'Income from farm products' and in some cases perhaps also 'Gifts', estimate the monetary value over the past month and record this figure in				
Income categories(to nearest currency unit)			Amount	
Wage work	1			
Casual work	2			
Remittances – Money	3			

Remittances - Food	4			
Income from rural farm products	5			
Income from urban farm products	6			
Income from formal business	7			
Income from informal business	8			
Income from renting dwelling	9			
Income from aid 1) food 2) cash 3) vouchers	10			
Pension/disability/other social grants	11			
Gifts	12			
Other (specify)				
Refused to answer				
Don't know				

B6. Living Poverty Index

Over the past year, how often, if ever, have you or your family (household) gone without:
(Read each question aloud and circle the most appropriate response. Circle only ONE answer for EACH ROW).

Conditions	Never	Just once or twice	Several times	Many times	Always	Don't know
a. Enough food to eat?	1	2	3	4	5	6
b. Enough clean water for home use?	1	2	3	4	5	6
c. Medicine or medical treatment?	1	2	3	4	5	6
d. Electricity in your home?	1	2	3	4	5	6
e. Enough fuel to cook your food?	1	2	3	4	5	6
f. A cash income?	1	2	3	4	5	6

SECTION C: KNOWLEDGE ABOUT FLOODS

C1. Are you aware of the risk associated with floods?

a. Yes	1		b. No	2

C2. Are you always alert all the time for possible flooding especially if it rains hard for several hours?

a. Yes	1		b. No	2

SECTION D: PAST FLOOD EXPERIENCES

D1. Have your area ever experienced flood?

Yes	1		Don't know	3
No	2			
D2. Has your household ever destroyed by floods?				
Yes	1		No	2
D3. If you answered 'No' what do you attribute the fact that your household was not damaged by floods?				
D4. If 'Yes', describe what happened and when did that happen.				
D5. If yes describe the damage or destruction that was done.				
D6. How prepared are you for a flood?				
a. Not prepared at all	1		**c. Very well prepared**	3
b. Don't know	2			
D7. If prepared, how are you prepared?				
D8. How often is your place flooded from heavy rains?				
a. Every month	1		c. Every year	3
b. Every 4 months	2		d. Other(specify)	4
D9. Did you or your family members experience any of the following?				
a. Evacuation	1		d. Minor injury (did not seek medical attention)	4
b. Serious injury (required medical attention)	2		e. Property damage	5
c. Death	3		f. Loss of business or livelihood activity	6
g. Other(specify)				7
D10. Have you ever had to rebuild your home or any part of your home because of a disaster?				
a. Yes	1		b. No	
D11. If yes, how did you pay for this?				
a. Loan	1		d. Savings	4
b. Community assistance	2		e. Home insurance	5
c. Family income	3		f. Other(specify)	6

SECTION E: FLOODS PREPAREDNESS AND EARLY WARNINGS

E1. As compared to the past flood experience, is your family more or less able to handle flood disaster?

a. More able	1		c. Less able	3
b. No change	2		d. Don't know	4

E2. If able, what would you do differently?

E3. If less able, why not change your strategies?

a. Yes	1		c. Don't know	3
b. No	2			

E4 Do you have access to weather forecast information do you access?

E5. How and which weather forecast information do you access?

Information source			frequency					Relevance				
			Ever y day	Once-twice a week	Ever y week	Once or twice a month		Most	very	relevan t	little	not
a. Television	1		1	2	3	4		1	2	3	4	5
b. Radio	2		1	2	3	4		1	2	3	4	5
b. Newspaper	4		1	2	3	4		1	2	3	4	5
c. Internet	5		1	2	3	4		1	2	3	4	5
d. Local authorities	6		1	2	3	4		1	2	3	4	5
e. Neighbours	7		1	2	3	4		1	2	3	4	5
f. Phone relatives.	8		1	2	3	4		1	2	3	4	5
g. Others(specify) ……………………………… ………..	9		1	2	3	4		1	2	3	4	5

E6. Does your community have an early warning system?

a. Yes	1		c. Don't know	3
b. No	2			

If yes what type of early warning systems does your community have?

E7. Have you ever received early warnings about floods?				
a. Yes	1		b. No	2
E8. If yes, how did you receive the information?				
E9. If yes, what did you do with the information received? Did you benefit from this information?				
a. Yes	1		b. No	2

This is the end of the interview.

Can we return to your household for any follow up questions at a later date?

Yes	1		No	2

Before I go, do you have any questions or is there anything else that you think I should know?

Yes	1		No	2

If yes
specify………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
……………………………………………………………………

Thank you

Appendix B: Ethical Clearance certificate

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2212, Fax: (015) 268 2306, Email:noko.monene@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE CLEARANCE CERTIFICATE

MEETING: **31 August 2017**

PROJECT NUMBER: **TREC/250/2017: PG**

PROJECT:

Title:	Vulnerability assessment of settlements to floods: A case study of Lephalale Local Municipality, Limpopo Province, South Africa
Researcher:	MC Mothapo
Supervisor:	Dr G Tawodzera
Co-Supervisor:	Dr J Mambo
School:	Agriculture and Environmental Sciences
Degree:	Masters in Geography

PROF TAB MASHEGO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:
i) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.**
ii) **The budget for the research will be considered separately from the protocol.**
PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

Appendix C: Request letter to conduct a study in Ward 7 and 9

University of Limpopo
P. O. Box X1106
Sovenga
0727
8th July, 2015

Municipal Manager
Lephalale Local Municipality
Private Bag X136
Lephalale
0557
Dear sir/madam

Request for permission to conduct Research in Lephalale Local Municipality

My name is Clodean Mothapo. I am a registered Masters' student in the Department of Geography and Environmental Studies at the University of Limpopo, under the supervision of Dr. Godfrey Tawodzera. I am hereby seeking your consent to conduct a research, titled 'Vulnerability assessment of human settlements to flood; A case study of Lephalale Local Municipality. The study requires that I use 360 questionnaire to collect household data and have 2 focus group discussion to achieve the undermentioned sets of objectives. Copy of the research instruments I intend using in my research is attached.

The study sets the following objectives:

i. To determine the drivers of settlements' vulnerability to floods.
ii. To develop a flood vulnerability index of the settlements.
iii. To map the vulnerability of settlements to floods.
iv. Suggest measures for reducing future flood vulnerability in the study area.

This study seeks to contribute towards understanding and advancement of relevant knowledge of the vulnerability of human settlements to flooding. The study findings will also be used to support decision makers to effectively plan for vulnerable communities and address high levels of susceptibility.

Should you require any further information, please do not hesitate to contact me or my supervisor on the following contact details;

mothapoclodean@yahoo.com or cell: 0727599181
Godfrey.tawodzera@ul.ac.za or phone: 015268 2330
Upon completion of the study, I undertake to provide you with a bound copy of the dissertation

Your permission to conduct research in Lephalale local Municipality will be highly appreciated.

Sincerely, yours

Clodean Mothapo

Appendix D: Permission Letter

Munisipaliteit
Municipality
LEPHALALE

Tel: 014 763 2193
Faks/Fax: 014 763 5662
E-pos/E-mail: munic@lephalale.gov.za
Webblad/Website: www.lephalale.com

Privaatsak/Private Bag X136
LEPHALALE
0555

Ons Verw/Our Ref 10/3/1 U Verw/Your Ref

Navrae/Enquiries MG Makgamatha Aandag/Attention

Clodean Mothapo
University of Limpopo
PO Box 1106
SOVENGA
0727

08 OCT 20[illegible]

Sir/Madam

APPROVAL TO CONDUCT EDUCATIONAL RESEARCH.

The above matter bears reference:-

1. This letter confirms that your request to conduct research in Lephalale Local Municipality has been approved.
2. You are to provide copy of your completed research to the accounting officer.
3. Your point of contact during your research period will be Makgamatha MG and can be contacted on 014 762 1414.

Yours faithfully

EM TUKAKGOMO
Municipal Manager

Op skriftelike versoek binne sewe (7) dae na datum van brief sal 'n soortgelyke brief in Afrikaans verskaf word	**Rig asseblief alle korrespondensie aan die Munisipale Bestuurder Please address all correspondence to the Municipal Manager**	*Upon written request made within seven (7) days from date of letter, a similar letter will be supplied in English*

Hartklop van die Bosveld **Heartbeat of the Bushveld**